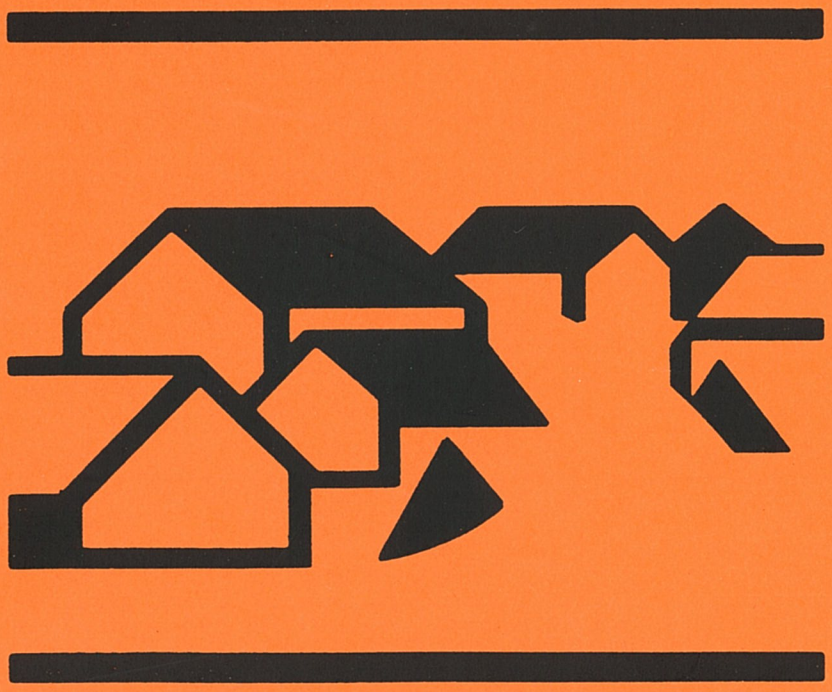
Description of Electric Energy Use in Single-Family Residences in the Pacific Northwest

End-Use Load and Consumer Assessment Program (ELCAP)



Bonneville
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DESCRIPTION OF ELECTRIC ENERGY USE IN SINGLE-FAMILY RESIDENCES IN THE PACIFIC NORTHWEST

END-USE LOAD AND CONSUMER ASSESSMENT PROGRAM (ELCAP)

PREPARED FOR
Bonneville Power Administration

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FOREWORD

The Office of Energy Resources of the Bonneville Power Administration is generally responsible for the agency's power and conservation resource planning. An associated responsibility which supports a variety of office functions is the analysis of historical trends in and determinants of energy consumption. The Office of Energy Resources' End-Use Research Section operates a comprehensive data collection program to provide pertinent information to support demand-side planning, load forecasting, and demand-side program development and delivery. Part of this on-going program is known as the End-Use Load and Consumer Assessment Program (ELCAP), an effort designed to collect electricity usage data through direct monitoring of end-use loads in buildings. This program is conducted for Bonneville by the Pacific Northwest Laboratory.

The purpose of this report is to provide detailed summary information from the residential portion of ELCAP. Equipment to meter the amount of electricity consumed for various end uses was installed in 499 residences. The data summaries presented here are based on metered data collected from September 1984 through May 1988. Specific information is provided on annual loads averaged over several years and their variation across residences, and descriptions are given of uses as associated with key demographic variables. Summaries are also provided for electricity use by month and time of day.

This is the first in a series of residential reports. Subsequent reports will be released as additional data is collected and insights generated. Comments regarding the interpretation of the data presented, additional useful data summaries, or modification of existing data summaries should be directed to:

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SECTION 1 – INTRODUCTION

The Bonneville Power Administration (Bonneville) began the End-Use Load and Consumer Assessment Program (ELCAP) in 1983. Prior to beginning ELCAP, there was an abundance of information regarding total power consumption for residential structures in the Pacific Northwest, through billing records for example, and limited information regarding power consumption by various end uses (such as hot water, heating and cooling). The purpose of ELCAP is to collect actual end-use load data from both residential and commercial buildings in the region.

There is presently at least two years worth of data available from a majority of the residences participating in ELCAP. Summarized data can be prepared to support various Bonneville functions related to demand-side planning, forecasting, and demand-side program development and delivery. This report provides both background information on the different residential studies and serves as a sourcebook of summarized residential end-use data for a broad audience, ranging from analysts to general managers, many of whom work with or need electricity end-use information. The sourcebook plots of residential end-use loads for all ELCAP residential studies are in various levels of temporal detail.

The unique design of ELCAP makes it possible to look at energy consumption at different times of the day. Time-of-day residential data provides an opportunity to study how consumption might be related to lifestyle. Extensive survey data makes it possible to examine which characteristics seem to most affect loads. The actual demographics of the residential studies, such as climate zone, household income and number of occupants, were determined in a variety of carefully planned surveys.

This report includes background information on the residential studies, the sourcebook, key observations based on analysis of data collected to date, descriptions of the various end uses metered, an explanation of how data plots are derived, and a summary comparing end-use loads and load shapes in the Base Study. It reports on one of the largest and most detailed sources of information on Pacific Northwest residential electric energy use that includes usage as measured in homes.

Most of the end-use information presented is in graphic, not in numeric form. The summaries represent averages across homes, not individual site information. Specific numbers for the summaries and homes are available from the End-Use Research Section of Bonneville.

This report is intended to be self-contained so that the reader can understand the composition of the studies and see data summaries from them. Future reports will update the information, and emphasize time series as well as averages across years.

SECTION 2 – KEY OBSERVATIONS

The primary purpose of collecting and analyzing residential end-use data is to provide useful information on how much electric energy is actually consumed in homes at the end-use level and insights about factors which affect usage. Here are key observations to date from looking at the residential data summaries.

- Annual space conditioning loads (heating and cooling) are the largest uses of electricity. All other electric energy uses when combined are nearly as large as space conditioning loads and about twice as large as water heating loads.

- Electric energy consumption for heating far exceeds that of cooling. A freezer uses slightly more energy than a refrigerator. Clothes washers and dishwashers run on very small amounts of energy, although their use is certainly reflected in water heating loads.

- All end uses show a remarkable degree of seasonal variation, as a percentage of their mean load, although the size of the variation in loads of smaller end uses tends to be overshadowed by the large seasonal swing in space conditioning loads.

- The heating load in the summer is significant and consists primarily of heating on cool days.

- Annual energy consumption varies greatly from one household to another--from almost zero to well over twice the mean load.

- The relative share of total household electricity use that each end-use occupies is highly variable from one household to another, as a result of family size, size of residence, income level, occupant behavior, and other characteristics.

- Some expected trends, such as that lights and conveniences loads tend to increase with the number of occupants, are borne out when mean loads are calculated for homes categorized by key characteristics variables.

- Categories with few homes in them can distort trends due to the previously noted large variations across homes. Relationships are clearer when categories include 15 or 20 residences.

- On first inspection, some expected trends are not borne out. For example, heating loads are not higher in the coldest climate zone, but dramatically lower. (Homes in the coldest climate zone tend to be better insulated and have more wood stoves.)

- Load shapes for all the different end uses vary strongly by time of day. The HVAC load shape in the winter shows a dual peak as a result of warm-up loads in the morning from nighttime thermostat setbacks and another warm-up upon returning home from work or other activities.

SECTION 3 – OVERVIEW OF RESIDENTIAL STUDIES

The original purpose of ELCAP was to study the existing housing stock in the region with permanent electric space heating equipment in order to gain the best possible knowledge of building energy characteristics and actual energy consumption for different end uses. Other research topics came to light as Bonneville developed conservation programs and project planning matured. As a result, studies of new homes were initiated to look closely at actual energy consumption in homes built to model conservation standards and homes built to current building practices, because they were expected to use less energy than older homes.

Within existing budget constraints it was also decided to do limited case studies that offered the opportunity to examine electricity use in residences that differ in one principal characteristic from homes in the Base Study. Subsequently, several specialized studies also were added that take advantage of ELCAP's data collection system.

This section provides a brief description of the ELCAP residential studies. Table 3.1 gives an overview of each kind of residential study.

BASE STUDY

The 288 homes in the Base Study are intended to be representative of the largest portion of the region's housing stock: single-family, detached, site-built, owner-occupied houses with permanent electric space-heating equipment (PESHE). The sample of homes in the Base Study is not more broadly representative since taking an adequate sample of all housing types would have been too costly.

The Base Study houses were randomly selected from the Pacific Northwest Residential Energy Survey (PNWRES), a random survey of 4,000

TABLE 3.1
RESIDENTIAL STUDIES WITHIN ELCAP

Class of Homes	Study	# Homes Initially Metered	# Homes Included in Annual Data Summaries a/	Principal Housing Characteristics b/
Existing Homes	Base Study	288	214	Single-family, detached, owner-occupied, site-built, PESHE c/
	Attached Case Study d/	2		Units attached to other single-family units on at least one side, excluding roof or floor
	Gas/Oil Case Study	22	14	Units with forced air, natural gas or oil heat
	Renter Case Study	14	7	Units occupied on a rental basis
	Manufactured Case Study	9	8	Mobile or manufactured homes (factory built)
	Special Study d/	9		Pilot demonstration homes or homes with a unique characteristic
New Homes	Model Conservation Standards	75	57	Homes built to demonstrate MCS
	Control	30	21	Homes built to demonstrate current building standards
	Manufactured Housing Demonstration Project (MHDP) d/	10		Manufactured homes, built to demonstrate MCS, not typical residents
	Multifamily d/	40		Multiple units occupied on a rental basis

a/ Due to the way data was aggregated some homes were excluded from the analysis. The aggregation methodology is explained in the appendix.

b/ All homes studied other than Base Study homes differ in a principal characteristic from existing, single-family, detached, owner-occupied, site-built PESHE homes.

c/ PESHE stands for permanently installed electric space heating equipment.

d/ This study is not represented in this report. Information on the study may be obtained from Bonneville's End-Use Research Section.

billing accounts designed to characterize the building structure of existing regional housing stock as well as behavior and attitudes of occupants (Harris, 1983). The selection process was stratified to maintain consistency with the regional survey demographics on five levels: climate zone, utility type (publicly-owned and privately-owned), construction vintage, occupant income and presence of wood heating equipment. In other words, the fraction of homes in the Base Study sample from each climate zone is in the same proportion as for single-family homes in the region. Similarly, the probability of selection of homes within the other four variables within each climate zone is equal to the proportion in the regional housing stock.

The sample design for the Base Study produced some biases, the effects of which are believed to be small. For example, the requirement for permanent electric space heating equipment resulted in the inclusion of more residences served by publicly-owned than by investor-owned utilities, since publicly-owned utilities have historically had lower electricity prices and therefore higher penetrations of electric space heat. Excluding rentals resulted in fewer pre-1950 homes in the Base Study sample and higher incomes than for the population as a whole. Stratification on wood-burning equipment also biased the sample toward rural areas (Windell, 1987).

Some demographic variables not in the sample frame are worth noting here: educational level, number of appliances, household size as measured by number of occupants, number of rooms and floor area. These variables were somewhat higher in the Base Study sample than in the region, probably because income levels in the Base Study sample are higher than regional income levels. Also, self-selection in the recruiting process resulted in a tendency for the occupants to be older and more likely to have recently installed conservation measures. However, the sample does conform well to the desired sample frame, providing a reasonably accurate and comprehensive picture of energy consumption in Pacific Northwest single-family, detached, owner-occupied, site-built PESHE residences. A detailed discussion of

differences between the Base Study and Pacific Northwest housing stock as a whole is provided by Windell (1987).

CASE STUDIES

Four different case studies of existing homes are in ELCAP. Each case study differs from the Base Study in one principal characteristic: (1) the Attached Case Study homes all share at least one common wall with another home, (2) the Gas/Oil Case Study homes do not have permanent electric space heating equipment, (3) the Renter Case Study homes are rented rather than owned, and (4) the Manufactured Case Study homes all are factory constructed (i.e., are mobile homes). The purpose of the case studies is to support comparisons of how these key differences affect end-use loads. Although the case studies are much smaller samples than the Base Study and do not support definitive conclusions, some useful working hypotheses can be derived. Table 3.1 lists the key characteristics that differentiate the case studies, and the number of metered and analyzed homes in each of them.

Like the Base Study sample, the case study samples were selected from the PNWRES homes, but the sample design for the case studies is somewhat different than for the Base Study. The Base Study stratification scheme is not practical for such small samples of homes (originally the combined size of the case studies was to be 100 homes; this was later reduced). Cost also made a standard random selection impractical. However, the distribution of the stratification variables for the case studies approximated the Base Study distributions, to avoid any severe bias in these key characteristics with respect to the region and the Base Study. Some biases do exist, as the small sample sizes and the nature of the case study homes made it impossible to maintain the stratification variable distributions exactly.

To reduce the marginal recruiting, installation and maintenance costs, the case study homes also were selected on the basis of having the same electric utility meter reading route and zip code as at least

one Base Study site. A short description of each case study follows. Each description includes a definition that shows how the case study homes differ from the region and the Base Study, the source of the homes selected for the study, what findings were expected, and observations of particular interest regarding the samples. A detailed discussion of differences between the case study samples and Pacific Northwest housing stock as a whole is provided by Windell (1987).

Attached Case Study*

The Attached Case Study consists of single-family dwellings that are, unlike the Base Study homes, not detached but attached to other single-family units on at least one side, exclusive of roofs and floors. This includes duplexes, triplexes and townhouses.

The attached homes were selected, as were the Base Study homes, from the PNWRES except as described in the general description of the Base Study. Interestingly, it was found during recruiting that many PNWRES sites classified as attached were deemed detached by ELCAP recruiters, and were subsequently moved to the Base Study.

It was expected that heating loads less than those in the regional housing stock and in the Base Study would result from the lower exposed surface area of the building envelope. Also, the townhouse style of construction has gained popularity in the region in recent years, so the attached homes might also be expected to be newer and hence better insulated.

As expected, none of the Attached Case Study homes were built prior to 1960. The number of appliances in the attached homes is as high or higher than for the Base Study homes. Observations of particular interest are that none of the Attached Case Study homes are served by

* Metered data from the Attached case study is not included in this report because there was not enough homes from which to report representative information.

investor-owned utilities and income levels are quite high. Also, the residents in the Attached Case Study have taken conservation measures at very high rates, even higher than in the Base Study.

Gas/Oil Case Study

Homes in the Gas/Oil Case Study, selected from PNWRES, do not have permanently installed electric space heating. The principal expected effect of fossil fuel heating systems was vastly reduced space heating requirements. Electric space conditioning equipment that is present includes circulation fans and air conditioners.

It was expected that homes with fossil fuel heat would be older on average than electrically heated homes in the region and in the base study, since the installation of electric space heating equipment has increased over time in the region.

The Gas/Oil Case Study homes are in fact generally older than homes with electric space heating. Homes with gas/oil heating also tend to have gas water heating and gas cooking appliances. Fossil fuel heated homes are larger than in other ELCAP study samples, except for the Base Study, and somewhat higher household incomes were noted.

Renter Case Study

What defined this study was the fact that none of the residences are owner-occupied. The sample of renter-occupied homes was selected from PNWRES.

The general expectation for the Renter Case Study homes was that the residents would have lower incomes, resulting in fewer appliances. It was also expected that the homes would be older and less likely to have received conservation retrofits, resulting in higher space heating consumption than newer or owner-occupied homes. There were in fact no high incomes in rental homes and relatively low numbers of appliances. The other expectations were also borne out.

Another difference from regional demographics is that only about a third of the rental sample is located west of the Cascade Mountains. Also, in the sample there were no new homes, a larger number of reported thermostat setbacks than in the Base Study, and few wood stoves. Baseboard heating systems predominate. The number of occupants in a renter-occupied home tends to be notably higher than found on average in either the region or the Base Study, reducing the potential for closing off unused rooms to save on heating.

Manufactured Case Study

Homes in the Manufactured Case Study, selected from PNWRES, are factory built, mobile homes. Manufactured homes represent an increasing share of the region's housing stock. The homes in the study were built after 1970. Many have wood stoves; all units have central forced air systems. These homes are usually smaller than site-built homes and it is commonly believed that their insulation levels are generally low. It is also thought that their low cost makes them attractive to occupants with lower incomes.

The Manufactured Case Study homes tend to have older residents and lower household incomes. Fewer appliances are present than for any other study, although they are about equal to the regional average.

SPECIAL STUDY*

The Special Study was comprised of homes metered for special reasons: as pilot demonstrations of the metering equipment and protocol in the early stages of the project or for some unique characteristic that made them of interest. Because they do not typify any regional group of homes or any Bonneville programs, data from them is not included in this report.

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* Metered data from the Special Studies is not included in this report because there was not enough homes from which to report representative information.

NEW RESIDENTIAL STUDIES

While the Base Study and the Case studies consist entirely of existing homes (as of the 1983 PNWRES survey), the New Residential studies encompass homes specially constructed as part of programs to demonstrate the ability to achieve energy conservation through energy standards for new construction. These new, single-family, detached, owner-occupied, site-built PESHE homes are classified into two studies: the homes built to the Model Conservation Standards (MCS) and those built to represent current practice (Control). (For a detailed discussion of differences between the MCS and Control samples and Pacific Northwest housing stock as a whole, see Windell (1987).) Data for two other new residential home studies do not appear in this report, but the studies are described in the next subsection, Other New Residential Studies.

Model Conservation Standards Study

MCS homes have very high levels of insulation in walls, floors and ceilings. They have energy efficient windows and very tight construction with ventilation air supplied by heat recovery air-to-air heat exchangers. The insulation levels required--a function of climate zone--are prescribed in the regional power plan (Northwest Power Planning Council, 1986). Several of the MCS Study homes have heat pump heating systems. An analysis of the actual insulation levels in the MCS Study homes shows that they are as prescribed on average, although some variation above and below requirements is evident.

There are three sources of homes classified as part of the MCS Study in this report. Bonneville's Residential Standards Demonstration Program (RSDP) supplied two sources--MCS homes from a matched pairs experiment and additional "un-paired" MCS homes--and the Tacoma Early Adopter Program supplied the third. Table 3.2 shows the number of MCS

Study homes from each source (and of the Control Study homes described in the next section).

RSDP's purpose was to demonstrate that homes meeting the MCS requirements as proposed by the Northwest Power Planning Council could be constructed. Additionally, it was decided to collect construction

TABLE 3.2
SOURCES OF MCS AND CONTROL HOMES

Source of Homes	Number of MCS Homes	Number of Control Homes
RSDP Matched Pairs	26	30
RSDP Un-Matched Pairs	44	0
Tacoma Early Adopters	5	0
TOTAL	75	30

cost and energy consumption data for the homes. The RSDP was administered through the Washington, Idaho, Montana and Oregon state energy offices, with allocation of homes roughly in proportion to the number of single-family homes in each state's housing stock. (No RSDP homes were constructed in the state of Wyoming.)

In the RSDP matched pairs experiment, some of the homes were constructed in pairs. Control homes that are counterparts to the MCS homes were built to current construction standards to provide a benchmark for comparison. The concept behind a "matched pair" of homes in the RSDP is of two homes built by the same contractor with identical floor plans and appliances, except one is designed to meet the MCS while the other is designed to represent current practice. Up to 100 pairs of homes were to be built by the RSDP. Unfortunately, the rate of construction of the matched pair dwellings was slower than anticipated. Only 26 pairs of dwellings were constructed in time and agreed to

participate in ELCAP residential metering. An additional matched pair of duplex units is also included, and metered as four separate homes.

In an effort to supplement this small sample, an additional 52 MCS dwellings were recruited from the RSDP homes under construction, for which the matched current practice homes had not yet been built. These MCS homes are largely in eastern Washington and Oregon, as these areas were under-represented by the matched pair homes with respect to the geographical allocation of homes in the RSDP. The matched pair homes average 1524 square feet of conditioned floor space, while the unmatched MCS homes are much larger with an average of a little over 2000 square feet. The number of occupants are nearly the same, although the unmatched MCS homes have slightly higher incomes and more appliances on average.

The metering method for the RSDP MCS and RSDP Control homes is unique. Metering was anticipated at the time of construction and to the extent possible all major appliances are served from separate circuits; thus more of the pure Refrigerator end use (see Section 4) is found in RSDP matched pair homes than in the Base Study and Case studies. Also, wire was pulled to three locations within the residence to measure indoor temperatures on a zone-by-zone basis, something that could not be accomplished in the Base Study without disturbing the structure unduly.

Finally, homes in the Tacoma Early Adopter's Program were used as a third source of MCS homes to increase the sample size further. The city of Tacoma, Washington, adopted the MCS as the building code for participants in the program, and paid rebates to builders to offset the costs of the MCS measures. The average size of conditioned floor space in the five homes recruited from this program was 1900 square feet.

If the MCS are adopted by local and state authorities throughout the region, as intended, then the metered MCS homes represent the "homes of the future" in the region as far as space heating is concerned. Therefore space heating loads in the MCS Study are similar to what might

be expected in the future if the MCS are adopted. The impact of new appliance efficiency standards is not yet reflected in the homes to any large extent.

Control Study

The source of the Control Study homes was the current practice halves of the RSDP matched pairs (described above). The Control Study homes from the RSDP matched pairs were built to represent "current practice" as defined in the development of the MCS (Northwest Power Planning Council, 1986). This definition of current practice was tested against characteristics survey data from ELCAP Base Study homes built after 1978, and the insulation levels were found to agree closely. The insulation levels in the Control Study homes were also found on average to agree with this definition of current practice.

The characteristics of the matched pair Control Study homes agree closely with their MCS Study counterparts, although they have slightly more occupants and slightly higher incomes. The average conditioned floor area of the Control Study homes is identical to that of the matched pair MCS Study homes.

OTHER NEW RESIDENTIAL STUDIES

There are two other new residential studies in ELCAP not represented in this report: Multifamily and Manufactured Housing Demonstration Project. These studies have unique features that make them unsuitable for inclusion in this report.

The Multifamily buildings are new apartment/condominium buildings built specially to the MCS. Multiple units are occupied on a rental basis and the building characteristics are different from the single-family residences. Currently the data has not been processed in a form that allows it to be included in this report. A report by Parker et al. (1989) provides results to date from the Multifamily Study.

Also not included in this report is a study of five manufactured homes specially constructed to meet the MCS under Bonneville's Manufactured Home Demonstration Program (MHDP). The initial metering program entailed data acquisition while the homes were unoccupied, with a subsequent period of metering under occupied conditions when the homes were dispersed to the U.S. Forest Service and other similar federal agencies for use as federally-supplied housing. Because these homes were not occupied by typical residents, and some were not even located within the Pacific Northwest during their occupied period, data from them is not included here. A report by Lee et al. (1986) provides results of the metering effort while these residences were unoccupied.

SECTION 4 – RESIDENTIAL END USES

In the ELCAP studies, all household electricity use is metered for 11 end uses. This metering is quite different from more conventional and less expensive triple metering, which uses three end-use categories: HVAC, Hot Water and Other. This section describes how end uses were specified in ELCAP, definitions of ELCAP end uses, and the conversion of ELCAP end-use definitions to conform with those used for forecasting.

ELCAP METERING PLAN

End-use definitions and metering are co-dependent. When measuring end uses in a large number of structurally dissimilar homes, it is important to apply consistent definitions of end uses in every home. The ELCAP metering plan (protocol) defines end uses and provides instructions for correct installation of metering hardware in homes. A detailed description of the metering protocol is given in a report by Parker, Pearson and Sandusky (1985).

ELCAP END-USE DEFINITIONS

End uses in residences are metered by measuring average power for individual circuits at the circuit breaker panel in the homes. Thus the end-use definitions are dependent on the circuitry in home wiring systems and the resulting level to which an end use can be isolated. End-uses and their descriptions used in ELCAP are listed in Table 4.1.

The term "pure" is used to refer to metering of an appliance without contamination by any other, small loads. For example, the load from a refrigerator is assigned to the Refrigerator end use if the circuit

TABLE 4.1

END-USE DESCRIPTIONS FOR ELCAP
RESIDENTIAL STUDIES a/

ELCAP End Uses	Notes on ELCAP End Uses
Hot Water	End use is pure
Heating	Used when pure (76% of sites) b/ c/
Cooling	Used when pure b/ c/ d/
Refrigerator	Used when pure (25% of homes)
Mixed Refrigerator	Used when primary refrigerator is mixed with a plug circuit (75% of homes)
Lights/ Convenience	Used for all other plug circuits not dedicated to a single end use
Freezer	Used when appliance is present and load is pure (10% of homes) e/
Range	End use is pure (a combination of ranges, stove tops & ovens)
Dryer	End use is pure
Clothes Washer	Used when appliance is present and load is pure (36% of homes) e/
Dishwasher	Used when appliance is present and load is pure (33% of homes) e/
Special Major Appliances	Used for hot tubs, kilns, workshops, etc.

ELCAP Triple-Metered Categories	Notes on Triple-Metered End-Use Categories
Heating, Ventilating Air Conditioning (HVAC)	The sum of Heating and Cooling, also used for mixed heating and cooling when not pure (primarily heat pumps, 24% of homes)
Hot Water	Same as the Hot Water end use above
Other	The sum of all loads except HVAC and Hot Water
Total	The sum of HVAC, Hot Water, and Other

a/ Percentages of homes with pure end uses are for the Base Study only.
b/ Includes circulation fans.
c/ Heat pump loads appear on HVAC end-use category only.
d/ Many window-unit air conditioner loads appear on the Lights/ Convenience end use.
e/ Load appears on Lights/Convenience end use when load is not pure.

serving it powers no other appliances or outlets.* If it does power other appliances, the load is assigned to the Mixed Refrigerator end use.

Similarly, clothes washers and freezers served by general purpose circuits, which is typically the case, usually appear on the general purpose Lights/Convenience end use. It is important to keep in mind that the Lights/Convenience end use includes lights, microwave ovens and miscellaneous kitchen equipment, small appliances, some window air conditioning units, portable heaters, as well as most bathroom heaters, clothes washers, ventilation fans and freezers.

Finally, the last common case of "un-pure" loads is heat pumps, where the same circuit (and hence metered load) is used for heating and cooling. In this case the HVAC (heating, ventilating and air conditioning) load appears in the HVAC end-use category and not in either the heating or cooling end uses.

HVAC, Other, and Hot Water are end-use categories defined in ELCAP as the sum of individual end uses to form the "triple-metered" end uses. Since triple-metered end use definitions are common to other regional metering projects, such as the RSDP and Hood River, this definition is convenient for making comparisons across these metered data sets.

The order of priority for capturing end uses in ELCAP residential studies is as follows: Heating, Hot Water, Cooling, Range (Food Preparation), Mixed or pure Refrigerator, Clothes Dryer, Lights/ Convenience, Special Major Appliances, Freezer, Clothes Washer, and Dishwasher. On average, seven are obtained from each site.

Total load for each residence is also metered separately. This total load is used to perform quality assurance checking, assuring all

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* Initial capital letters are always used to designate end uses and appliances are designated by all lower case.

loads are accounted for. The manner in which building total channels are used for quality assurance checking is described elsewhere (Pearson, Stokes, and Crowder, 1985).

APPLICATION OF ELCAP END-USE DEFINITIONS

The primary goal of ELCAP residential studies is to provide resource planners with a more detailed picture of how much electricity is actually consumed for specific purposes in Northwest homes. Because ELCAP end-use definitions correspond to the type of circuits used in home wiring systems, as described in Section 3, these definitions are not directly applicable to all situations in which end use is a concern.

For example, the end-use definitions used in Bonneville residential forecasting models differ from the definitions used in Bonneville's ELCAP. The forecasting model end-use definitions are not constrained to conform with home wiring practices, so they are defined in terms of "pure" appliance loads. An outline of the forecasting model end uses and their relationship to corresponding ELCAP end uses is shown in Table 4.2.

The majority of the differences between forecasting and ELCAP end-use definitions are related to how ELCAP metering deals with the issue of "purity". The only exception is the forecasting "other" end use, which is used for all small appliance and electronics loads not specifically in other forecasting end uses. As such, "other" includes ELCAP loads metered as special major appliances. Also, the forecasting end use "other" has no relation to the ELCAP triple-metered end-use category Other. (There are no forecasting counterparts to the triple-metered end-use categories.)

The forecasting end use "lighting" has no counterpart in ELCAP since lights are usually powered by the same circuits that serve the plug outlets. Lights in the ELCAP residential studies are metered on the Lights/Convenience end use.

TABLE 4.2

BONNEVILLE FORECASTING AND ELCAP END-USE DEFINITIONS COMPARED

Forecasting End Uses	Corresponding ELCAP End Uses	Notes on End-Use Definitions
Water Heating	Hot Water	Definitions are identical
Space Heating	Heating	ELCAP does not include portable heaters or bathroom heaters that typically are metered on Lights/ Convenience
Air Conditioning	Cooling	Many window unit air conditioners in the ELCAP sample are metered on Lights/Convenience; heat pump loads are on HVAC only
Lighting	(None)	Lighting in ELCAP metering is on Lights/Convenience
Other	Lights/ Convenience	The end use in ELCAP includes lights, some room A/C units, most bathroom and portable heaters, and most freezers
Refrigeration	Refrigerator	Definitions are identical
Refrigeration	Mixed Refrigerator	The majority of refrigerator loads are on the Mixed Refrigerator end use along with miscellaneous small appliances
Freezer	Freezer	Definitions are identical
Cooking	Range	Definitions are identical
Clothes Drying	Clothes Drying	Definitions are identical
(None)	Special Major Appliances	These loads appear in "other" for Bonneville forecasting
a/	Heat, Ventilation, & Air Conditioning	This end use is the sum of Heating & Cooling, also used for mixed heating & cooling (as in heat pumps)
a/	Other	The sum of all end uses except Heating and Cooling, HVAC, and Hot Water

a/ This is a "triple metered" end-use category. There is no Bonneville forecasting counterpart.

The most important difference between the two sets of end-use definitions are for the refrigeration end uses. Most of the refrigerators in ELCAP residences are on circuits that serve plug outlets and lighting in the kitchen and sometimes adjacent areas (although the refrigerator is undoubtedly the dominant load for these circuits). These refrigerators are metered as Mixed Refrigerator end uses because they are contaminated with other, small loads not in the forecasting definition of refrigeration. The ELCAP Refrigerator end use can be directly compared to the Bonneville end use. It must also be recognized that the small miscellaneous loads metered on the Mixed Refrigerator end use in ELCAP therefore do not appear on Lights/ Convenience for those homes.

One way to create comparable end-use loads is to create a common end use that might be termed mixed general. The mixed general end use for forecasting would consist of the sum of "other" and lights. In ELCAP, the Mixed General end use would consist of a combination of the Lights/ Convenience, Special Major Appliance, Clothes Washer, and Dishwasher end uses. It would also include the average difference between Mixed Refrigerator and Refrigerator for those sites with mixed refrigeration. (However, those refrigerators that are individually metered on the ELCAP Refrigerator end use can be directly compared to the forecasting refrigerator loads.) The majority of freezer loads in the ELCAP residential sample are also metered on the Lights/Convenience end use (although, again, those that are on the Freezer end use can be directly compared to the forecasting freezer loads). The product of the average load for freezers and the number of freezers present is subtracted from the mixed general combination for these sites. This conversion on the basis of a mixed general end use is made in Section 6 of this report.

Finally, there are several subtle differences between forecasting and ELCAP heating and cooling loads. First, heat pump loads in ELCAP do not appear in either the Heating or the Cooling end use as they do in forecasting models, but are placed in the HVAC triple-metered end-use category with the sum of heating and cooling loads from all the other

homes without heat pumps. Second, many window air conditioners are powered from normal wall plug outlets, and so in ELCAP these will appear on the Lights/Convenience end use instead of "cooling" as they do in forecasting. Third, portable space heaters and bathroom heaters are also typically powered from lighting and wall plug circuits, and so will appear in Lights/Convenience in ELCAP.

SECTION 5 – DERIVATION OF RESIDENTIAL END-USE PLOTS

To assist the reader in the use of the plots in Sections 6 and 7, this section briefly discusses the data, the process used to summarize the data for each home (referred to here as aggregation), and the averaging of aggregations across homes. In Section 6 the plots and tables highlight observations about the overall nature of end-use loads in the Base Study homes. Section 7 serves as a data sourcebook describing the general characteristics and magnitude of each residential end-use load across all of the ELCAP residential studies.

DATA SET USED

All available on-line data collected during the period September 1984, when the first installations were completed and verified, through May 1988 are used in the preparation of the data summaries in this report. The bulk of the time-series data begins in October 1985, when most of the installations were complete. Thus, the data set typically includes three heating seasons for each residence.

As a routine part of data collection operations in ELCAP, the energy data from each site is screened for errors to assure that all measured end uses add up to (equal) the electricity measured as the building total. This assures an hourly energy balance. This energy balance, termed sum-checking, involves comparing the total consumption metered for the home to the sum of the end uses (for each of the two phases of residential electrical service). Any hourly observations where this energy balance lies outside a narrow tolerance band are removed (made missing) from the data set prior to the analysis.

TIME AGGREGATIONS

The first challenge associated with developing meaningful summaries of the residential end-use data was how to deal with the huge number of observations collected. The volume of data is roughly 20,000 hourly observations (2.5 years of data) per home for each of an average of seven end uses and three end-use categories plus Total. This volume of data is reduced through a process of aggregating the hourly end-use observations across time for each home to produce monthly and annual loads and load profiles. The term load profile is used here to describe a 24-hour average load shape for a period of time (a month, for example). From among numerous possibilities for summarizing the data, these time aggregations are selected as having the broadest application common to uses such as forecasting, conservation planning and conservation program evaluation.

The time aggregations prepared for the sourcebook are: (1) average load profile by month, (2) average load profiles for weekdays and weekends by month, (3) average monthly load, (4) average annual load profiles, (5) average annual load profiles for weekdays and weekends, and (6) average annual load. These aggregations are created by a five-step process, building upon each other as described below.

Step 1. The monthly load profile for a month and year is calculated, solely for convenience, as an intermediate step in creating the other higher aggregations listed below. Each hour of the 24-hour profile is the mean of the available data for that hour in the specific month and year. This implicitly fills missing hourly data with the average values for that hour for the data actually present. Two additional monthly load profiles are created using only weekday and weekend data.

Step 2. The average load profile for a calendar month is calculated as the mean for each hour of the monthly load profiles across all the years for which data is present. This

implicitly fills missing monthly load profiles with the average of the monthly load profiles for the same calendar month but from other years. Two additional average monthly load profiles are created using the monthly load profiles for weekdays and weekends.

Step 3. The average load for a calendar month is calculated as the mean of the hourly loads in the average of the monthly load profiles. This also implicitly fills missing monthly profiles with the average of the monthly load profiles from other years.

Step 4. The average annual load profile is calculated as the weighted mean of the twelve average monthly load profiles. [a/] The hourly profiles for each calendar month are weighted by the number of days in the month to properly account for the varying length of the months. Two additional average annual load profiles are created using the twelve average monthly load profiles for weekdays and weekends.

Step 5. The average annual load is calculated as the mean of the average annual load profile. [a/]

In order to have a "complete" data set for these aggregations, data filling is usually required. Note that all data filling is accomplished implicitly by the aggregation process, and is always the average of other existing data from the same month and hour of day. A more rigorous and complete discussion of the aggregations, including the missing value criteria and how they are applied, is presented in a technical appendix at the end of this report.

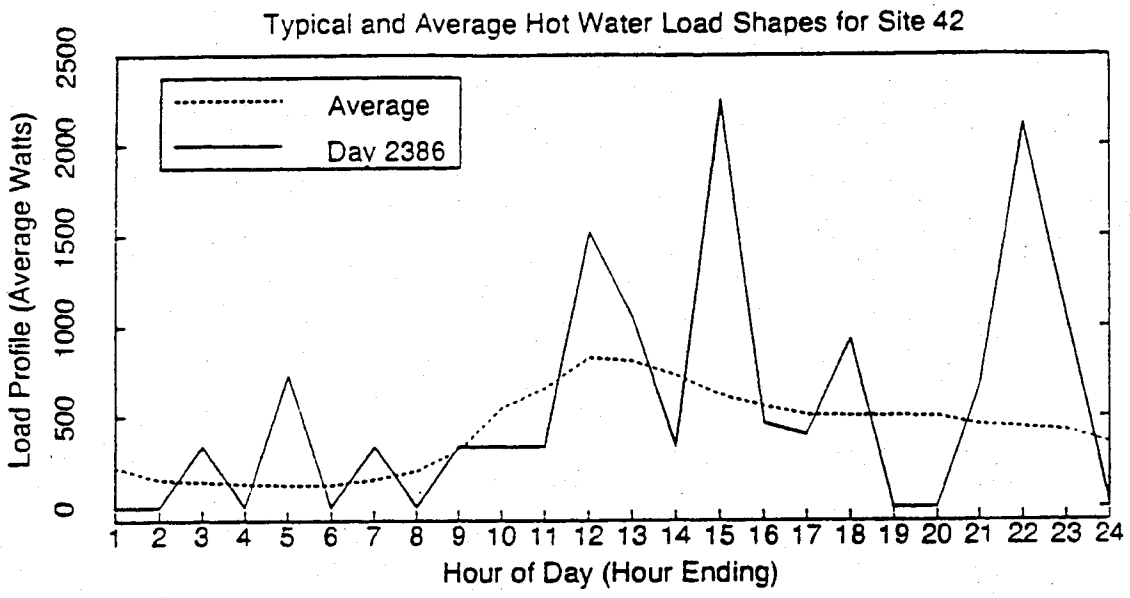
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a/ Note that the average annual load profile and the average annual load are, in concept, created as described here. However, these aggregations are actually derived directly from the monthly load profiles, using less restrictive missing value criteria than are used in creating the average monthly load profiles. (See the appendix for details.)

It is important to note that the average load shape often differs dramatically from a "typical day" load shape for a residence. As illustrated in Figure 5.1, the hot water load for a typical day (selected to have an average load equal to the average for the home) is seen to be much more variable than the average annual load profile.

Average load profiles are literally the product of the probability of an end use being active and the magnitude of the load when active. They serve to characterize average time of day load patterns for a site, but more importantly are a convenient step in producing the cross-site averages that form the end use load shape from the utility perspective.

FIGURE 5.1



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

"Typical" load shapes are more properly used as inputs into computer simulations of heating and cooling loads than are average load profiles. These simulations take into account the timing of internal gains and their interaction with space conditioning loads. The "peakedness" of the internal gains in typical load shapes may increase heating requirements since the heat gain may occur too rapidly to be useful. For example, during meal preparation the waste heat may cause the kitchen air temperature to exceed the thermostat setting, and use of a "typical" load shape more realistically represents the actual rate of heat gain.

AVERAGES ACROSS SITES

All loads reported in the data sourcebook and the Base Study summary are simple averages of the time aggregations across the sites in a study. No attempt has been made to weight data from the sites to adjust the load estimates to either the sample frame or the region. The variability illustrated in the data sourcebook plots of the distribution of loads across homes suggests that such an adjustment requires a more sophisticated understanding of cause and effect than the five variables upon which the Base and Case Study sample frame were stratified.

All end-use loads reported are on a per unit appliance basis, typically termed the unit energy consumption, except for Freezer which has an average of 1.19 freezers metered on the end use. For example, sites without a given end use (like dishwasher) do not have a "zero load" averaged in with the sites that do have the metered end use. The reported loads are simply the average for all sites in which the end use (i.e., appliance) is present and separately metered. Thus, except for the Total end use, the reported consumption and load shapes are <u>not</u> residential single-family class loads, due to the variation in appliance saturations and fuel-type penetrations across homes in the region. The only exceptions to this are highlighted in the Base Study summary of Section 6, where simple estimates of regional loads are developed and discussed.

SECTION 6 – BASE STUDY SUMMARY: END-USE LOADS AND LOAD SHAPES

This section looks at summaries of electricity end uses in a single residential study--the Base Study--in some detail. The plots presented conveniently support comparisons of loads and load shapes from one end use to another. The sourcebook of end-use aggregations in Section 7, on the other hand, best supports comparisons of loads across studies or development of insights about the general nature of individual end uses.

Using direct scales of consumption levels for the different end uses, as is done in the plots in Section 7, can make it difficult to make useful comparisons across some end uses. For example, in monthly loads and hourly load shapes the scale dictated by the magnitude of the variations in larger end uses completely masks proportionally similar variations in the smaller end uses. To avoid this masking, the end-use loads can be normalized, or scaled to a common level. Normalization was performed for the loads and load shapes in the Base Study. Observations are made based on comparisons across the end uses.

The Base Study is by far the largest residential study in ELCAP, hence the most suitable for the development of summary comparisons across end uses. The comparisons across end uses include annual loads and load shapes, variations of loads seasonally and average hourly load shapes. Simple estimates are presented of regional annual loads for average all-electric homes and average single-family homes (taking into account fossil fuels and appliances). (By all-electric is meant every appliance is electric except for possibly a wood stove.) The potential usefulness of load shares in explaining variability is also discussed.

ABOUT THE PLOTS

Many of the figures in Section 6 and all of the plots in the end-use sourcebook in Section 7 have dual vertical axes, the left side in units of kWh and the right side in average watts. Each bar in the plot has at its top the corresponding mean annual load (annual load averaged over several years) for the study in average watts. Above this value, at the very top of the plot area, are sample sizes, (n), indicating the number of homes averaged to obtain the end-use load summary for the study.

Average watts, a unit of energy consumption, is simply the average consumption per hour over the time period of an aggregation. For example, a load of 1000 average watts for each of the 8,760 hours in a year is equivalent to 8,760 kWh. Within units of average watts, the loads remain the same size regardless of the time period over which they are aggregated. By using units of average watts, the analyst builds intuition about relative sizes of loads instead of trying to keep in mind what is large or small for an hourly, daily, monthly and annual load for each end use. As will be shown, average watts are also particularly useful for creating normalized loads.

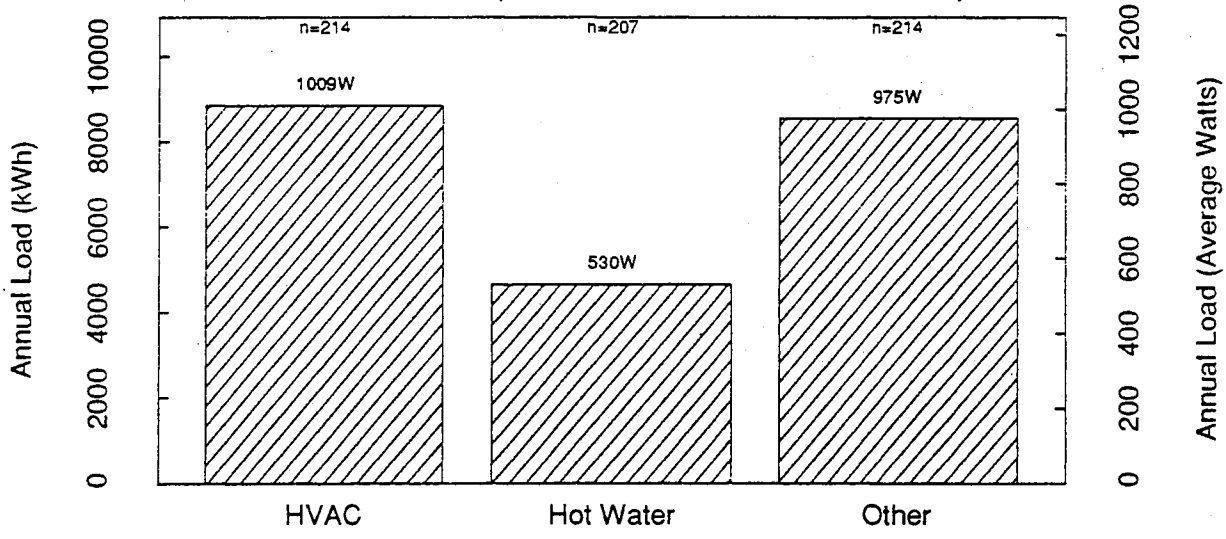
BASE STUDY MEAN ANNUAL UNIT ENERGY CONSUMPTION

The term unit energy consumption (UEC) is used by other metering projects outside the region and in literature on conditional demand models to describe the load per appliance (per refrigerator or per freezer, for example). Defined in this way, UEC is not directly applicable to either the Lights/Convenience end use or the Other end-use category, which are comprised of loads from multiple appliances where the number and type of appliances differ across homes. When used for these loads, the term UEC should be understood to indicate the average consumption per home instead of per appliance.

The annual aggregations of the UECs for the Base Study are, like the aggregations for six residential studies in the end-use sourcebook (Section 7), simple averages across the Base Study homes in which the end use is metered. No adjustment is made, for example, only 43% of the homes in the region have electric space heat. The only exception to this is that the average Freezer end-use load is divided by 1.19, which is the average number of freezers in Base Study homes with a Freezer end use present.

Annual UECs for the three end-use categories of the triple-metering protocol are shown in Figure 6.1. As indicated in this bar chart, the heating, ventilating and cooling (HVAC) loads, which include circulation fans for central forced air and heat pump systems, have the highest UEC of any end-use category. The UEC for the Other end-use category is nearly as large as that for HVAC loads. This is undoubtedly in part due to the high frequency of the wood stoves in the region and the Base

FIGURE 6.1
Mean Annual Triple-Metered Loads for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Study homes. Furthermore, although the Base Study sample design requires electric heating equipment to be present in the homes, it is not necessarily used as the primary heating source. The hot water UEC is only about half that of the other two categories. Note that seven of the homes in the sample use another fuel for water heating, as indicated by the smaller sample size for this end use.

Table 6.1 is a list of abbreviations of the full end-use names. The abbreviations in this section are used to promote ease of use and to prevent the labels on figures from becoming too small.

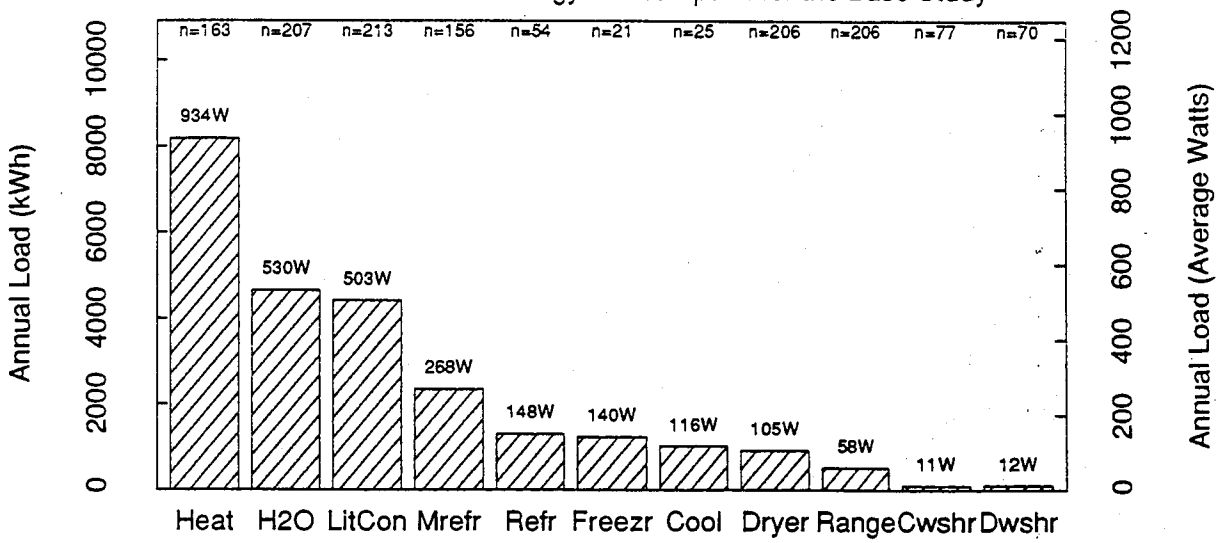
TABLE 6.1

END-USE ABBREVIATIONS USED IN BASE STUDY SUMMARY FIGURES

Abbreviation	End Use
Heat	Heating
Cool	Cooling
H2O	Hot Water
Range	Food Preparation
Dryer	Clothes Drying
Refr	Refrigerator
Mrefr	Mixed Refrigerator
Cwshr	Clothes Washer
Dwshr	Dishwasher
Freezr	Freezer
LitCon	Lights/Convenience
MixGen	Mixed General

Figure 6.2 is a plot of mean annual UECs for each of the ELCAP residential end uses. Note that there is substantial variation in the sample size (n) for each end use in Figure 6.2. Sample size depends on how many homes have the appliance and how many of those homes have the appliance metered individually on an end use. (For a discussion of how loads are metered see Section 4.)

FIGURE 6.2
Mean Annual Unit Energy Consumption for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.2 indicates that heaters consume more energy than air conditioners. About 75% of the primary refrigerators in the Base Study are metered on the Mixed Refrigerator end use, as indicated by the relative sample sizes of the Refrigerator and Mixed Refrigerator end uses. About 120 average watts of miscellaneous loads which would be metered on the Lights/Convenience end use if the refrigerator was not on a mixed circuit appear on the Mixed Refrigerator end use. This is indicated by the difference between the mean Mixed Refrigerator and mean Refrigerator end uses. Freezers are seen to use nearly the same energy per unit as refrigerators.

Also in Figure 6.2, clothes washers and dishwashers are shown to use very small amounts of energy, although their use certainly increases water heating loads. The Range end use (stove top and oven) indicates remarkably low consumption--less than 500 kWh (60 average watts). Not shown in Figure 6.2 is the special major appliance end use, consisting

of such items as hot tubs, pottery kilns and power tool shops. The average UEC for this end use, 64 average watts in 45 Base Study homes, is not shown because the diverse mixture of appliances represented makes the meaning of this UEC highly uncertain.

REGIONAL END-USE LOAD ESTIMATES

The ELCAP is not regionally representative (even of PESHE) but preliminary development of regional numbers is useful. These numbers are simple estimates using regional appliance saturations and should be used as general guides not as explicit numbers. Other, more statistical means of developing regional numbers may yield different results. (Estimates from the draft end-use modeling report, a project whose emphasis is regional estimates, are available upon request from the End-Use Research Section.)

Appliance saturations were used to make a simple adjustment to the Base Study UECs (already shown in Figures 6.1 and 6.2). The term saturation is used to indicate the fraction of homes that have a specific appliance. For example, although freezers in the Base Study consume 140 average watts, every house does not have a freezer. The Base Study UECs must be multiplied by the corresponding appliance saturations if to obtain simple regional end-use estimates.

The estimates presented were made from Base Study UECs. Strictly speaking, these estimates are limited insofar as they represent single-family owner-occupied homes and not homes that are rented or attached on one or more sides to adjacent homes. Regional load forecasts generally account for these smaller sub-classes, although not explicitly. In any case, the reader may use the estimates presented here to represent only owner-occupied detached homes, or assume that these distinctions are of lesser importance and can be ignored (see Section 7 to examine this issue). The latter assumption allows comparisons to be made with loads for single-family homes from regional forecasting models.

In this report simple end-use load estimates were developed for two classes of single-family homes: the regional average homes (regardless of primary heating fuel) and the regional average all-electric home. Explicit assumptions have already been noted. The reader should also keep in mind that there are also two other assumptions that are fundamental to the whole study approach:

- the distribution of home characteristics in the Base Study is reasonably representative of that for regional single-family homes (including the share of homes in each climate zone)

- wood use is indigenous in regional homes and implicit in the estimates for space heat

The ELCAP regional estimates were developed using end-use definitions consistent with the definitions used in regional forecasting. A mixed general end use was created. In forecasting, the mixed general end use is the sum of the "other" and lights. In ELCAP, Mixed General is the combination of Lights/Convenience, Special Major Appliance, Clothes Washer, and Dishwasher end uses. The ELCAP Mixed General also includes the average difference between the mean Mixed Refrigerator and Refrigerator end uses (an estimate of the miscellaneous portion of the Mixed Refrigerator end use), for those homes with a Mixed Refrigerator end use.

Since freezer is a specific forecasting end use it is desirable to maintain a separate estimate for freezer consumption. Loads from freezers in most homes metered in ELCAP appear on the Lights/ Convenience end use, therefore the product of the average load for the Freezer end use and the number of freezers present is subtracted from the mixed general combination for these homes.

The resulting set of end uses are: Heating (therefore excluding homes with heat pumps), Hot Water, Mixed General, Refrigerator, Freezer, Cooling, Dryer, and Range.

Regional Appliance Saturations

The Base Study consists of homes with permanent electric space heating equipment (PESHE). The PESHE homes do not use electricity exclusively; many use wood as secondary heating sources and a few use gas or oil. All-electric homes are therefore defined here as PESHE homes in which all appliances other than supplementary space heating are powered by electricity. In any case, it is assumed that any all-electric homes can and in some climate zones many do use wood stoves to supplement electric space heating. It is assumed that the reduction of the Base Study heating UEC due to the effects of fossil fuel use (primarily natural gas) are small enough to be ignored.

Table 6.2 shows the regional appliance saturations for single-family dwellings from the 1985 Bonneville load forecast for the year 1987 (roughly the mid-point of the metered data time series) for public and private utilities in the Pacific Northwest. The share of the single-family dwelling (SFD) population in the forecast for each utility type is shown on a separate line. An estimate of the saturation of electric appliances in all SFDs in the region is shown in the third column. For example, 43.3% of the SFDs in the region are indicated as having electric space heat. The regional appliance saturation is obtained by simply multiplying the appliance saturation and regional share of SFDs in each of the two utility types, and adding the two products.

The fourth column in Table 6.2 shows assumed appliance saturations for all-electric SFDs. Note that the assumed saturations are equal to those for the regional SFDs for mixed general, refrigerators, freezers, air conditioners and clothes dryers, as it is reasonable to assume that penetrations of these appliances are not significantly different in all-electric homes. However, Heat, Hot Water, and Range are assigned saturations of 100% in all-electric homes, as it is reasonable to assume that all the homes have these appliances.

TABLE 6.2

Regional Electric Appliance Saturations in Single-Family Dwellings (SFDs) and Share of Regional SFDs, for the Region and by Utility Type

End Use	Publicly Owned Utility	Privately Owned Utility	All Regional SFDs	Regional All-Electric SFDs (Assumed)
Heat	0.581	0.327	0.433	1.000
Hot Water	0.901	0.811	0.849	1.000
MixGen	1.000	1.000	1.000	1.000
Refr	1.164	1.155	1.159	1.159
Freezr	0.527	0.523	0.525	0.525
A/C	0.100	0.130	0.117	0.117
Dryer	0.718	0.704	0.710	0.725
Range	0.951	0.950	0.950	1.000
Share SFDs	0.417	0.583	1.000	1.000

Data for all SFDs: 1985 BPA Forecast Saturations for 1987

Regional End-Use Load Estimates for All-Electric Single-Family Homes

The regional estimates of end-use loads for all-electric homes have two fundamental applications. The first is simply to provide estimates of electricity consumption where all appliances are electric for the average regional single-family home. This type of estimate is typically used for conservation program design and resource assessment. Many programs are implemented at the household level instead of the appliance level, and so the loads affected are solely from households that use electricity for a given end use. The end-use estimates for all-electric homes provide this viewpoint.

A second use of these load estimates is to estimate the energy delivered whether the end-use load is electric or gas. For example, the same quantity of energy must be delivered to a pot of water to bring it to a boil, regardless of whether that energy is delivered from gas or electricity. While ELCAP does not meter hourly gas consumption, ELCAP data can be used to provide estimates of gas end uses, since the energy

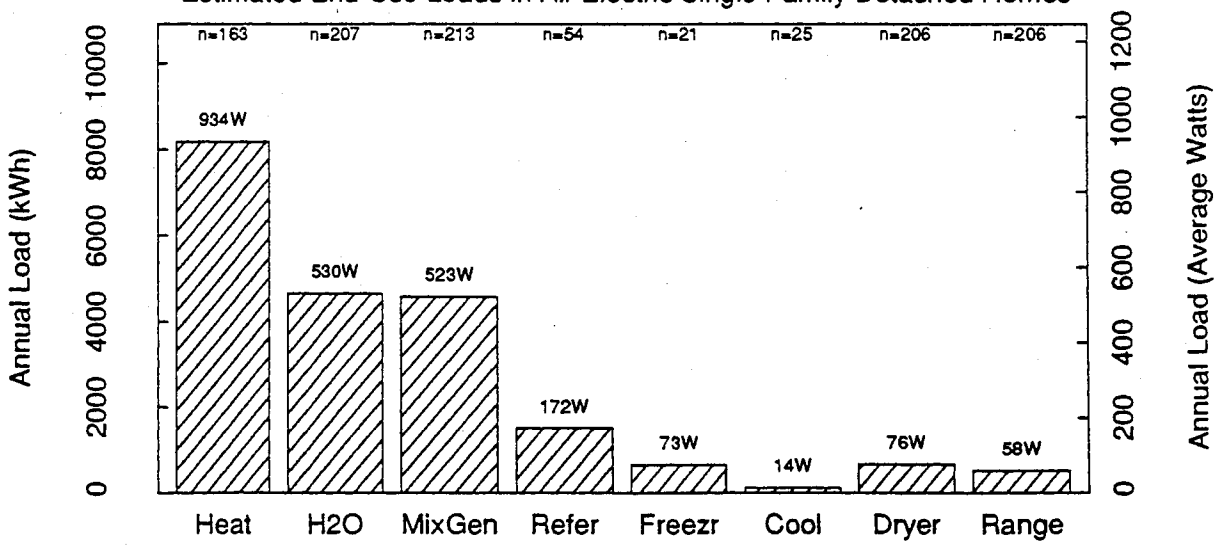
delivered (after combustion in the case of gas or oil) to a load for any purpose is the same regardless of the energy source.

These estimates of energy delivered may be useful, for example, for aspects of conservation program design such as estimating displacement of heat due to heat generated by other appliances. Estimates of energy consumed by an appliance (as opposed to delivered by an appliance to a load) that is powered by gas or oil can also be derived if the load is divided by a known or assumed combustion efficiency.

The regional end-use load estimates in Figure 6.3 are produced by multiplying the UECs in Figure 6.2 by the assumed appliance saturations in the fourth column in Table 6.2. Note that the loads for air conditioners and freezers are far lower than in Figure 6.2 because only about 12 percent of the homes in the region have air conditioners and only 53 percent have freezers. A similar, smaller adjustment is made for clothes dryers and refrigerators.

FIGURE 6.3

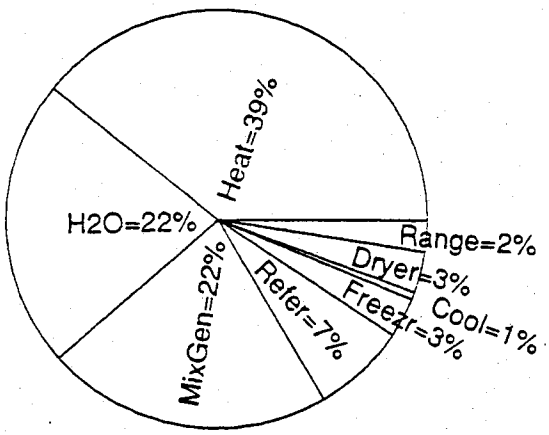
Estimated End-Use Loads in All-Electric Single Family Detached Homes



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

A pie chart indicating end-use shares for the average all-electric home is shown in Figure 6.4. This shows the estimated end-use shares for homes if all appliances were electric.

FIGURE 6.4
Estimated End-Use Shares in All-Electric Single Family Detached Homes



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

End-Use Load Estimates for All Regional Single-Family Dwellings

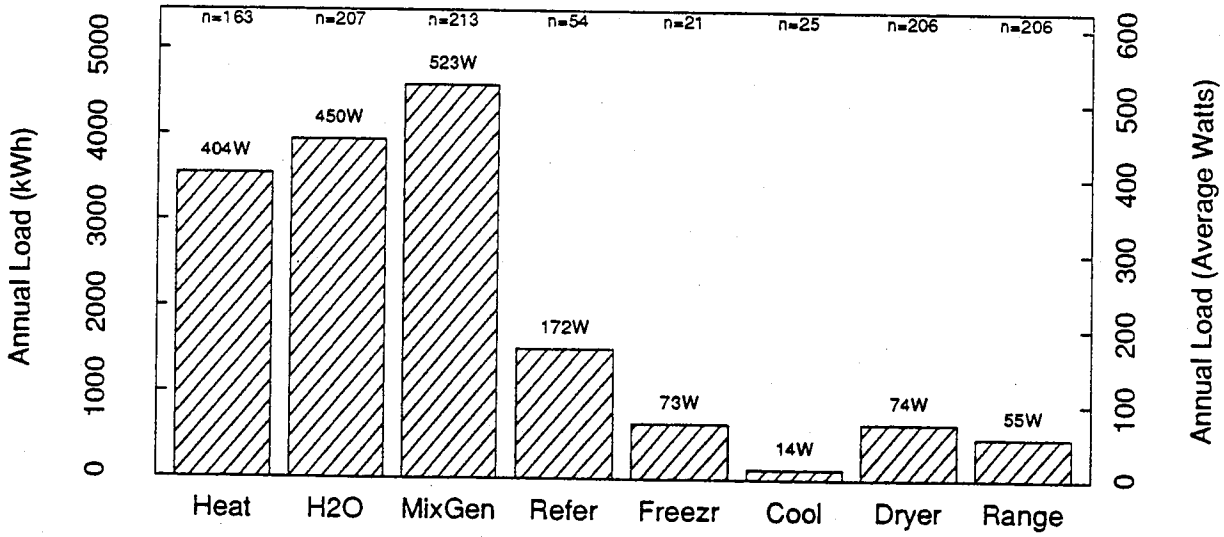
The end-use loads for average regional single-family homes can be applied in load forecasting. They provide estimates of electricity consumption where an average fraction of the appliances are electric for single-family homes. These estimates indicate the relative share of the electricity going to each end use in the region's single-family homes. This view of regional end-use loads indicates their relative size and hence the relative potential of conservation programs per percentage reduction in load.

Producing simple end-use estimates for all regional SFDs (including homes with gas and oil) is a simple extension of the process used to produce estimates for all-electric homes. The UECs are reduced by the fraction of homes that use fossil fuel for each end use. The appliance saturations for all the SFDs in the region are used (third column in

Table 6.2). All other end-use estimates are the same as shown in Figure 6.3 for all-electric homes. The resulting estimates are shown in Figure 6.5.

Note that the consumption of the region's electricity supply for heating is greatly reduced when the effect of regional use of fossil fuels is included. Hot water loads are also noticeably reduced. The contribution of electric heat to the regional load is actually slightly less than the contribution of the hot water load.

FIGURE 6.5
Estimated Electrical End-Use Consumption in
Average Regional Single Family Detached Homes

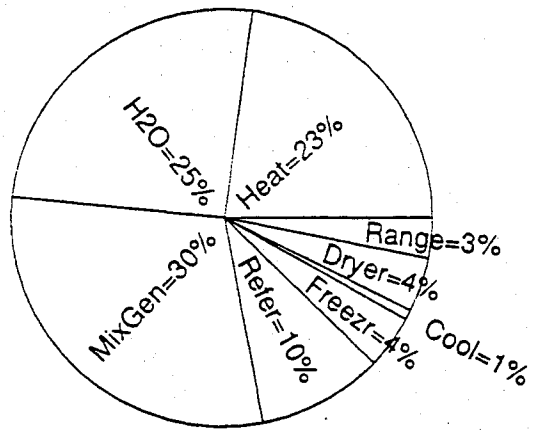


Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.6 is a pie chart indicating estimated end-use shares for all regional SFDs. This shows estimated end-use shares of the region's residential single-family electricity consumption. The mixed general load is seen to comprise a 30% share of the regional load for single-family dwellings when estimated from the Base Study. Hot Water and Heating loads comprise nearly equal shares: 25% and 23%

respectively. Refrigerators are estimated to consume 10% of the load. These figures indicate the relative size of end-use loads that are the targets of present or future conservation programs.

FIGURE 6.6
Estimated End-Use Shares of Regional Electricity
Supplied to Single Family Detached Homes



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

VARIABILITY IN ANNUAL END-USE LOADS

In Figure 6.7 and nearly all subsequent plots in this section, the end-use loads plotted are all normalized by (divided by) the mean UEC for the end-use in the Base Study homes. As noted previously, this has the convenient property of scaling loads from each end use to similar magnitudes, so that the variability of the smaller end uses is not masked by the scale required to plot the larger end uses. By definition, the mean load for any end use is thus indicated by a value of one on the y-axis. This normalization also serves to express the range of the distribution as a fraction of the mean load in box plots showing the distribution of annual end-use loads across homes.

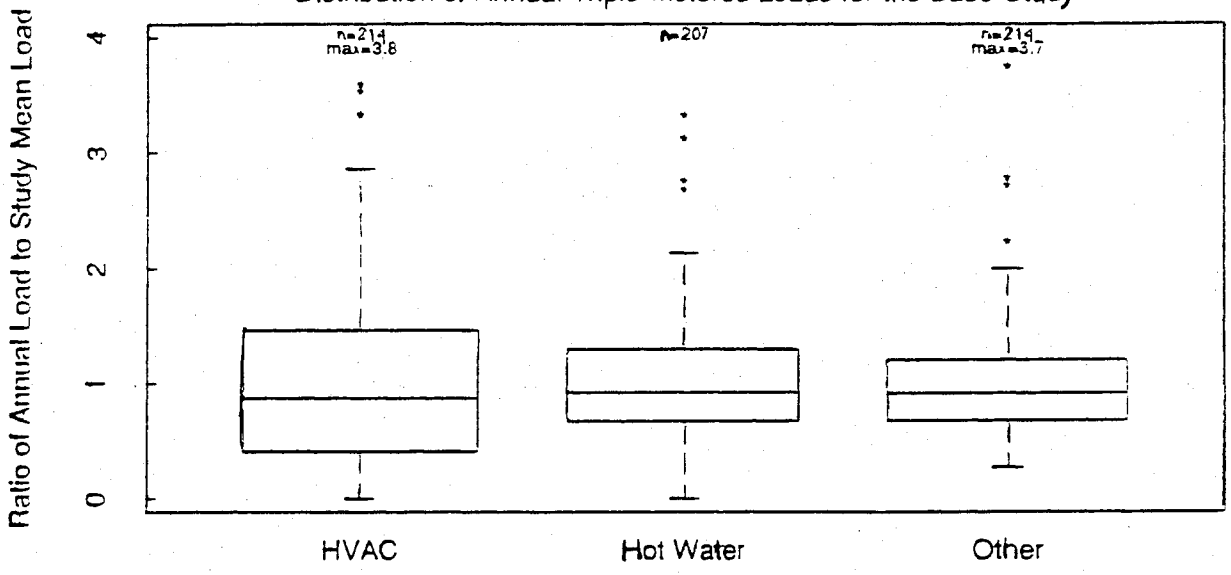
Dimensional (not normalized) loads can be extracted from normalized plots by simply multiplying the normalized load by the average annual UEC for the end use (from Figures 6.1 and 6.2).

Figure 6.7 is a box and whisker plot of the distribution of the triple-metered end-use categories (HVAC, Hot Water, and Other), normalized by (divided by) the mean annual load for each end-use category.

Box and whisker plots are useful for indicating the range of the loads across homes, and the degree to which these distributions are skewed (not distributed about the mean in the form of a normal distribution). The center line of each box indicates the median, and the lower and upper extent of the boxes indicate the range of the second and third quartiles. Thus, the box contains 50% of the values of the distribution. The whiskers extending above and below the box indicate the range of the upper and lower quartiles, up to a maximum of 1.5 times the inter-quartile range (the height of the box). Outliers outside this range are shown as individual points above or below the whiskers. Extreme outliers above 3.7 times the mean load are not plotted here, where they would reduce the scale and hence the usefulness of the plots. Instead, a maximum value is noted at the top of the plotting region for any outliers that have been truncated.

Figure 6.7 shows that the variability of loads for all the triple-metered end-use categories is very large, with loads ranging from zero to over three times the mean load in the Base Study homes. The variability is notably larger in proportion to the mean load for the HVAC than for the Hot Water or Other categories. Interestingly, the loads constituting the Other category have the lowest variability, where occupant behavior might be expected to dominate consumption and hence induce added variability. The end-use category Other may also have the lowest variability because it can include different appliances across households.

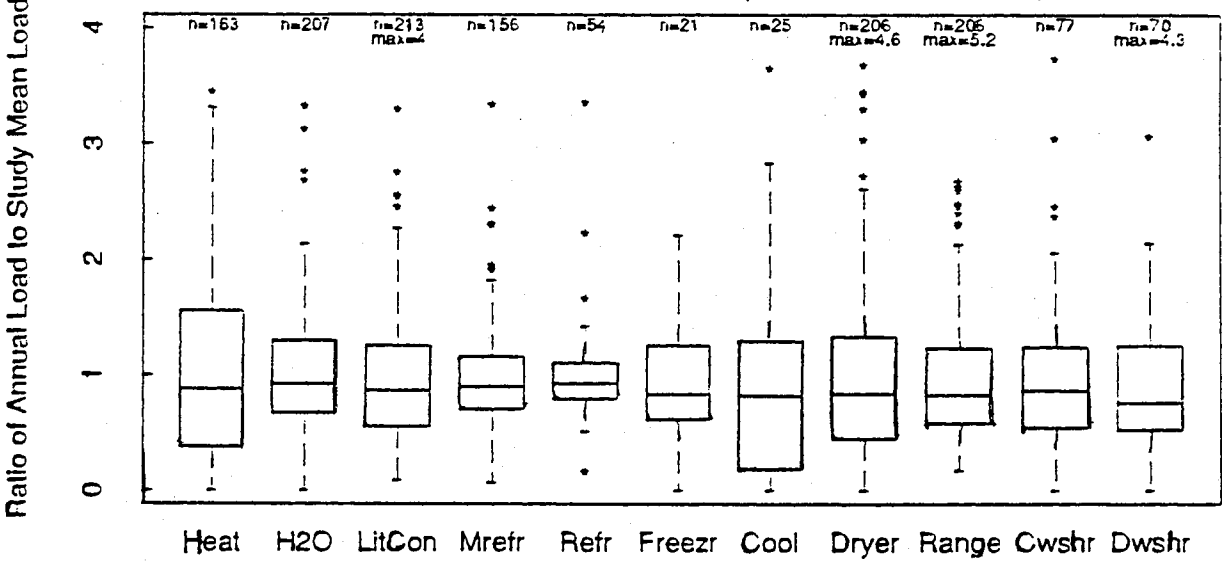
FIGURE 6.7
Distribution of Annual Triple-Metered Loads for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.8 is a box plot of the distributions for the individual ELCAP end uses. The relatively narrow ranges of the Refrigerator and Mixed Refrigerator end uses relative to all other end uses are notable. The probable cause for this narrow range of variability, observed in other work in progress, is that refrigerator loads are dominated by their standby load (steady-state heat gain from their surroundings) which does not vary much across refrigerators, and not by demand loads induced by occupant behavior through door openings and cooling of warm food. The dominance of the refrigerator standby load is therefore probably also the cause of the relatively low variability in the end-use category Other in Figure 6.7, since refrigerator loads comprise a large fraction of this load. It is also notable that the two space conditioning end uses (Heating and Cooling) in Figure 6.8 both show the highest variability, undoubtedly the result of both the broad range of physical heat loss characteristics of the houses and the thermostat behavior of the occupants.

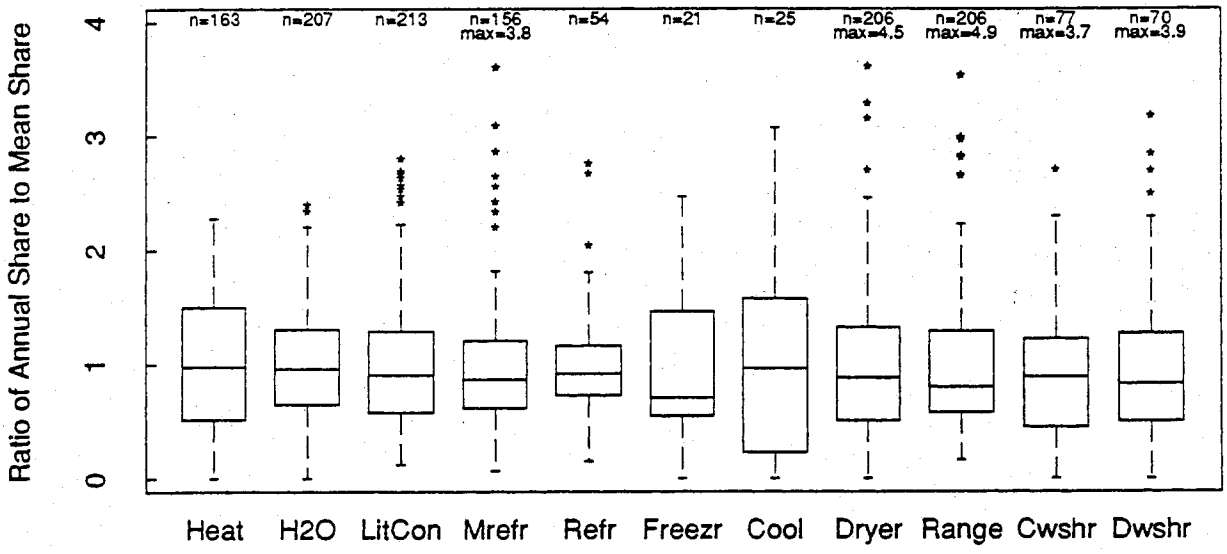
FIGURE 6.8
Distribution of Unit Energy Consumption for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.9 is a box plot of the distributions of the end-use shares for each household, normalized by the mean end-use share for homes in the Base Study. Comparison of these distributions with the distributions of loads in Figure 6.8 shows that the variability is not greatly reduced. The only exception is space heating, where reduced variability may be due solely to the fact that space heating is the largest component of the total load and therefore highly correlated with it. This suggests that load shares are of limited value in explaining variability, and that the relative magnitude of end-use loads within households tends to vary somewhat randomly rather than systematically.

FIGURE 6.9
Distribution of End-Use Shares for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Households that have high consumption for one end use may tend to be large energy consumers for other end uses as a result of family size, house size, or occupant income level and attitudes. All of these characteristics might be expected to correlate and therefore be reinforcing. (For example, large families tend to occupy large homes that require more heat, have less opportunity to close off rooms to save

heat, have more food to cook, more clothes and dishes to wash, take more baths, and may provide lights and entertainment to more people in more rooms. Thus every end use might be affected.) For this reason it might be easier to construct models predicting end-use shares (from utility bills) instead of absolute end-use loads. The potential usefulness of an end-use share model would be shown if the end-use shares across households showed less variability than the absolute loads. Traditionally, shares are used to disaggregate end-use loads from total loads. However, Figure 6.9 suggests that the best approach may be to model absolute loads for all end uses while investigating the value of modeling load share only for the Heating end use.

ANNUAL LOADS CATEGORIZED BY HOUSEHOLD CHARACTERISTICS

The extensive characteristics data associated with each home in ELCAP residential studies provides a means of examining which characteristics seem to most affect end-use loads. To obtain an early view of the influence of different characteristics, mean annual end-use loads for the three largest residential studies were computed based on dividing the homes in the studies into cells for one characteristic category at a time. The categories used were climate zone, number of occupants, household income, utility type, floor area and vintage of construction.

The climate zones are defined in Bonneville's Super Good Cents Technical Reference Manual, September 1987 as 4,000 to 6,000 heating degree days (Climate Zone 1), 6,000 to 8,000 heating degree days (Zone 2), and more than 8,000 degree days (Zone 3). (Climate Zone 3 contains areas of Montana that have over 10,000 heating degree days.) Annual heating degree days indicate severity of climate. Heating degree days, as determined by the National Weather Service, are the sum of the differences between 65° F and the average of the maximum and minimum outdoor temperatures for each day of the year. Therefore, heating loads

are generally expected to increase in proportion to the number of heating degree days, if housing and occupant characteristics are held constant.

The utility-type cells included homes served by private, by generating public, and by non-generating public utilities. Private utilities in the Pacific Northwest historically have higher electricity rates than do the public utilities. The public utilities with generating resources of their own tend to have somewhat higher prices than the non-generating public utilities, but not as high as the private utilities. Therefore any trend indicated by the annual means for each cell in the utility-type category can be an indicator of long-term price response.

Influence of Sample Size on Trends

The results of the one-dimensional categorizations are illustrated in Table 6.3 for the Lights/Convenience end use. (One-dimensional categorizations are the mean of cells differentiated by variations on only one characteristic.) Similar tables for each end use can be found in the end-use sourcebook in Section 7. Mean loads for each cell of the characteristics categories are shown in the table for four samples of single-family homes: the sample for the Base Study (representing existing single-family homes), two samples of new homes (the MCS and Control studies), and the union of all three studies. Although this discussion has been focused on the Base Study homes, the two new residential studies are the second and third largest in ELCAP and are used to illustrate the influence of sample size on the trends indicated by the categorizations.

Two important observations can be made regarding Table 6.3 that are generally valid for all end uses. First, the variability as indicated by the standard deviation is always at least half of the mean annual load. It ranges upward to values greater than the mean load for many end uses, even when categorized by the characteristics variables. This

indicates that none of these characteristics variables explains a high degree of the variability in the load.

The second observation is that relationships that intuitively might seem strong, such as the relationship of the Lights/Convenience loads with number of occupants, are often only weakly or not at all evident in the two smaller studies. This is principally the result of the high variability and small sample size in each cell of a characteristics category. Cell sizes of at least 15 to 20 appear necessary if the categorizations are to provide meaningful information. This suggests that applying simple case weights to the homes in the Base Study may not provide better regional estimates than do the simple average aggregations themselves. More sophisticated models are required to explain the variability in the Base Study and improve the regional load estimates made in this report.

TABLE 6.3

Lights/Convenience Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	213	4405	2764	21	2715	1297	56	3790	2032	290	4164	2594
Climate Zone 1	125	4155	2288	13	2518	836	35	3492	1817	173	3898	2168
Climate Zone 2	66	4612	3412	4	3745	2468	17	4382	2391	87	4527	3180
Climate Zone 3	22	5207	3001	4	2327	745	4	3876	2185	30	4646	2852
Occupants=1	9	2040	1149	1	2163	0	2	3063	946	12	2221	1094
Occupants=2	85	3454	2148	7	2321	777	14	2979	1588	106	3316	2033
Occupants=3	32	4625	2561	3	1465	591	7	4760	1911	42	4422	2491
Occupants=4	48	4995	2159	3	3846	1603	7	3970	1625	58	4812	2092
Occupants>4	28	6721	3882	1	6027	0	5	4684	2309	34	6401	3876
Income<8K	8	2689	1221	0	-	-	1	2938	0	9	2717	1145
Income=8-16K	26	3851	2622	1	1135	0	1	1576	0	28	3673	2608
Income=16-25K	40	3796	2986	1	3285	0	7	3234	1382	48	3703	2772
Income=25-35K	48	4569	2664	8	2956	1177	12	3971	2083	68	4274	2474
Income=35-60K	57	5149	2881	3	3223	2509	13	4039	1918	73	4872	2747
Income>60K	13	4164	1987	1	1516	0	1	5045	0	15	3995	1978
Invest_Own_Util	69	4147	2270	10	2549	1419	31	4028	2178	110	3968	2212
Pub_Gen_Util	32	4590	3513	7	2758	742	10	3045	808	49	4013	2968
Pub_Nongen_Util	110	4502	2839	4	3053	1957	11	3331	2229	125	4352	2783
Size<850 sqft	32	2873	1644	1	5669	0	1	1576	0	34	2917	1681
Size<1350 sqft	65	3599	2179	13	2517	854	25	3010	1404	103	3320	1919
Size<2100 sqft	75	4700	2545	6	2676	1769	17	4010	2049	98	4456	2464
Size>2475 sqft	31	6262	3713	0	-	-	9	5517	2145	40	6095	3413
Pre-1940	32	4770	3960	0	-	-	0	-	-	32	4770	3960
1940-1950	15	2422	1346	0	-	-	0	-	-	15	2422	1346
1950-1960	22	3766	2693	0	-	-	0	-	-	22	3766	2693
1960-1970	34	4783	2699	0	-	-	0	-	-	34	4783	2699
1970-1978	70	4525	2512	0	-	-	0	-	-	70	4525	2512
Post-1978	30	4581	1965	21	2715	1297	56	3790	2032	107	3801	1965

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Typical Trends Illustrated for the Base Study

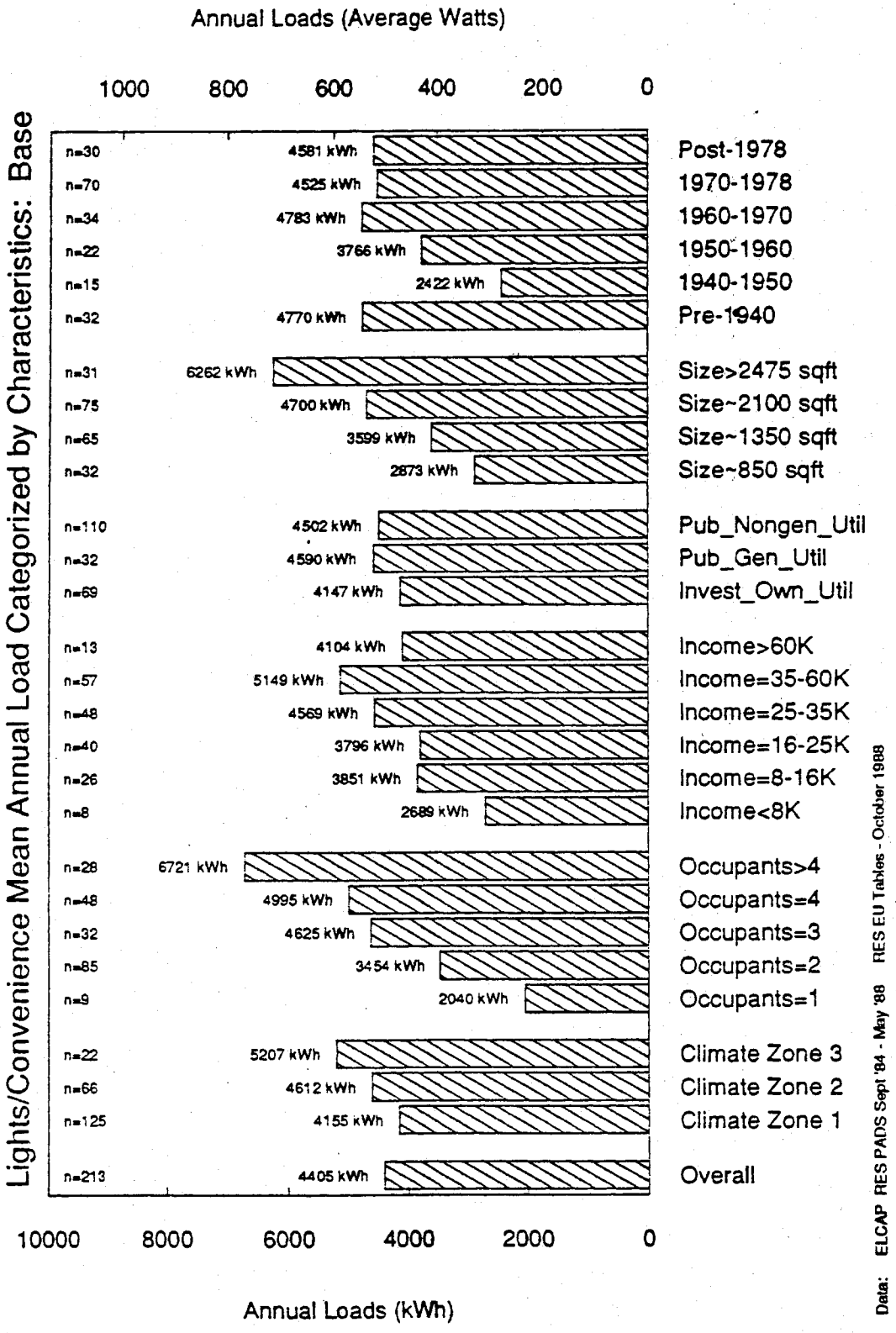
Plots of the mean annual loads of the Base Study sample categorized by the characteristics variables for the Lights/Convenience and Heating end uses are shown in Figures 6.10 and 6.11. These figures illustrate the type of conclusions that can be drawn using one- dimensional categories. The figures are plots of the Base Study cell means from tables like Table 6.3. (Similar plots for the Base Study for each end use are in the end-use sourcebook in Section 7.)

The Lights/Convenience end use in Figure 6.10 shows several expected relationships similar to those found for many end uses. There is a strong relationship of Lights/Convenience to the number of occupants and house size, and to a lesser extent to income. It appears likely that, as expected, more occupants use more energy, larger houses have more appliances to use and rooms to light and heat, occupants with higher incomes have more money to spend on discretionary energy uses, and all three of these characteristics tend to be cross-correlated.

Households served by private utilities show somewhat lower consumption than those served by public generating and public non-generating utilities, as would be expected from normal response to their higher electricity prices. Lower consumption is generally seen across end uses. The strong relationship of Lights/Convenience loads across climate zones is perhaps explained by a longer season and increased levels of indoor activity in colder climates.

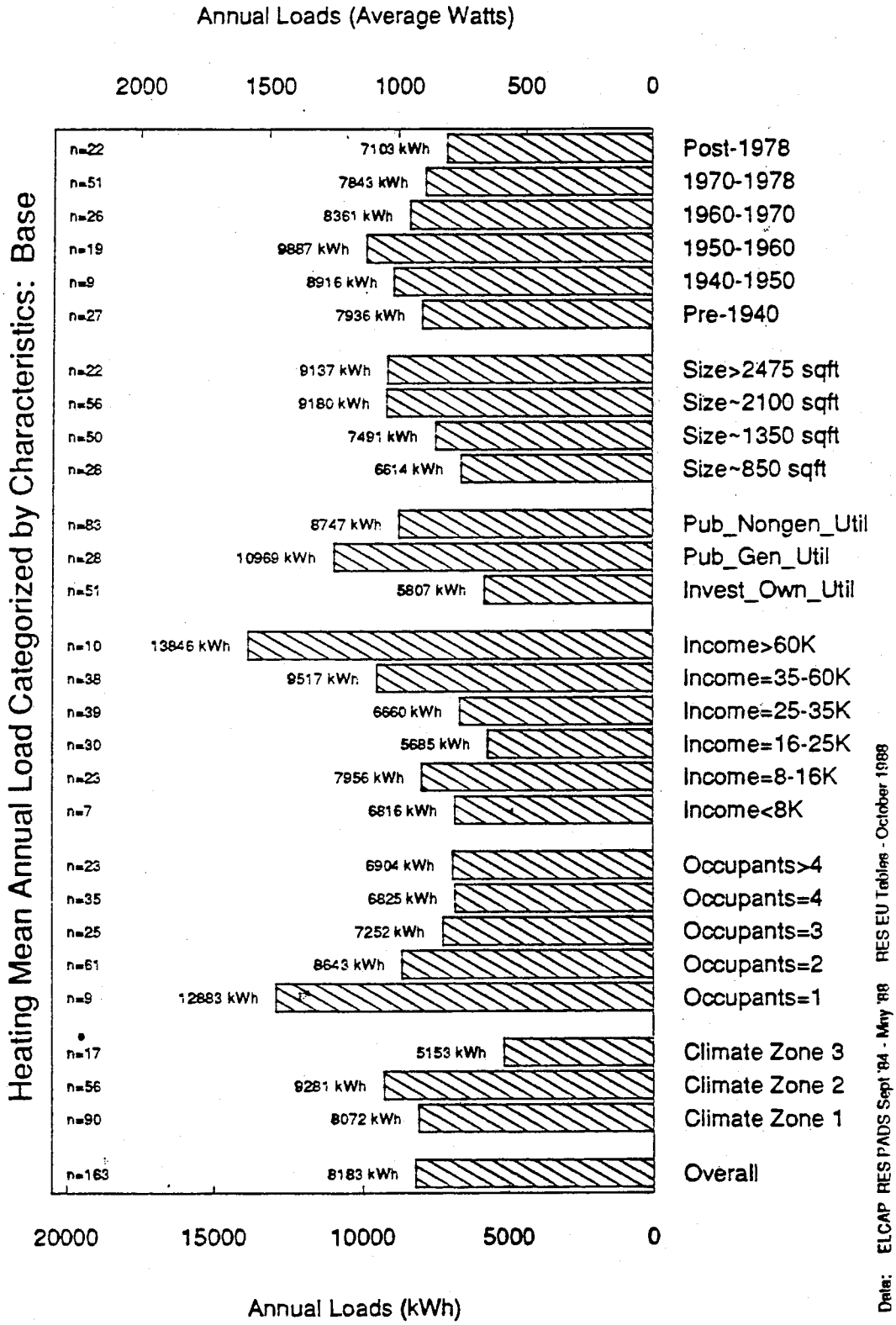
The annual heating loads split by characteristics variables shown in Figure 6.11 illustrate how one-dimensional characteristics categorizations can produce misleading results that confound expectations. The trends with income, floor area and number of occupants are as expected. The number of occupants is a driver for the level of internal heat gains from the lights and conveniences appliances, thereby displacing heating requirements. On the other hand, loads dramatically decrease in the coldest climate zone where the

FIGURE 6.10



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 6.11


Heating Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
2000
1500
1000
500
0
n=22 7103 kWh Post-1978
n=51 7843 kWh 1970-1978
n=26 8361 kWh 1960-1970
n=19 9887 kWh 1950-1960
n=9 8916 kWh 1940-1950
n=27 7936 kWh Pre-1940
n=22 9137 kWh Size>2475 sqft
n=56 9180 kWh Size~2100 sqft
n=50 7491 kWh Size~1350 sqft
n=26 6614 kWh Size~850 sqft
n=83 8747 kWh Pub_Nongen_Util
n=28 10969 kWh Pub_Gen_Util
n=51 5807 kWh Invest_Own_Util
n=10 13846 kWh Income>60K
n=38 9517 kWh Income=35-60K
n=39 6660 kWh Income=25-35K
n=30 5685 kWh Income=16-25K
n=23 7956 kWh Income=8-16K
n=7 6816 kWh Income<8K
n=23 6904 kWh Occupants>4
n=35 6825 kWh Occupants=4
n=25 7252 kWh Occupants=3
n=61 8643 kWh Occupants=2
n=9 12883 kWh Occupants=1
n=17 5153 kWh Climate Zone 3
n=56 9281 kWh Climate Zone 2
n=90 8072 kWh Climate Zone 1
n=163 8183 kWh Overall
20000
15000
10000
5000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

largest loads would be expected. Similarly, heating loads do not consistently decrease across the cells of the vintage category, as might be expected due to better insulation.

Such confounding results are produced by the high degree of correlation between the important explanatory variables. For example, newer homes are larger than older homes, tending to offset their much higher insulation levels. Homes in the colder climate zone tend to be better insulated and have a much higher penetration of wood stoves. The effects of climate zone and vintage on insulation levels are verified to have the expected result on Heating loads, based on a thermal analysis of the Base Study homes (in progress) in which weather, size, insulation levels, vacancies, wood stove use and internal temperatures are all carefully controlled.

The results of the one-dimensional categorizations of end-use loads have led to the exploratory development of physical/demographic models of end-use loads that control for the correlation between explanatory variables. Such models can be used for comparisons with forecasting and conditional-demand models commonly used in regional planning.

SEASONAL VARIATION OF END-USE LOADS

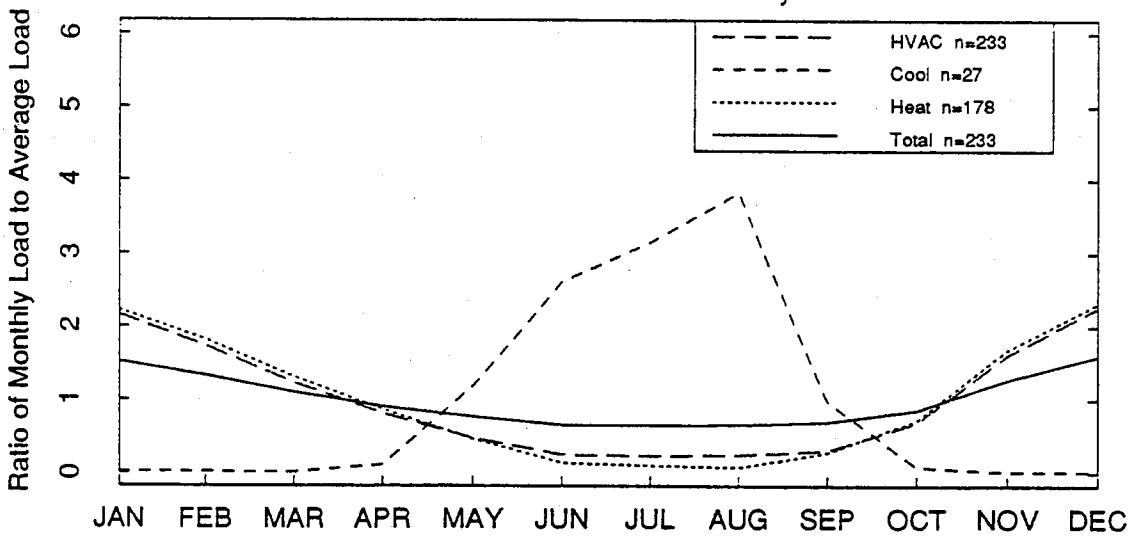
Seasonal loads are becoming increasingly important for regional resource planning. All end-use loads show a remarkable degree of seasonal variation, although the absolute magnitude of the variation of the smaller end uses tends to be overshadowed by the large seasonal swing in space conditioning loads.

The ratio of an end use's largest monthly load to its mean annual load provides a good measure of the degree to which an end use varies seasonally. This process is identical to that of normalizing used in the previous plots: both are scaled to a common level for the purpose of comparison. In this case, if the ratio is high, the end use varies

strongly according to season. If the ratio is low, season does not have a lot of influence on the end-use load.

Figure 6.12 shows the monthly variation in the mean loads for the Total, HVAC, Heating and Cooling end uses. The Total load varies by almost 50% from the mean while HVAC and Heating loads each vary by over 100%. The Heating end use in the summer is significant and consists primarily of heating on cool days by homes in western regions of Oregon and Washington. The Cooling end use shows the highest ratio: four times the annual mean. A ratio this large means that the Cooling end use load is highly variable according to season. This is due to the very short cooling season in the region.

FIGURE 6.12
Seasonal Variation of Total, Heating, Cooling and HVAC Loads for the Base Study



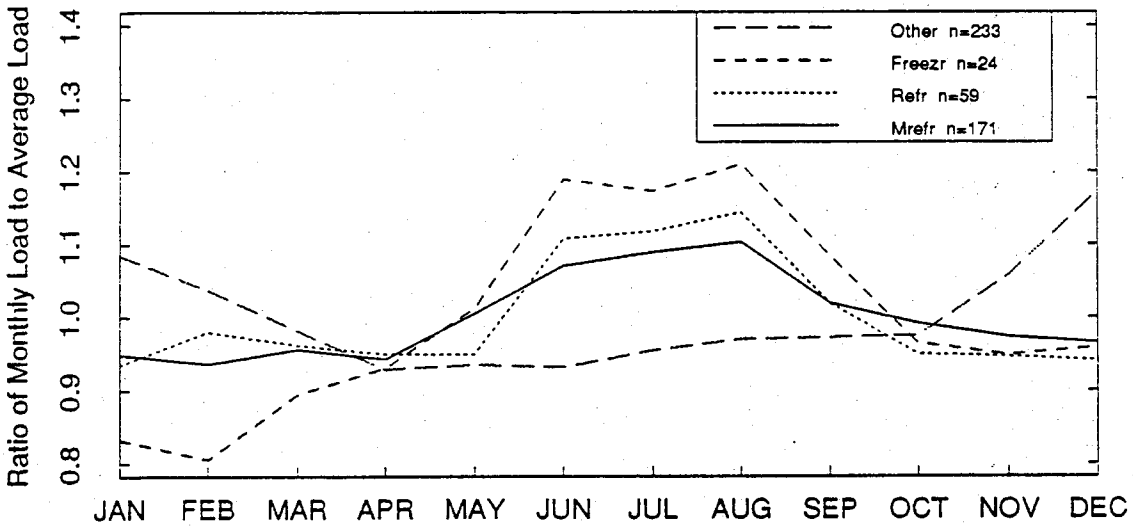
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.13 shows the degree to which food storage end uses (Freezer, Refrigerator, and Mixed Refrigerator) are high in the summer, as contrasted with the Other end-use category that peaks in the winter

months. The ratio of largest monthly load to mean annual load for the Refrigerator end use is 1.12 while the ratio for the Freezer end use load is 1.2. The maximum monthly load for each end use occurs in August. A strong relationship to indoor temperatures is suggested, as expected due to increased heat gains.

FIGURE 6.13

Seasonal Variation of Refrigerator, Mixed Refrigerator, Freezer and 'Other' Loads for the Base Study

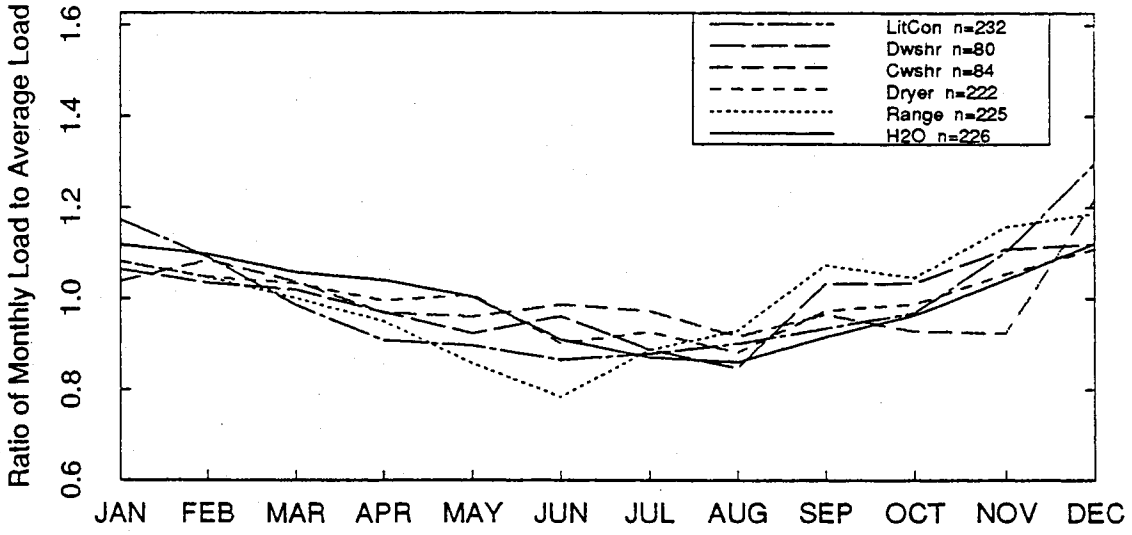


Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

The ratios of largest monthly loads to mean annual load for the remaining end uses are plotted in Figure 6.14. These loads can be thought of as related to sanitation (Hot Water, Dryer, Dishwasher, Clothes Washer), food preparation (Range), and general indoor activity (Lights/Convenience). These curves show a remarkable degree of similarity: all have ratios from 1.1 to 1.3 and all have very high loads in December (most notably Lights/Convenience and Clothes Washers). Water heating undoubtedly tracks the seasonal variation in the temperature of water entering the house, as well as changing usage patterns. The number of holidays and vacation days taken in December probably explains the unusual loads in this month.

FIGURE 6.14

Seasonal Variation of Hot Water, Range, Dryer, Clothes Washer, Dishwasher, and Lights and Convenience Loads for the Base Study



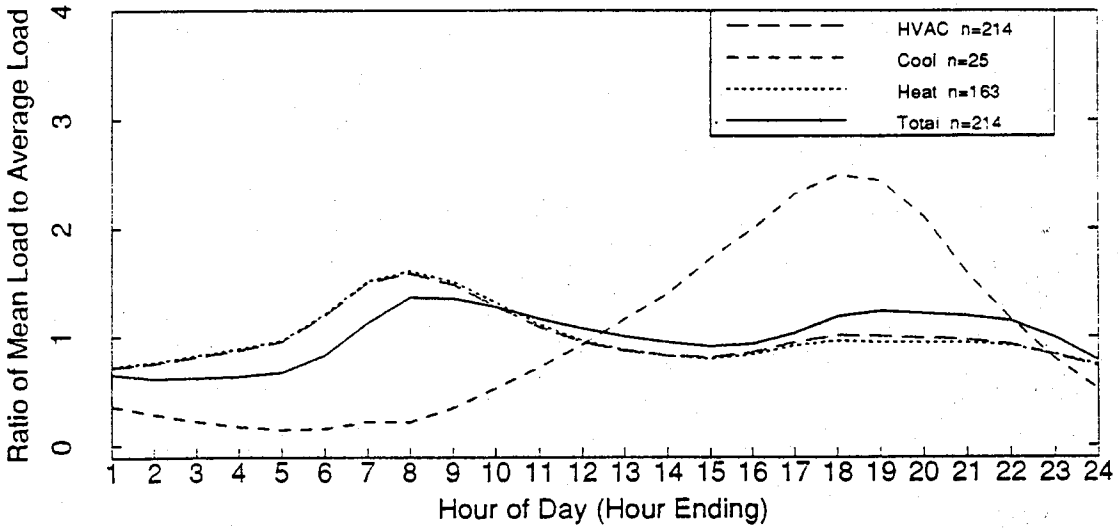
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

AVERAGE HOURLY END-USE LOAD SHAPES

Figures 6.15-6.18 illustrate hourly load shapes for end uses, grouped in the same way as the monthly load variations. Again, all loads are normalized by the mean Base Study UECs presented earlier, to highlight the load shapes and allow comparisons of shapes across end uses. The peak of each curve is the load factor for the average annual end-use load shape (the peak of the average load shape is divided by the average annual load).

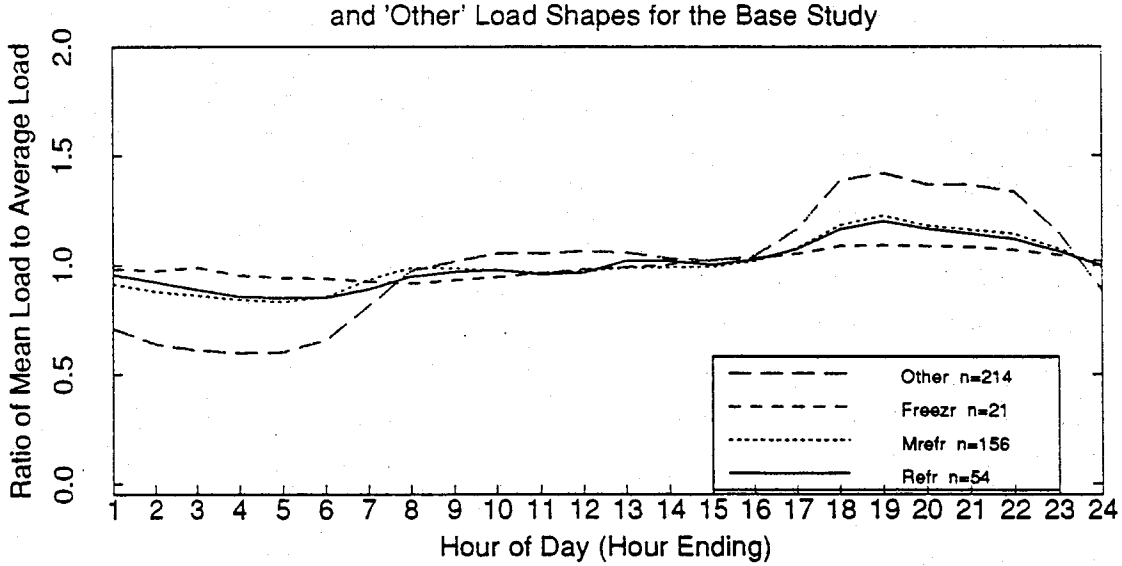
As discussed in Section 5, it should be noted that average hourly profiles do not represent actual end-use loads. Rather they represent a long-term average load for each hour (literally an energy-weighted probability distribution of the load's occurrence at any given hour), as illustrated in Figure 5.1.

FIGURE 6.15
Mean Annual Total, Heating, Cooling and HVAC
Load Shapes for the Base Study



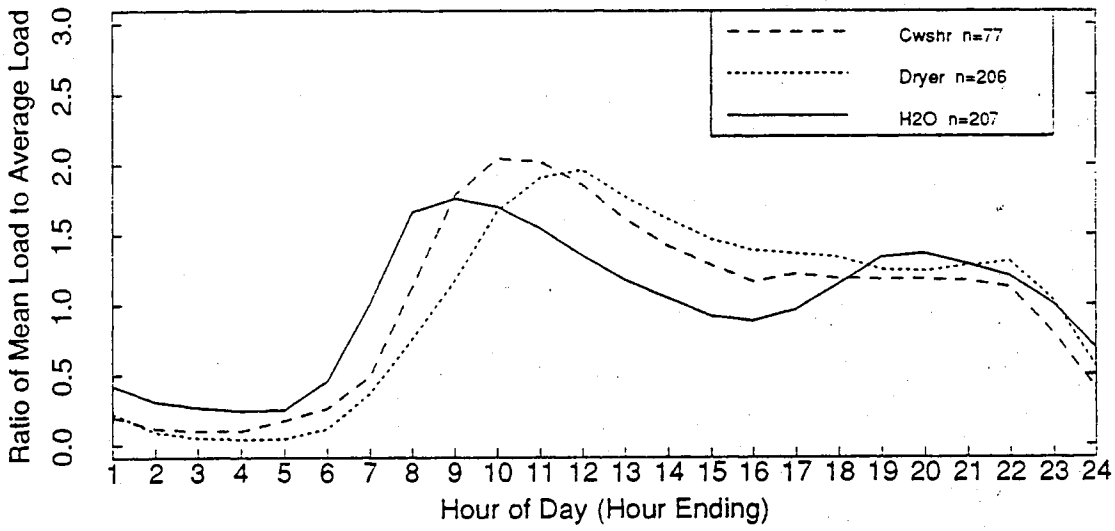
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 6.16
Mean Annual Refrigerator, Mixed Refrigerator, Freezer
and 'Other' Load Shapes for the Base Study



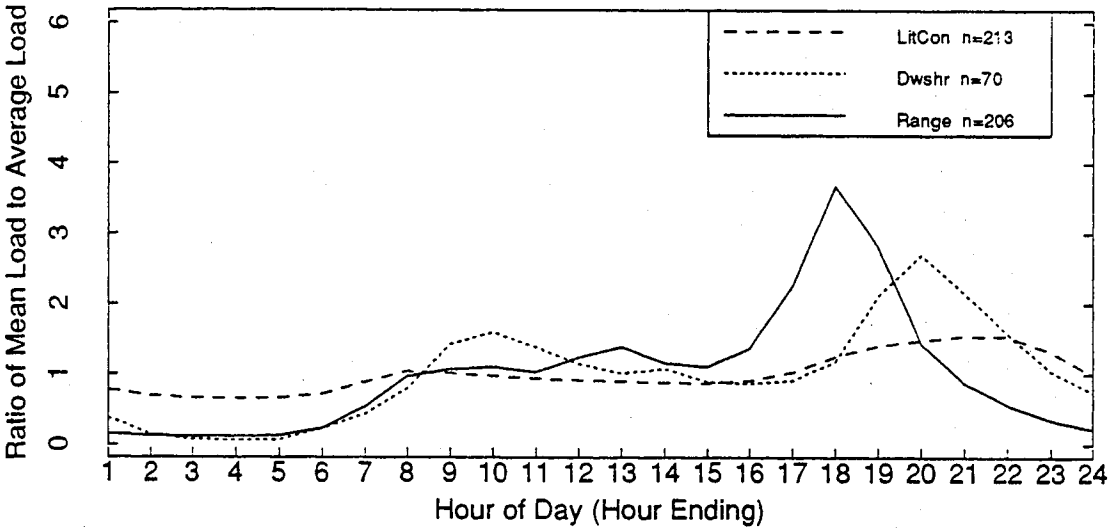
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 6.17
Mean Annual Hot Water, Dryer and Clothes Washer
Load Shapes for the Base Study



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 6.18
Mean Annual Range, Dishwasher, and Lights and Convenience
Load Shapes for the Base Study

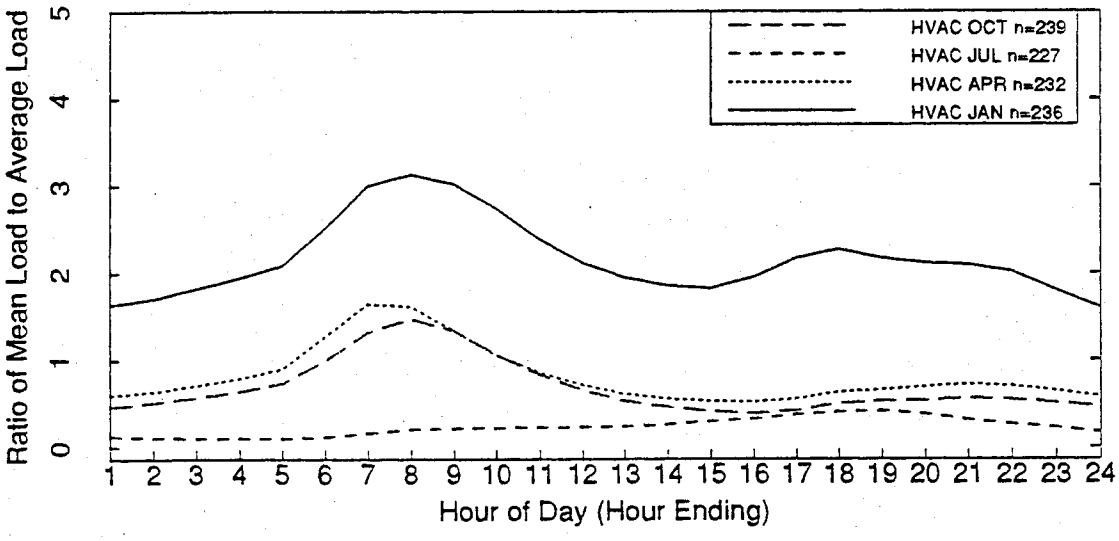


Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

There are no surprises in these load shapes, except perhaps for the relatively high Lights/Convenience load in the early morning hours (70% of the mean) in Figure 6.17. Figure 6.17 also shows the hot water peak to be higher in the morning than in the evening.

Figure 6.19 shows HVAC load shapes for four months, representing the end use for which the seasonal variation in load shape is the greatest. The strong dual peak in the January HVAC shape results from warm-up loads from nighttime thermostat setbacks and an evening peak that may be associated with warm-up loads upon returning from work or other daytime activities.

FIGURE 6.19
Seasonal HVAC Load Shapes for the Base Study

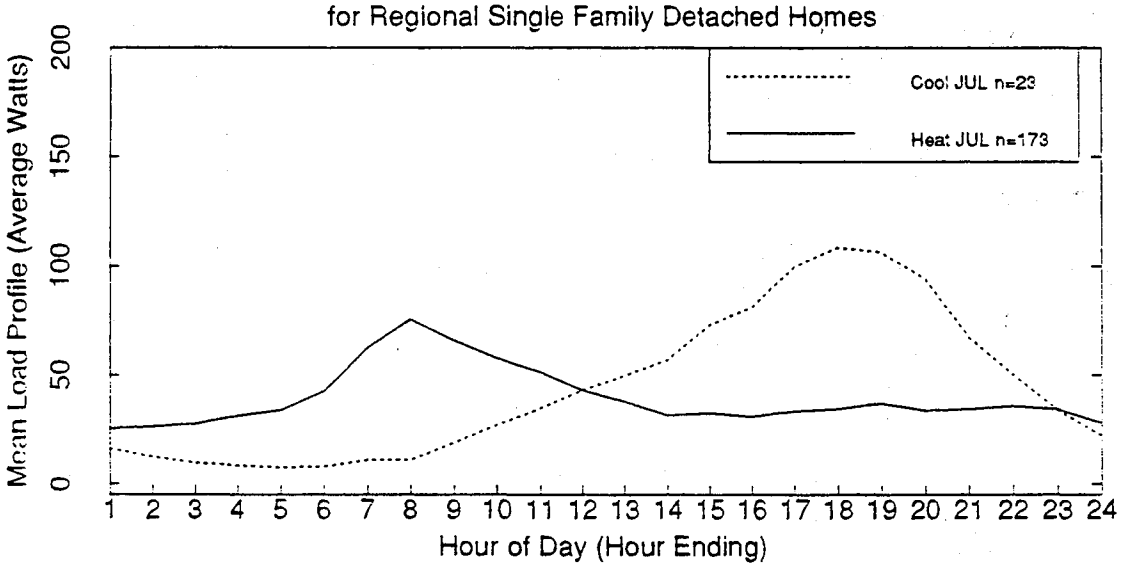


Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

Figure 6.20 shows the degree to which heating and cooling are contributing to the regional summer HVAC loads in single-family homes. The Heating and Cooling end-use load shapes are weighted by their respective regional all-electric appliance saturations (column 4 of Table 6.2). As can be seen, regional summer heating loads are estimated to be roughly the same magnitude as cooling loads, probably due to the predominance of the Base Study (and regional) homes located in the cool areas west of the Cascade Mountains.

FIGURE 6.20

Estimated July Heating and Cooling Load Shapes
for Regional Single Family Detached Homes



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

SECTION 7 – SOURCEBOOK OF RESIDENTIAL ENERGY USE INFORMATION

This section provides 12 sets of plots, or figures, and one table of average aggregations summarizing each end-use load for six residential studies (Base, Gas/Oil, Renter, Manufactured, MCS, and Control). The organization of the figures is listed in Table 7.1. Table 4.1 in Section 4 provides a more detailed description of each end use. Direct scales of consumption levels are used in these plots instead of normalized scales, scaling to a common level, as used in Section 6 when focusing on end-use comparisons. In this section the focus is more on the different residential studies. There is not as much concern about the larger loads overshadowing the smaller loads because all plots are for a single end use and so the scales are similar.

Section 3 of this report has a more detailed discussion of how the seven residential studies (the Base Study, four case studies and two New Residential studies) are defined and how the samples of metered homes were selected. Briefly, the Base Study sample, by far the largest, contains single-family, detached, owner-occupied, site-built homes with permanent electric space heating equipment (PESHE). The homes in the Renter, Manufactured, and Gas/Oil case studies are much smaller samples designed to illustrate differences from the Base Study homes and test hypotheses about the nature of their end-use loads compared to the Base Study. The Base Study homes and those in the Case studies represent existing residences as of 1983. The New Residential studies, on the other hand, are newly constructed residences most of which are MCS and Control homes built as part of the RSDP.

TABLE 7.1

END USE SUMMARIES IN THE DATA SOURCEBOOK

Figures	End-Use Description
7A.1 - 7A.12	Total
7B.1 - 7B.12	Hot Water
7C.1 - 7C.12	HVAC (Heating + Air Conditioning + Heat Pumps)
7D.1 - 7D.12	Heating
7E.1 - 7E.12	Cooling
7F.1 - 7F.12	Other (Total - HVAC - Hot Water)
7G.1 - 7G.12	Lights/Convenience (plug and light circuits not dedicated to any other end use)
7H.1 - 7H.12	Refrigerator
7I.1 - 7I.12	Mixed Refrigerator (plug circuits with the primary refrigerator as a major load)
7J.1 - 7J.12	Freezer
7K.1 - 7K.12	Range (stove, cooktop, or oven)
7L.1 - 7L.12	Dryer
7M.1 - 7M.12	Clothes Washer
7N.1 - 7N.12	Dishwasher

The plots and tables summarizing each end use (A-N in Table 7.1) are listed in Table 7.2. Organizing the sourcebook by end use does not easily facilitate comparisons of one end use to another. Because end-use loads vary in magnitude to such a large degree, it is not generally possible to plot different end uses on the same scale with any useful resolution. The detail in smaller end-use loads is simply masked by the larger end uses. Comparisons across end uses can be made by comparing corresponding plots of the same time aggregation (annual or monthly loads or load shares) for the end uses, being careful to note any changes to the y-axis scales. (By normalizing each end-use load by its annual mean, comparisons of loads across end uses can be effectively illustrated as is done for the Base Study summary in Section 6.) A footnote at the bottom of each plot indicates the data set and the corresponding aggregations used to develop the summaries. This allows identification of the specific end-use report from which plots or tables may be extracted. (Subsequent updated versions of this report are planned).

TABLE 7.2

LIST OF SUMMARY PLOTS AND TABLES FOR EACH END USE IN THE SOURCEBOOK

Figure 1	Mean Annual Loads (for each residential study)
Figure 2	Annual Usage Distributions (cumulative percentiles, for each residential study)
Figure 3	Monthly Loads (for each residential study)
Figure 4	Monthly Standard Deviations (for each residential study)
Figure 5	Monthly Usage Distributions for the Base Study (box plots)
Figure 6	Annual Load Profiles (for each residential study)
Figures 7a-7f	Annual Weekday/Weekend Load Profiles (for each study)
Figures 8a-8d	Monthly Load Profiles (plotted for each residential study January, April, July and October)
Figures 9a-9f	Monthly Load Profiles (plotted for January, April, July and October for each residential study)
Figures 10a-10f	January and July Weekday and Weekend Load Profiles (for each study)
Figure 11	Mean Annual Loads Categorized by Characteristics for the Base Study
Figure 12	Mean Annual Load Distribution Categorized by Characteristics for the Base Study (box plots)
Table 1	Mean Annual Loads and Standard Deviations Categorized by Characteristics for the Base, MCS, and Control Studies

The first plot, Figure 1 for each end use (A-N), is a bar chart of the mean annual load for each ELCAP residential sample. These plots illustrate the relative magnitudes of end-use loads across the residential studies. The left vertical axis shows a kilowatt-hour (kWh) scale; the right vertical axis indicates the same scale of values in average watts. Average watts, used in all these plots, are simply the average consumption per hour over the time period of an aggregation. For example, a load of 1000 average watts for each of the 8,760 hours in a year is equivalent to 8,760 kWh. By using units of average watts, the analyst builds intuition about relative sizes of loads instead of trying to keep in mind what is large or small for an hourly, daily, monthly and annual load for each end use. Average watts are also useful for creating normalized loads. Each bar in the plot has at its top the corresponding mean annual kWh load value for the study. Above this value, at the very top of the plot area, are sample sizes (n) indicating the number of sites averaged to obtain the end-use load summary for each study.

Figure 2 for each end use is a line plot indicating the percentage of homes in each study that have an annual usage at or below a certain value. For example, the median load for each sample is indicated by the value of its cumulative distribution at the 50th percentile mark on the x-axis. These plots are similar in function to box plots (see description of Figure 5) but indicate the full detail of the distribution rather than only the quartiles. They are useful for comparing the degree of variability of the end use in each study, and for illustrating how many homes are near the center or the edges of the distribution. The left and right vertical axes show usage values in kWh and average watts, respectively. The legend in this plot also indicates the number of homes (n), mean power consumption (in kWh) and standard deviation of each sample.

Figure 3 for each end use shows the mean monthly usage of each study as an annual profile. These plots show how much loads vary by time of year (are "seasonal"). As in previous plots, the left and right axes show usage values in kWh and average watts, respectively. The number of homes in each sample (n) is indicated in the legend.

Figure 4 for each end use shows the standard deviation of the distribution of monthly loads for each study. Thus these plots show the degree to which end-use loads vary across sites, as a function of time of year, and also the degree to which the variability changes across the studies. Each sample's size (n) is again shown in the legend.

A box and whisker plot is used in Figure 5 for each end use to show, for the Base Study only, the distribution of monthly loads within the sample. These plots are useful in indicating the range of the loads across homes for each month, and the degree to which these distributions are skewed (not distributed according to a normal distribution). The center line of each box indicates the median, and the upper and lower extent of the boxes indicate the 1st and 3rd quartiles. The whiskers extending above and below the box indicate the range of the upper and lower quartiles up to a maximum of 1.5 times the inter-quartile range. Outliers outside the range are shown as individual points above or below the plot.

Dual axes showing kWh and average watts are again used and the number of homes with good data used for a particular monthly value (n) is indicated at the top of the plotting region. Extreme outliers are not plotted where they would radically reduce the scale of the boxes. Instead, a maximum outlier value is noted at the top of the plotting region. Usually only one or two outliers, if any, are truncated in these plots. The mean load for each category is indicated by the small "+" superimposed on the boxes.

Figure 6 for each end use is the mean annual load profile (24-hour load shape) for each study in average kilowatts (left vertical axis) and average watts (right vertical axis). Sample size (n) is again shown in the legend. These plots allow comparisons of the annual average load hourly shape for end uses for each of the studies.

Figure 7 for each end use shows the mean annual load profiles for weekends and weekdays for the Base Study. The units are average

kilowatts (left vertical axis) and average watts (right vertical axis), and sample size (n) is shown in the legend. These plots are useful for examining the effect of daytype on end-use loads.

Figures 8a through 8d are monthly load profiles of each study for a representative month in each season of the year. The four plots are for January, April, July and October. These plots indicate the degree to which seasonal load shapes are affected by the characteristics differentiating the studies. Average kilowatt and watt values and sample sizes (n) are the same as for Figure 6.

Each of the next six figures (9a - 9f) depicts the monthly load profiles for each of the four representative months for one of the six residential studies. These plots indicate the degree to which load shapes are seasonal within each of the studies. The left vertical axis is in units of average kilowatt values, the right axis in units of average watts, and the sample size (n) is noted in the legend.

For each end use, the six figures Figure 10a-10f compare weekday and weekend profiles for a winter month (January) and a summer month (July) for one of the seven residential studies. These plots are useful for examination of how the daytype affects load shapes seasonally. Again, the left vertical axis is in units of average kilowatts, the right axis is in units of average watts, and the sample size (n) is noted in the legend.

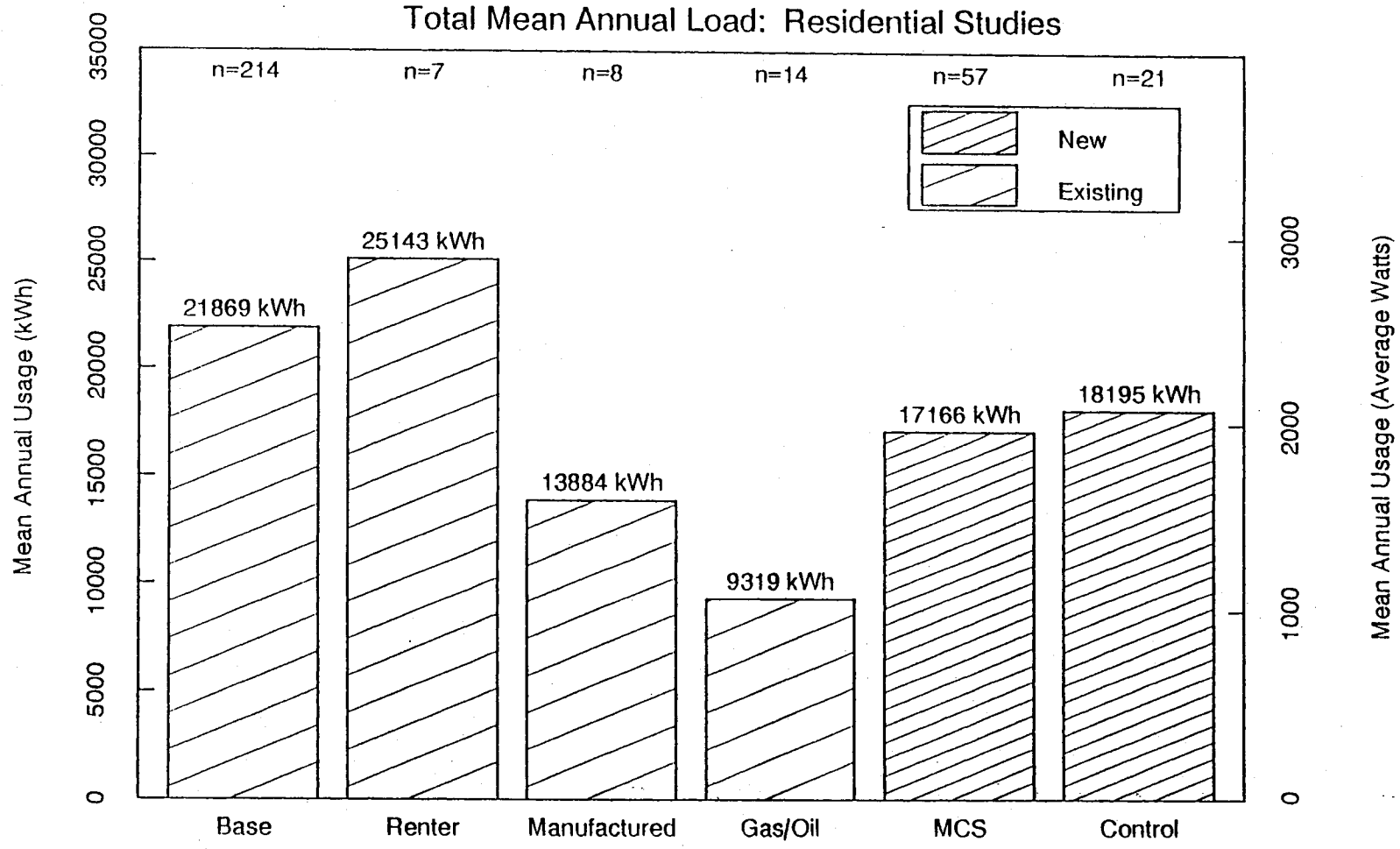
Figure 11 for each end use is a bar chart that shows the mean annual load of the Base Study for homes categorized by the selected demographic variables: climate, occupant number, household income, utility type, home size and age of home. Also included is an overall mean value for the study. These plots are useful for examining general trends of load size with respect to characteristics, as indicated by mean loads. Note that each bar represents the average load for homes with the indicated characteristic, but does <u>not</u> control for any bias in the characteristics of those homes with respect to any of the other demographic variables. Thus there may be cross-correlations in the trends indicated by the

pattern of mean loads for the categories of any particular variable. For example, newer homes may also tend to be larger. Above each bar is a mean annual load value and the category sample size (n). The left vertical axis is again scaled in kWh, and the right axis in average watts.

Figure 12 for each end use is a box plot that shows the distribution of loads for the Base Study for homes categorized by the same demographic variables used in Figure 11. These plots show the range of loads in each category of home, indicating the degree to which the difference in the mean loads illustrated in Figure 11 are overshadowed by the overall variability in the end-use loads. Again, the left vertical axis is scaled in kWh, the right axis in average watts, and sample sizes (n) are shown at the top of the plotting region. As in Figure 5, extreme outliers are not plotted, but the maximum outlier value for each box is noted at the top. Usually only one or two outliers, if any, are truncated in this manner. The mean load for each category is indicated by the small "+" superimposed on the boxes.

Table 1 for each end use shows the sample size (n), mean annual load (kWh), and the standard deviation of the three largest studies when categorized by the same demographics as those used in Figure 11. The four sets of columns are for the Base, Control, and MCS studies, and the union of these three studies. These tables indicate trends in mean loads as a function of characteristics variables for two additional studies, and also are particularly useful for examining how smaller sample sizes degrade the indication of trends in mean loads. Notations at the bottom of the table indicate the sources of the metered end-use data and the characteristics information used for the splits.

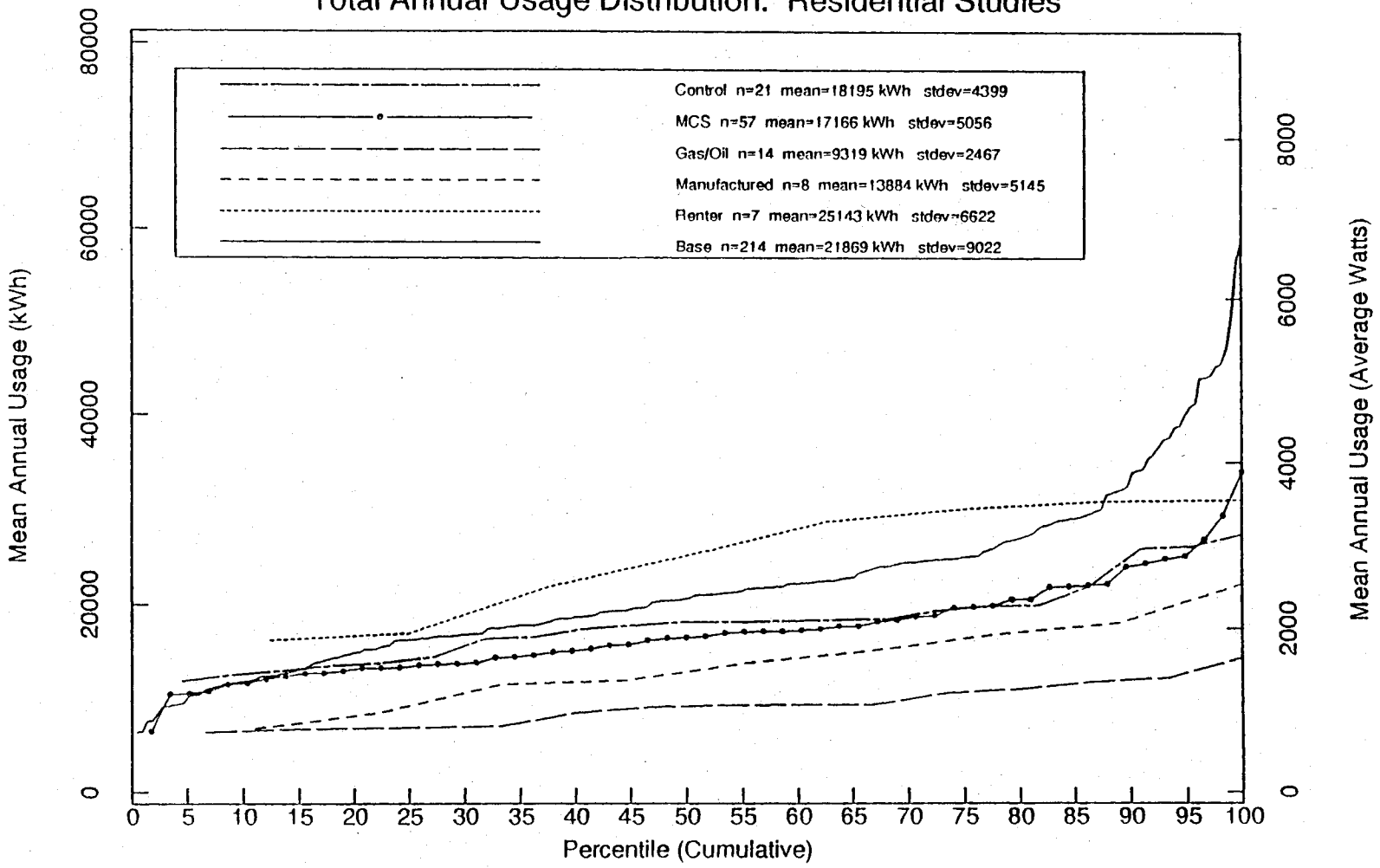
FIGURE 7A.1



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.2

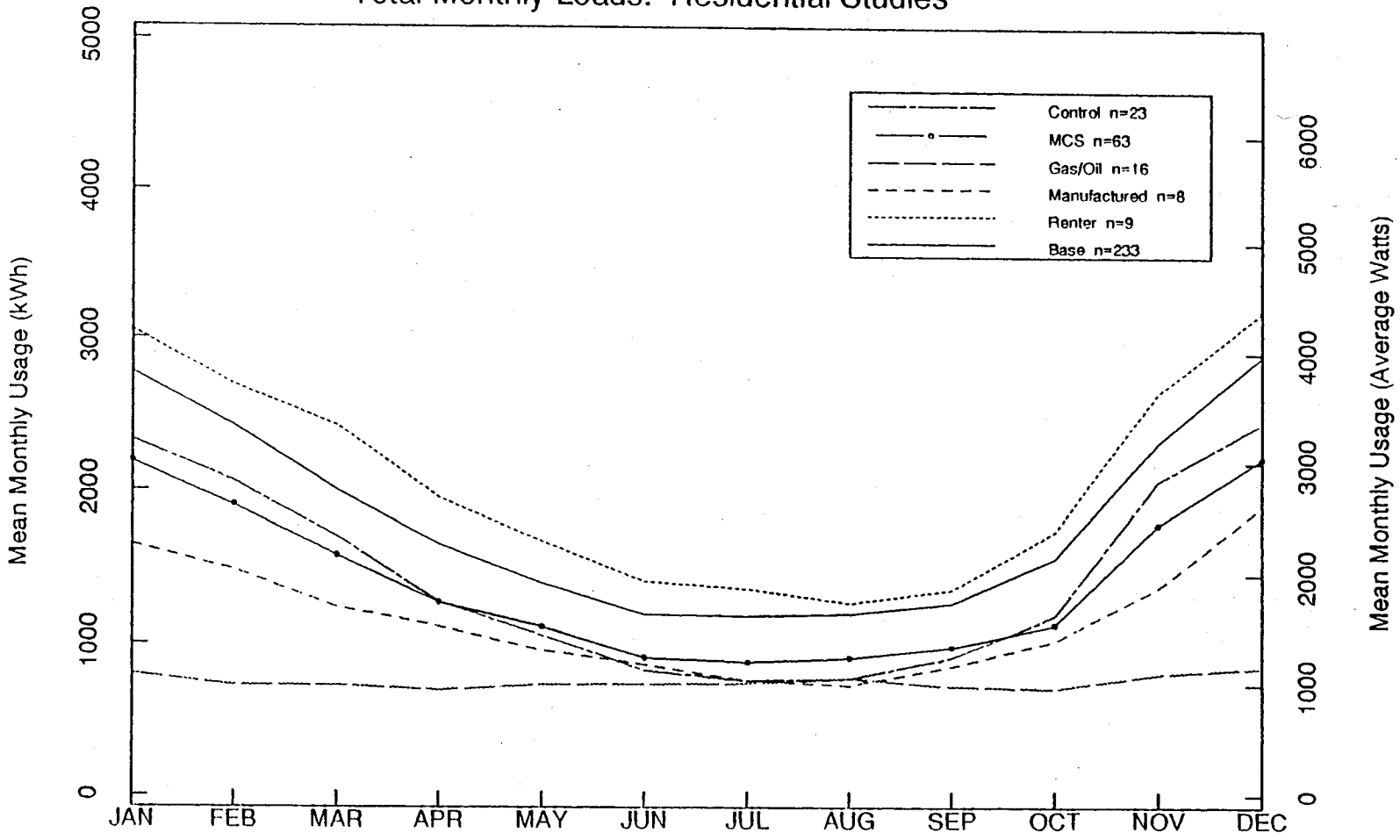
Total Annual Usage Distribution: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.3

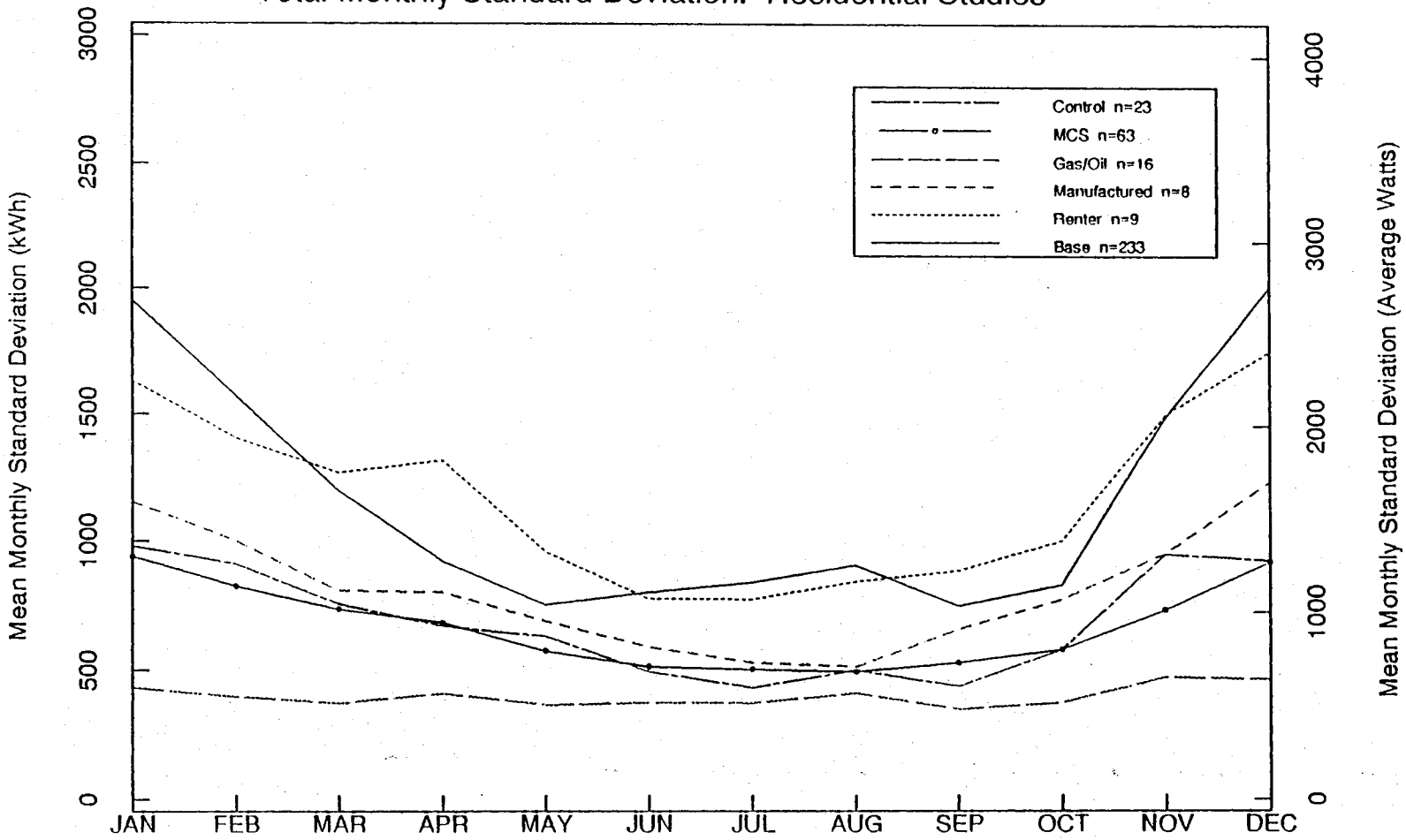
Total Monthly Loads: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

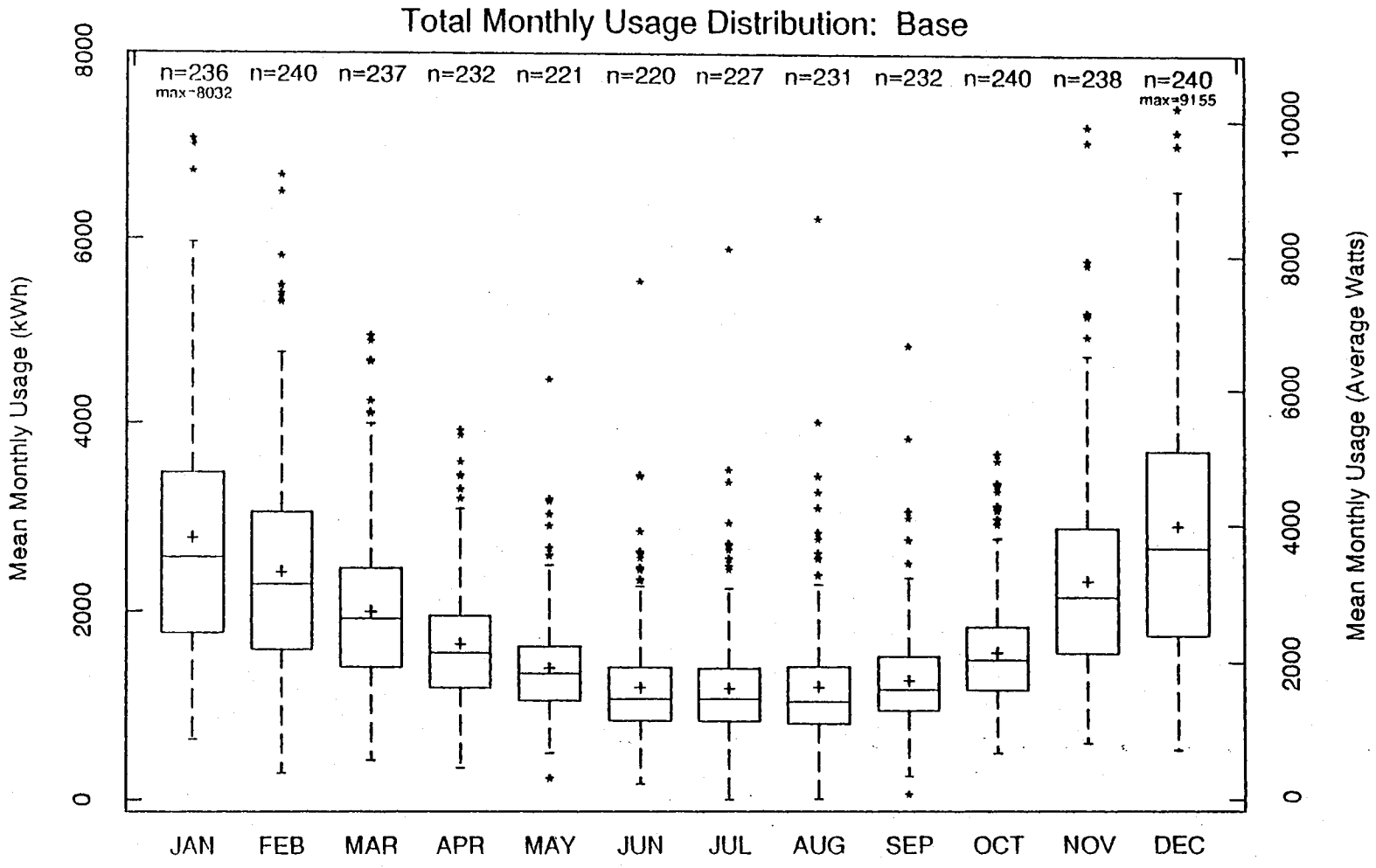
FIGURE 7A.4

Total Monthly Standard Deviation: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

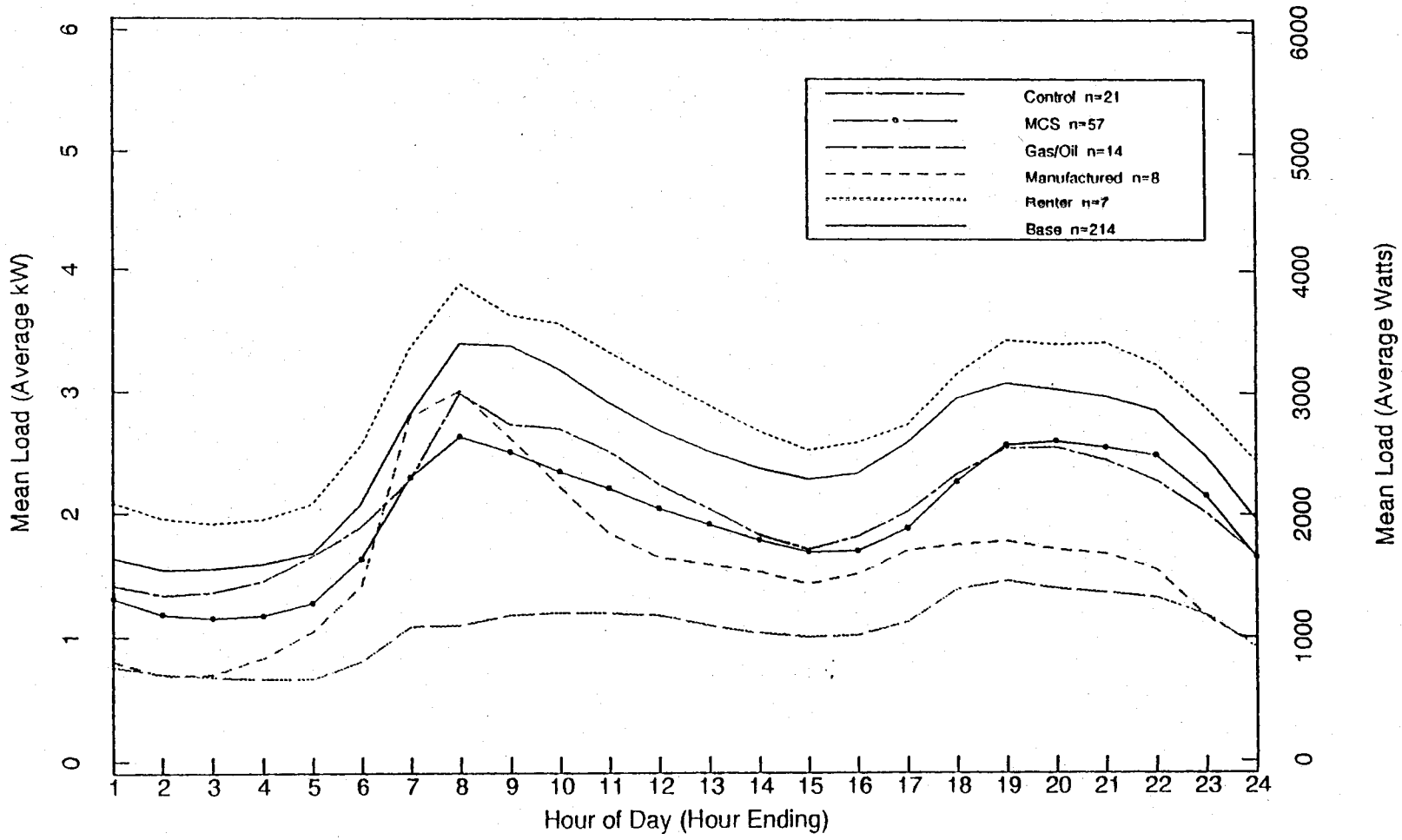
FIGURE 7A.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

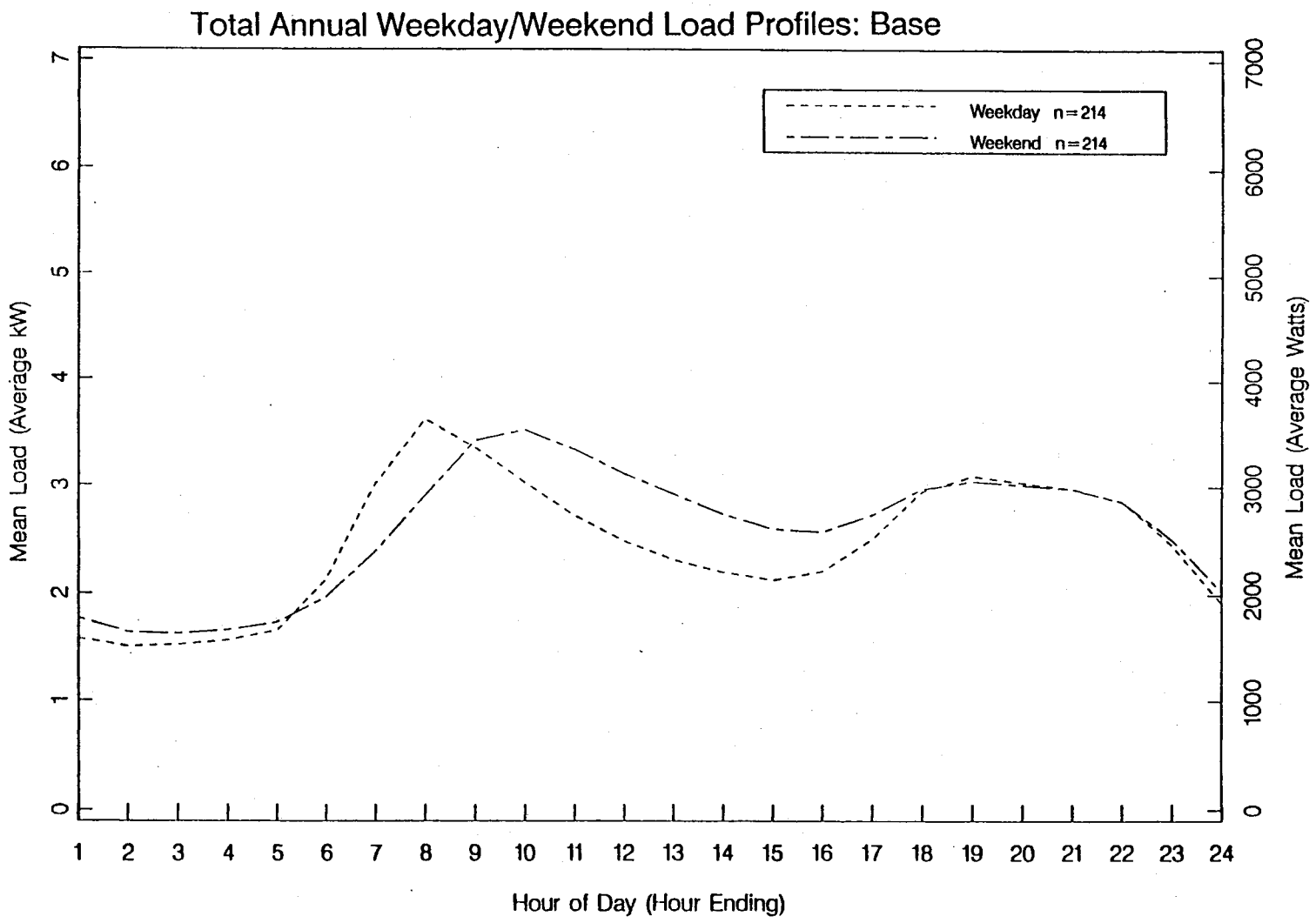
FIGURE 7A.6

Total Annual Load Profile: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

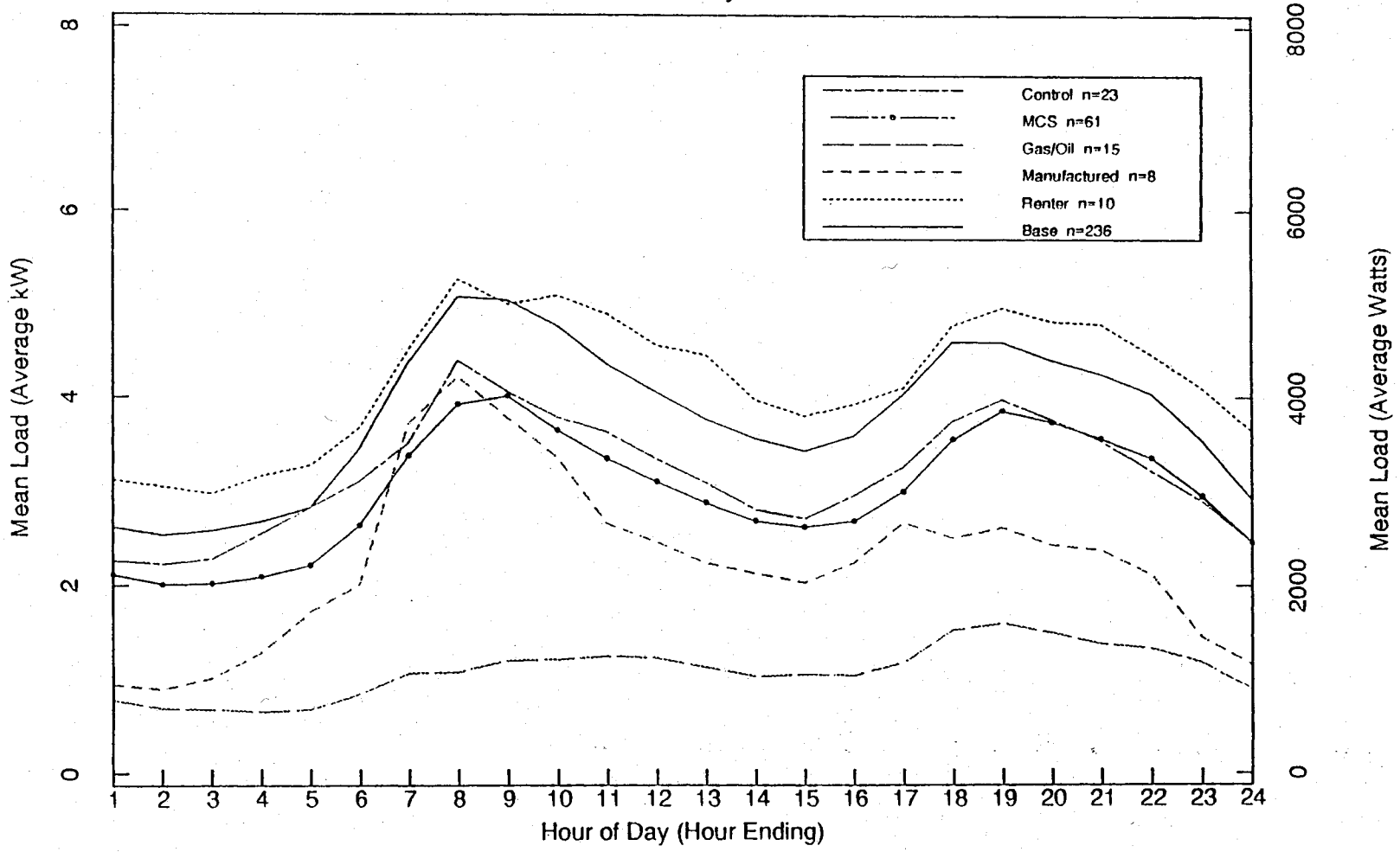
FIGURE 7A.7



Data: ELCAP RES PADS Sept'84–Mar '88 SAS/PADS November 1988

FIGURE 7A.8(a)

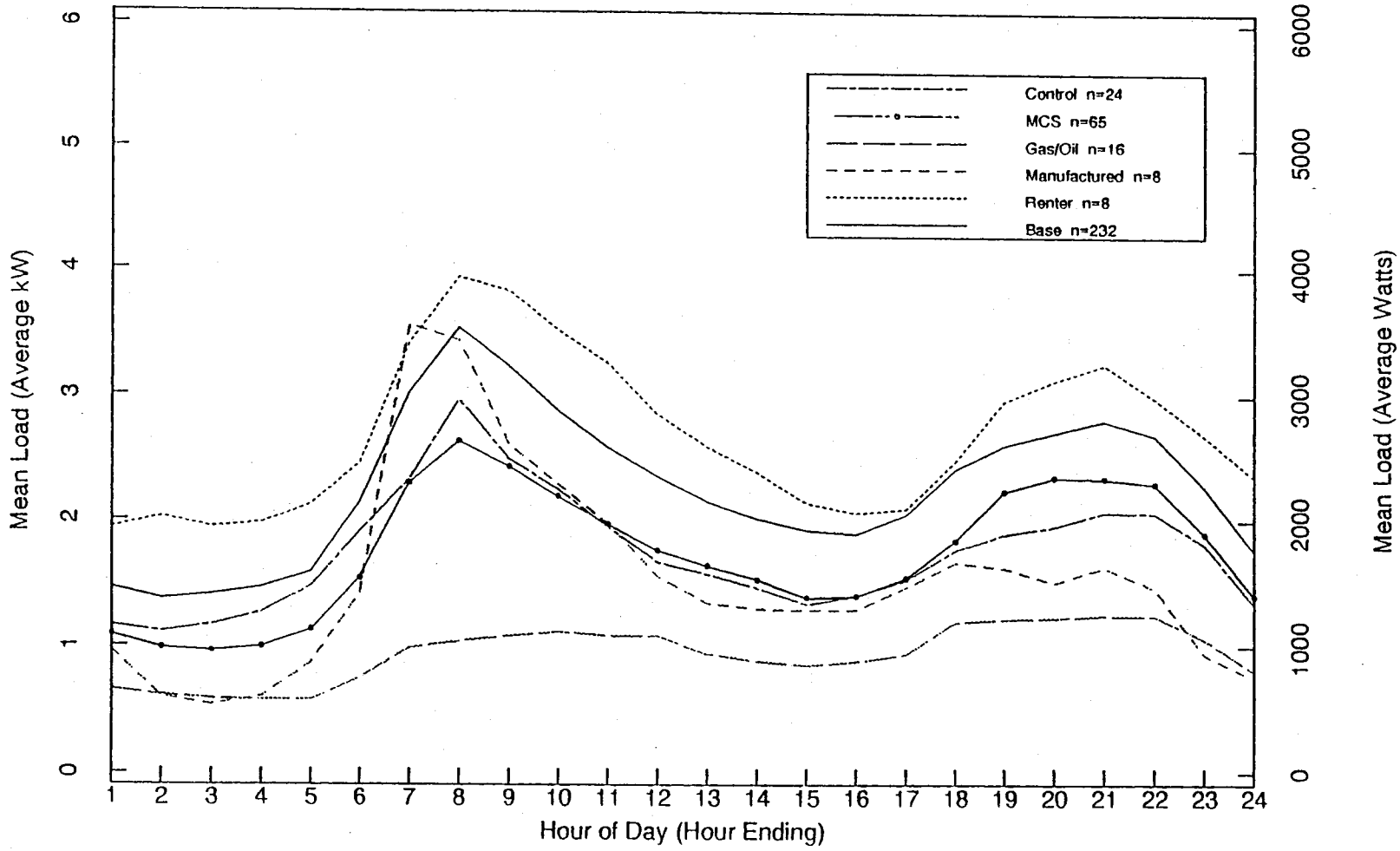
Total Load Profile for January: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.8(b)

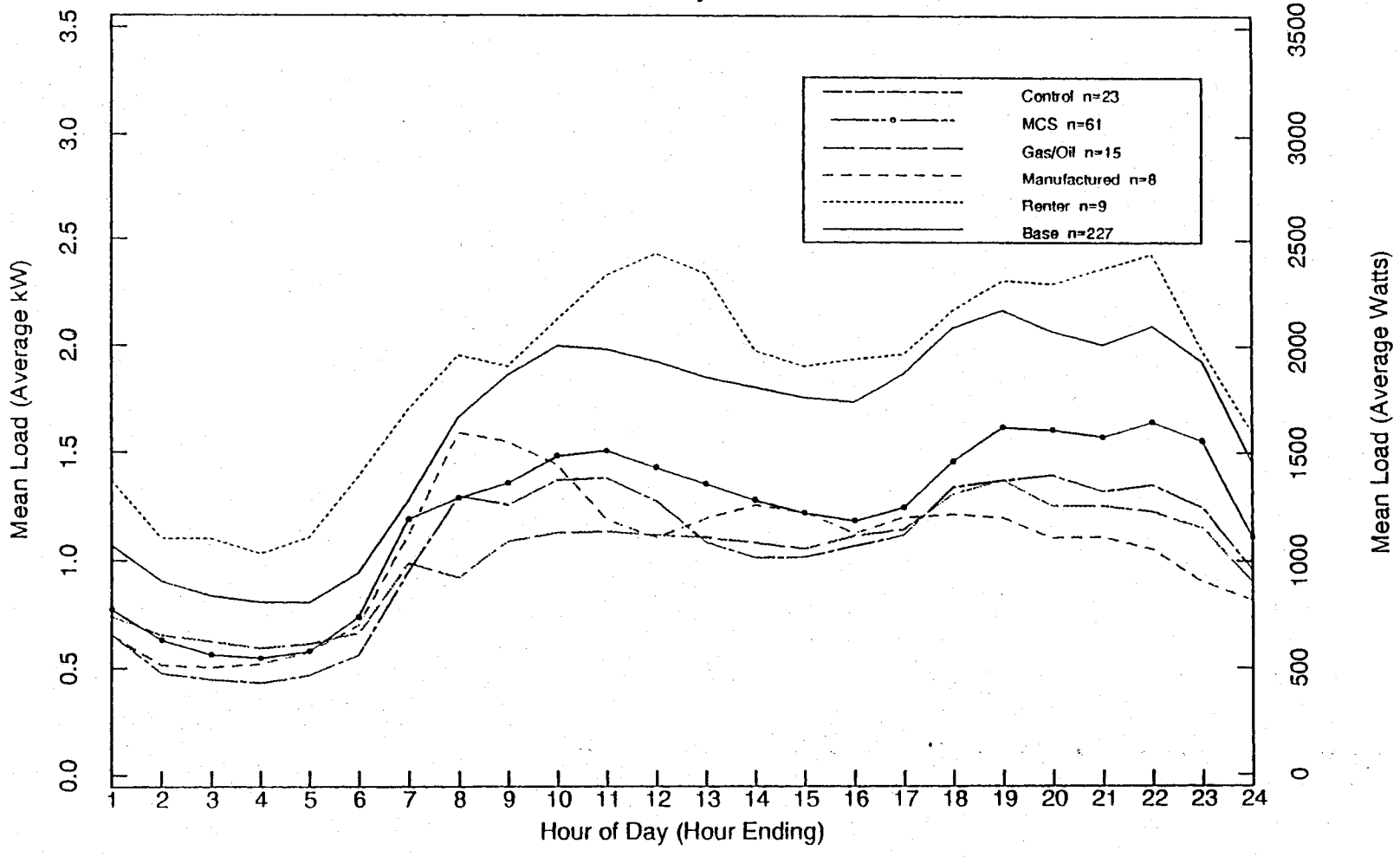
Total Load Profile for April: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.8(c)

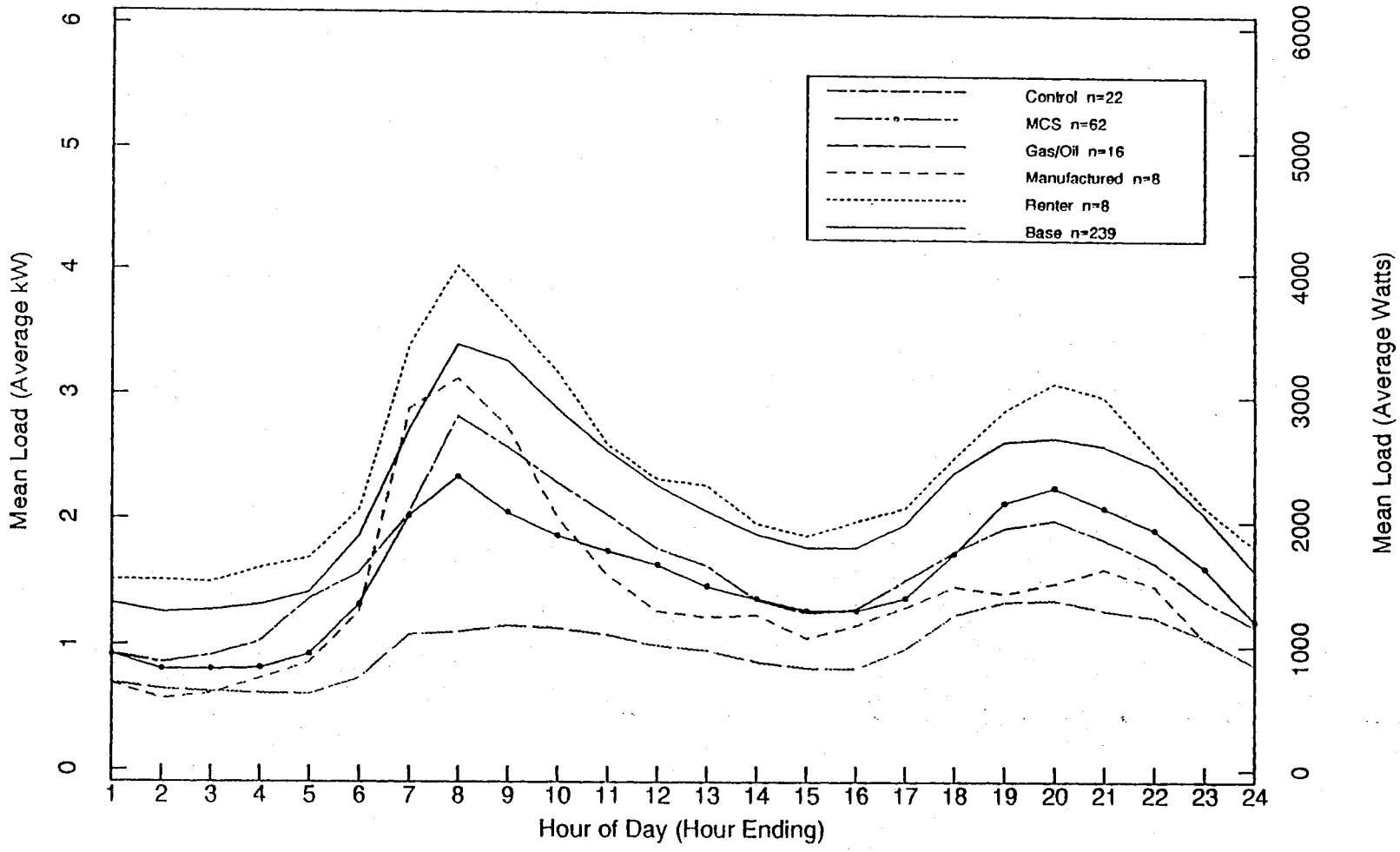
Total Load Profile for July: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.8(d)

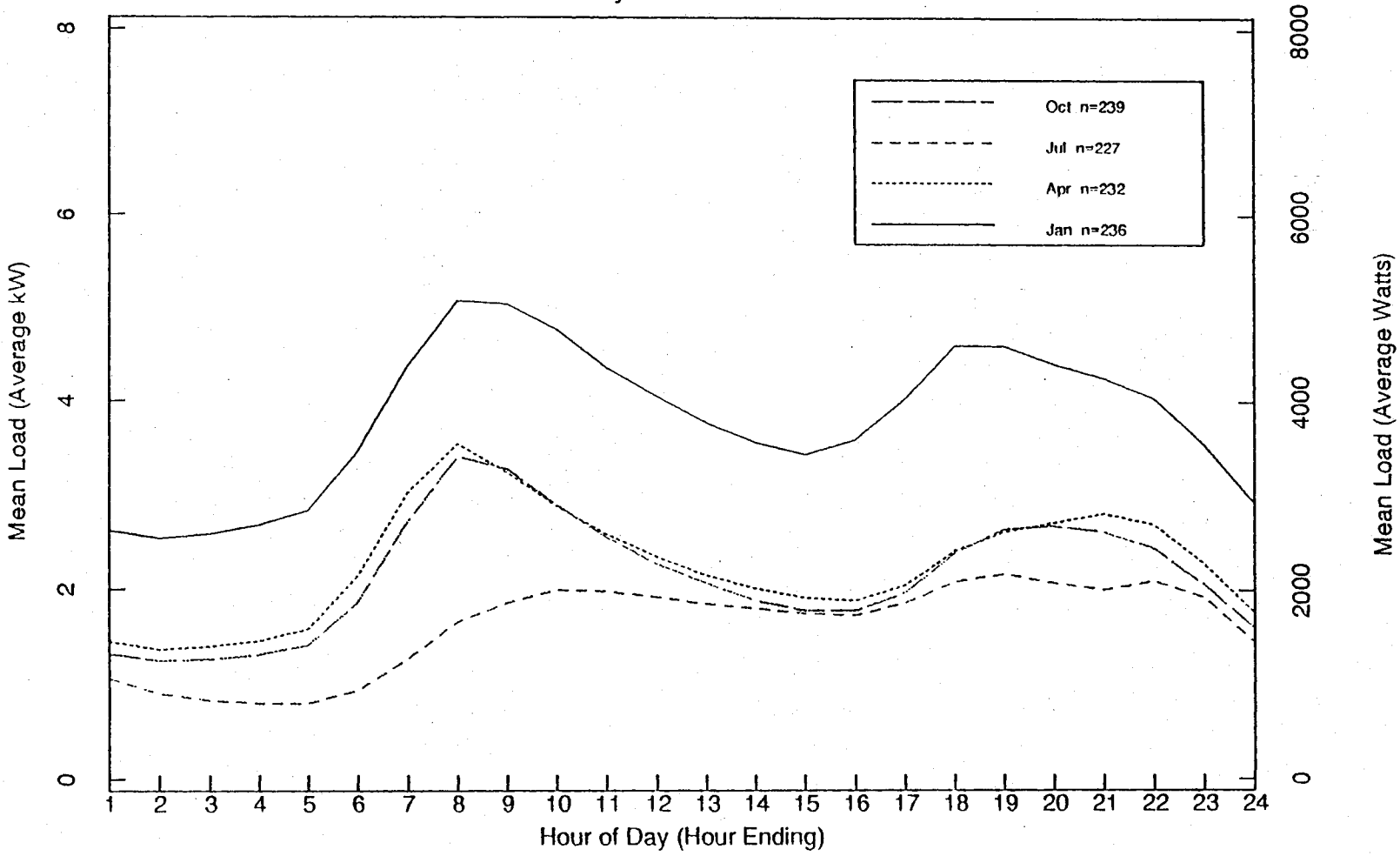
Total Load Profile for October: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.9(a)

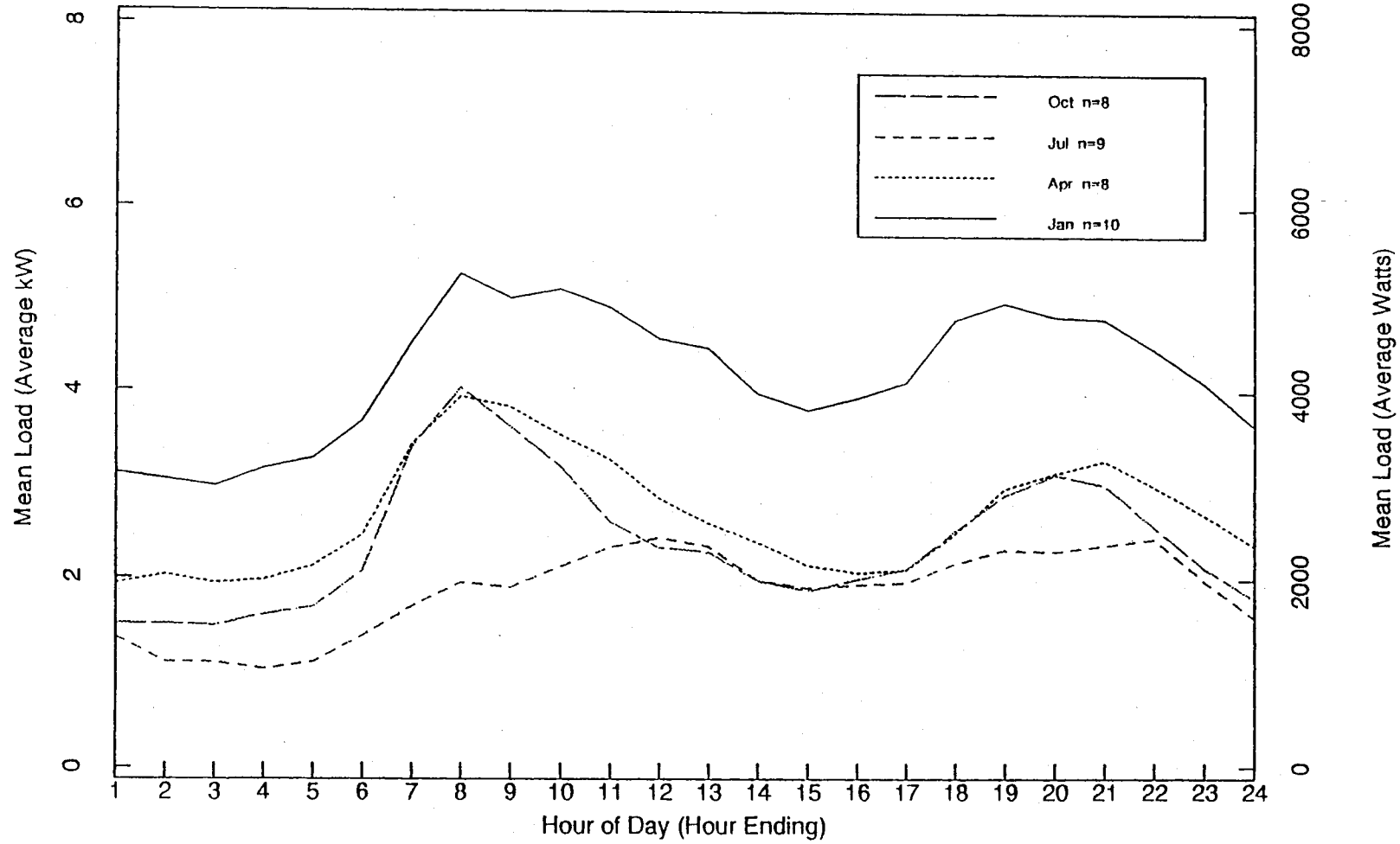
Total Monthly Load Profiles: Base



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.9(b)

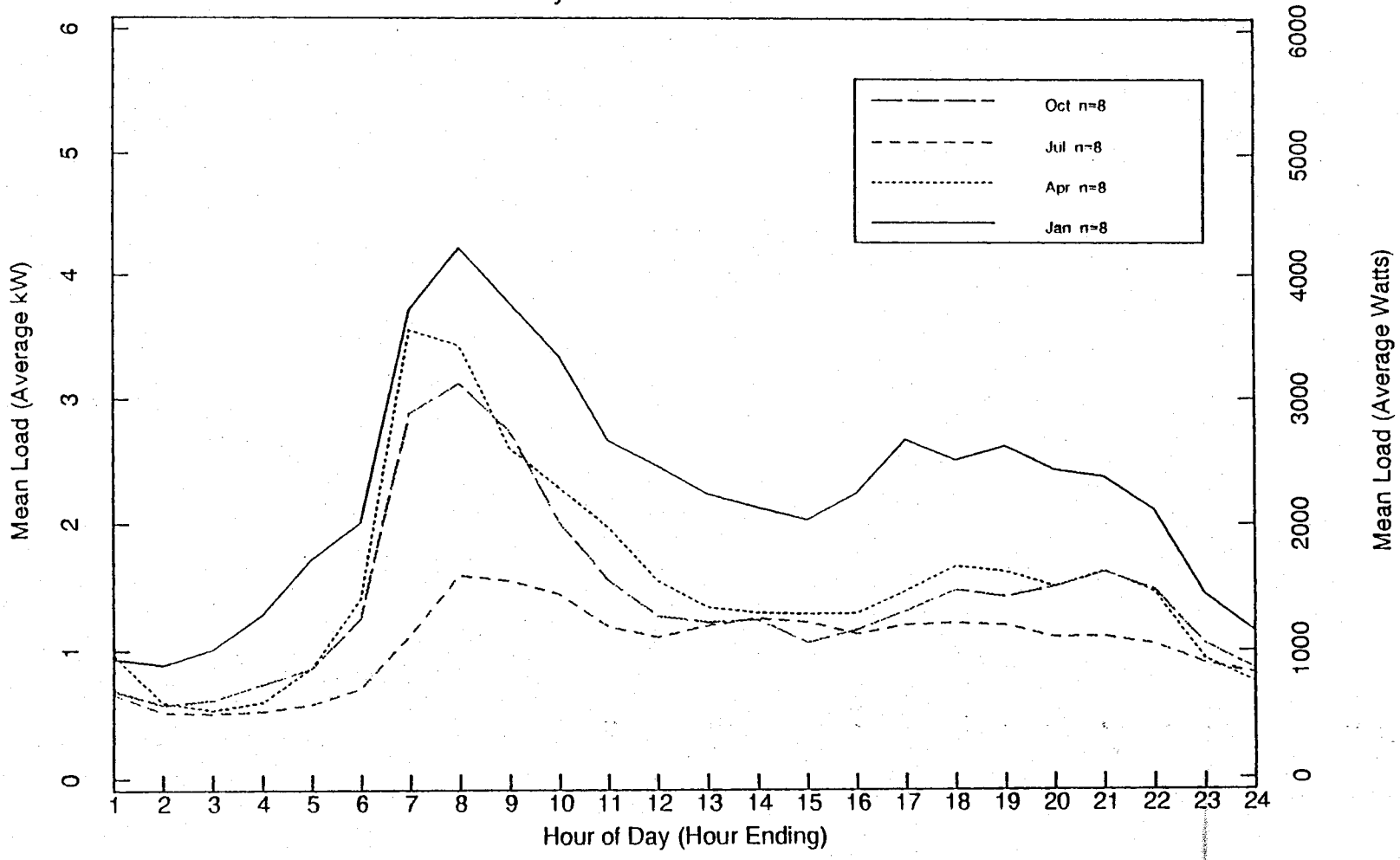
Total Monthly Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.9(c)

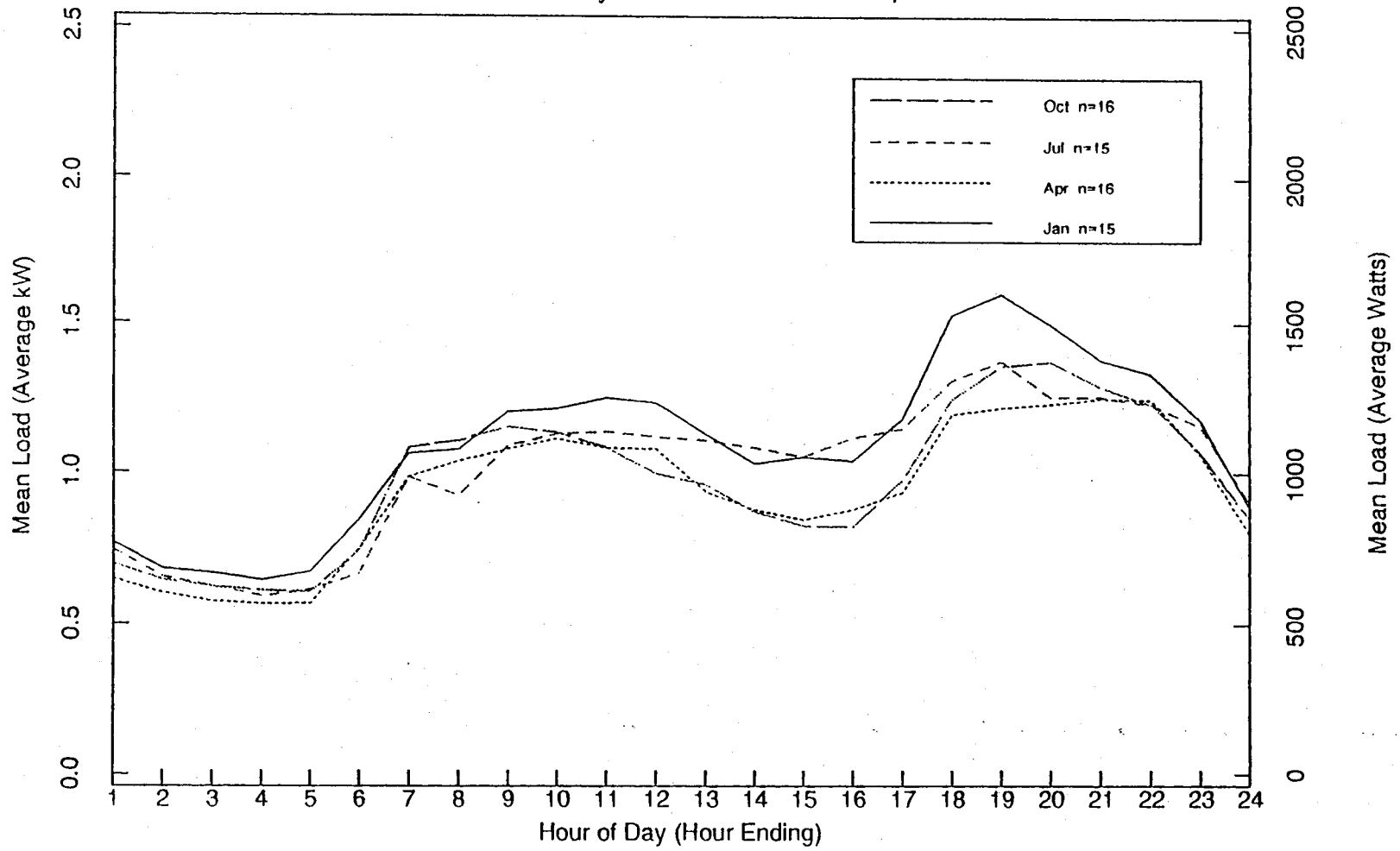
Total Monthly Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

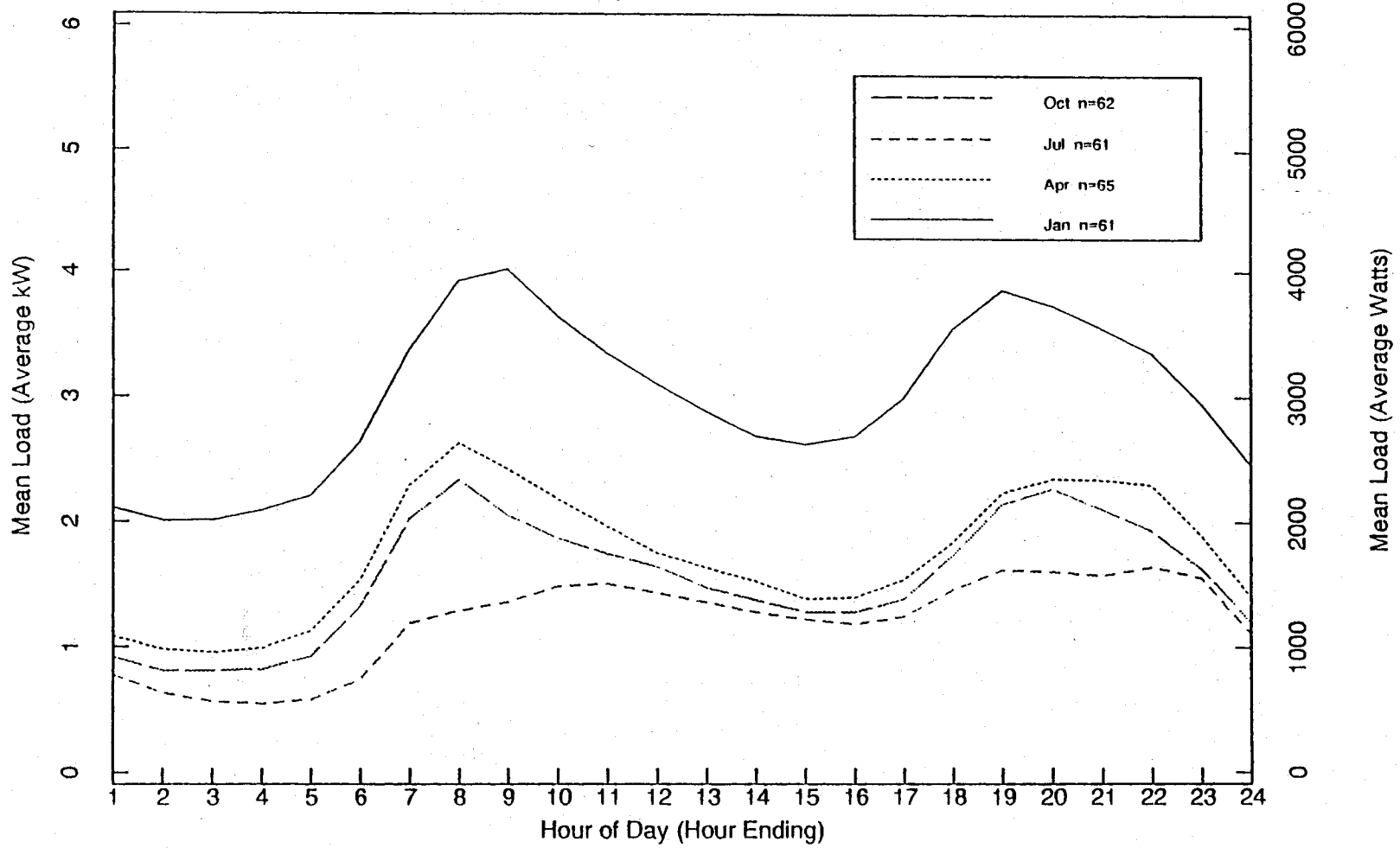
FIGURE 7A.9(d)

Total Monthly Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

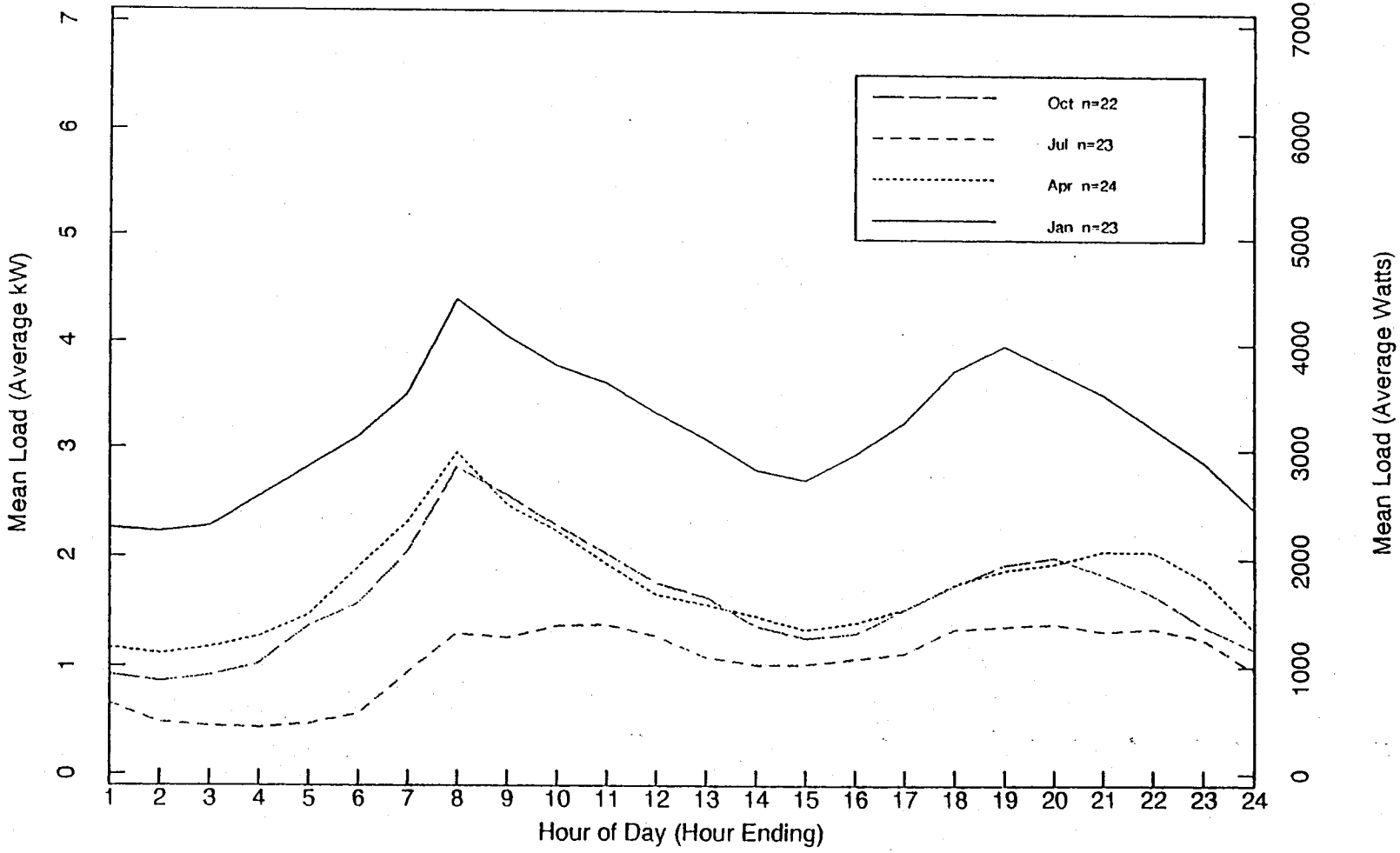
FIGURE 7A.9(e)
Total Monthly Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

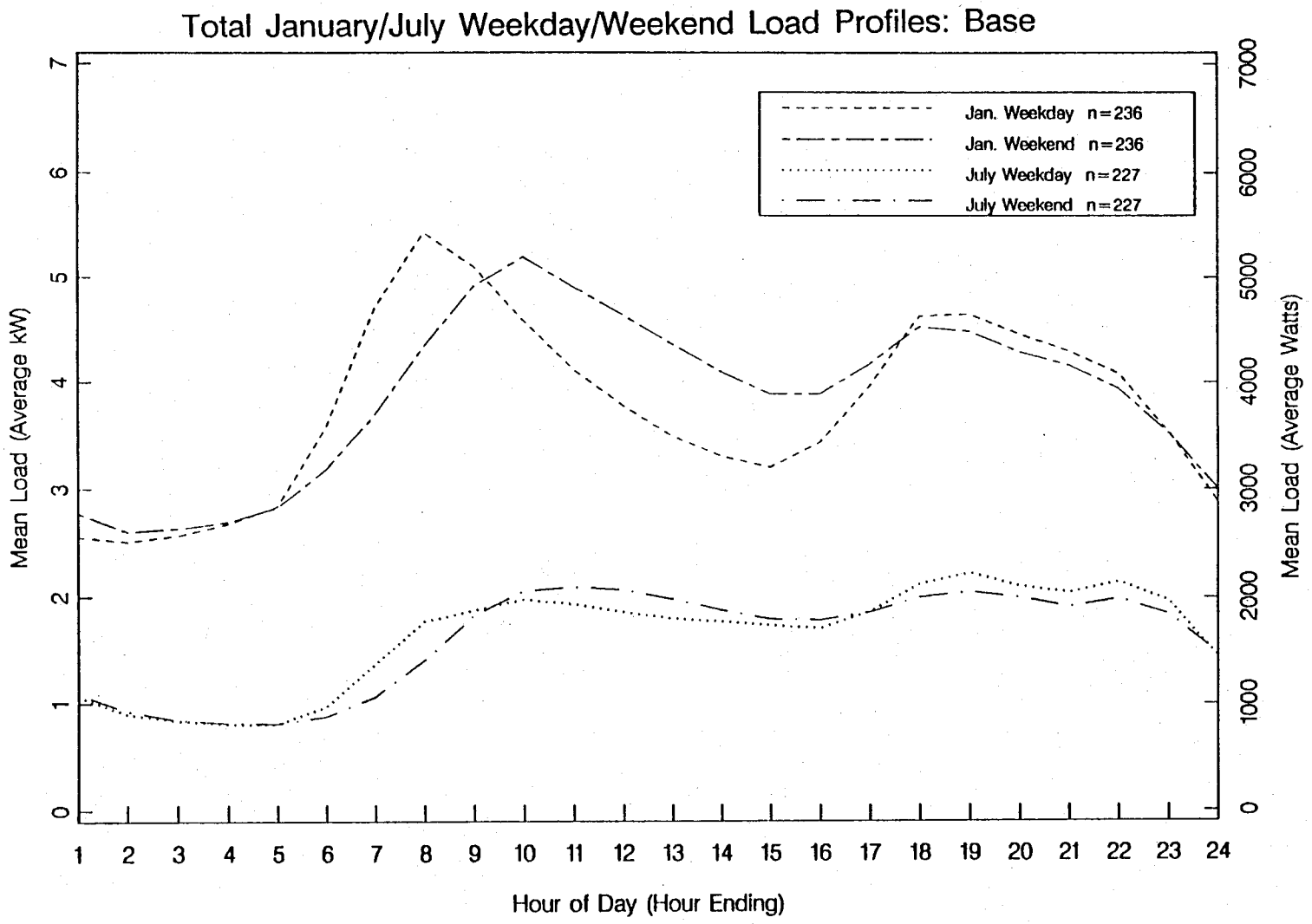
FIGURE 7A.9(f)

Total Monthly Load Profiles: Control



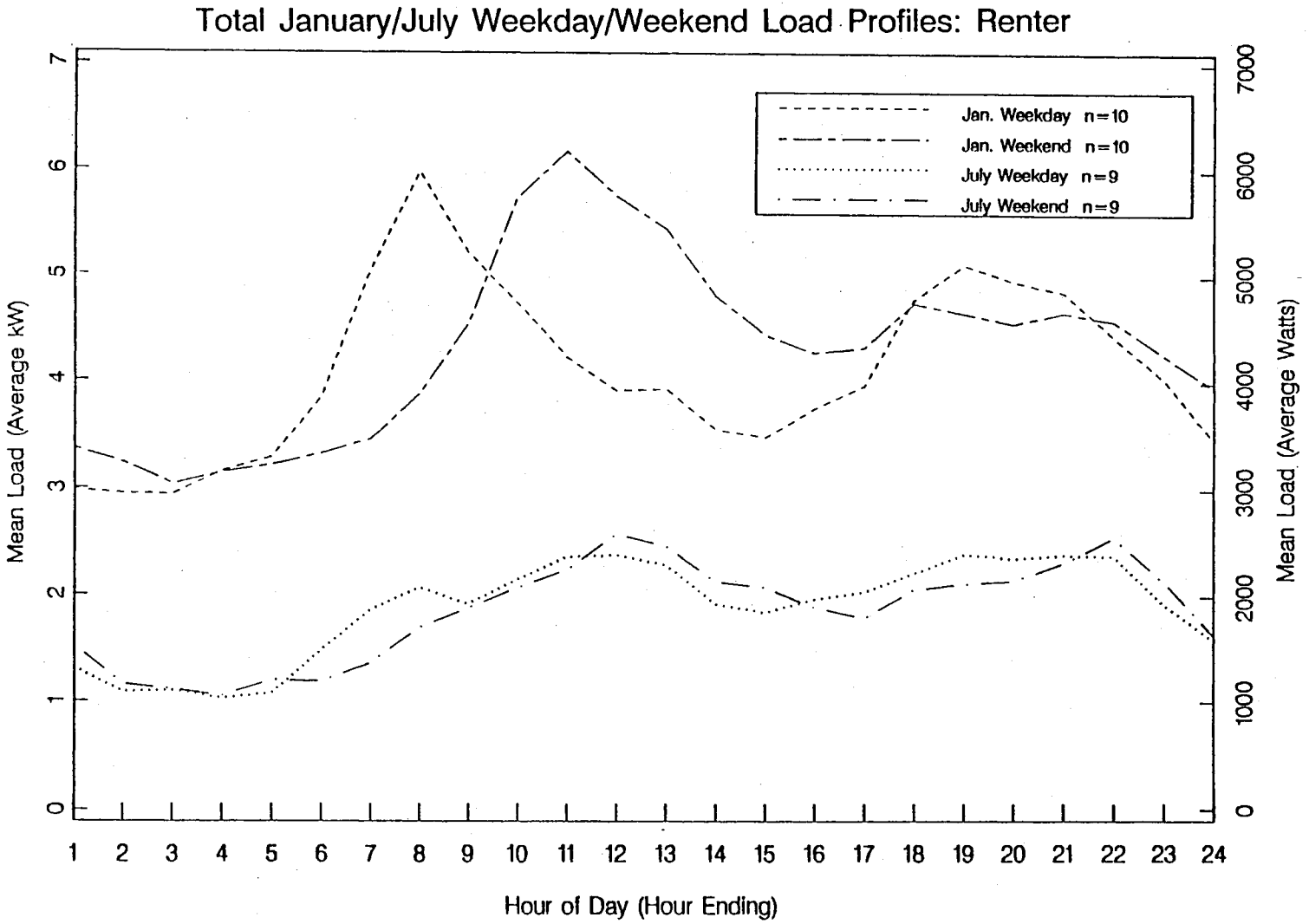
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7A.10(a)



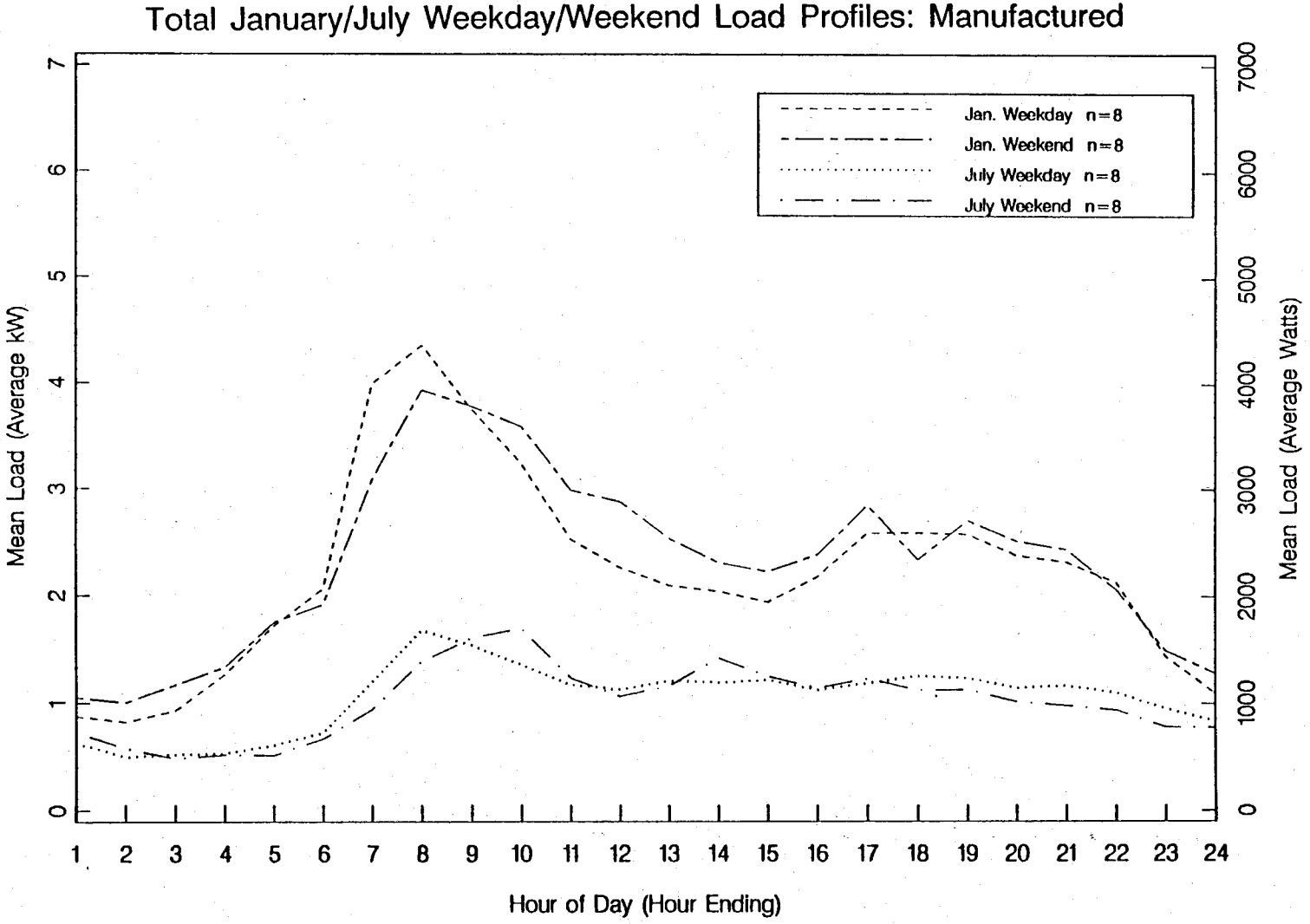
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7A.10(b)



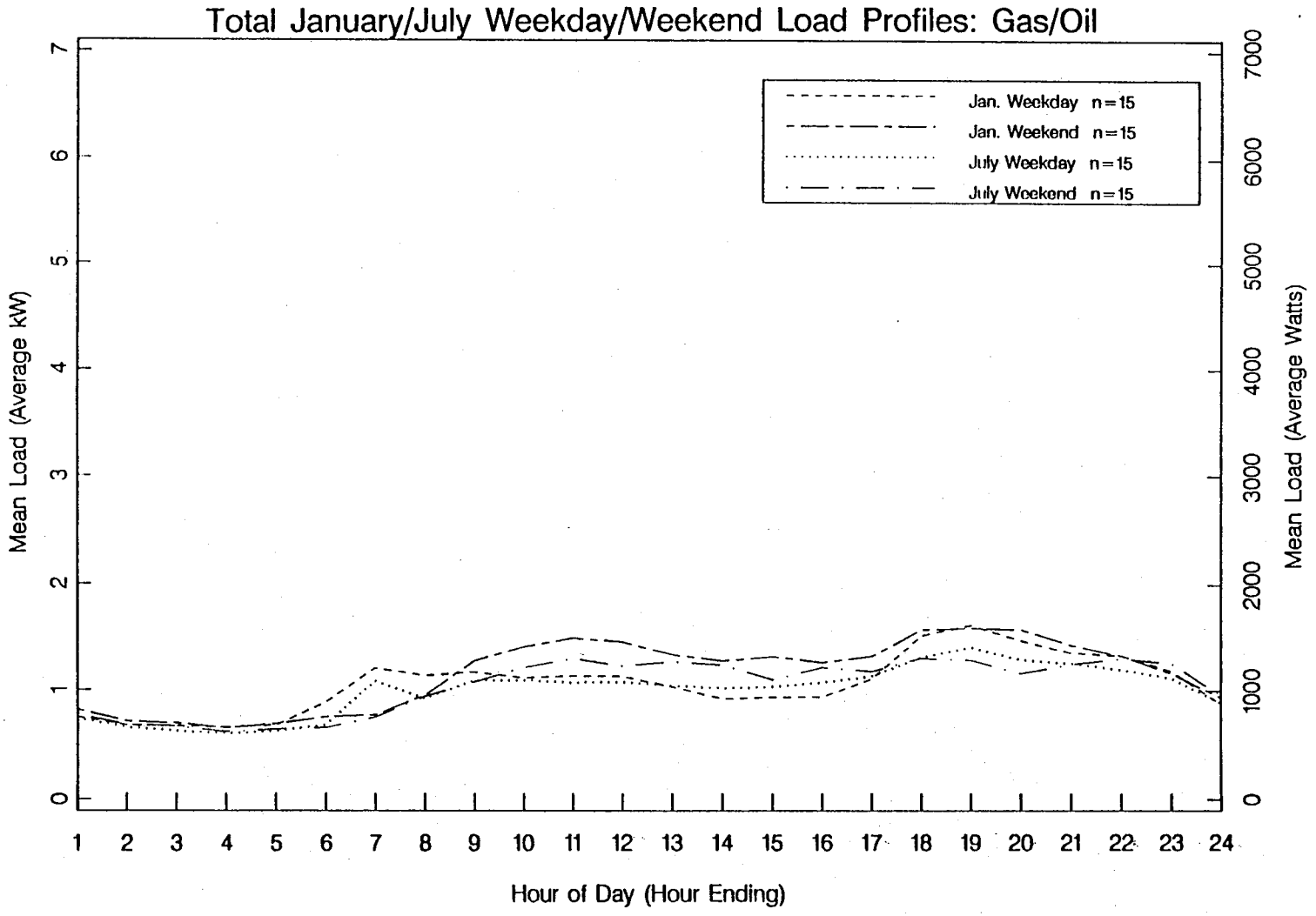
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7A.10(c)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

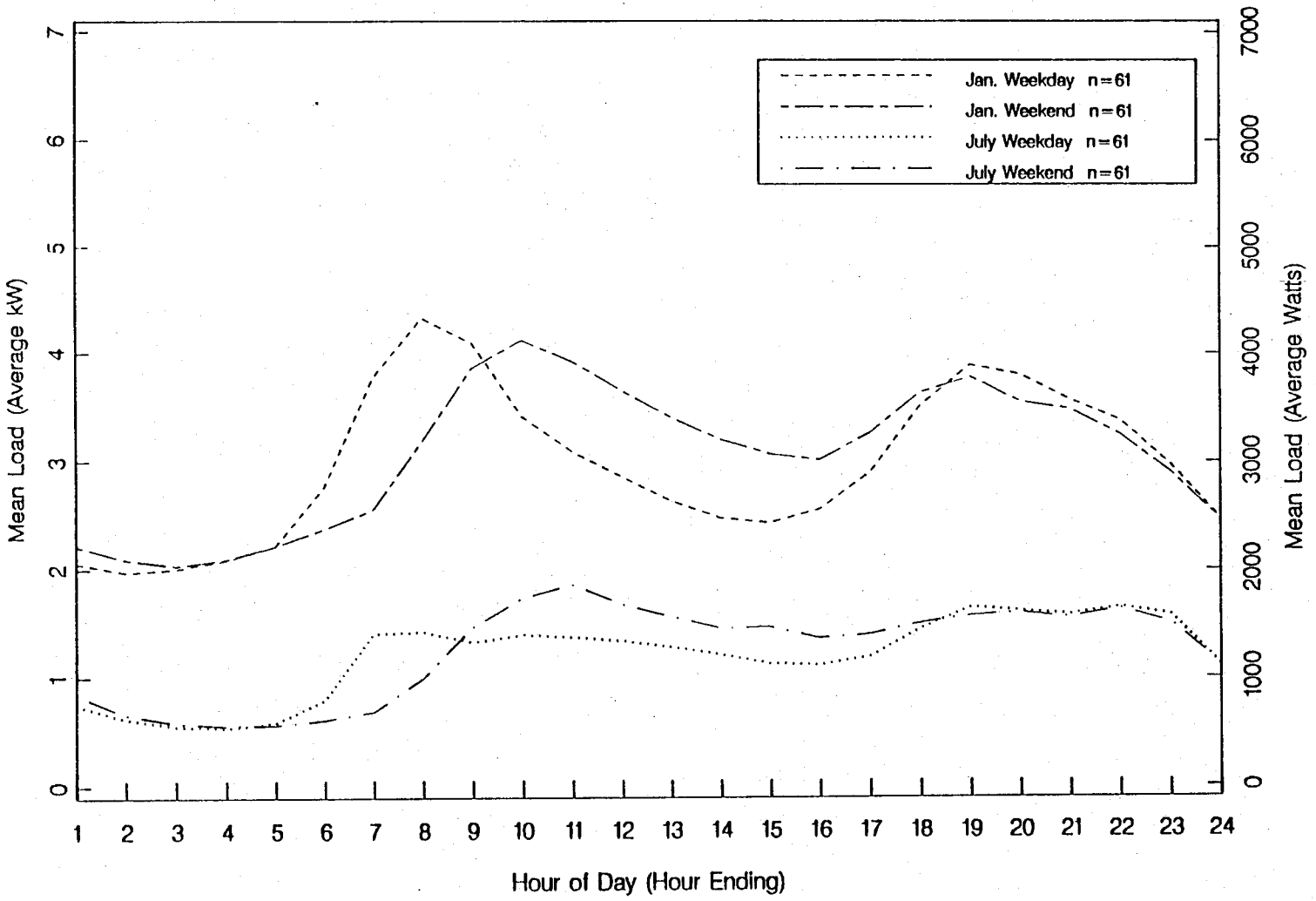
FIGURE 7A.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

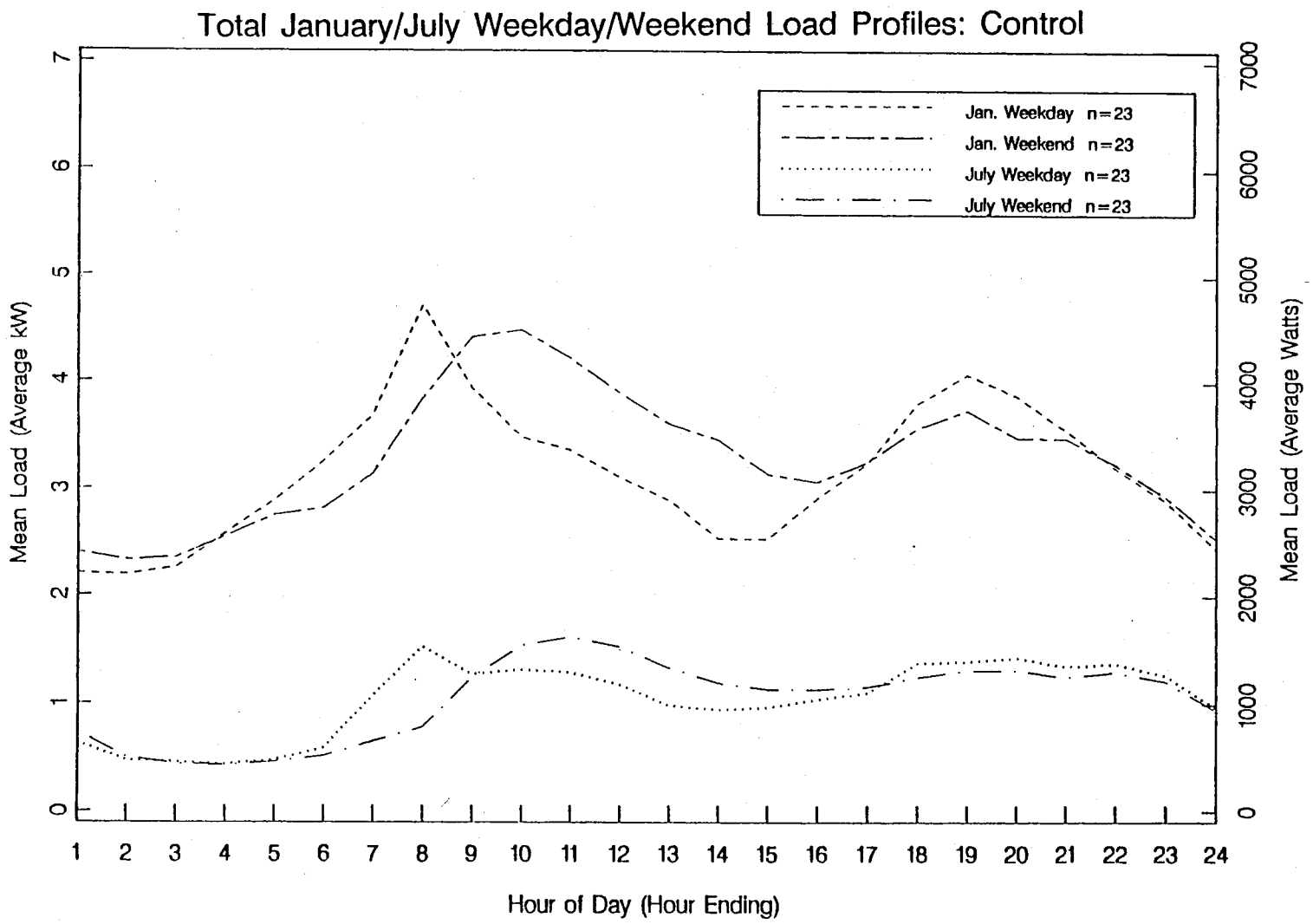
FIGURE 7A.10(e)

Total January/July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7A.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7A.11

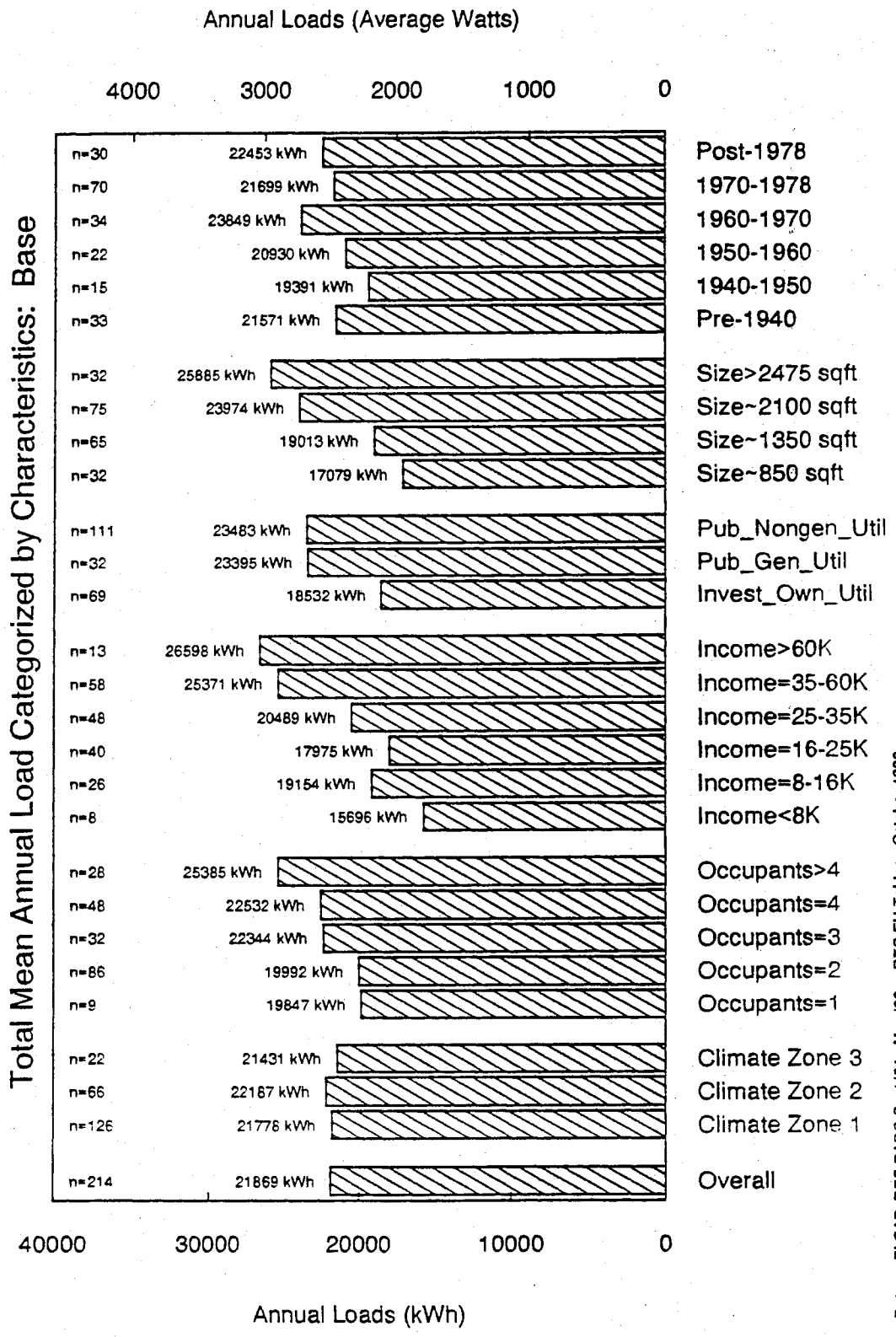
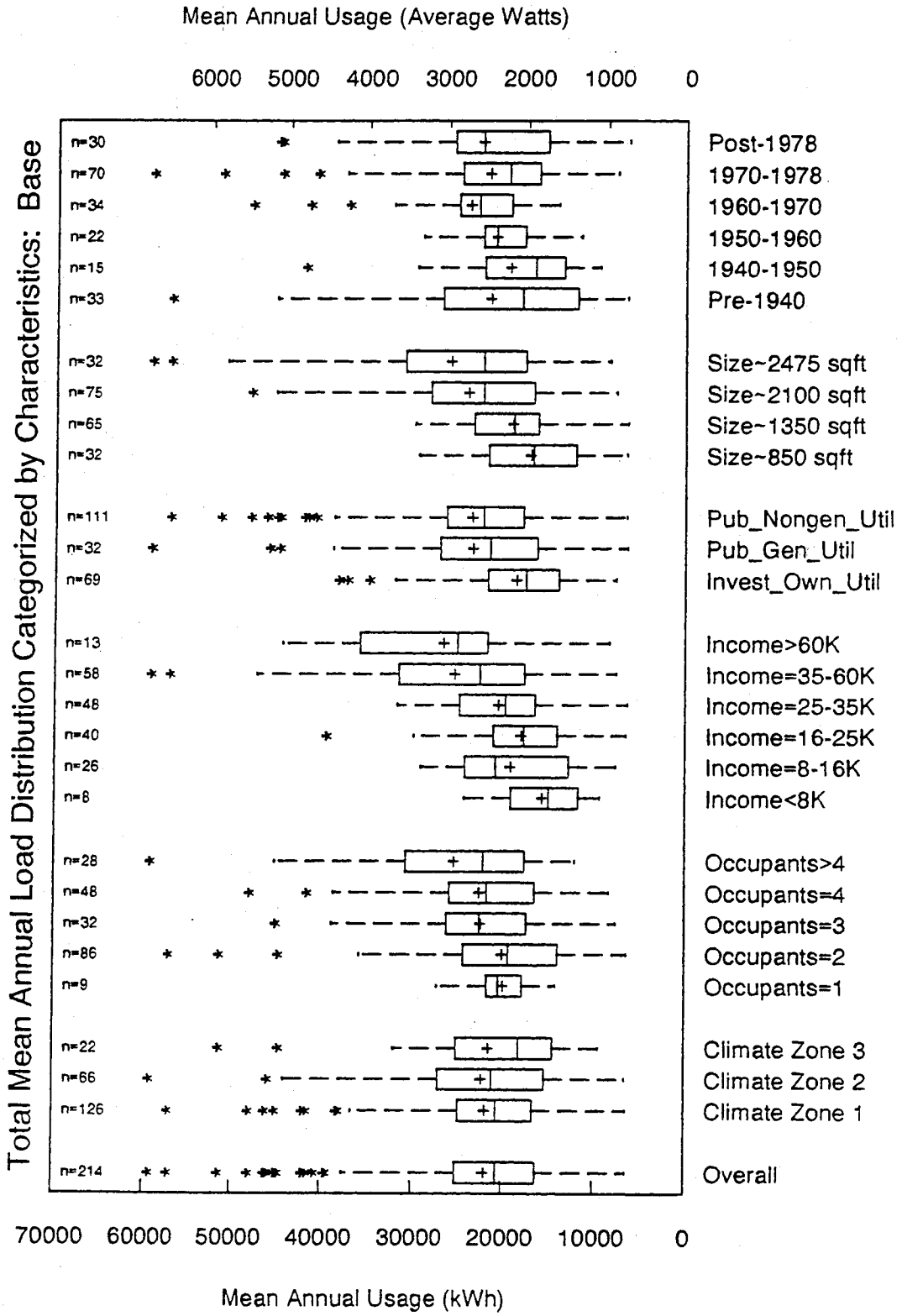

Total Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
4000
3000
2000
1000
0
n=30 22453 kWh Post-1978
n=70 21699 kWh 1970-1978
n=34 23849 kWh 1960-1970
n=22 20930 kWh 1950-1960
n=15 19391 kWh 1940-1950
n=33 21571 kWh Pre-1940
n=32 25885 kWh Size>2475 sqft
n=75 23974 kWh Size~2100 sqft
n=65 19013 kWh Size~1350 sqft
n=32 17079 kWh Size~850 sqft
n=111 23483 kWh Pub_Nongen_Util
n=32 23395 kWh Pub_Gen_Util
n=69 18532 kWh Invest_Own_Util
n=13 26598 kWh Income>60K
n=58 25371 kWh Income=35-60K
n=48 20489 kWh Income=25-35K
n=40 17975 kWh Income=16-25K
n=26 19154 kWh Income=8-16K
n=8 15696 kWh Income<8K
n=28 25385 kWh Occupants>4
n=48 22532 kWh Occupants=4
n=32 22344 kWh Occupants=3
n=86 19992 kWh Occupants=2
n=9 19847 kWh Occupants=1
n=22 21431 kWh Climate Zone 3
n=66 22187 kWh Climate Zone 2
n=126 21776 kWh Climate Zone 1
n=214 21869 kWh Overall
40000
30000
20000
10000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7A.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7A.1

Total Mean Annual End-Use Loads and Standard Deviations (kWh)

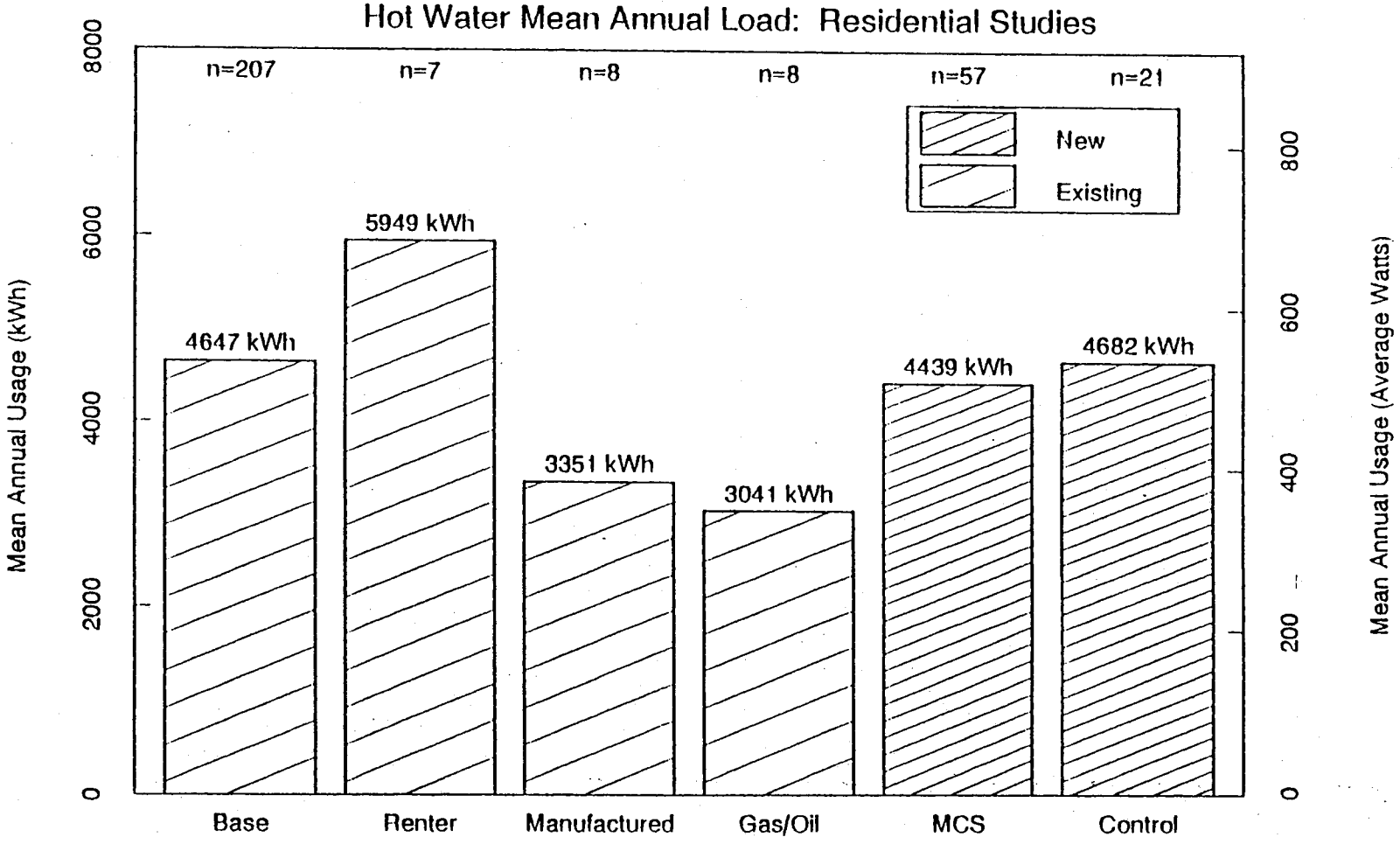
Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	214	21869	9022	21	18195	4399	57	17166	5056	292	20687	8351
Climate Zone 1	126	21778	8361	13	18130	4073	36	16333	3801	175	20387	7710
Climate Zone 2	66	22187	9866	4	21216	5817	17	19259	6586	87	21570	9174
Climate Zone 3	22	21431	10377	4	15385	2474	4	15775	6452	30	19871	9479
Occupants=1	9	19847	3859	1	19796	0	2	13947	1661	12	18860	4043
Occupants=2	86	19992	8546	7	17024	2734	14	14880	4301	107	19129	8033
Occupants=3	32	22344	8565	3	14886	3140	8	17661	4242	43	20952	7987
Occupants=4	48	22632	8558	3	23641	5402	7	17896	3913	58	22030	8091
Occupants>4	28	25385	11050	1	26201	0	5	22384	8845	34	24968	10516
Income<8K	8	15696	5059	0	-	-	1	13625	0	9	15466	4782
Income=8-16K	26	19154	6133	1	18200	0	1	6453	0	28	18666	6371
Income=16-25K	40	17975	6300	1	18385	0	8	15003	5298	49	17498	6130
Income=25-35K	48	20489	5813	8	19567	5036	12	16968	3160	68	19759	5456
Income=35-60K	58	25371	10919	3	19749	6285	13	19690	6133	74	24145	10290
Income>60K	13	26598	10851	1	16418	0	1	15002	0	15	25146	10755
Invest_Own_Util	69	18532	6606	10	19247	4672	32	17423	5852	111	18277	6225
Pub_Gen_Util	32	23395	11457	7	16973	3059	10	16423	1921	49	21054	9858
Pub_Nongen_Util	111	23483	9044	4	17701	6108	11	16042	4681	126	22650	8937
Size<850 sqft	32	17079	5750	1	25959	0	1	6453	0	34	17028	6072
Size<1350 sqft	65	19013	5718	13	16984	4186	26	15305	3020	104	17832	5211
Size<2100 sqft	75	23974	8806	6	18902	4011	17	19190	5539	98	22834	8327
Size>2475 sqft	32	25885	13006	0	-	-	9	19935	6439	41	24579	12067
Pre-1940	33	21571	11667	0	-	-	0	-	-	33	21571	11667
1940-1950	15	19391	7949	0	-	-	0	-	-	15	19391	7949
1950-1960	22	20930	4649	0	-	-	0	-	-	22	20930	4649
1960-1970	34	23849	7119	0	-	-	0	-	-	34	23849	7119
1970-1978	70	21699	9510	0	-	-	0	-	-	70	21699	9510
Post-1978	30	22453	9370	21	18195	4399	57	17166	5056	108	18835	6784

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

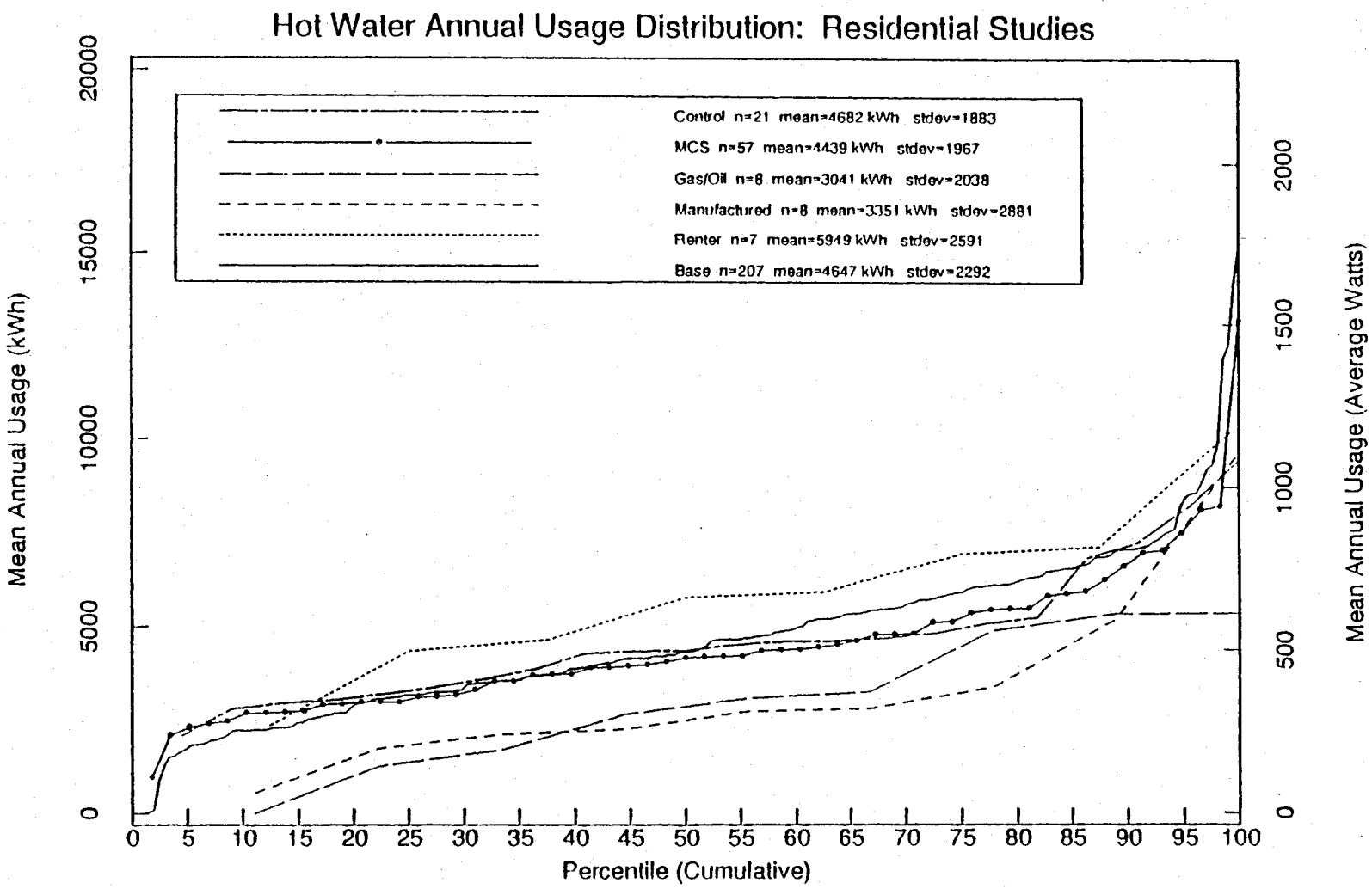
FIGURE 7B.1

Hot Water Mean Annual Load: Residential Studies



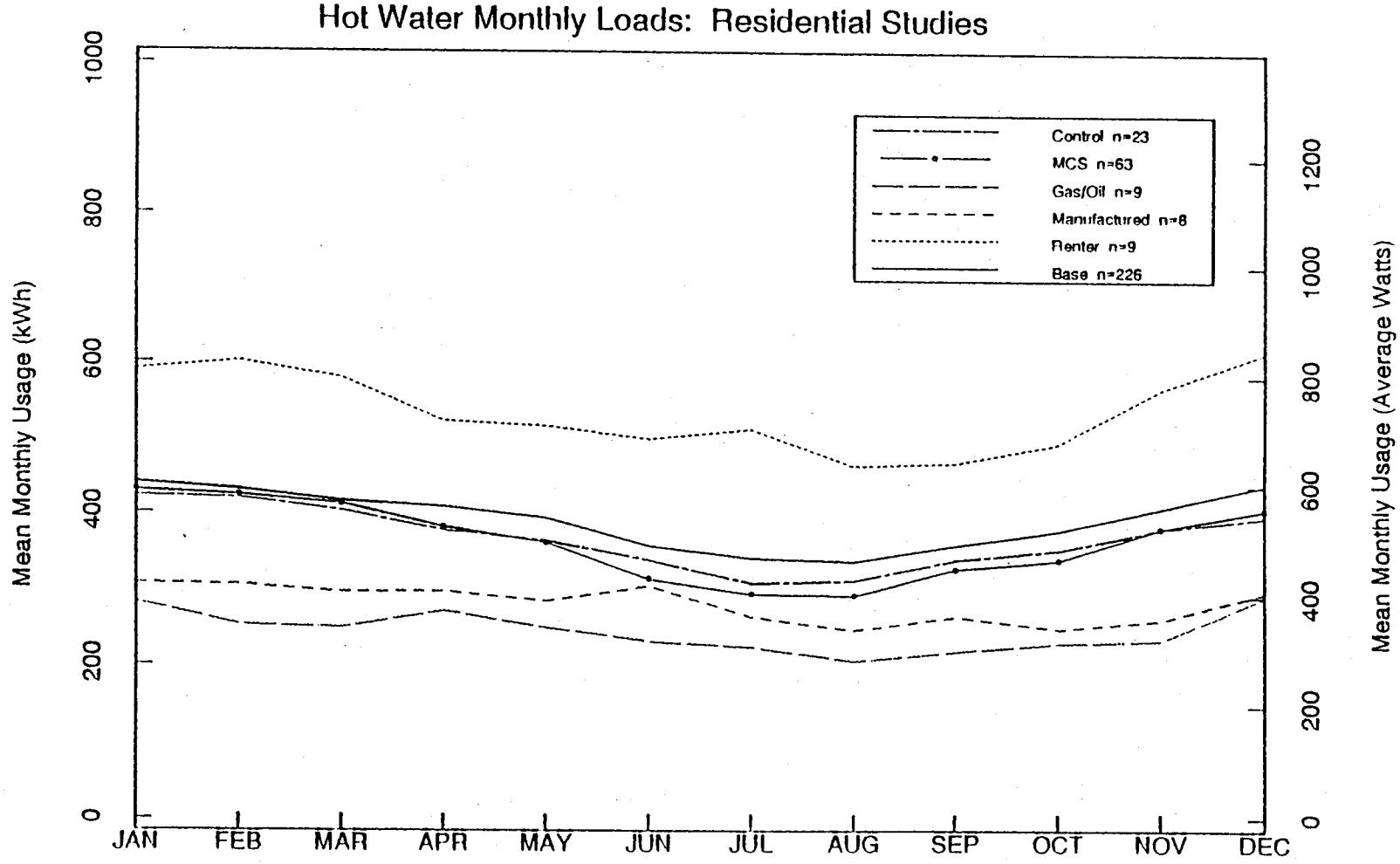
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.2



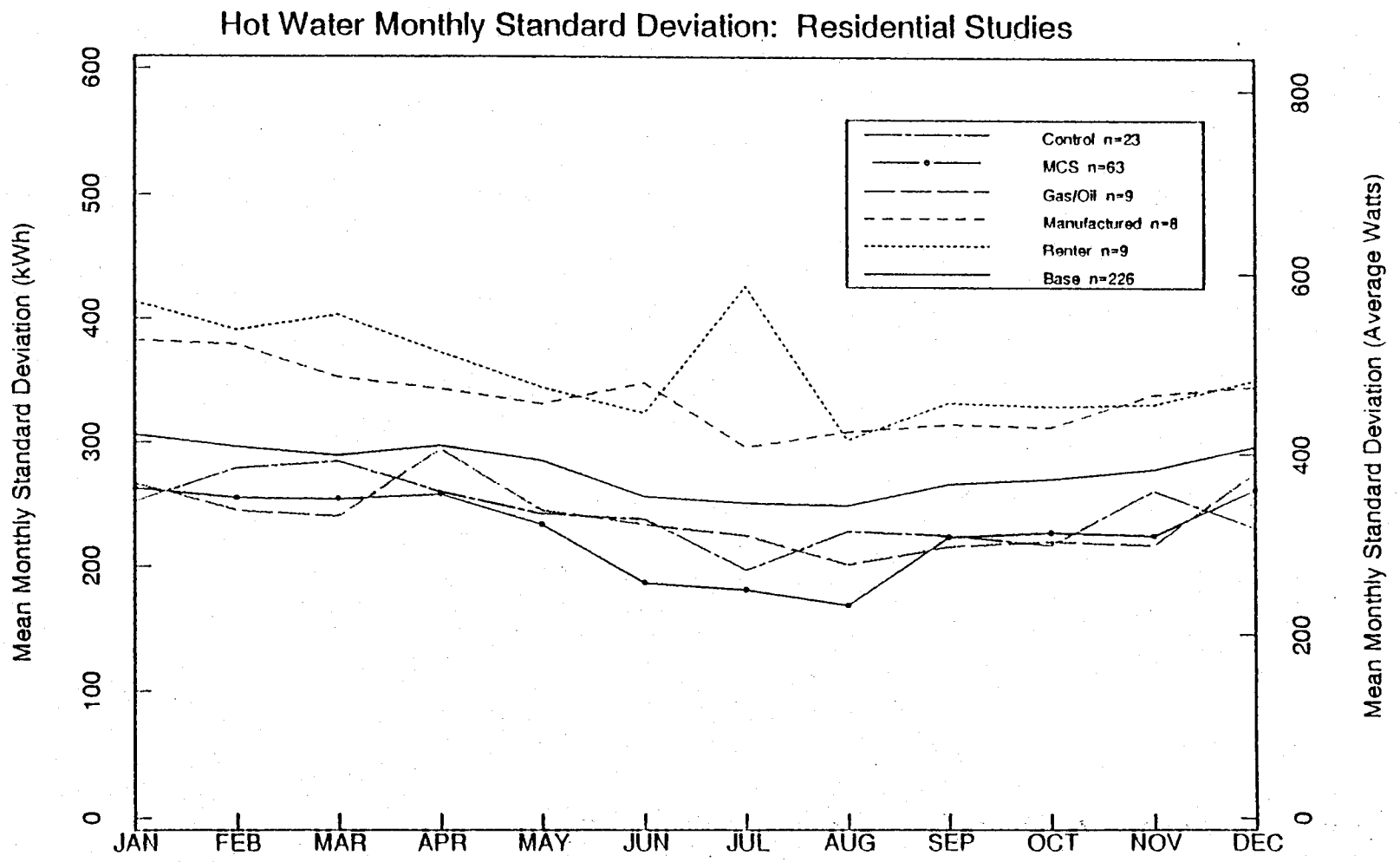
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.3



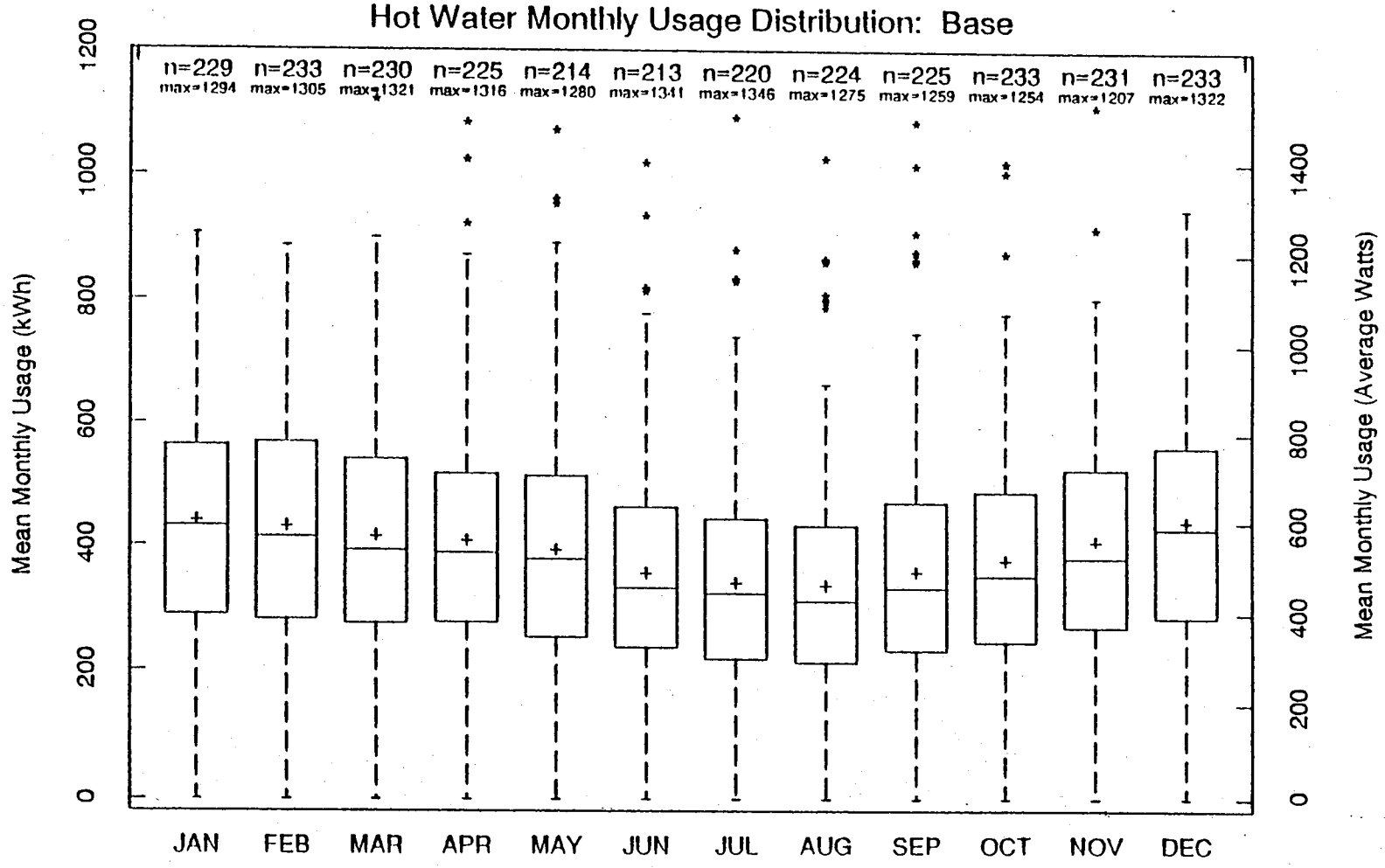
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.4



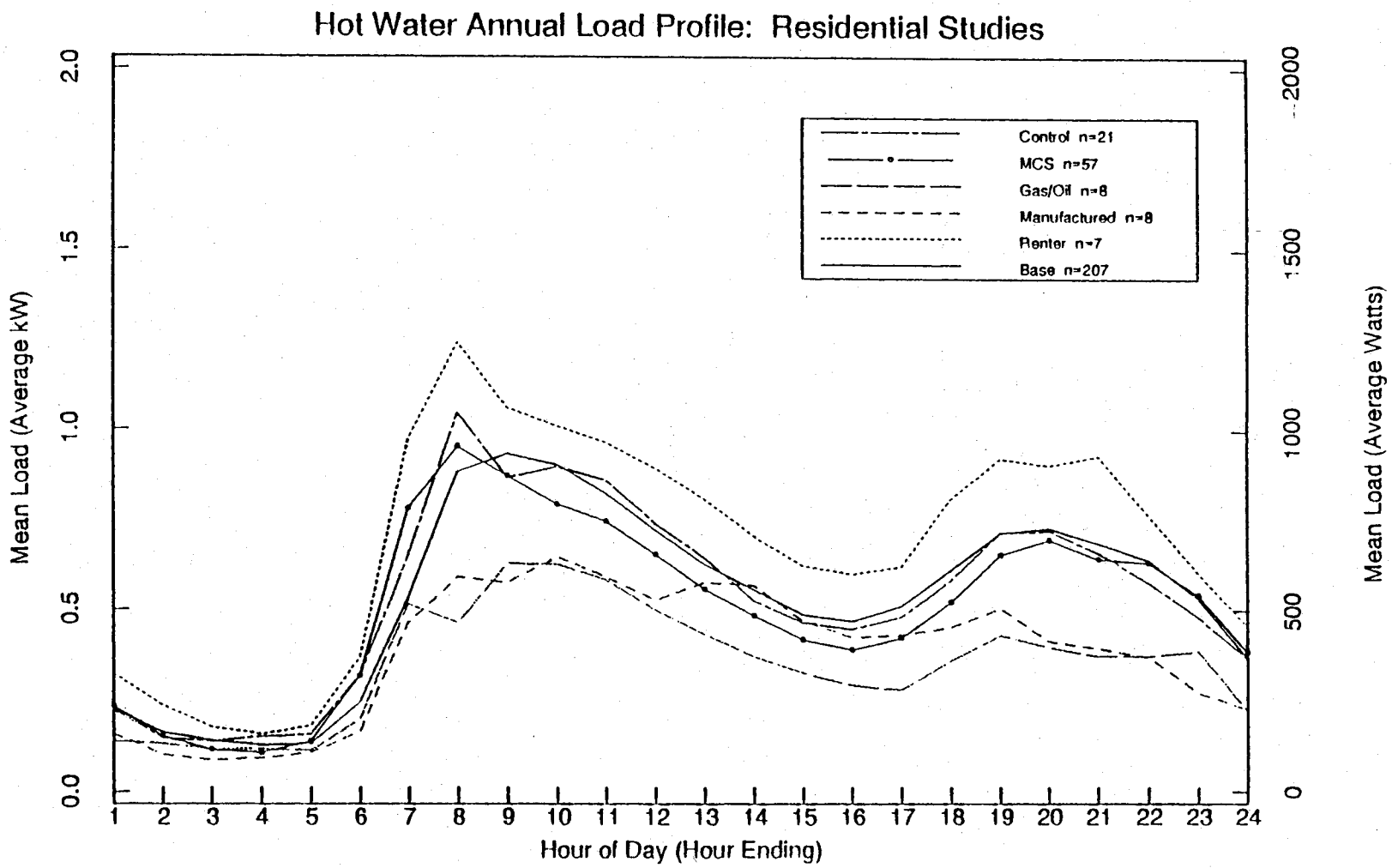
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.5



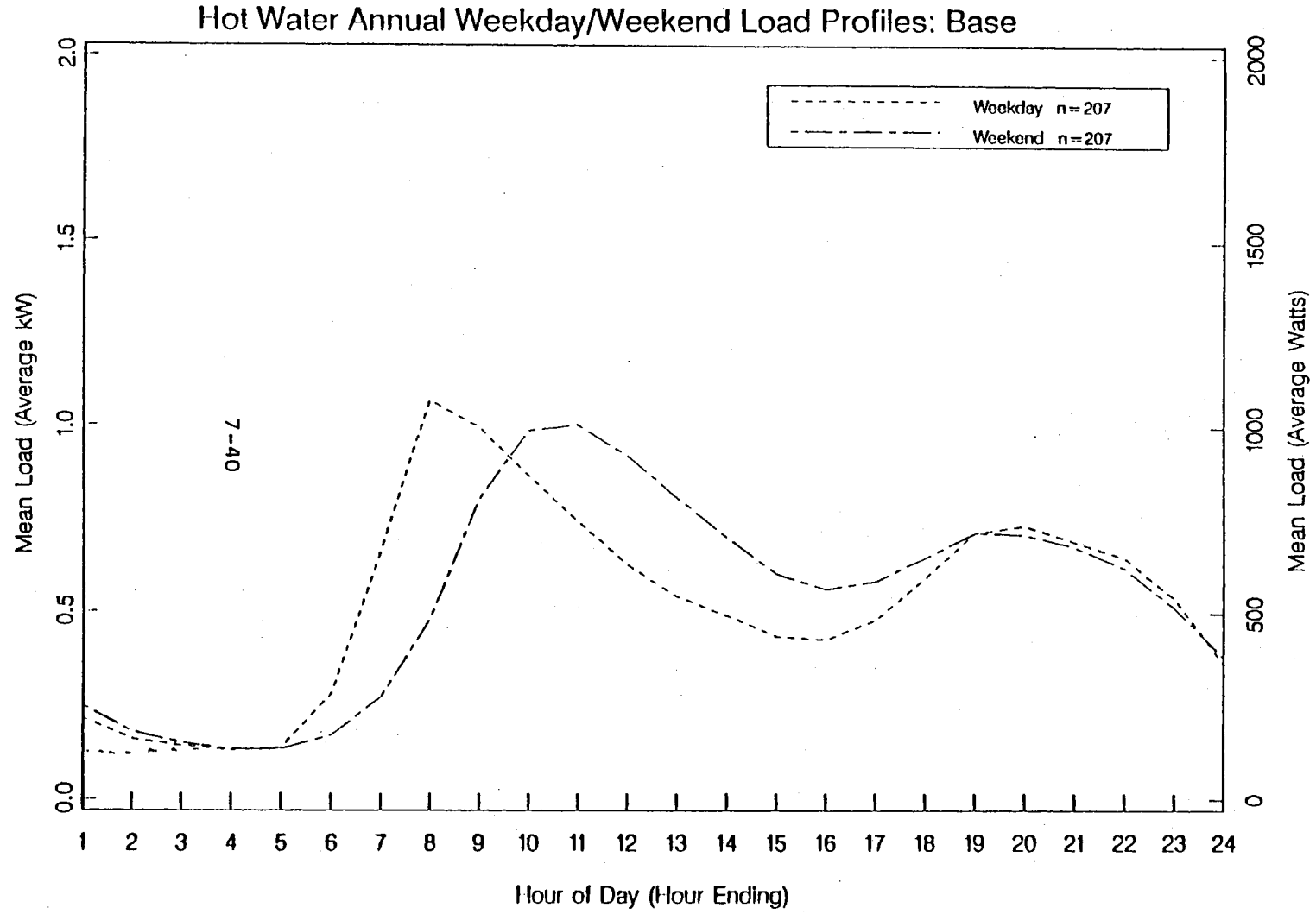
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

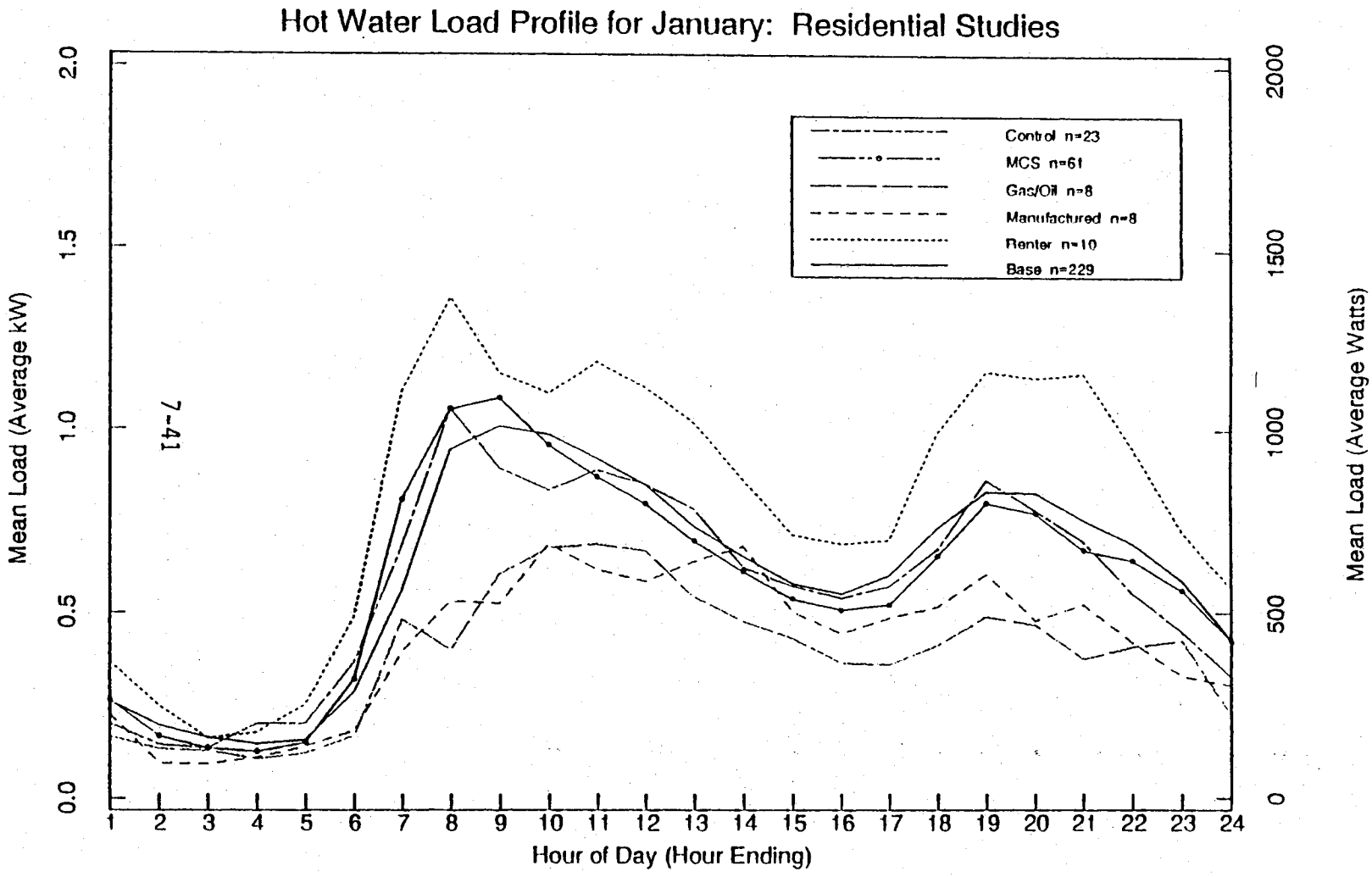
FIGURE 7B.7



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

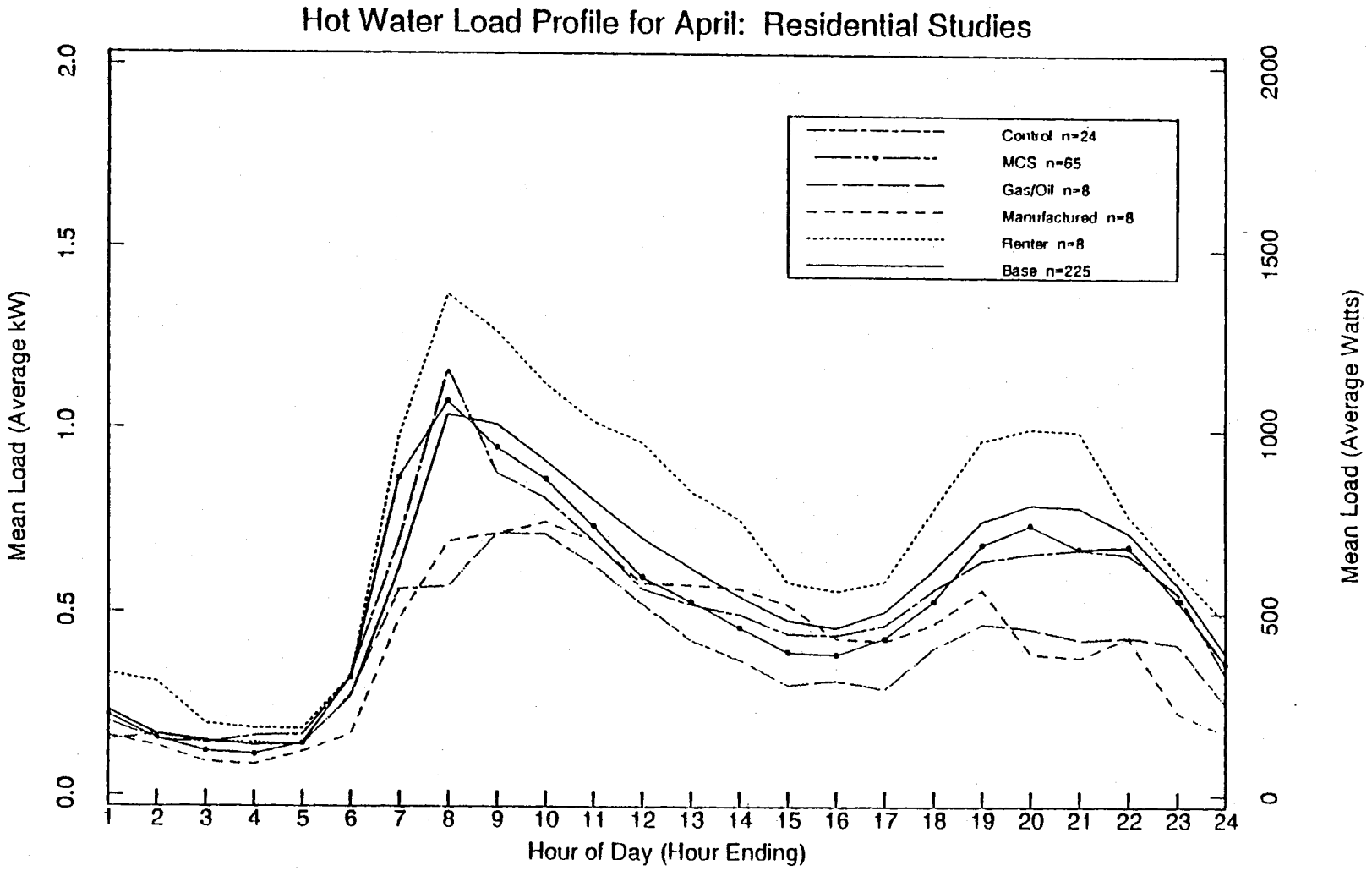
7-40

FIGURE 7B.8(a)



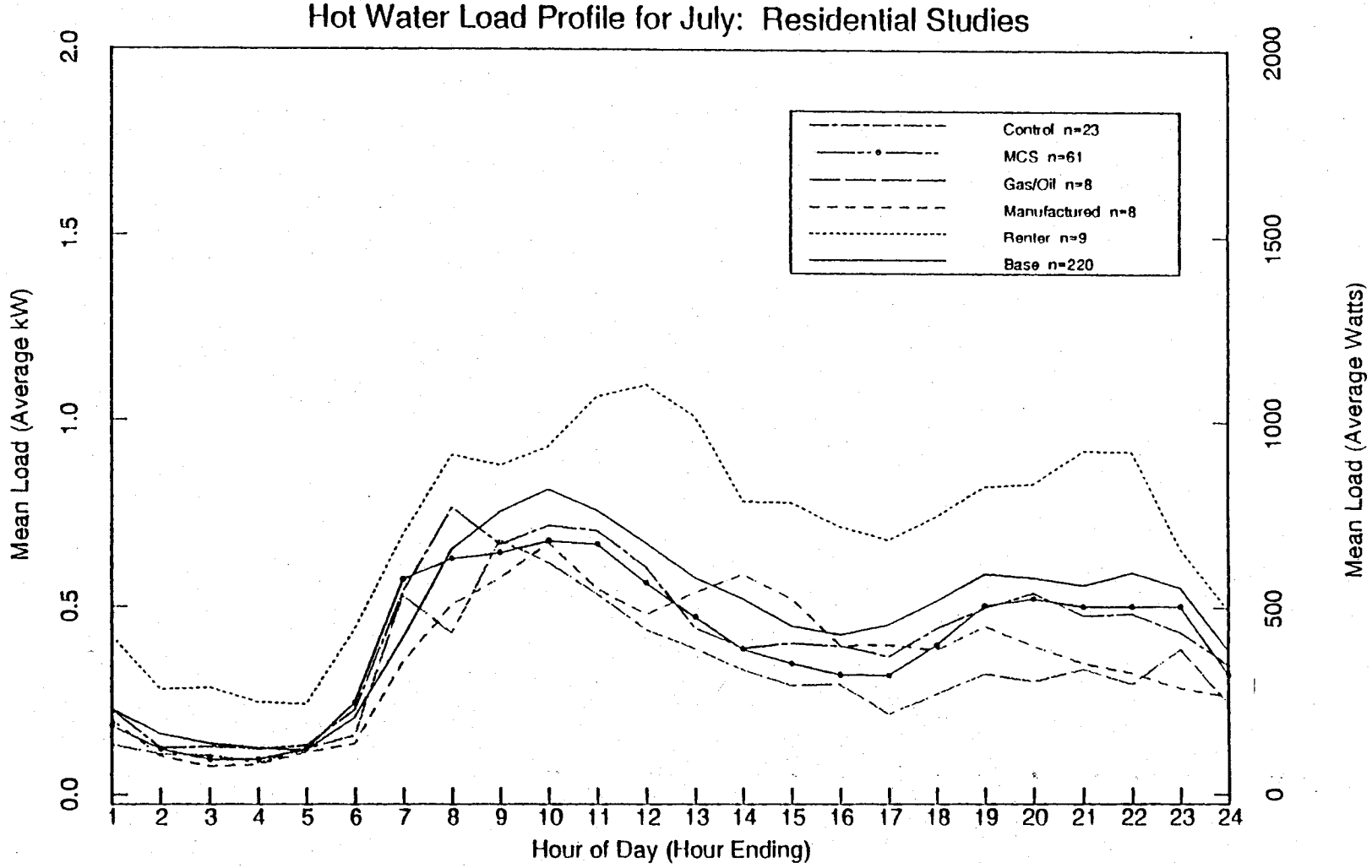
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.8(b)



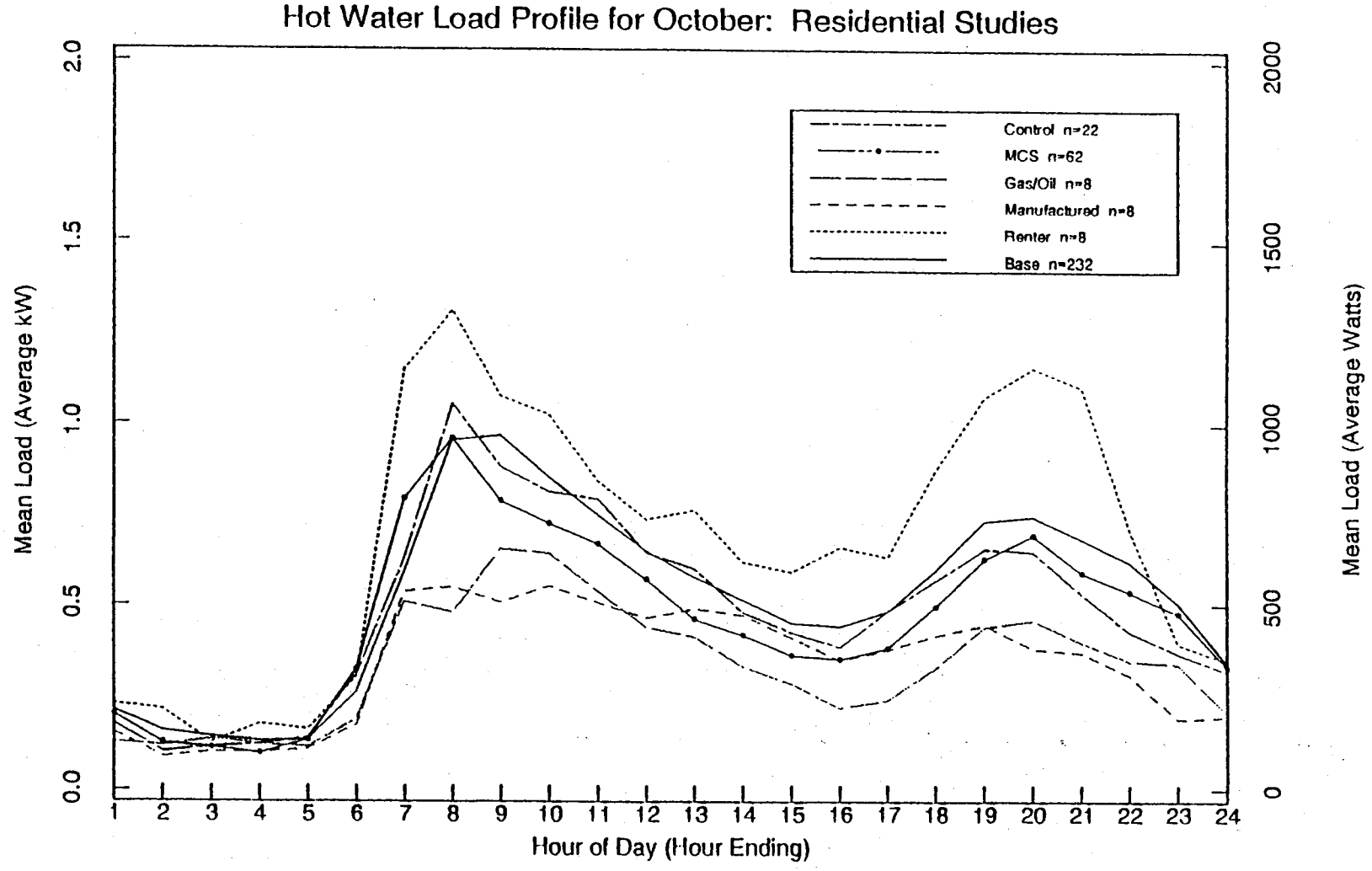
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.8(c)



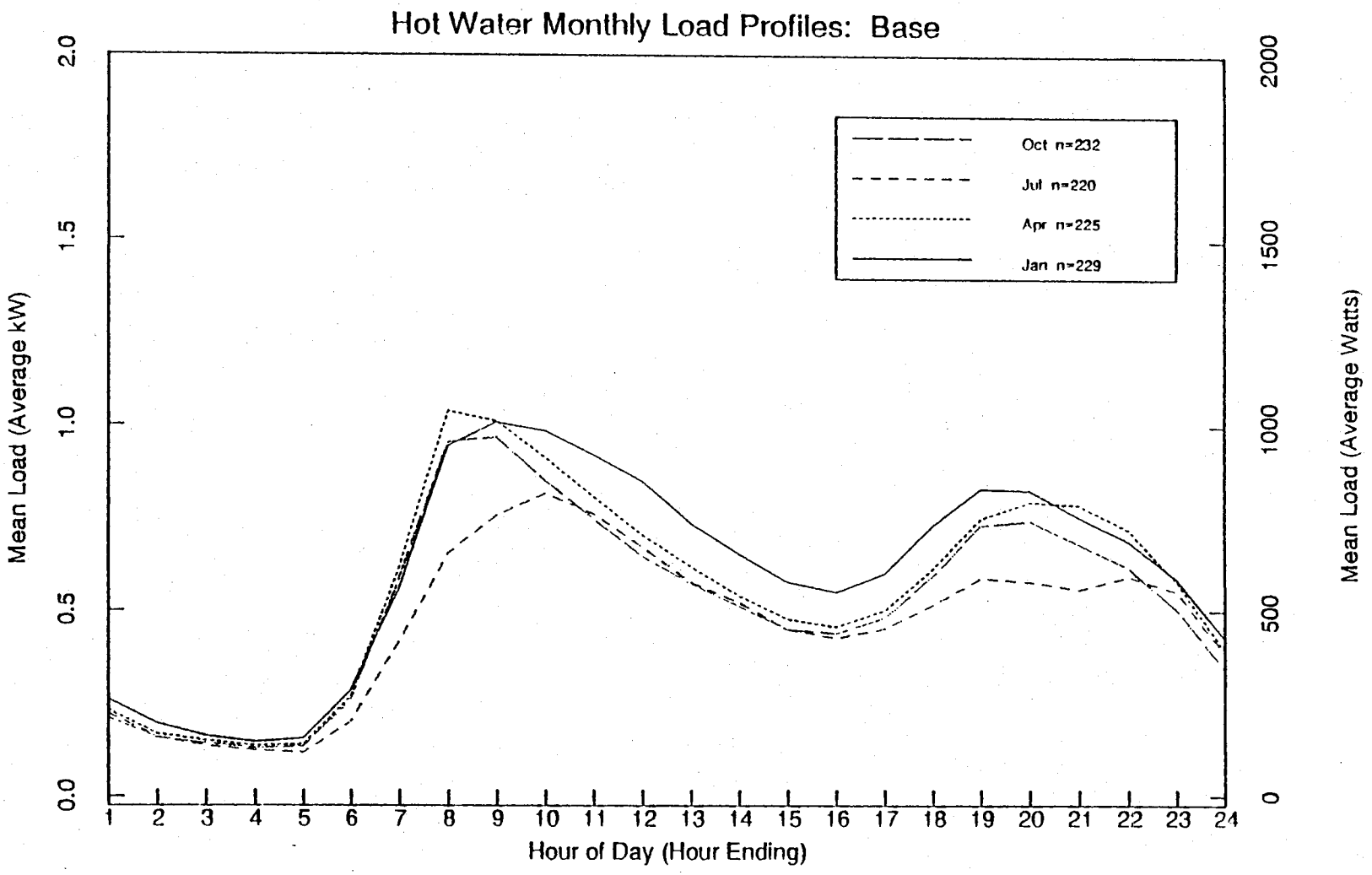
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.8(d)



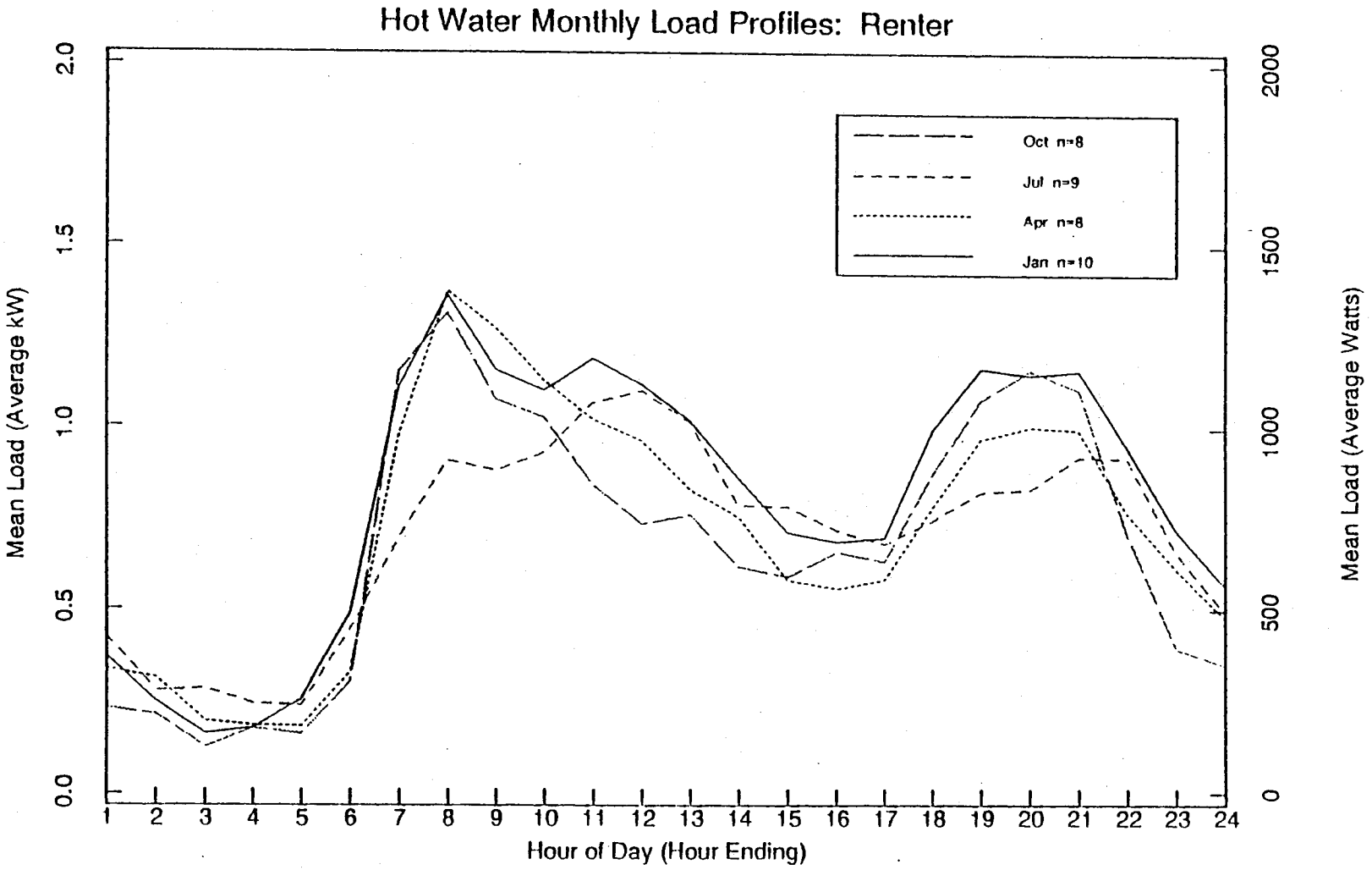
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.9(a)



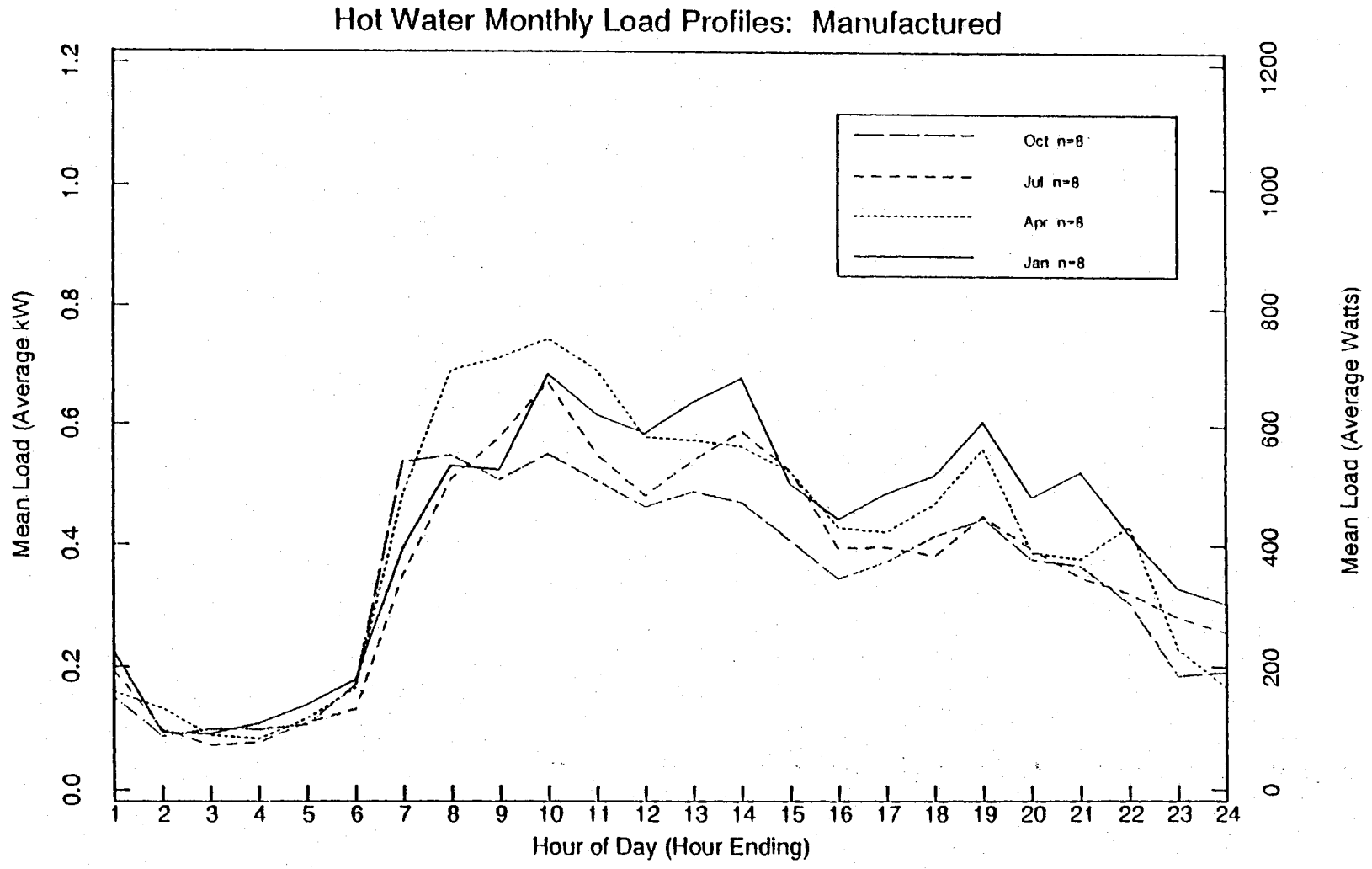
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.9(b)



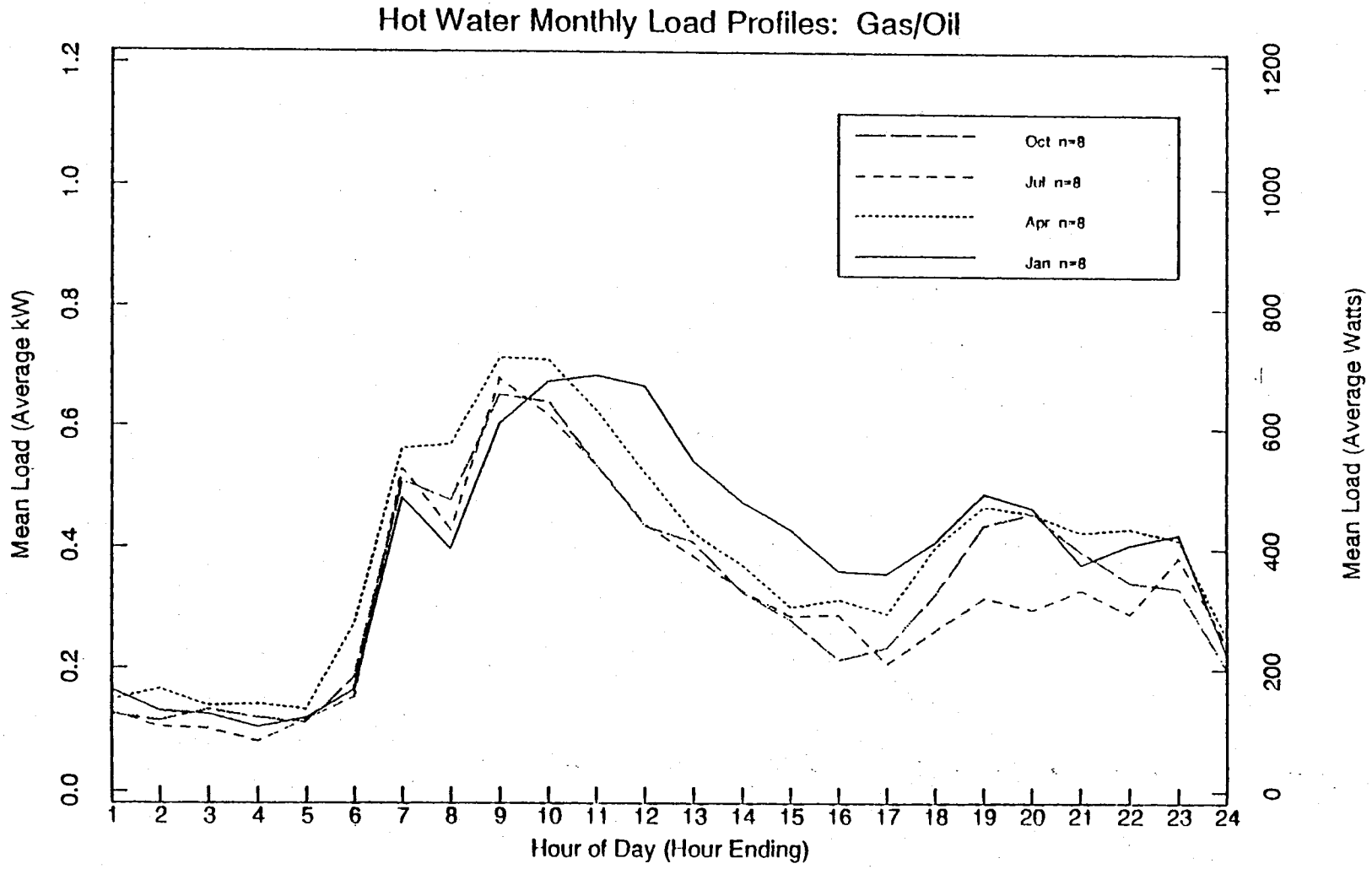
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.9(c)



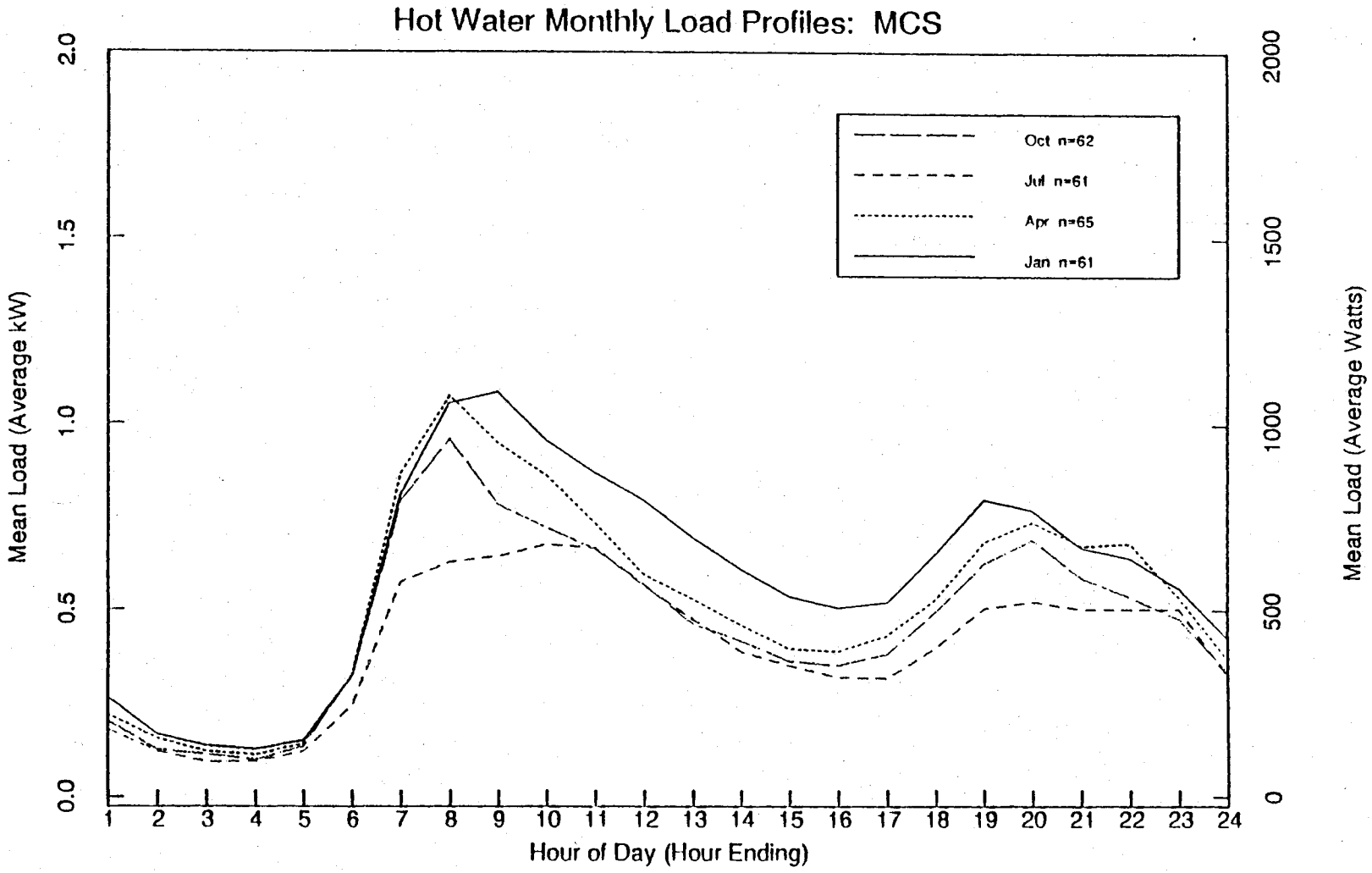
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.9(d)



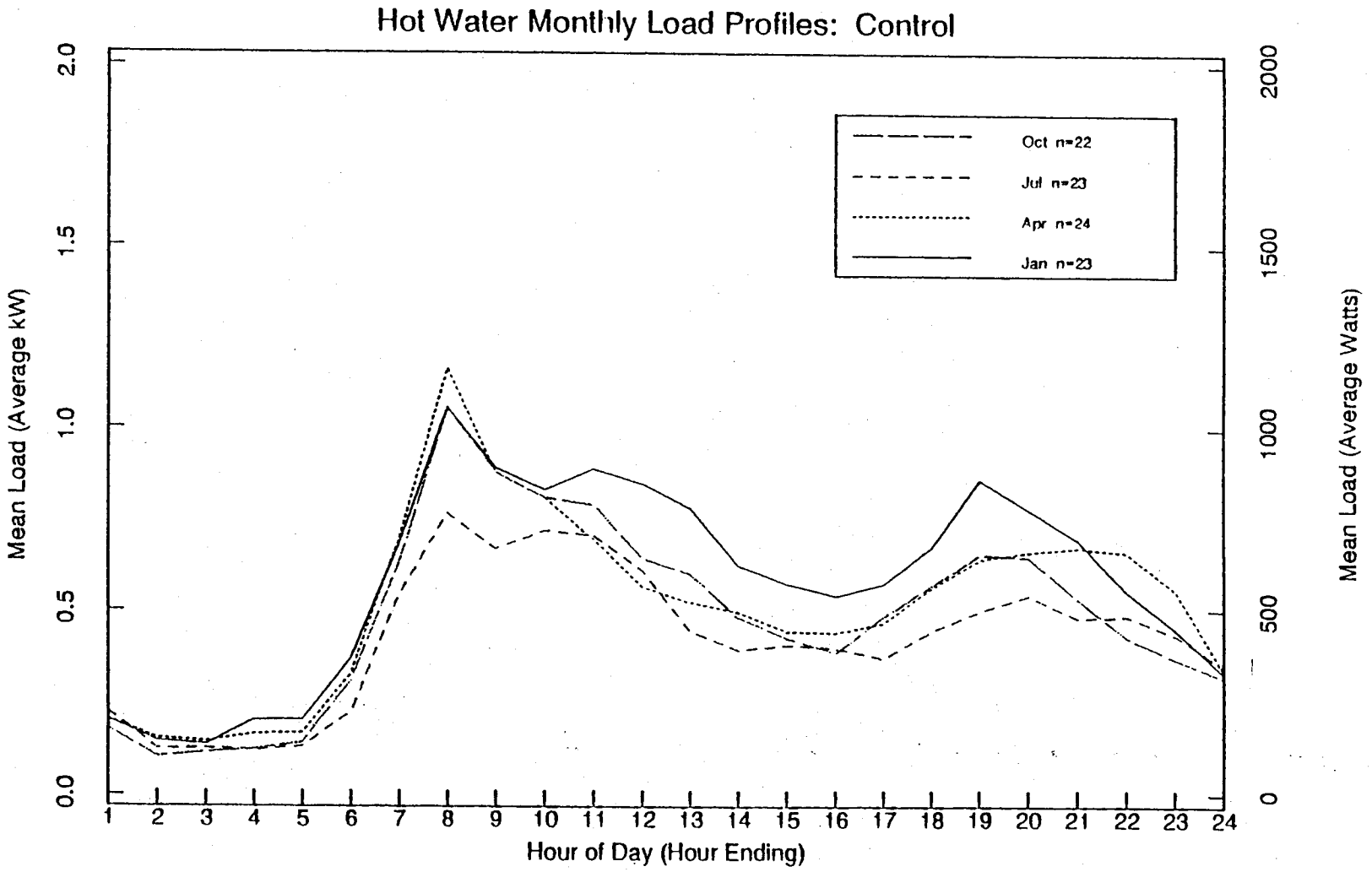
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7B.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

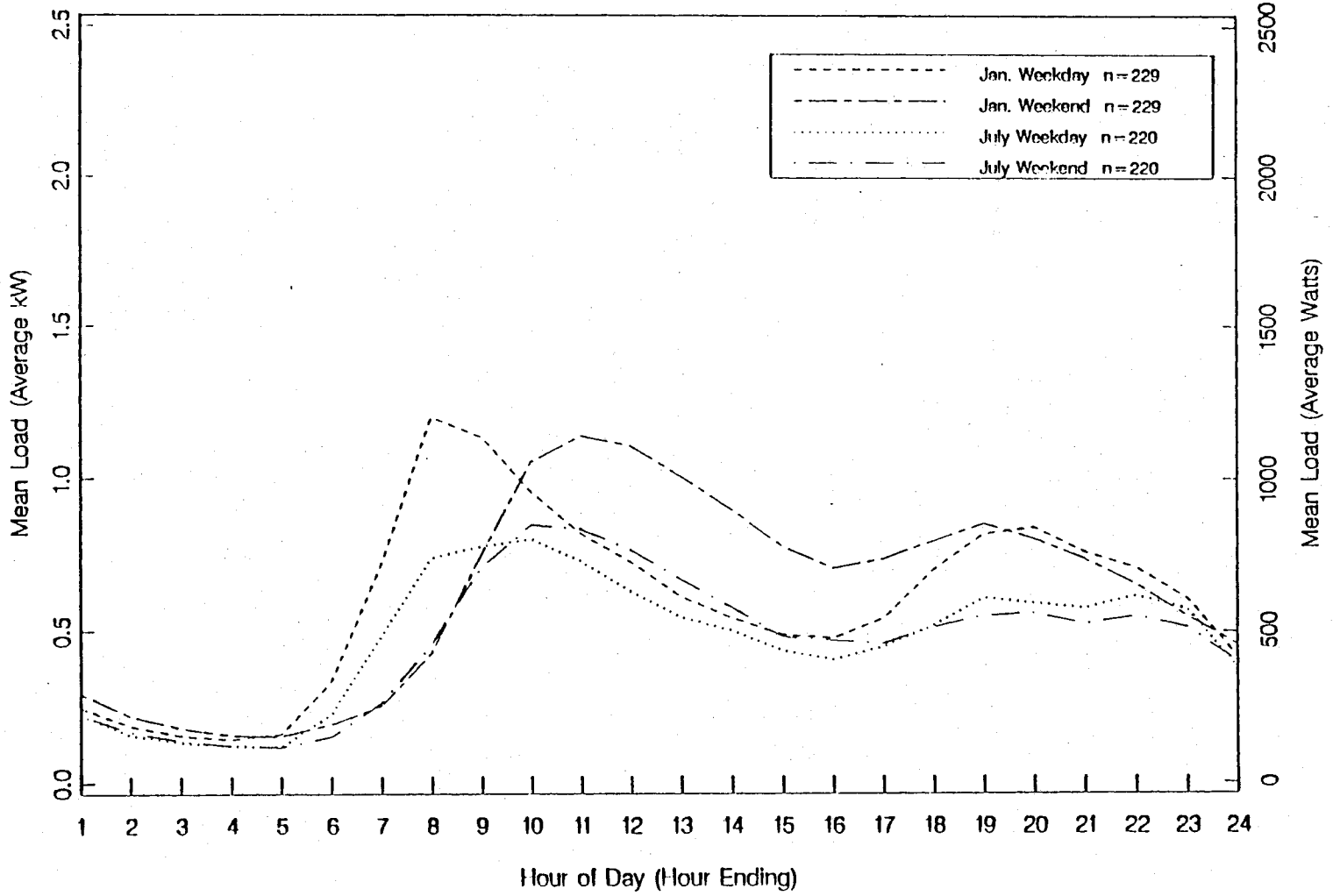
FIGURE 7B.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

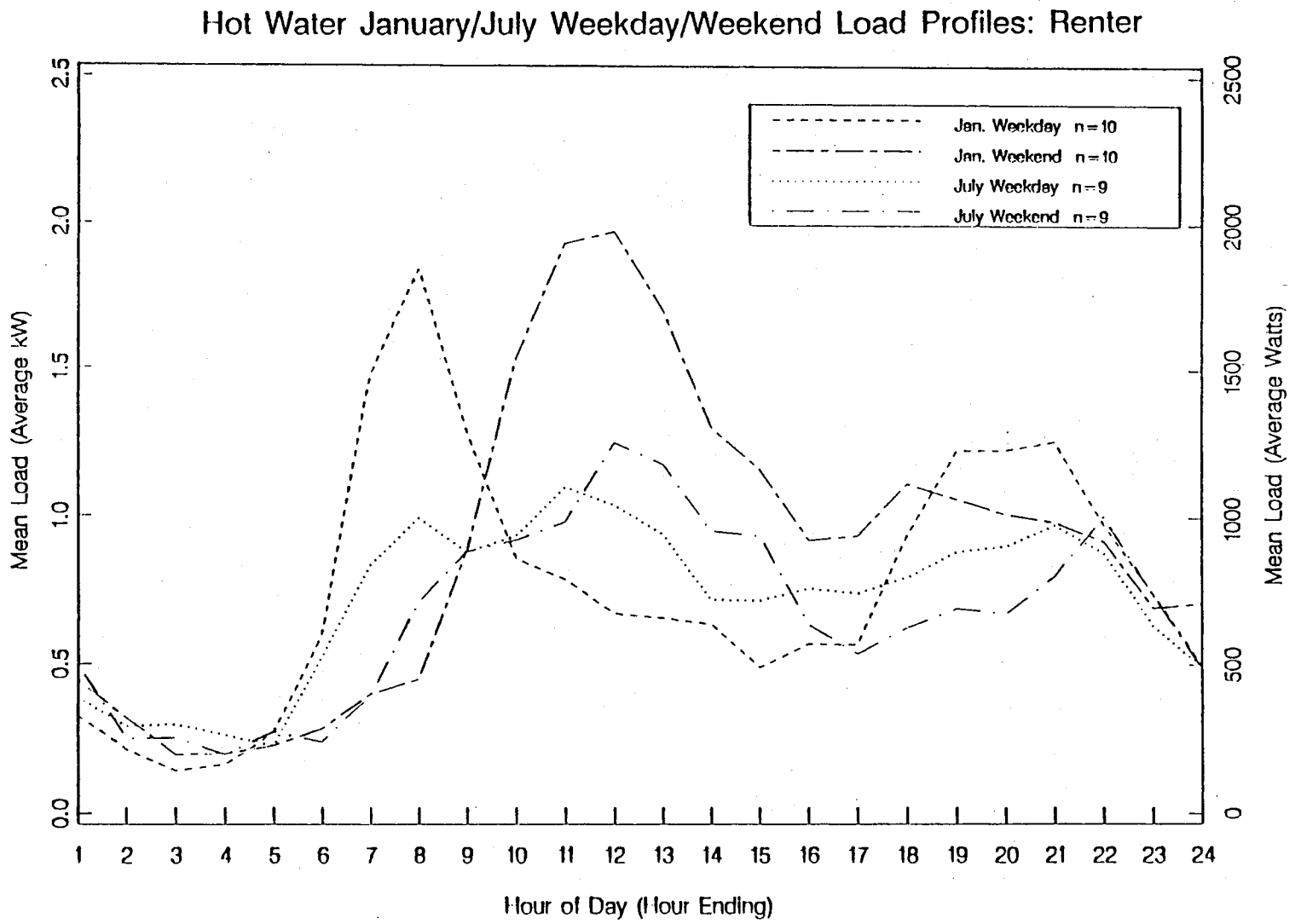
FIGURE 7B.10(a)

Hot Water January/July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

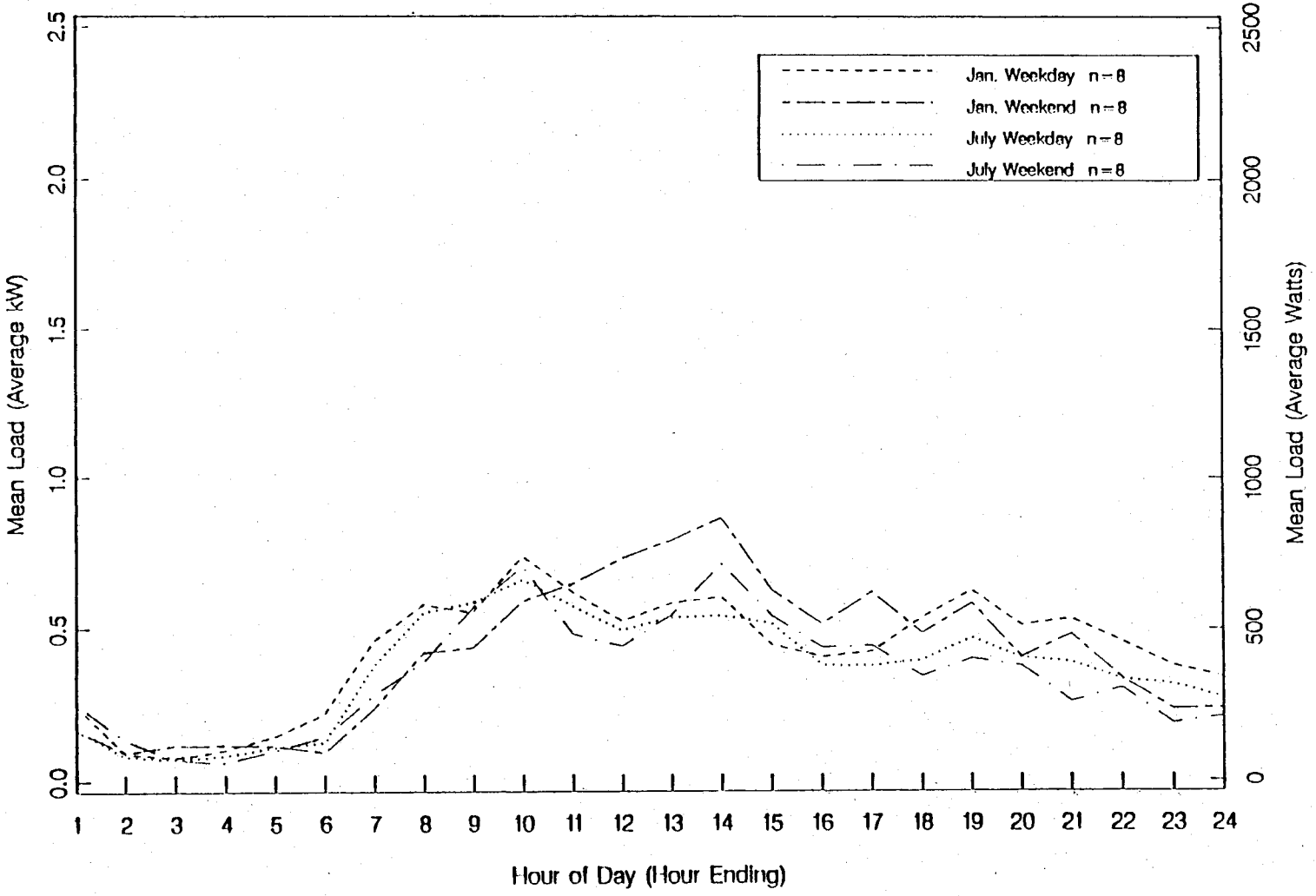
FIGURE 7B.10(b)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

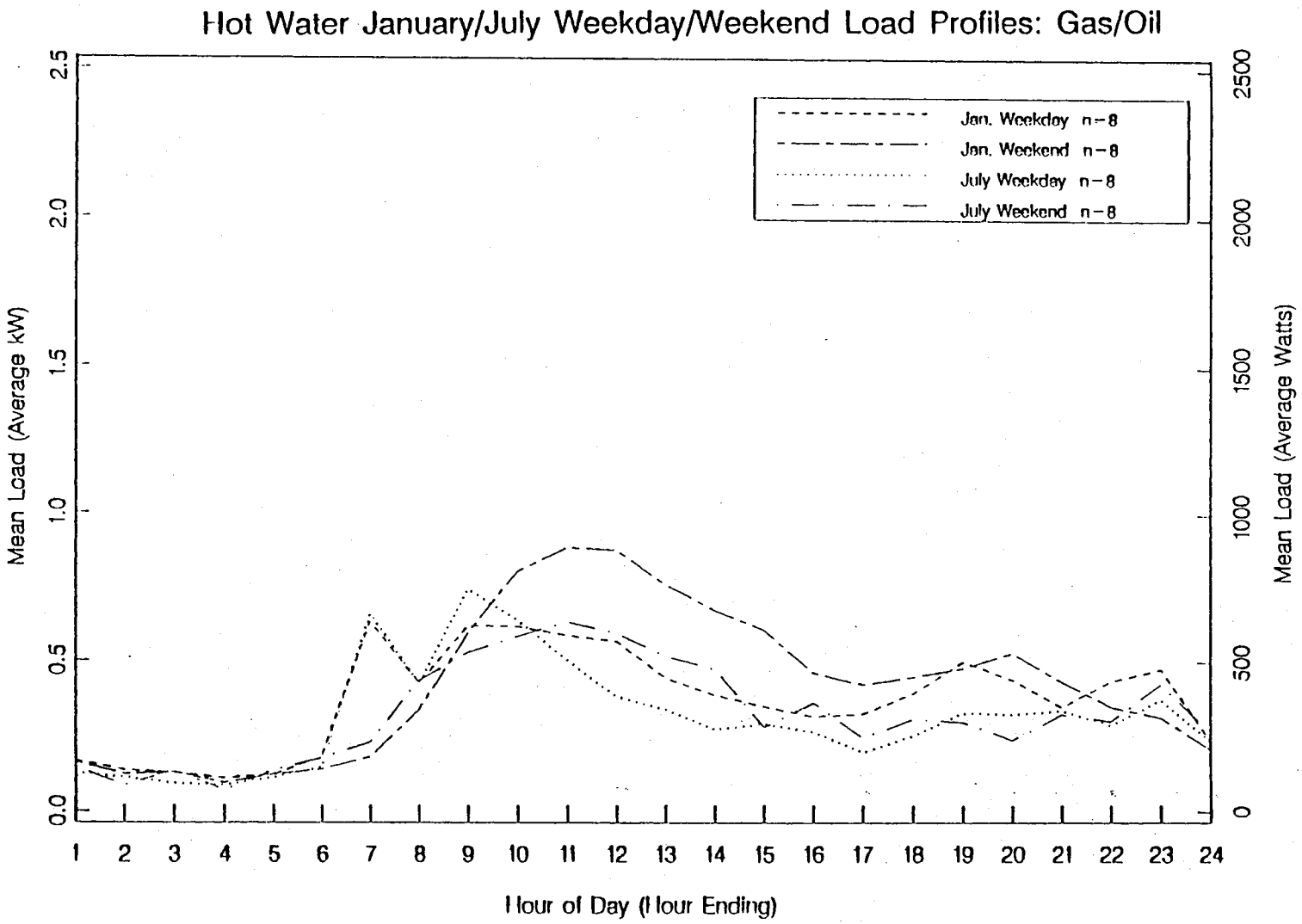
FIGURE 7B.10(c)

Hot Water January/July Weekday/Weekend Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

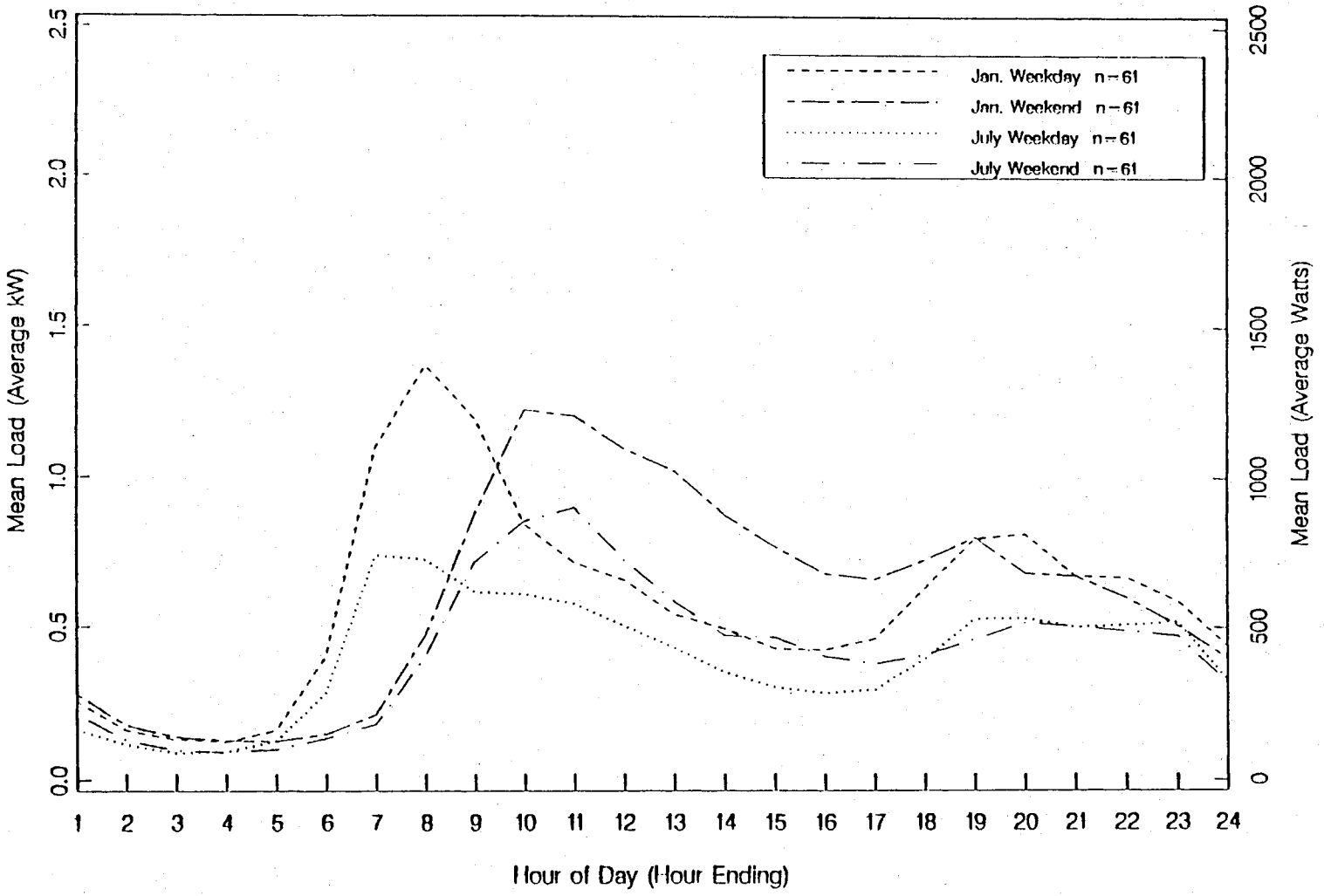
FIGURE 7B.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7B.10(e)

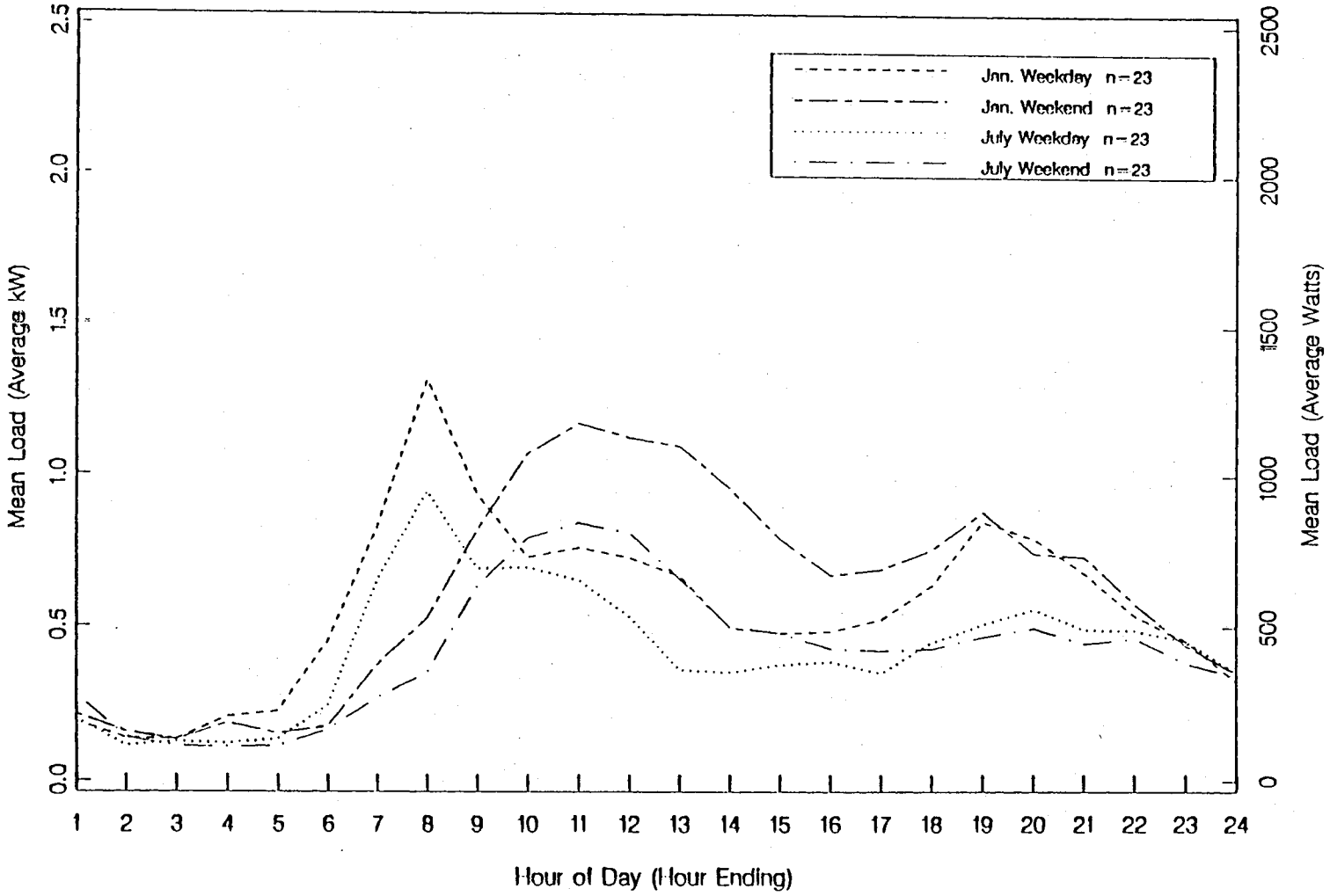
Hot Water January/July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7B.10(f)

Hot Water January/July Weekday/Weekend Load Profiles: Control



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7B.11

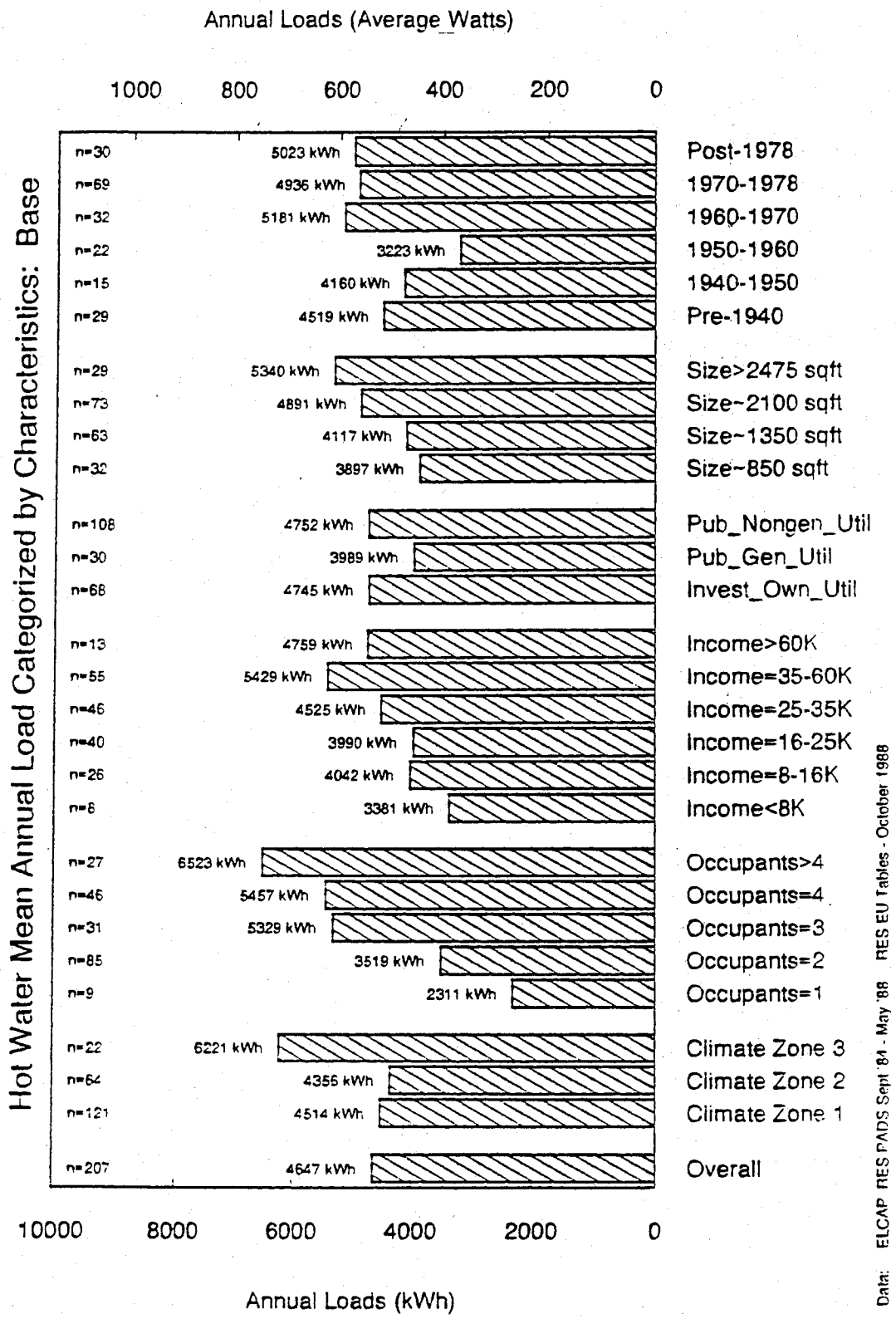

Hot Water Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
1000
800
600
400
200
0
n=30 5023 kWh Post-1978
n=69 4936 kWh 1970-1978
n=32 5181 kWh 1960-1970
n=22 3223 kWh 1950-1960
n=15 4160 kWh 1940-1950
n=29 4519 kWh Pre-1940
n=29 5340 kWh Size>2475 sqft
n=73 4891 kWh Size~2100 sqft
n=63 4117 kWh Size~1350 sqft
n=32 3897 kWh Size~850 sqft
n=108 4752 kWh Pub_Nongen_Util
n=30 3989 kWh Pub_Gen_Util
n=68 4745 kWh Invest_Own_Util
n=13 4759 kWh Income>60K
n=55 5429 kWh Income=35-60K
n=46 4525 kWh Income=25-35K
n=40 3990 kWh Income=16-25K
n=26 4042 kWh Income=8-16K
n=6 3381 kWh Income<8K
n=27 6523 kWh Occupants>4
n=46 5457 kWh Occupants=4
n=31 5329 kWh Occupants=3
n=85 3519 kWh Occupants=2
n=9 2311 kWh Occupants=1
n=22 6221 kWh Climate Zone 3
n=64 4356 kWh Climate Zone 2
n=121 4514 kWh Climate Zone 1
n=207 4647 kWh Overall
10000
8000
6000
4000
2000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7B.12

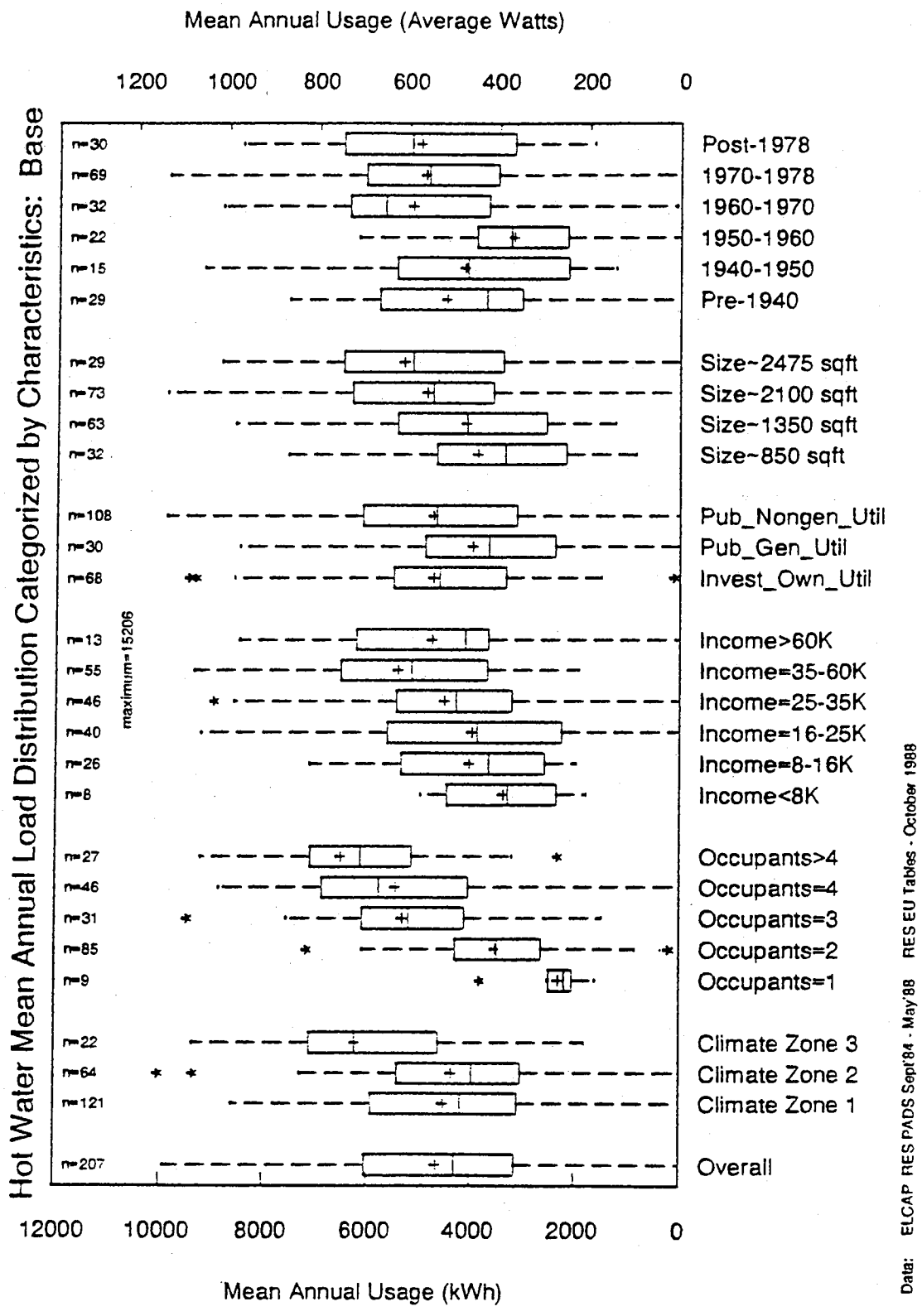

Hot Water Mean Annual Load Distribution Categorized by Characteristics: Base
Mean Annual Usage (Average Watts)
1200
1000
800
600
400
200
0
n=30
n=69
n=32
n=22
n=15
n=29
Post-1978
1970-1978
1960-1970
1950-1960
1940-1950
Pre-1940
n=29
n=73
n=63
n=32
Size~2475 sqft
Size~2100 sqft
Size~1350 sqft
Size~850 sqft
n=108
n=30
n=68
Pub_Nongen_Util
Pub_Gen_Util
Invest_Own_Util
maximum=15206
n=13
n=55
n=46
n=40
n=26
n=8
Income>60K
Income=35-60K
Income=25-35K
Income=16-25K
Income=8-16K
Income<8K
n=27
n=46
n=31
n=85
n=9
Occupants>4
Occupants=4
Occupants=3
Occupants=2
Occupants=1
n=22
n=64
n=121
Climate Zone 3
Climate Zone 2
Climate Zone 1
n=207
Overall
12000
10000
8000
6000
4000
2000
0
Mean Annual Usage (kWh)
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7B.1

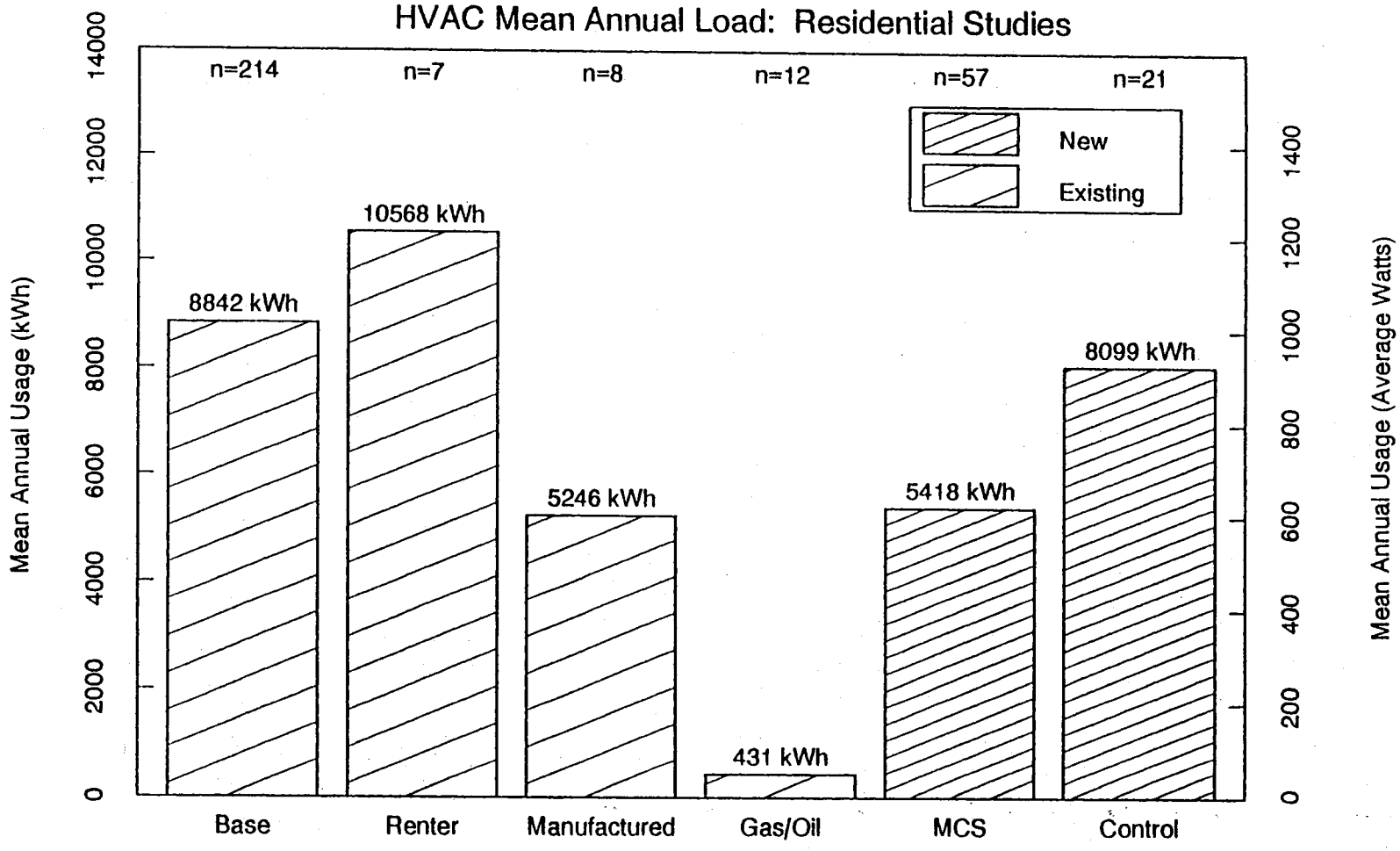
Hot Water Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	207	4647	2292	21	4682	1883	57	4439	1967	285	4608	2197
Climate Zone 1	121	4514	2182	13	4398	1481	36	4410	1418	170	4483	1989
Climate Zone 2	64	4356	2097	4	6783	2471	17	4611	2946	85	4521	2332
Climate Zone 3	22	6221	2855	4	3505	819	4	3974	1416	30	5560	2728
Occupants=1	9	2311	602	1	3172	0	2	4297	1702	12	2714	1065
Occupants=2	85	3519	1286	7	3789	808	14	3289	1252	106	3506	1251
Occupants=3	31	5329	2053	3	3819	1590	8	4968	1505	42	5152	1938
Occupants=4	46	5457	2311	3	6989	2441	7	4707	1598	56	5446	2250
Occupants>4	27	6523	2882	1	8232	0	5	6618	4150	33	6589	2999
Income<8K	8	3381	1221	0	-	-	1	4039	0	9	3454	1163
Income=8-16K	28	4042	1658	1	5100	0	1	2949	0	28	4040	1622
Income=16-25K	40	3990	1953	1	2914	0	8	4332	2416	49	4024	1998
Income=25-35K	46	4525	2285	8	5048	2173	12	4162	1263	66	4523	2110
Income=35-60K	55	5429	2519	3	5137	2692	13	4974	2926	71	5333	2570
Income>60K	13	4759	2173	1	4504	0	1	4166	0	15	4702	2018
Invest_Own_Util	68	4745	2149	10	4699	1707	32	4495	2122	110	4668	2091
Pub_Gen_Util	30	3989	2444	7	4655	1374	10	5461	1155	47	4401	2153
Pub_Nongen_Util	108	4752	2331	4	4689	3332	11	3301	1889	123	4620	2346
Size<850 sqft	32	3897	2222	1	9485	0	1	2949	0	34	4034	2365
Size<1350 sqft	63	4117	1666	13	3992	1275	26	4047	1356	102	4083	1534
Size<2100 sqft	73	4891	1997	6	4943	1728	17	4878	2684	96	4892	2096
Size>2475 sqft	29	5340	3222	0	-	-	9	4679	2153	38	5184	2990
Pre-1940	29	4519	2601	0	-	-	0	-	-	29	4519	2601
1940-1950	15	4160	2052	0	-	-	0	-	-	15	4160	2052
1950-1960	22	3223	1525	0	-	-	0	-	-	22	3223	1525
1960-1970	32	5181	2341	0	-	-	0	-	-	32	5181	2341
1970-1978	69	4936	2321	0	-	-	0	-	-	69	4936	2321
Post-1978	30	5023	2313	21	4682	1883	57	4439	1967	108	4649	2050

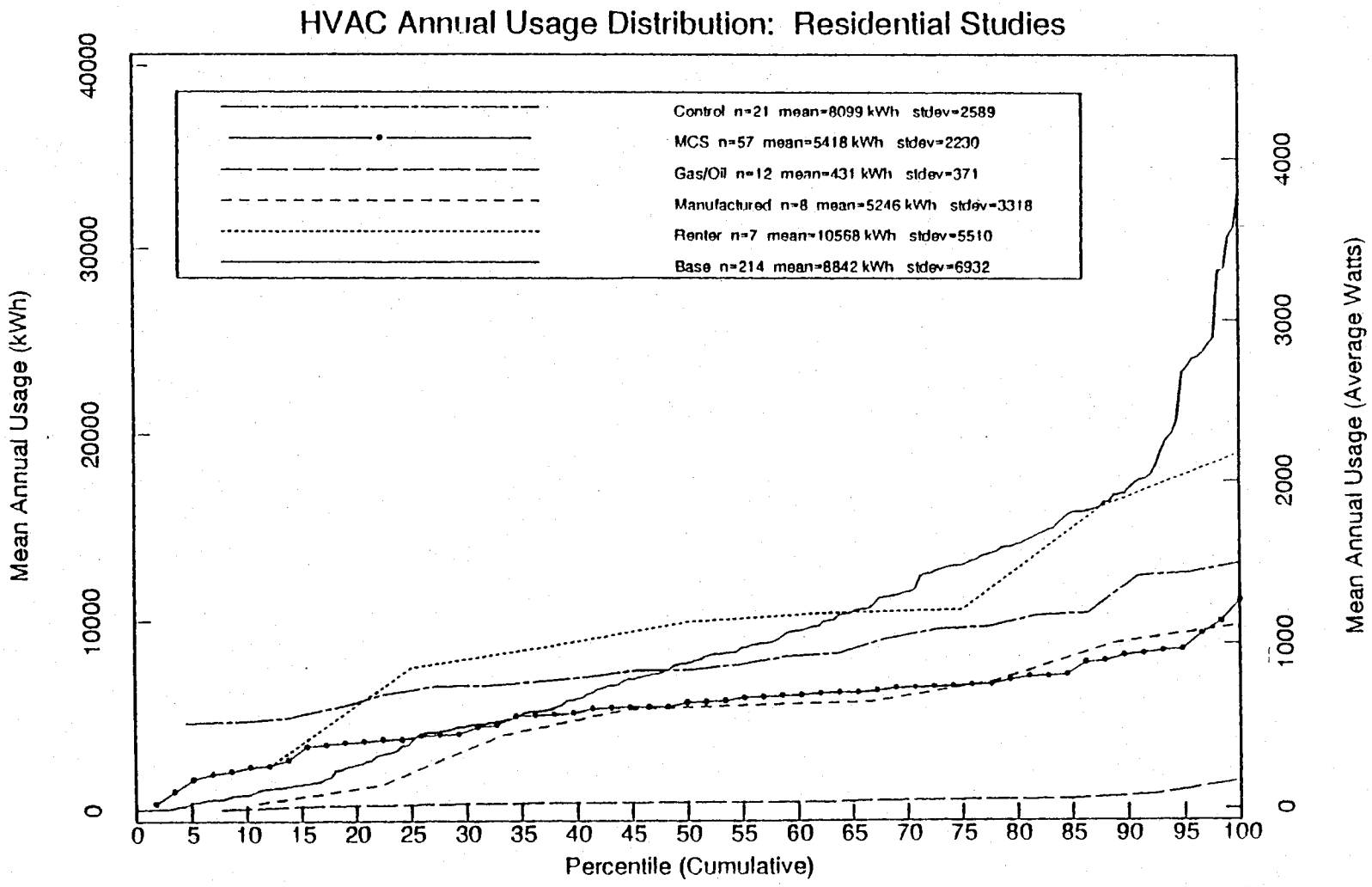
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7C.1



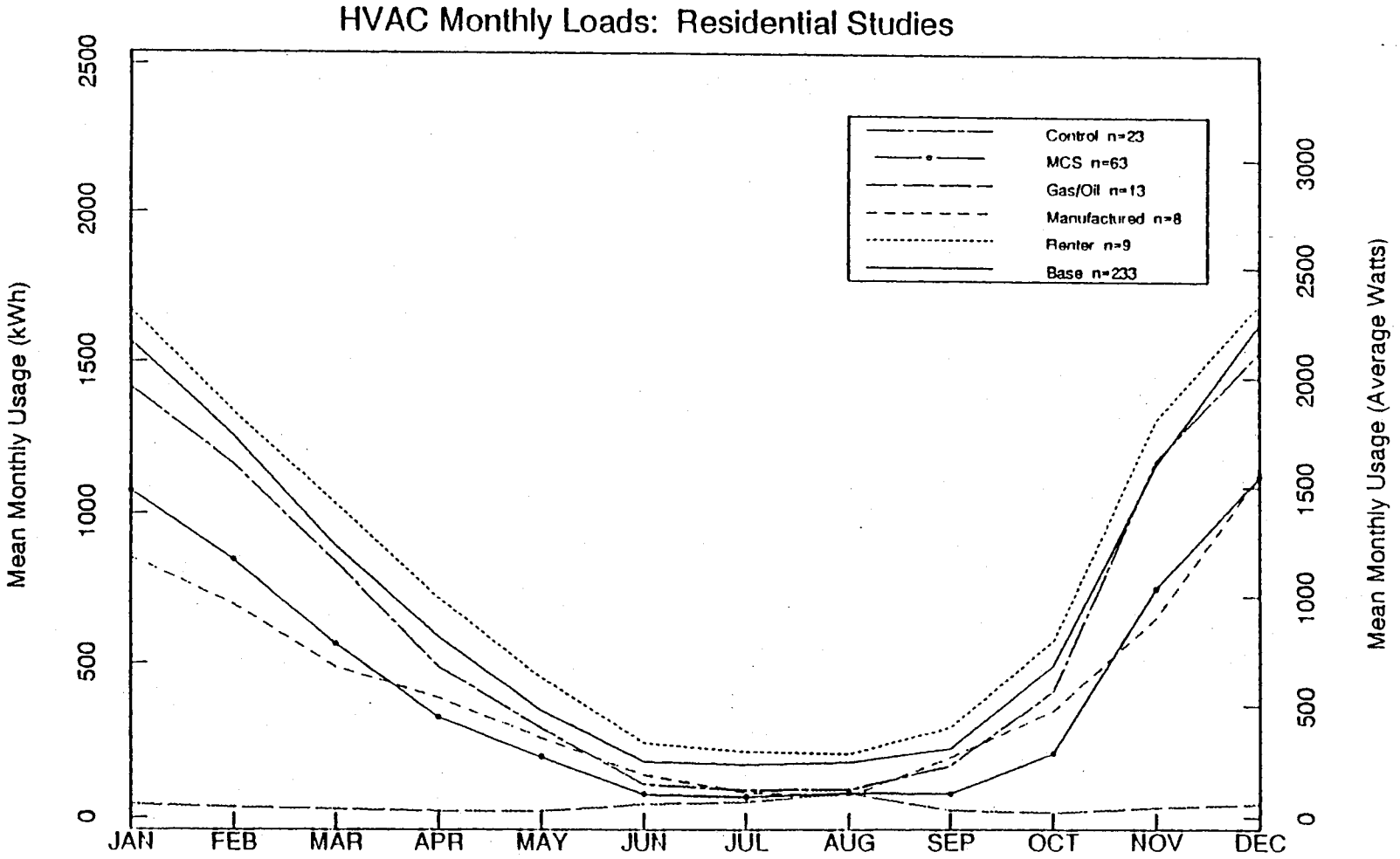
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.2



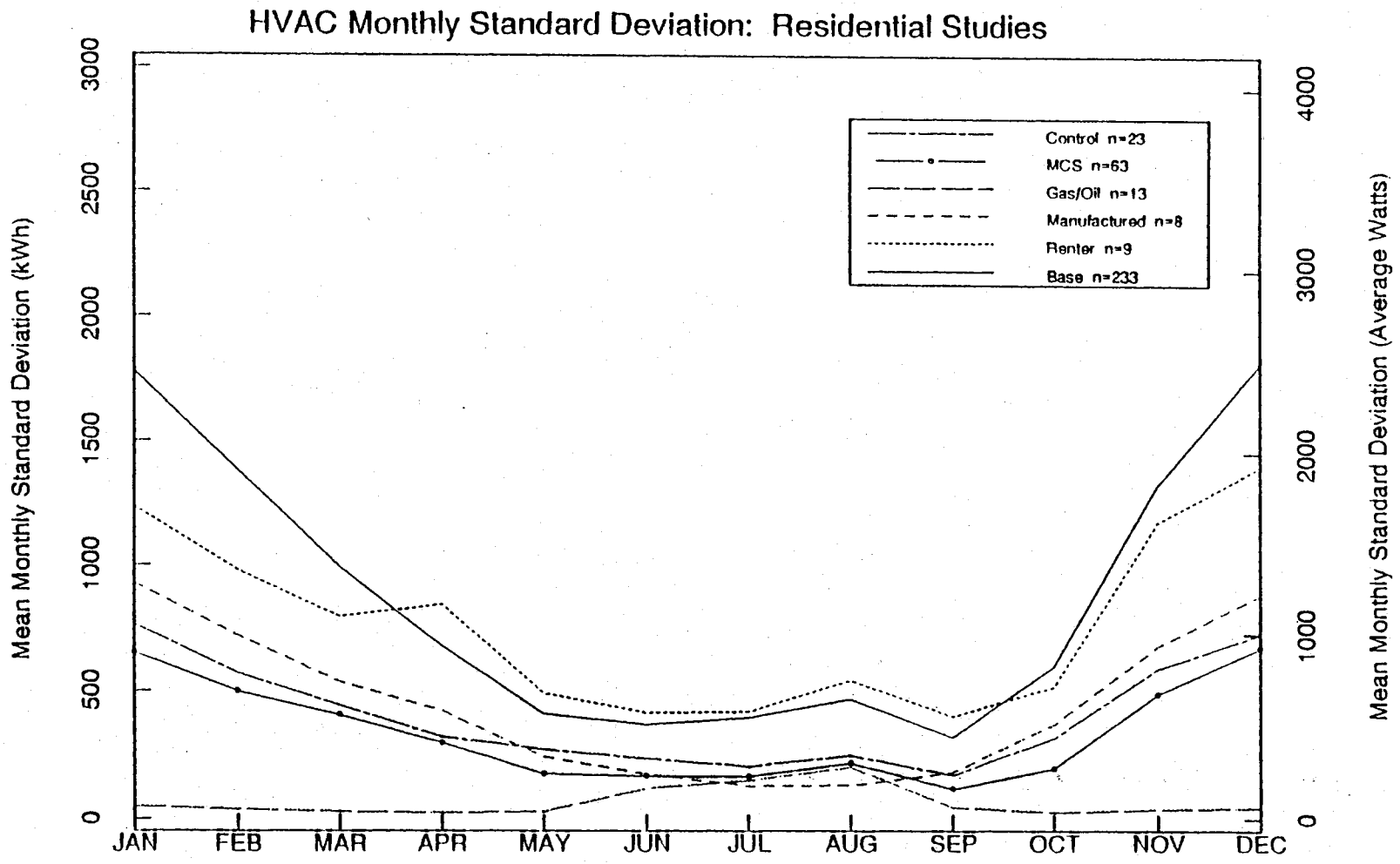
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.3



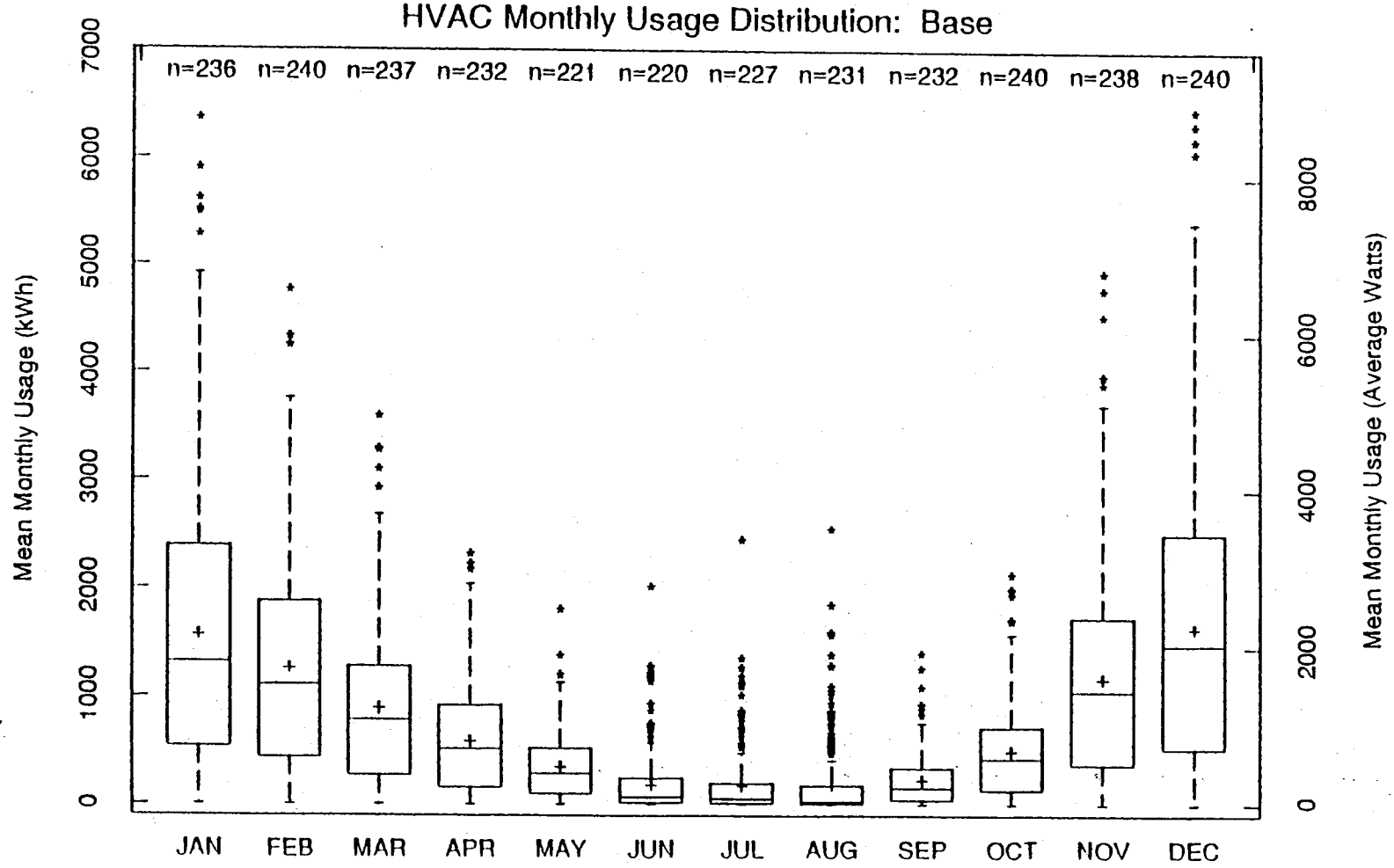
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.4



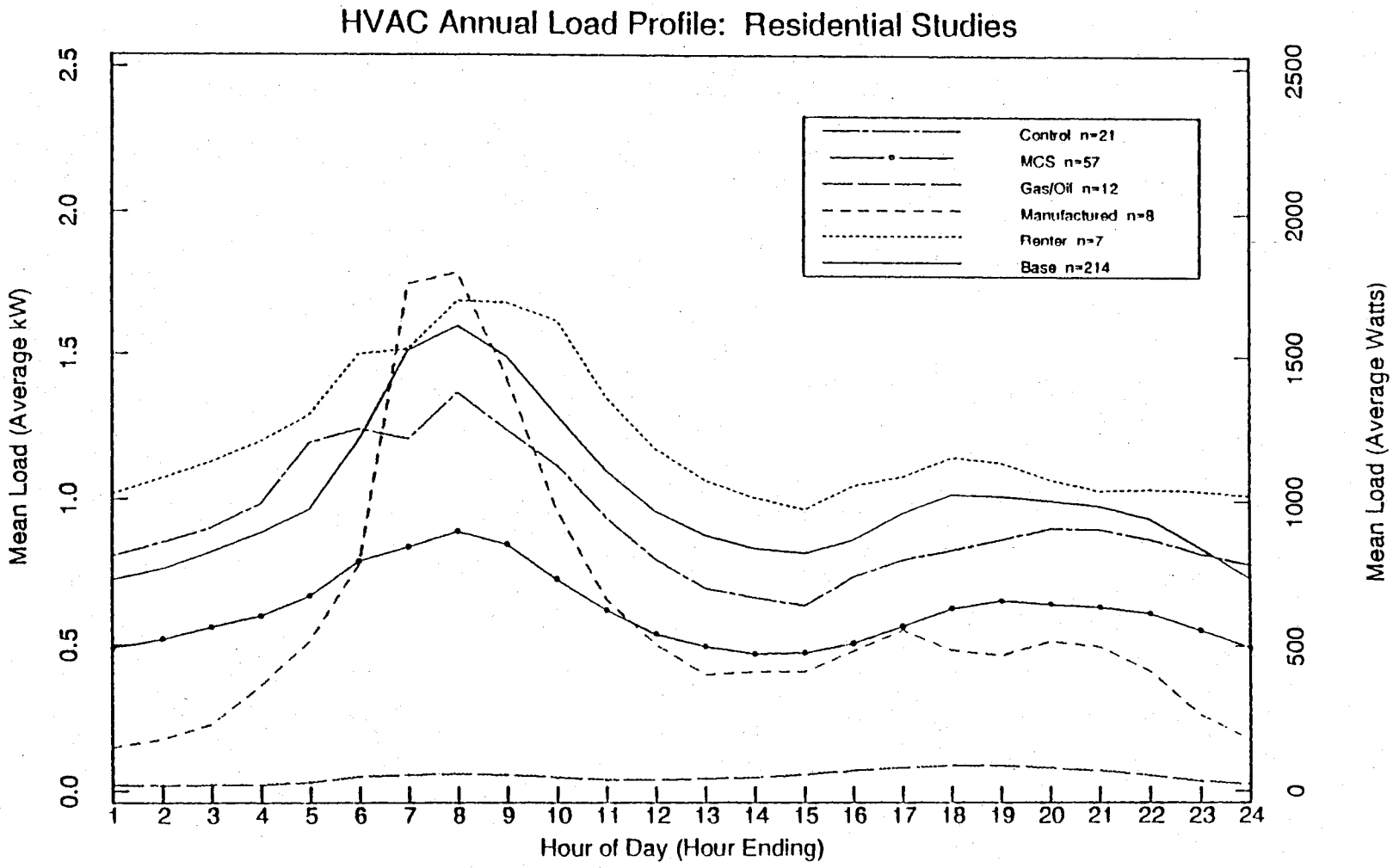
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.5



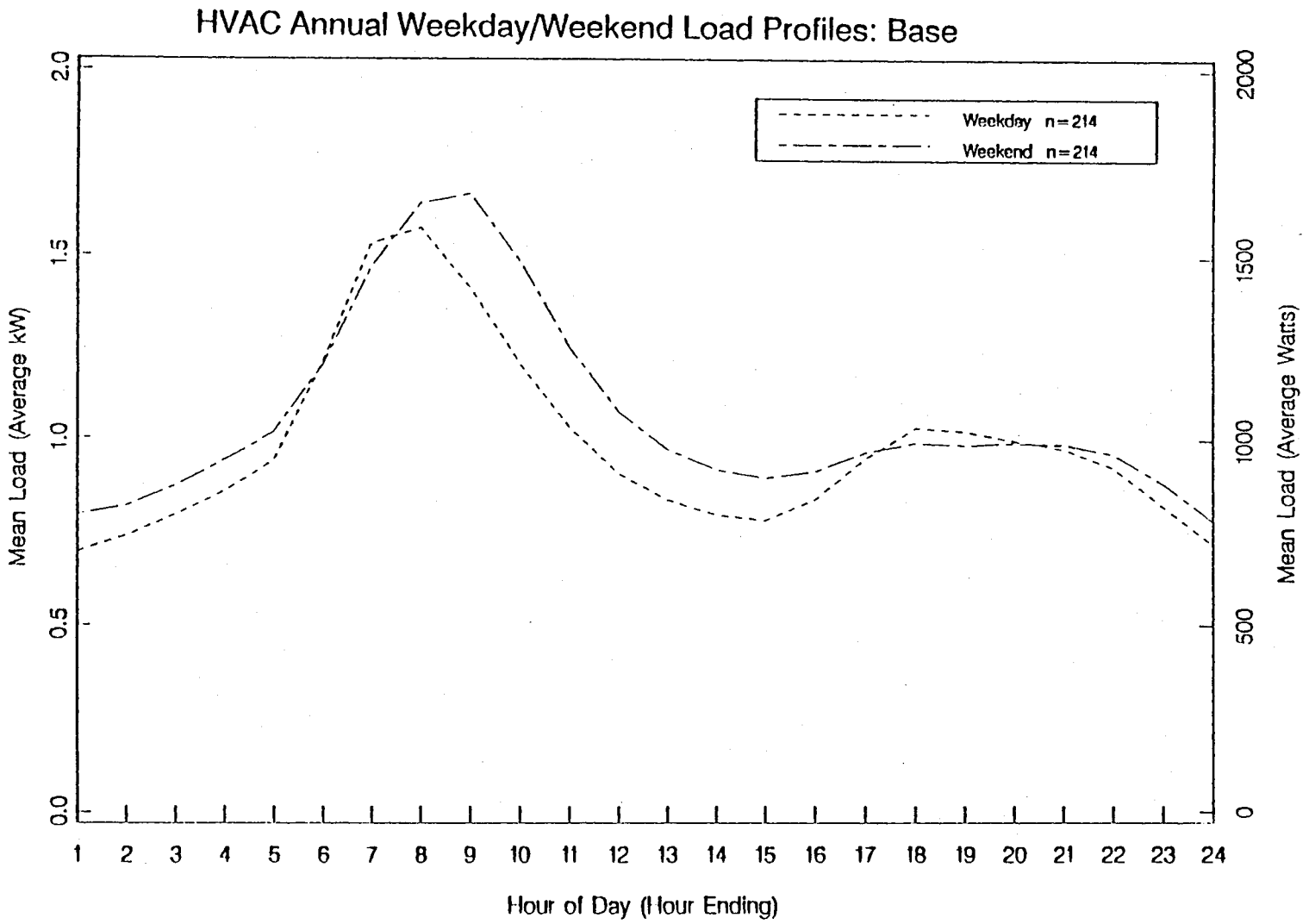
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

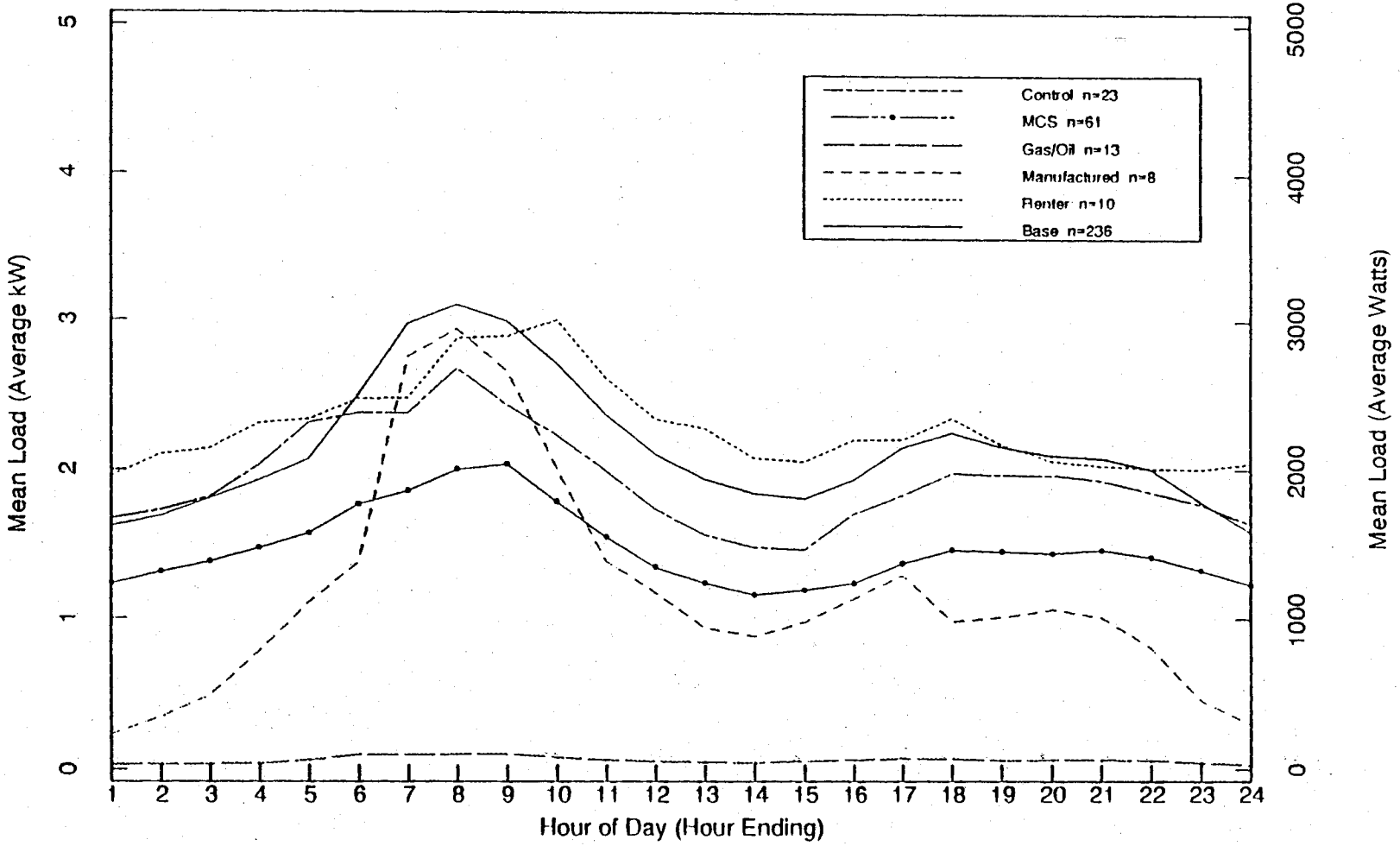
FIGURE 7C.7



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

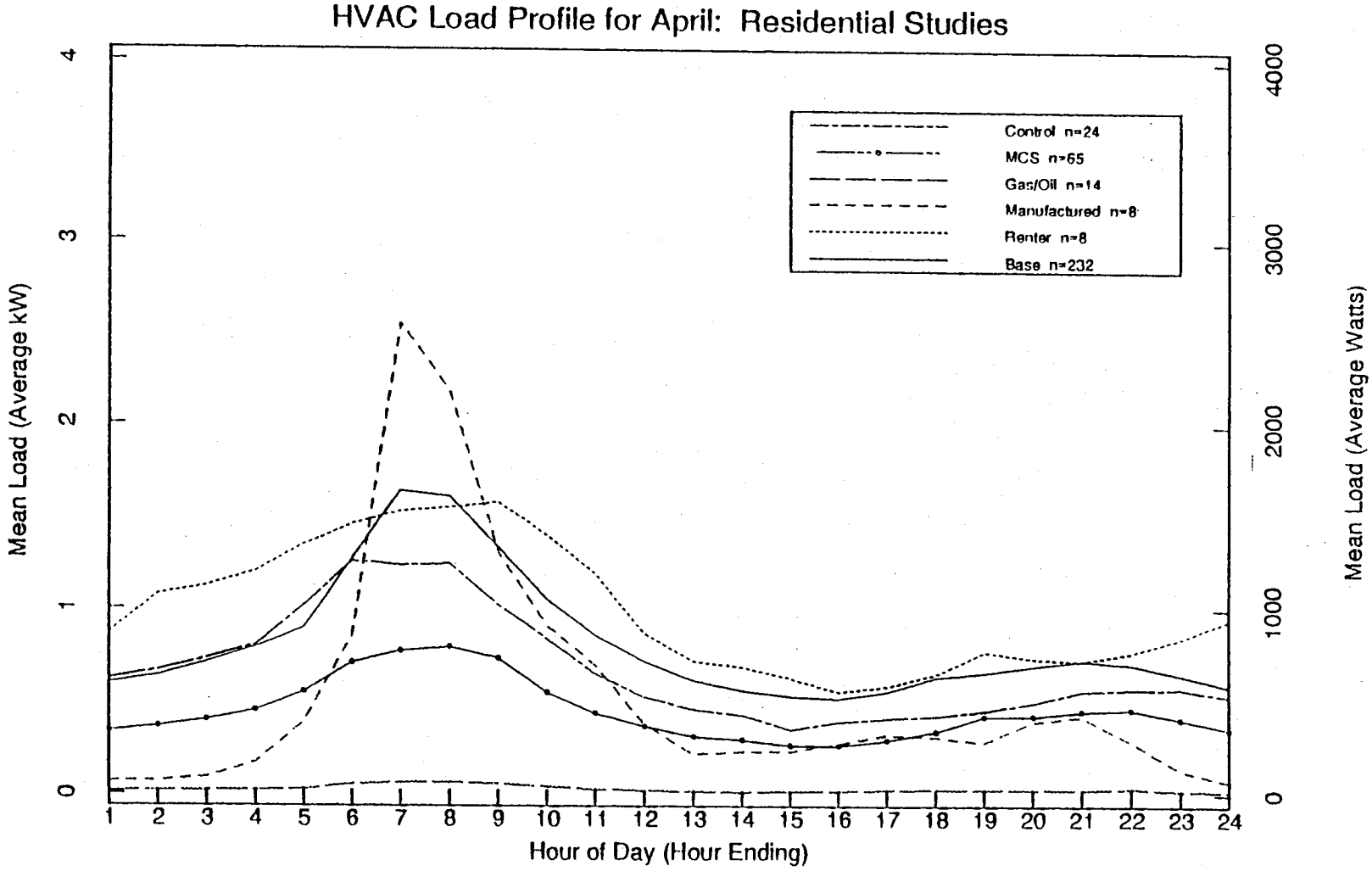
FIGURE 7C.8(a)

HVAC Load Profile for January: Residential Studies



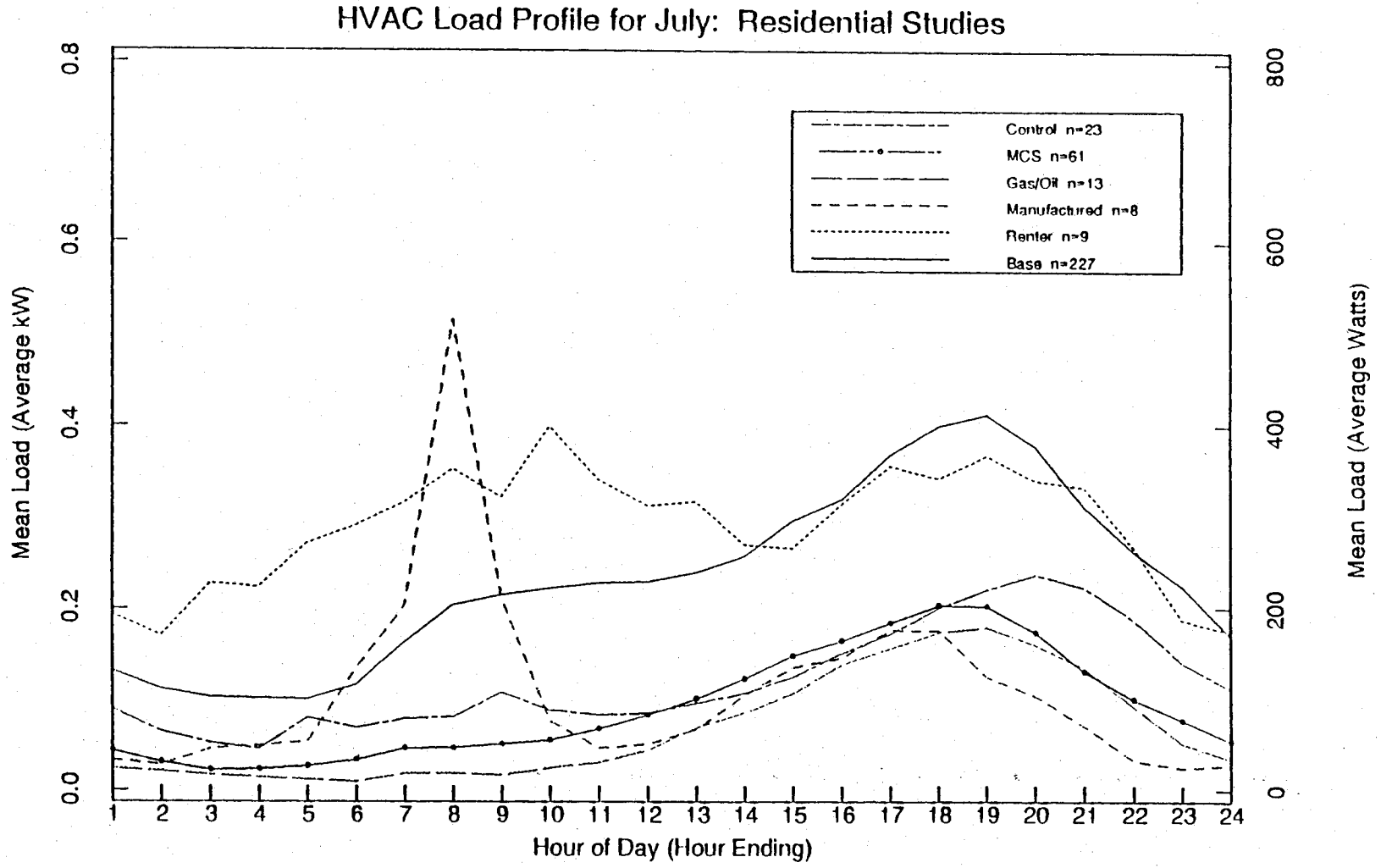
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.8(b)



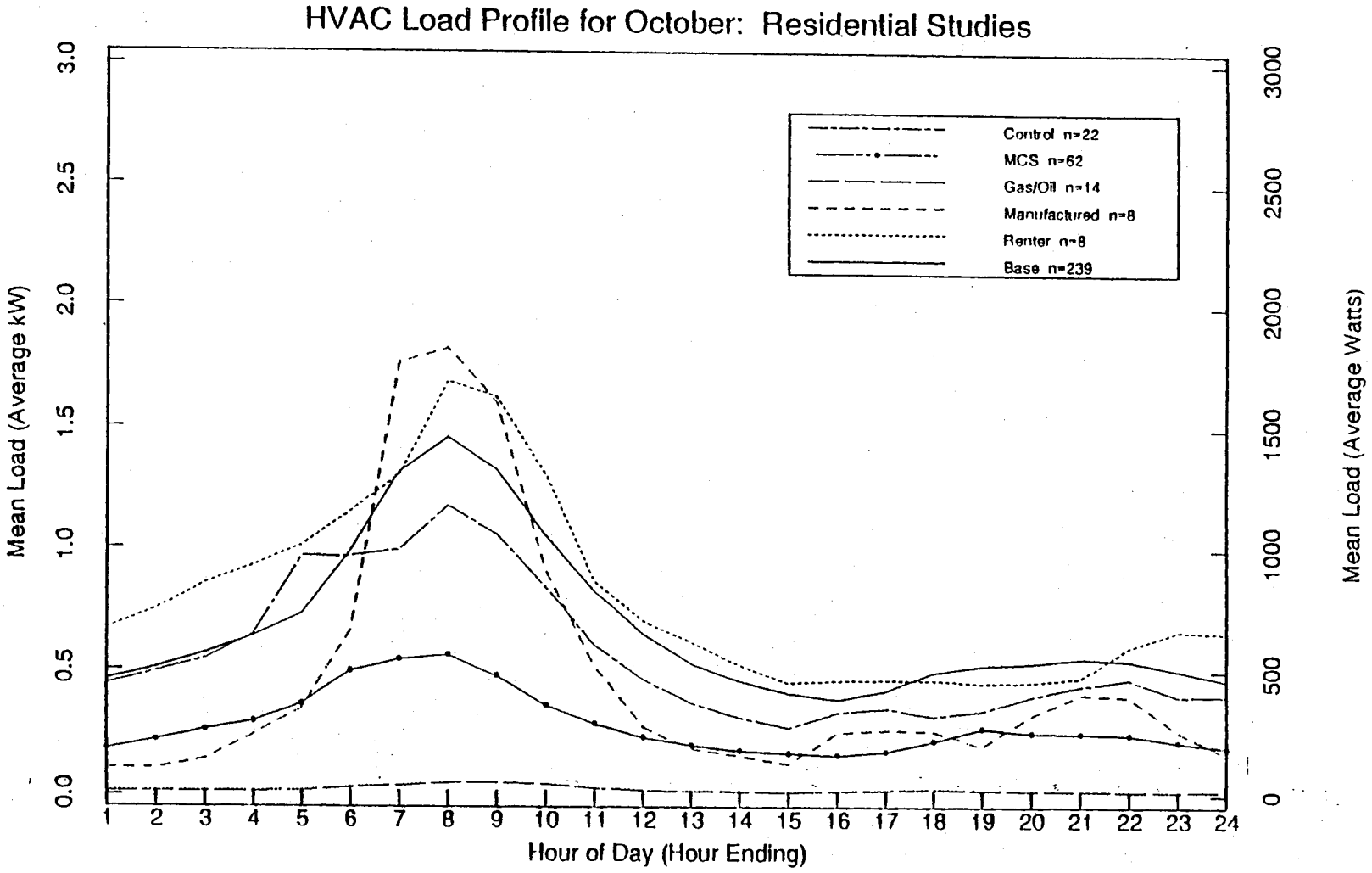
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.8(c)



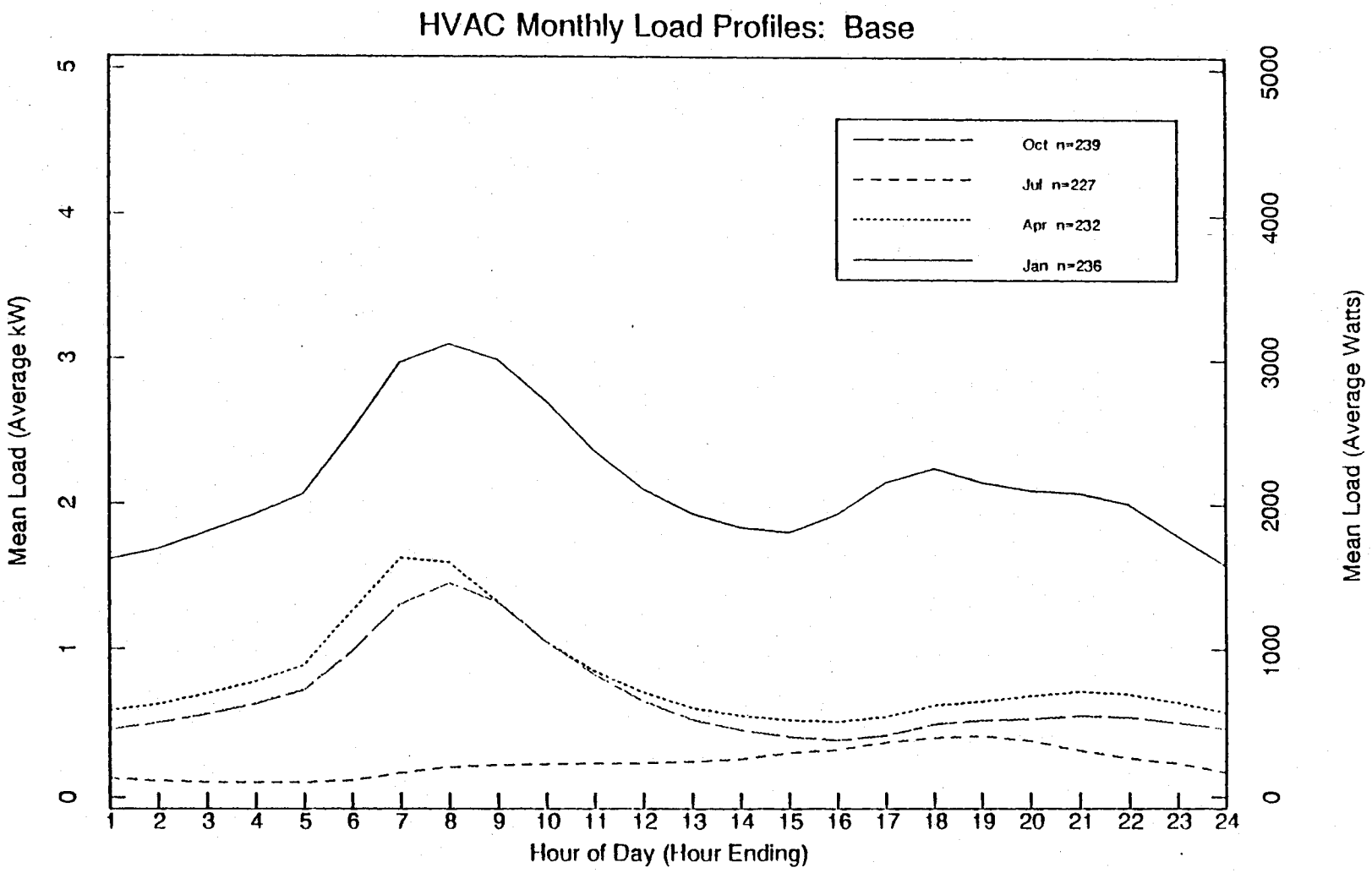
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.8(d)



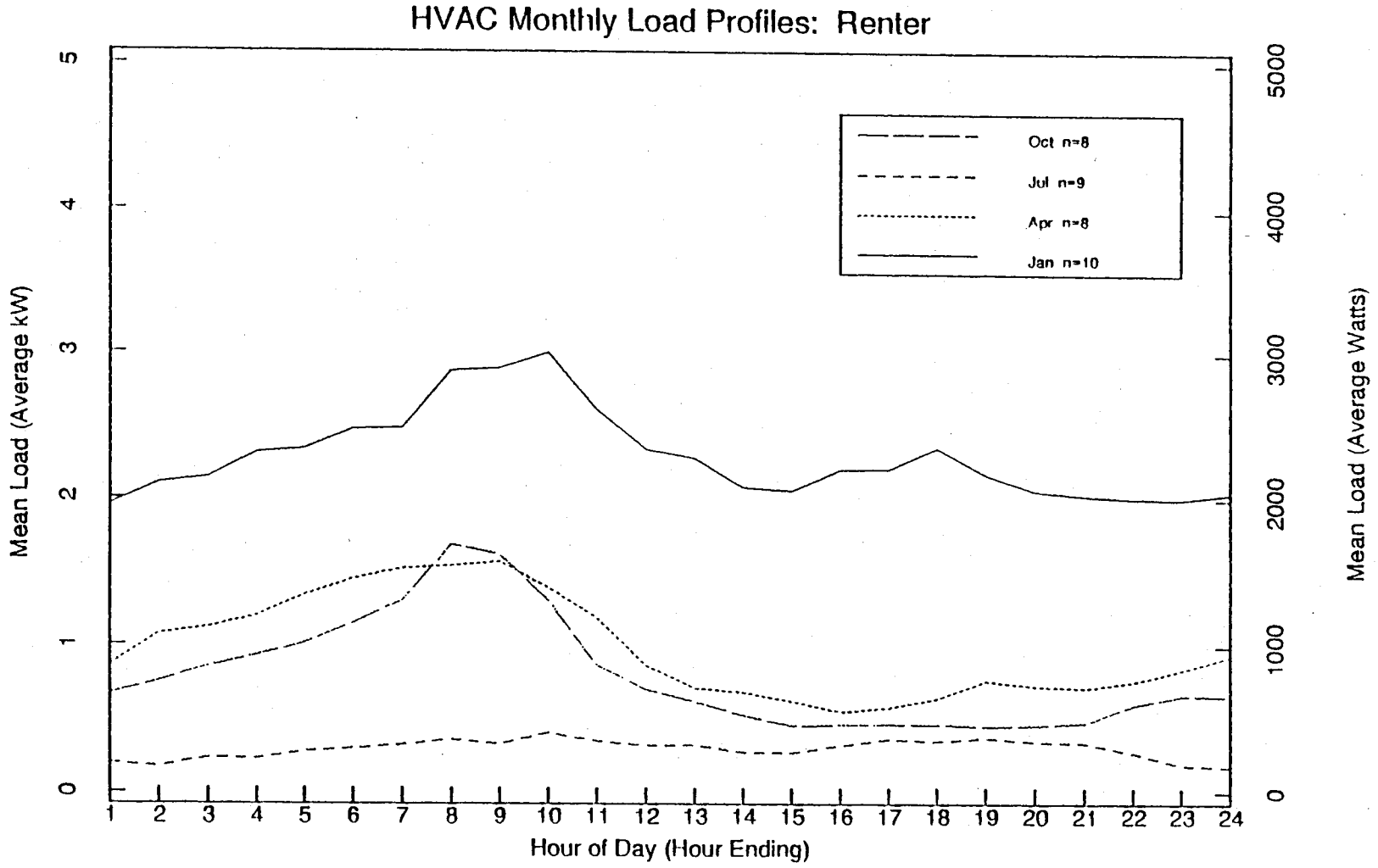
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(a)



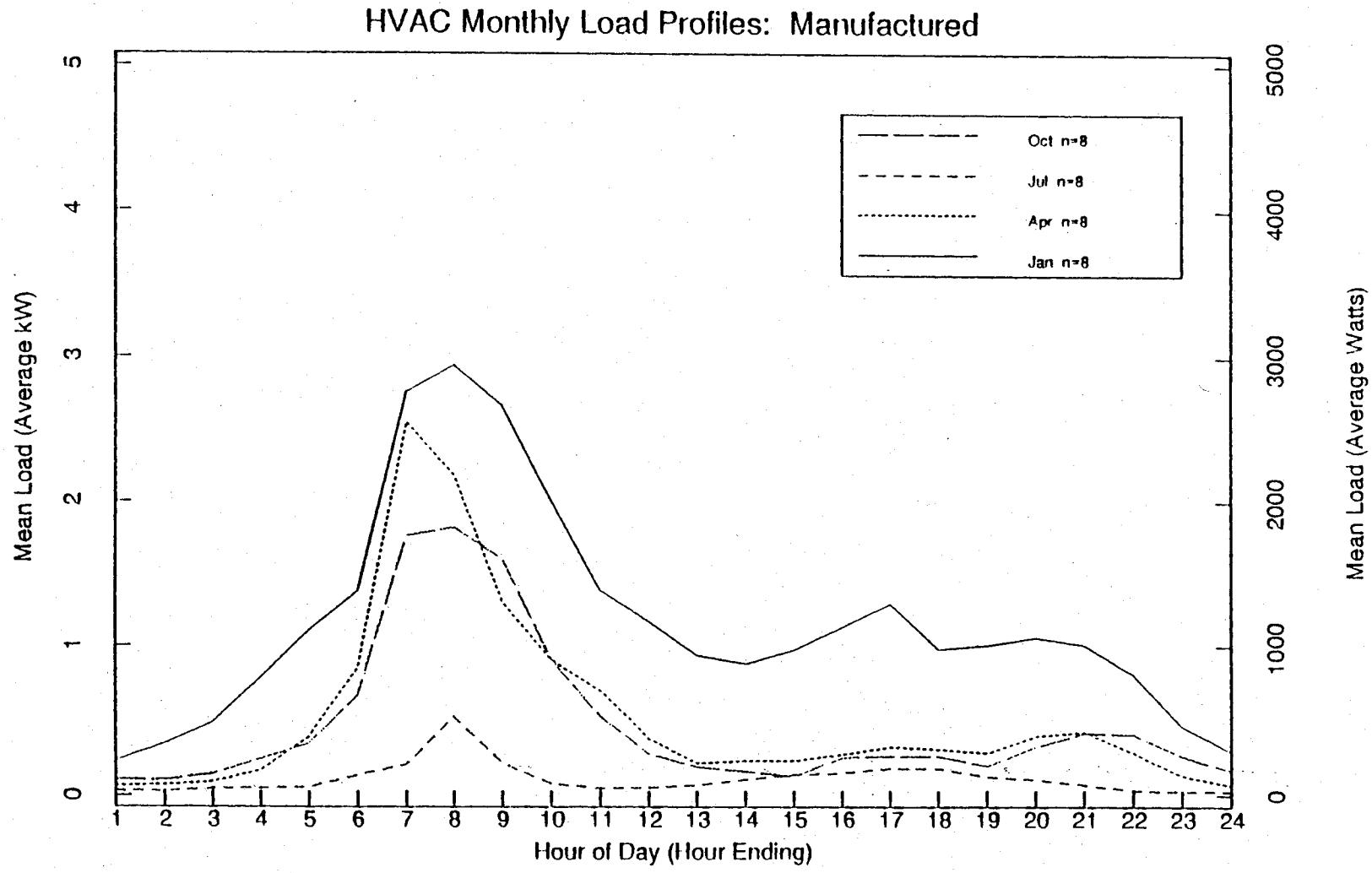
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(b)



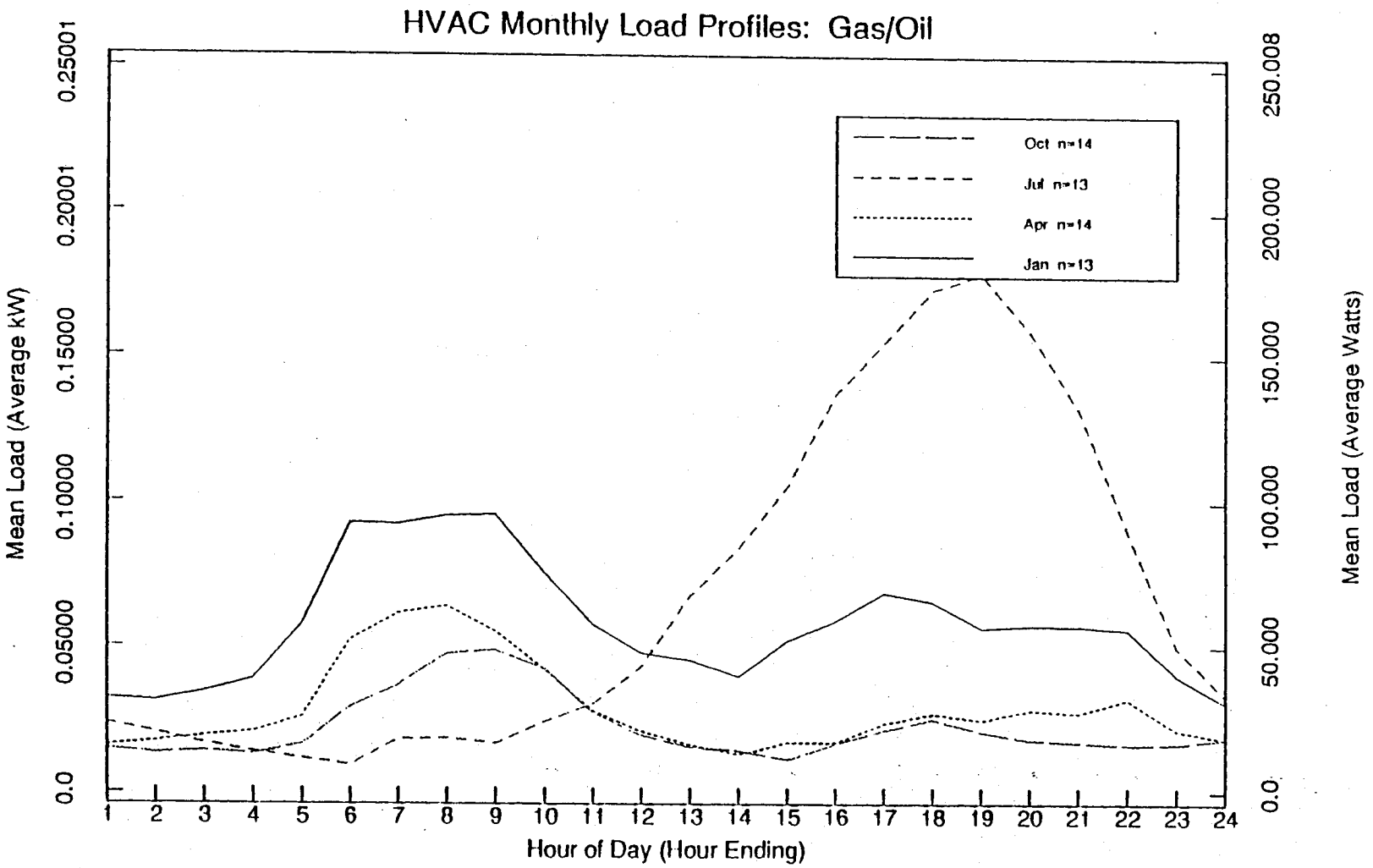
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(c)



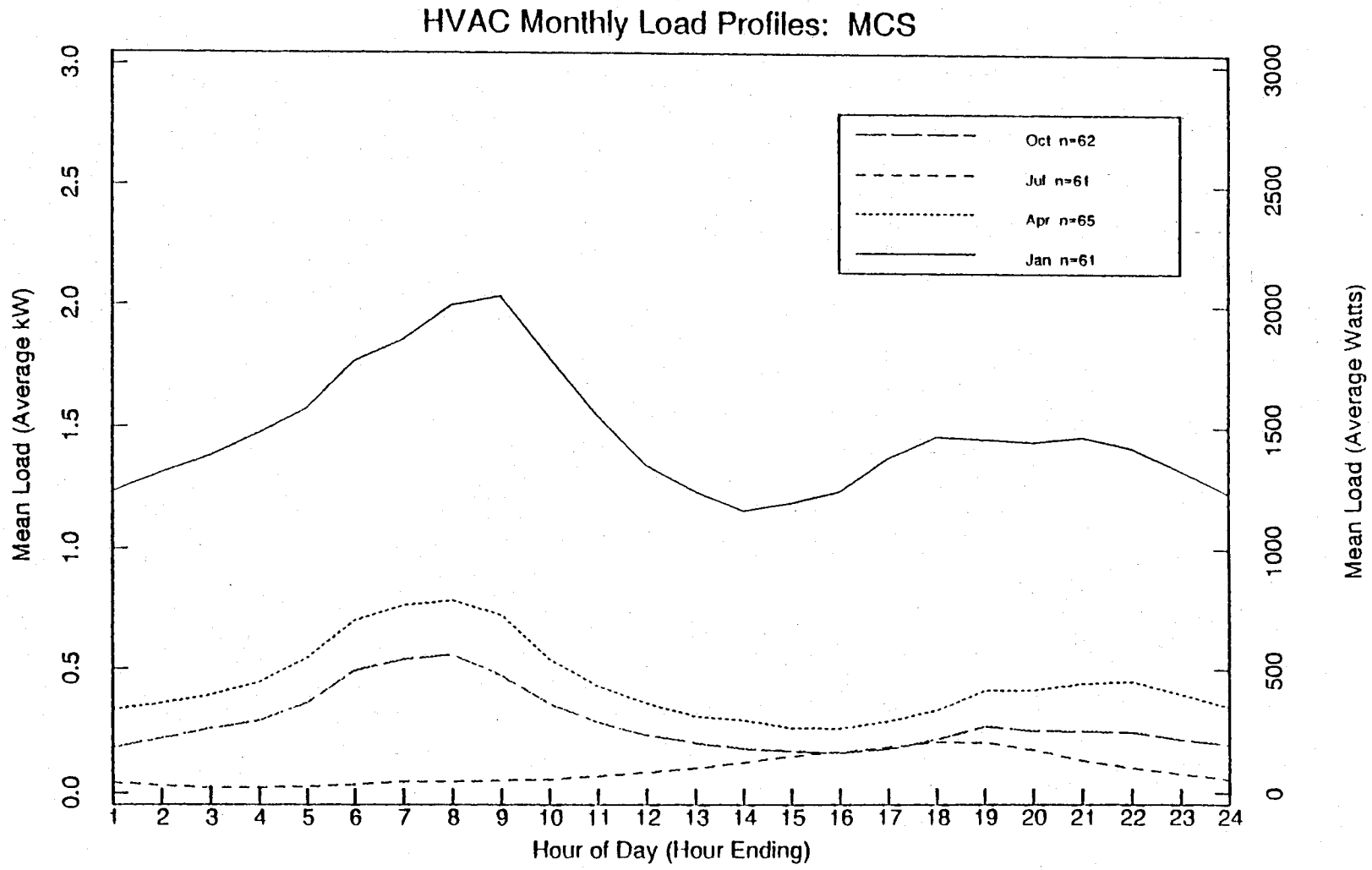
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(d)



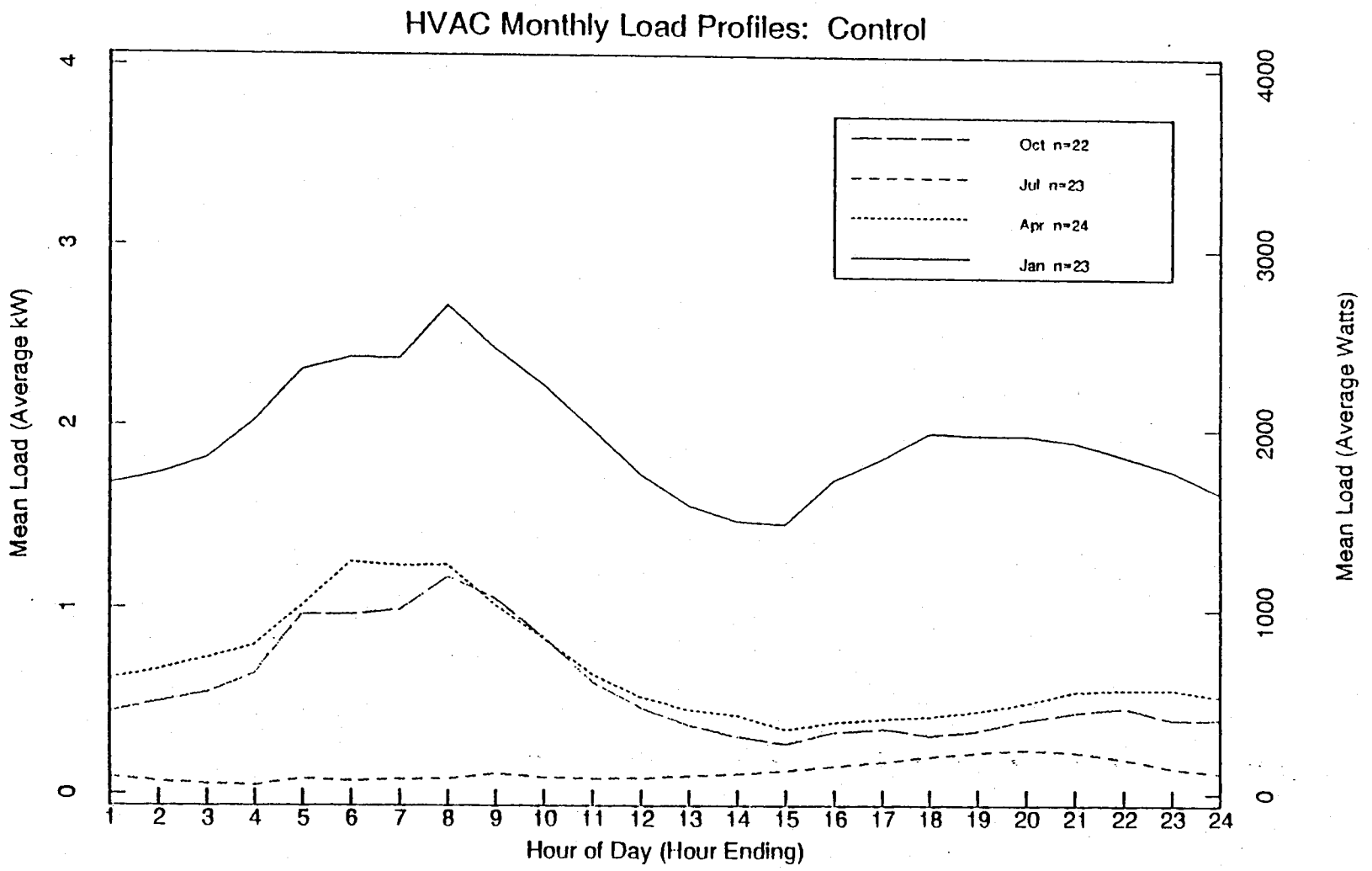
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(e)



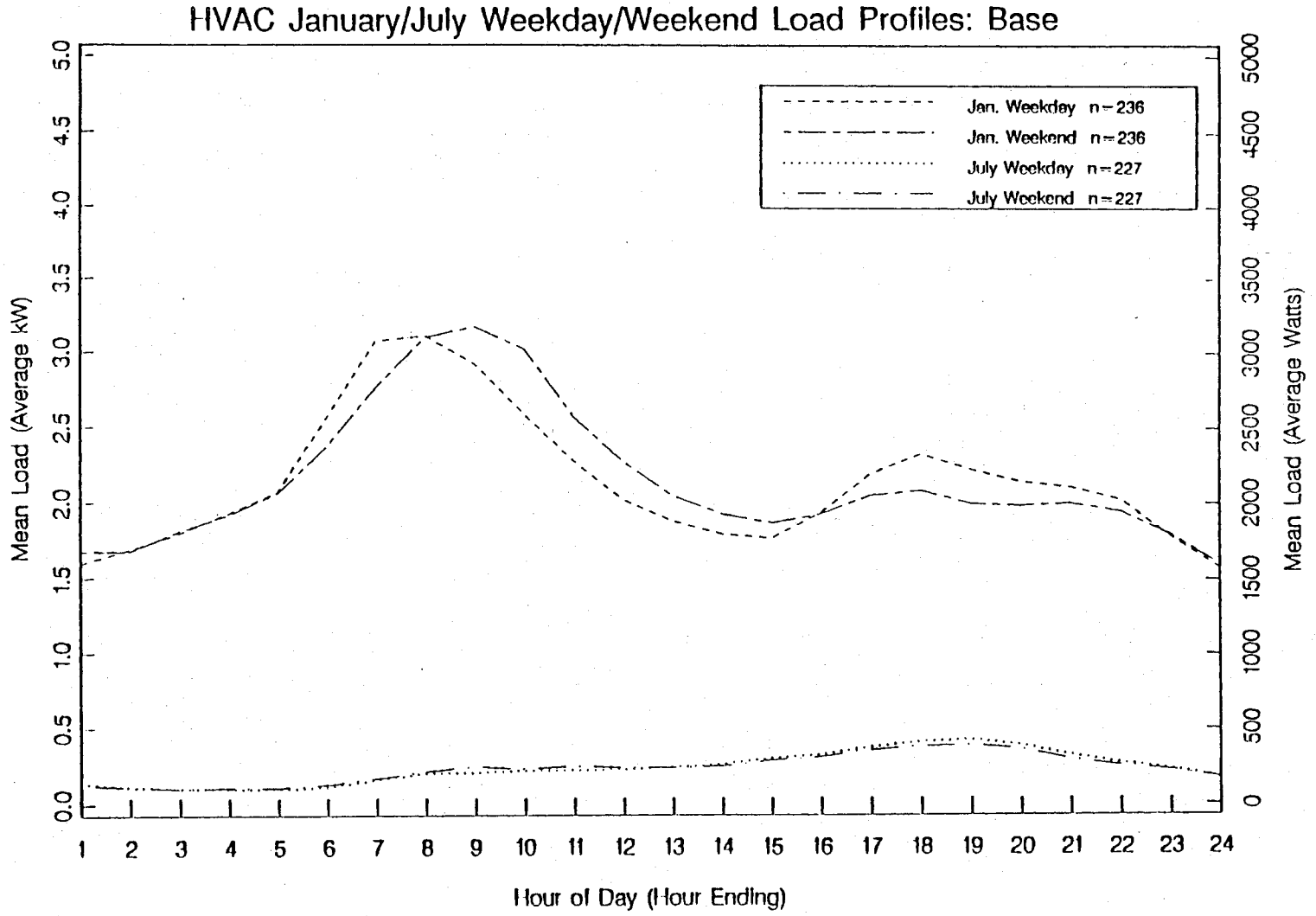
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.9(f)



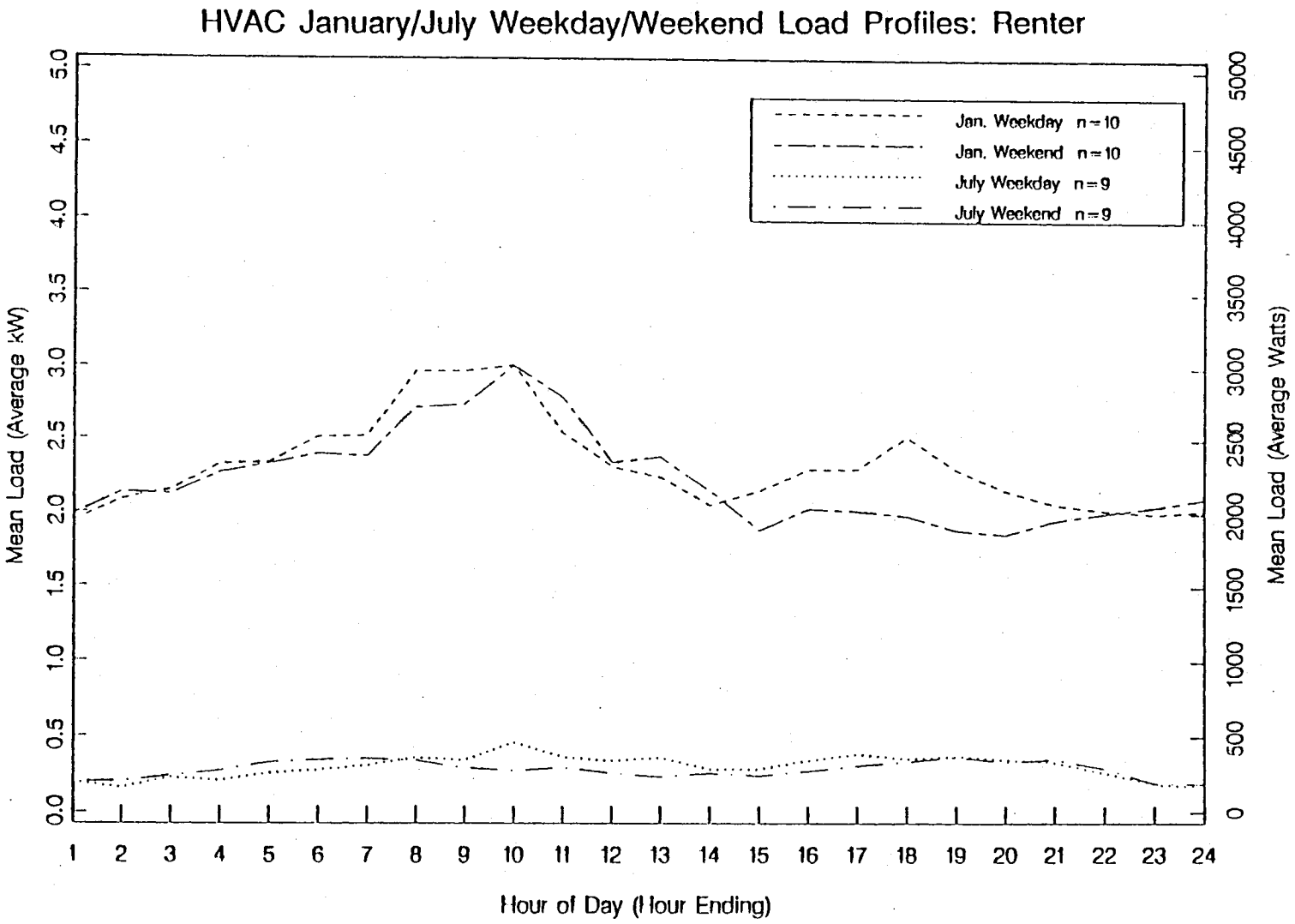
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7C.10(a)



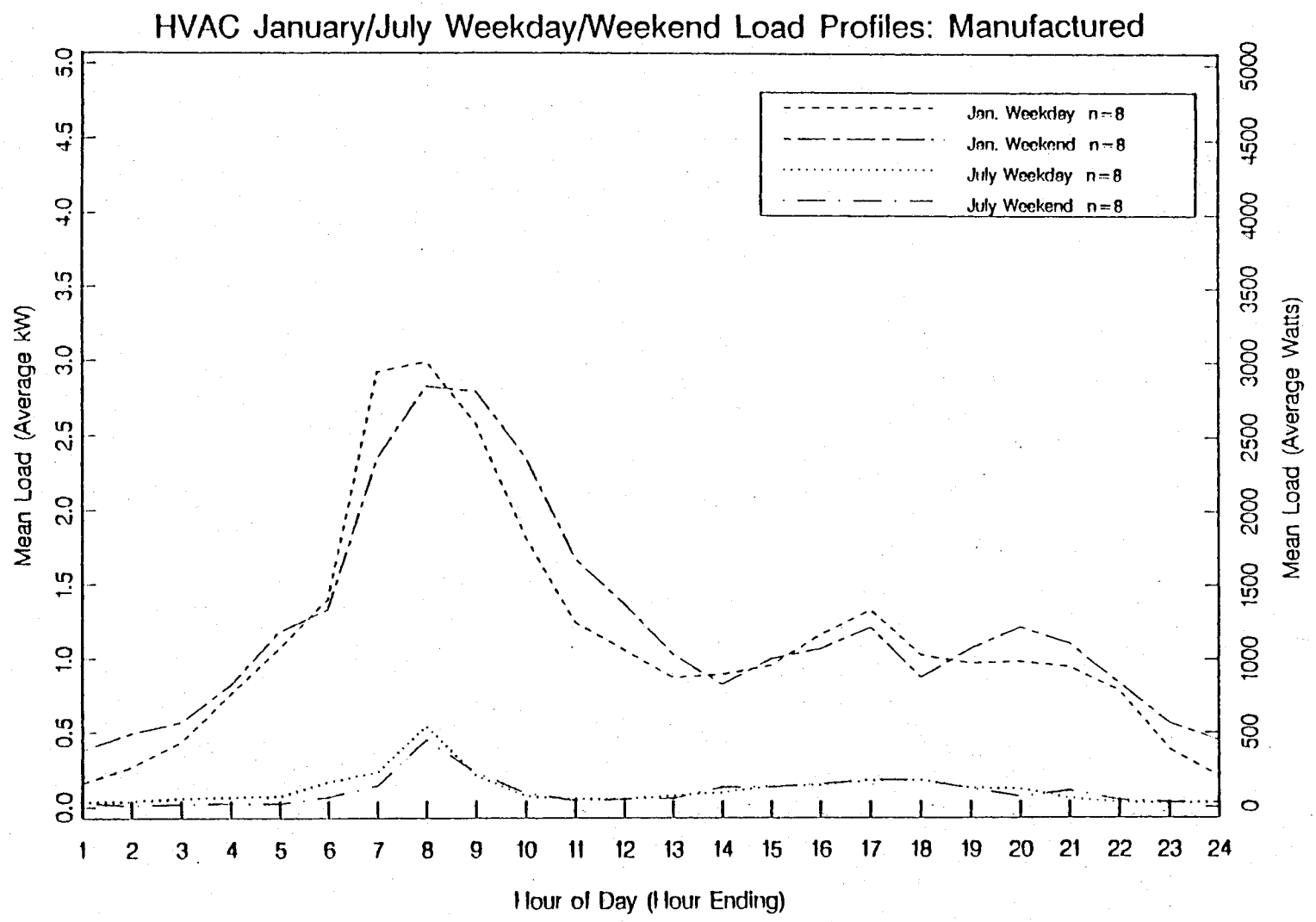
Data: ELCAP RES PADS Sept'84–Mar '88 SAS/PADS November 1988

FIGURE 7C.10(b)



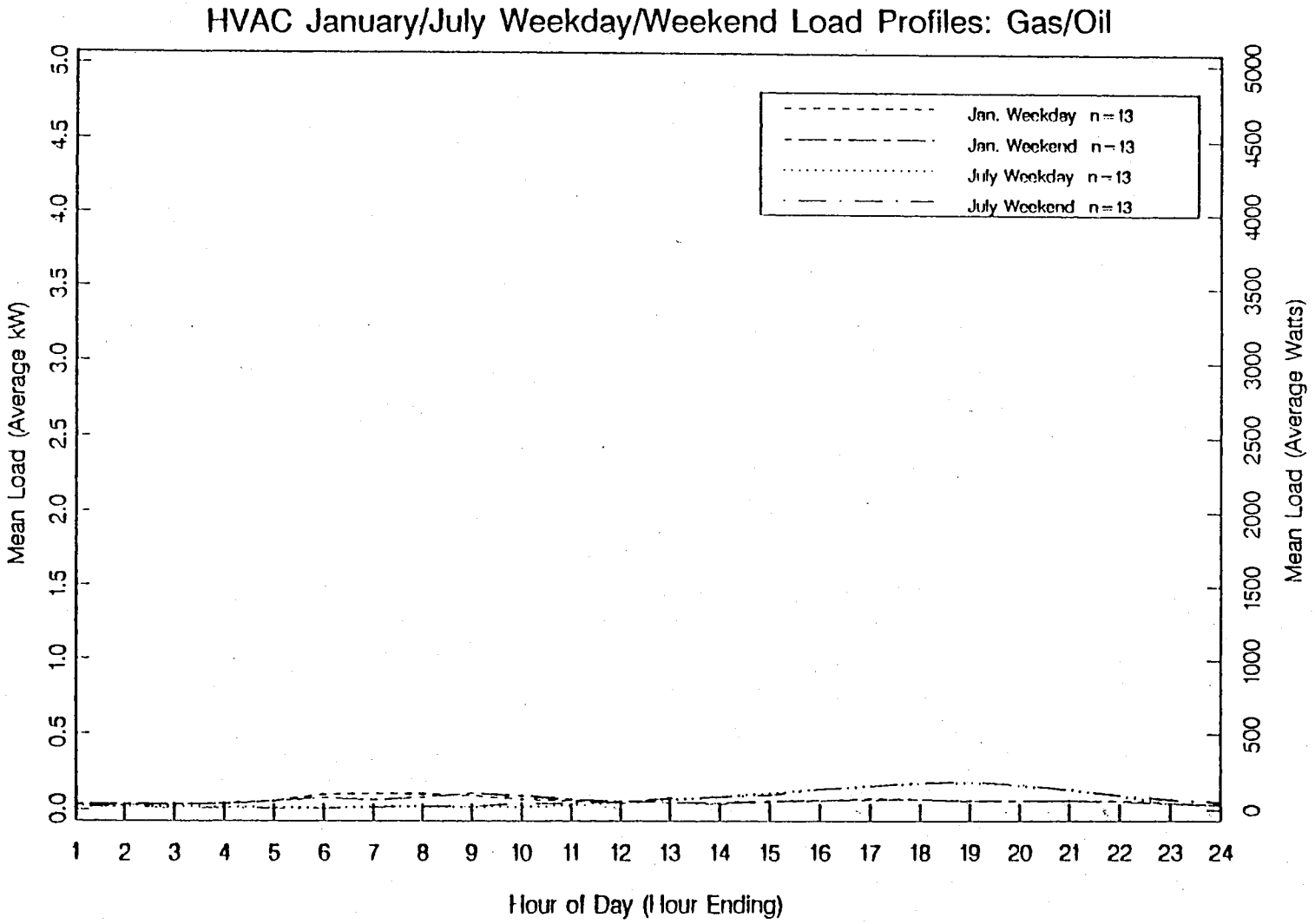
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7C.10(c)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

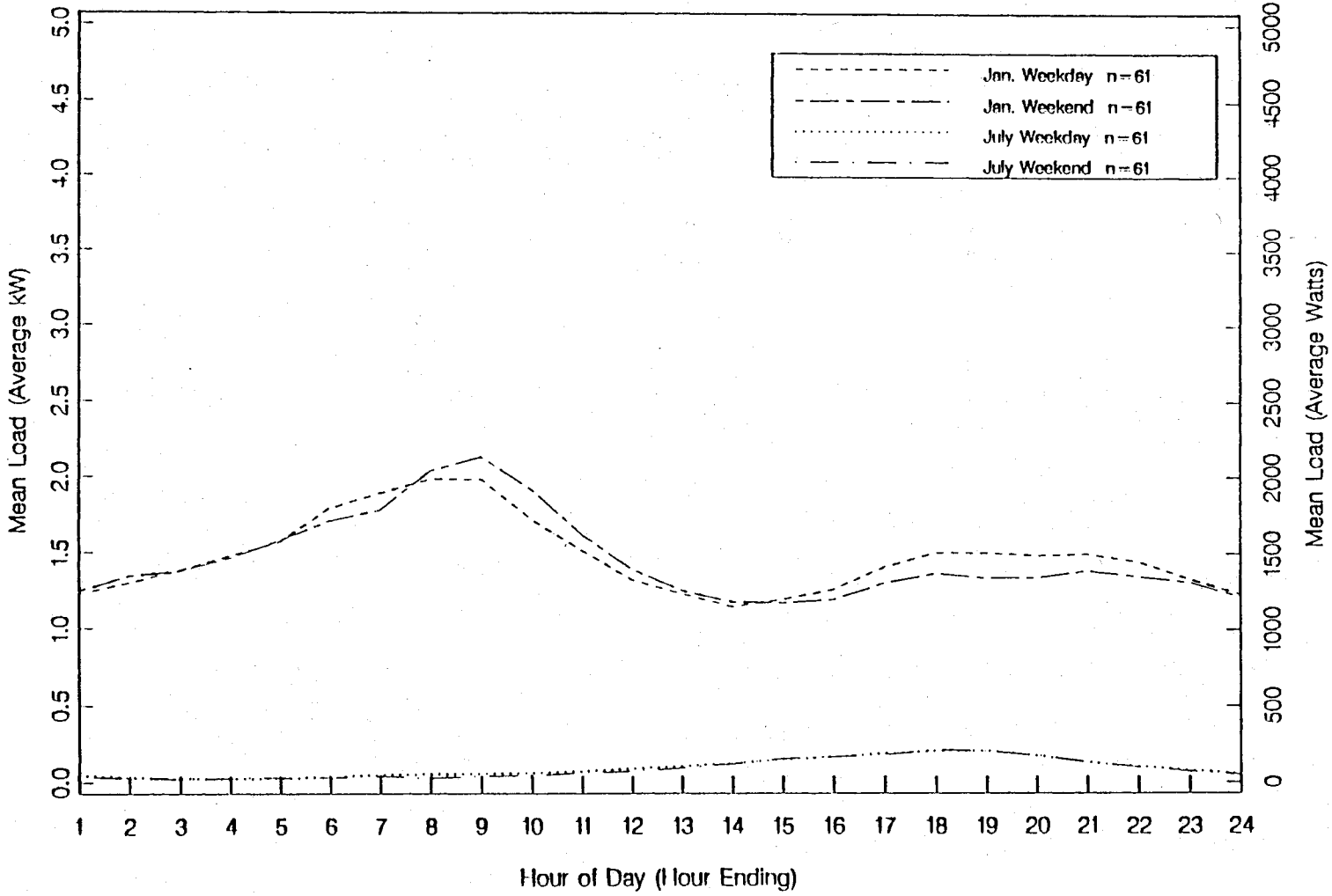
FIGURE 7C.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

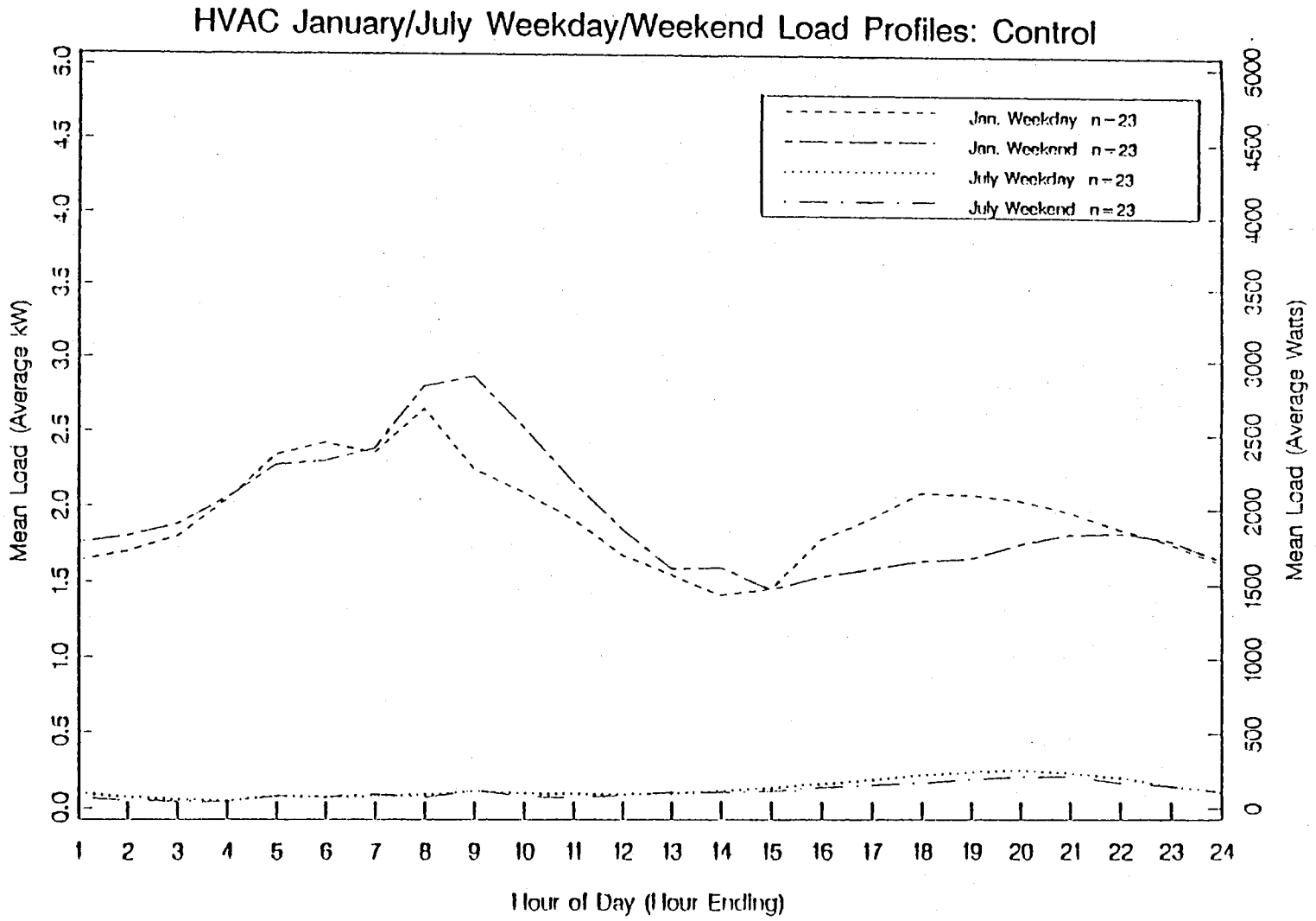
FIGURE 7C.10(e)

HVAC January/July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7C.10(f)



Data: ELCAP IIES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7C.11

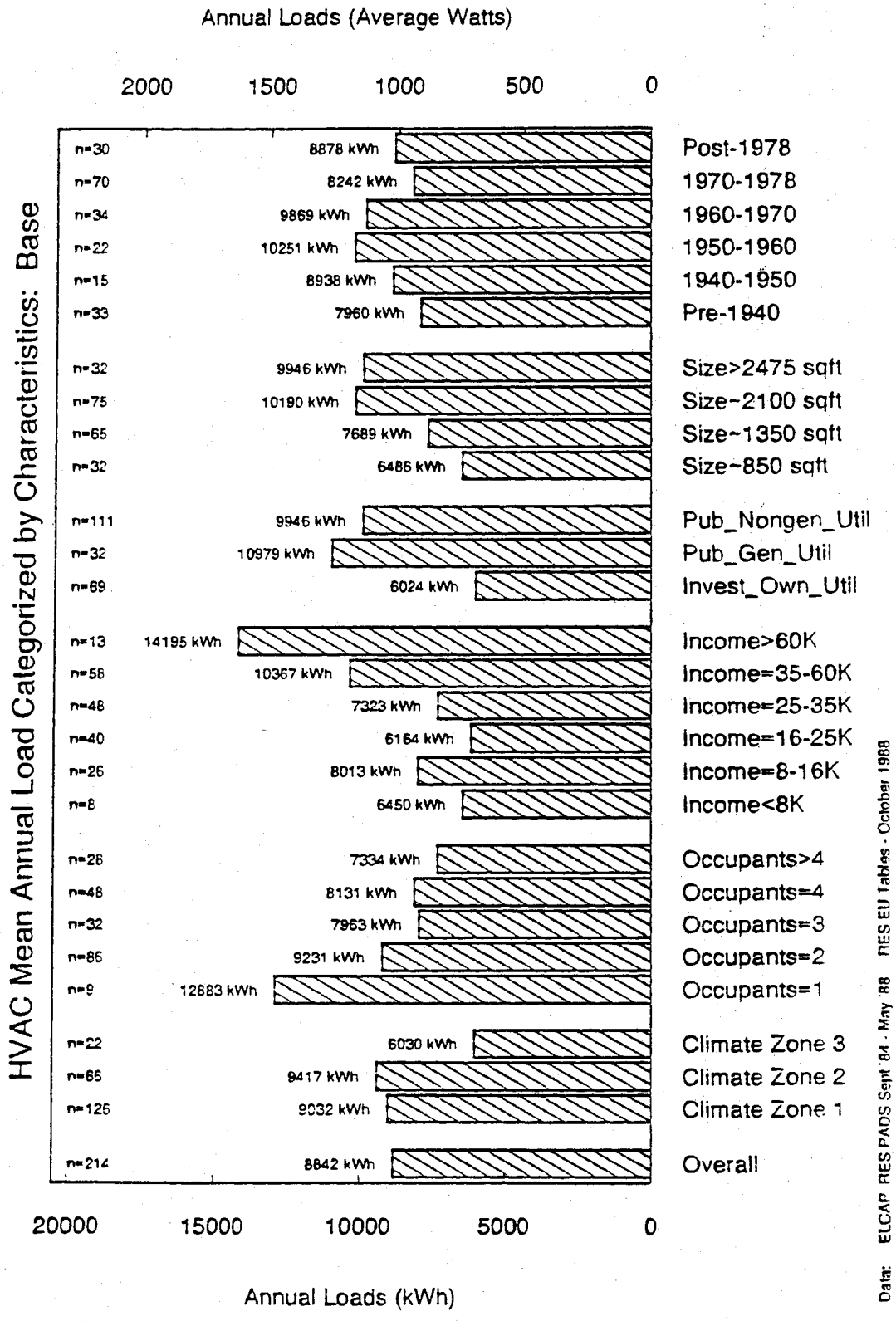

HVAC Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
2000
1500
1000
500
0
n=30 8878 kWh Post-1978
n=70 8242 kWh 1970-1978
n=34 9869 kWh 1960-1970
n=22 10251 kWh 1950-1960
n=15 8938 kWh 1940-1950
n=33 7960 kWh Pre-1940
n=32 9946 kWh Size>2475 sqft
n=75 10190 kWh Size~2100 sqft
n=65 7689 kWh Size~1350 sqft
n=32 6486 kWh Size~850 sqft
n=111 9946 kWh Pub_Nongen_Util
n=32 10979 kWh Pub_Gen_Util
n=69 6024 kWh Invest_Own_Util
n=13 14195 kWh Income>60K
n=56 10367 kWh Income=35-60K
n=48 7323 kWh Income=25-35K
n=40 6164 kWh Income=16-25K
n=26 8013 kWh Income=8-16K
n=8 6450 kWh Income<8K
n=28 7334 kWh Occupants>4
n=48 8131 kWh Occupants=4
n=32 7963 kWh Occupants=3
n=86 9231 kWh Occupants=2
n=9 12883 kWh Occupants=1
n=22 6030 kWh Climate Zone 3
n=66 9417 kWh Climate Zone 2
n=126 9032 kWh Climate Zone 1
n=214 8642 kWh Overall
20000
15000
10000
5000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7C.12

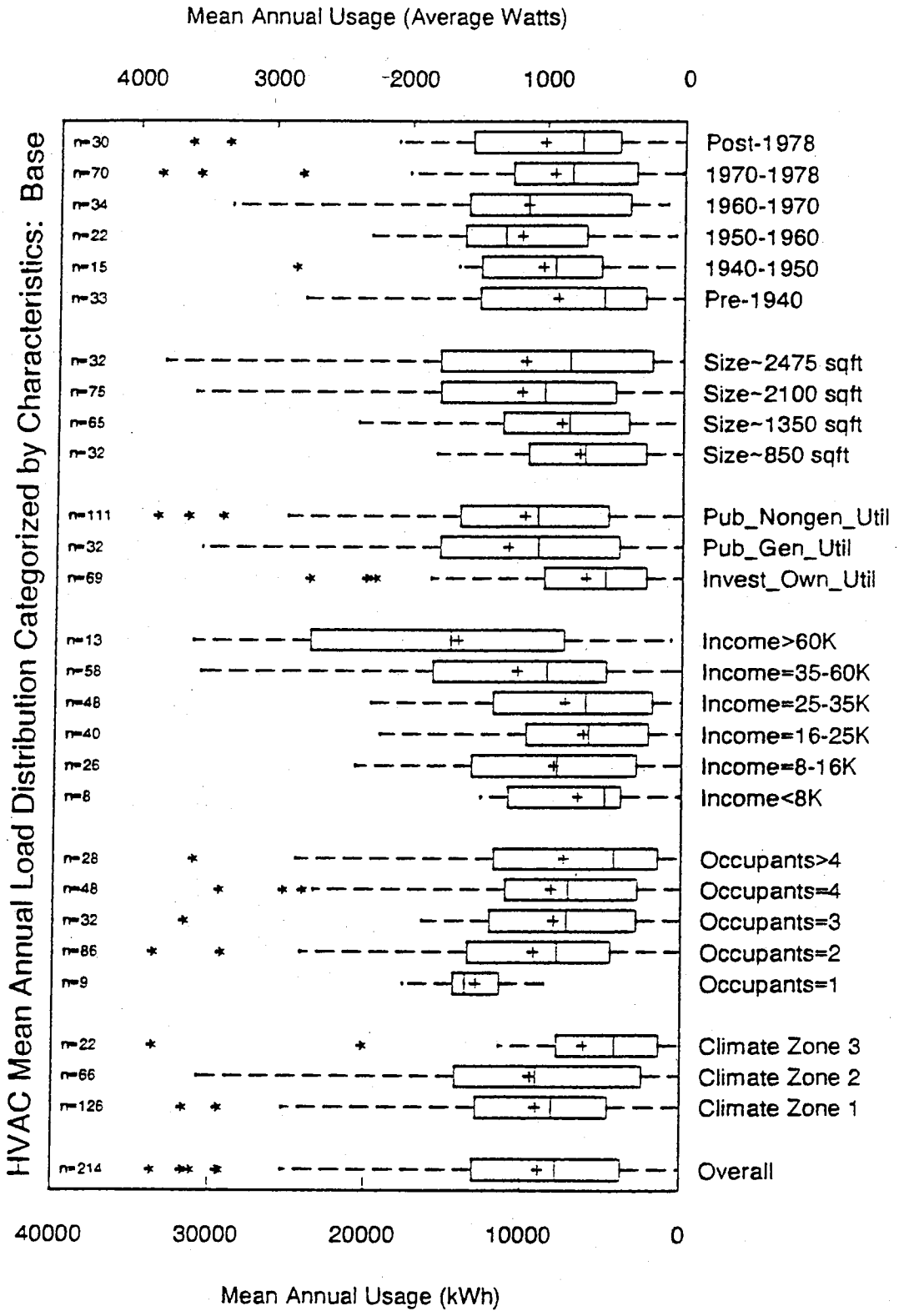

HVAC Mean Annual Load Distribution Categorized by Characteristics: Base
Mean Annual Usage (Average Watts)
4000
3000
2000
1000
0
n=30
n=70
n=34
n=22
n=15
n=33
Post-1978
1970-1978
1960-1970
1950-1960
1940-1950
Pre-1940
n=32
n=75
n=65
n=32
Size~2475 sqft
Size~2100 sqft
Size~1350 sqft
Size~850 sqft
n=111
n=32
n=69
Pub_Nongen_Util
Pub_Gen_Util
Invest_Own_Util
n=13
n=58
n=48
n=40
n=26
n=8
Income>60K
Income=35-60K
Income=25-35K
Income=16-25K
Income=8-16K
Income<8K
n=28
n=48
n=32
n=86
n=9
Occupants>4
Occupants=4
Occupants=3
Occupants=2
Occupants=1
n=22
n=66
n=126
Climate Zone 3
Climate Zone 2
Climate Zone 1
n=214
Overall
40000
30000
20000
10000
0
Mean Annual Usage (kWh)
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7C.1

HVAC Mean Annual End-Use Loads and Standard Deviations (kWh)

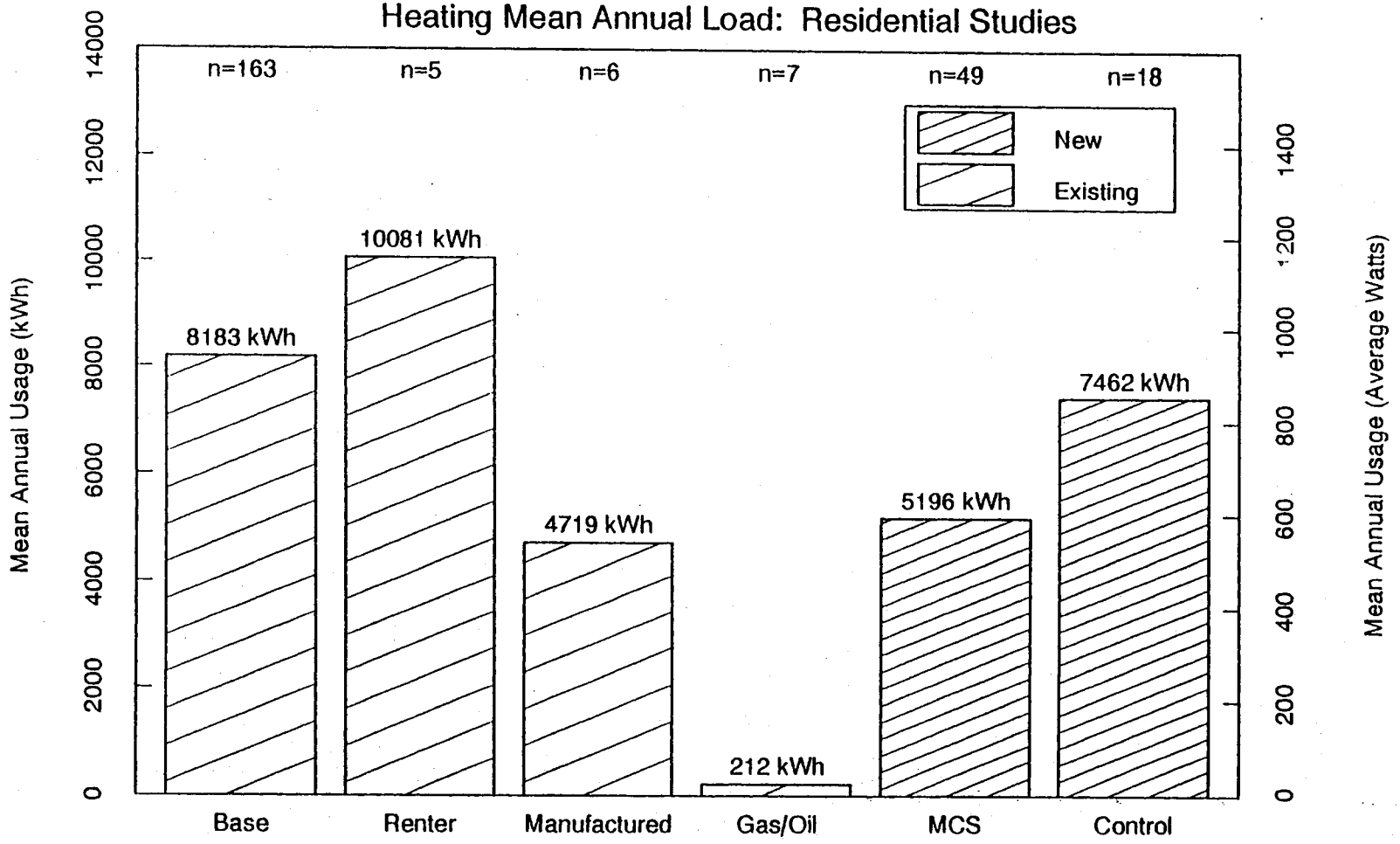
Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	214	8842	6932	21	8099	2589	57	5418	2230	292	8120	6197
Climate Zone 1	128	9032	6408	13	8600	2791	36	5179	2082	175	8207	5772
Climate Zone 2	66	9417	7523	4	7223	2097	17	5970	2552	87	8643	6790
Climate Zone 3	22	6030	7627	4	7346	2501	4	5231	2239	30	6099	6604
Occupants=1	9	12883	2780	1	12405	0	2	2084	699	12	11043	4816
Occupants=2	86	9231	6729	7	8822	2715	14	5602	1965	107	8729	6221
Occupants=3	32	7963	6710	3	7203	2550	8	5273	3001	43	7410	6012
Occupants=4	48	8131	6980	3	8970	3577	7	5306	1961	58	7834	6478
Occupants>4	28	7334	8207	1	7648	0	5	5707	2418	34	7104	7495
Income<8K	8	6450	4481	0	-	-	1	4429	0	9	6225	4245
Income=8-16K	26	8013	6212	1	9653	0	1	319	0	28	7797	6162
Income=16-25K	40	6164	4704	1	10370	0	8	4968	2301	49	6054	4398
Income=25-35K	48	7323	5576	8	8723	3079	12	5465	1745	68	7160	4912
Income=35-60K	58	10367	7599	3	8292	4014	13	6009	2412	74	9517	7022
Income>60K	13	14195	9934	1	8247	0	1	2262	0	15	13003	9785
Invest_Own_Util	69	6024	5262	10	9418	2818	32	5269	2517	111	6112	4558
Pub_Gen_Util	32	10979	8363	7	6648	1362	10	4861	1029	49	9112	7251
Pub_Nongen_Util	111	9946	6923	4	7339	2380	11	5810	1966	126	9502	6644
Size<850 sqft	32	6486	4612	1	7030	0	1	319	0	34	6320	4595
Size=1350 sqft	65	7689	5225	13	7844	2821	26	5021	2002	104	7041	4499
Size=2100 sqft	75	10190	7470	6	8672	2597	17	6113	1574	98	9390	6762
Size>2475 sqft	32	9946	9469	0	-	-	9	5755	2989	41	9026	8623
Pre-1940	33	7960	7416	0	-	-	0	-	-	33	7960	7416
1940-1950	15	8938	6038	0	-	-	0	-	-	15	8938	6038
1950-1960	22	10251	5353	0	-	-	0	-	-	22	10251	5353
1960-1970	34	9869	7085	0	-	-	0	-	-	34	9869	7085
1970-1978	70	8242	6701	0	-	-	0	-	-	70	8242	6701
Post-1978	30	8878	8043	21	8099	2589	57	5418	2230	108	6901	4893

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

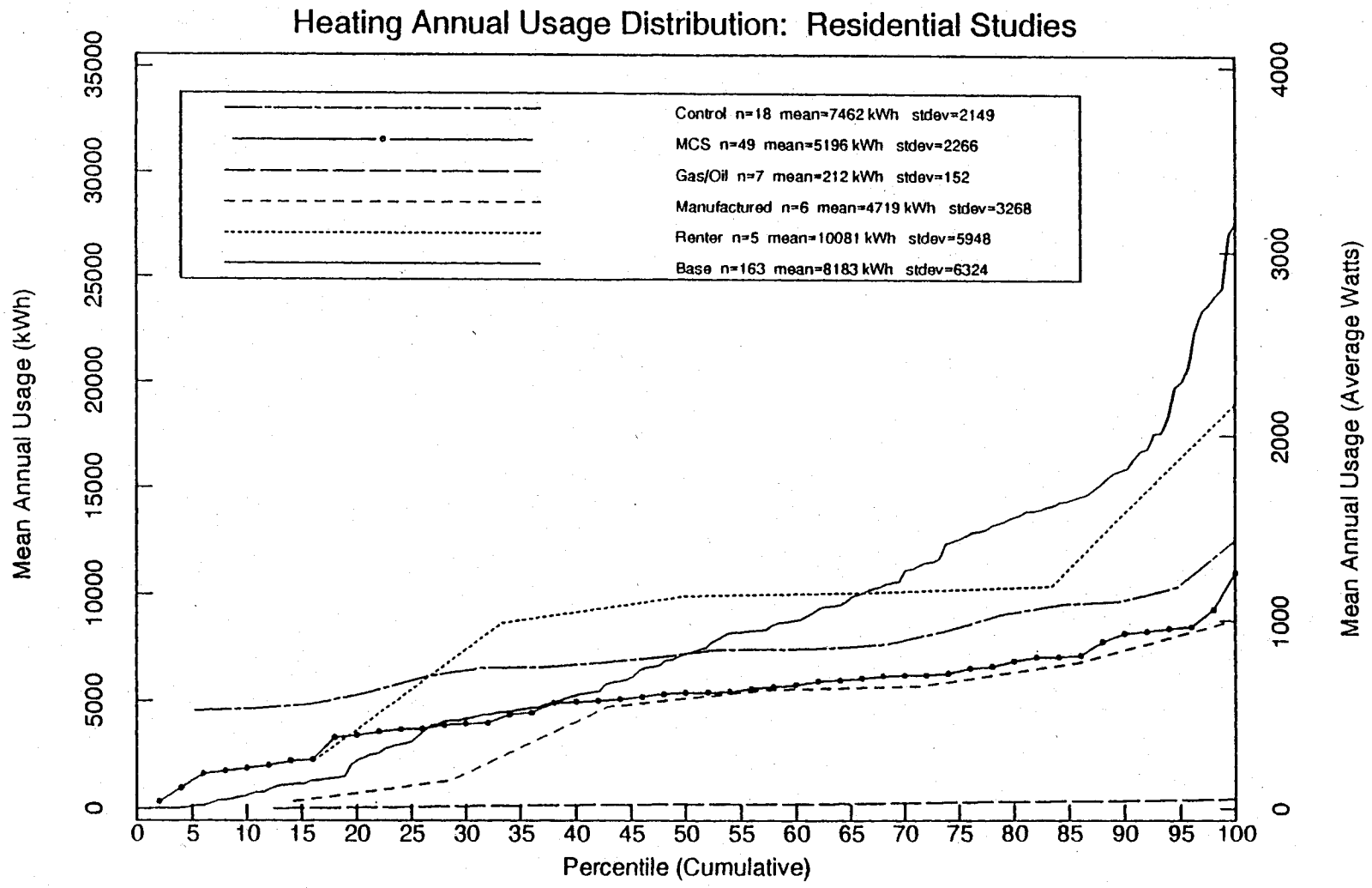
FIGURE 7D.1

Heating Mean Annual Load: Residential Studies



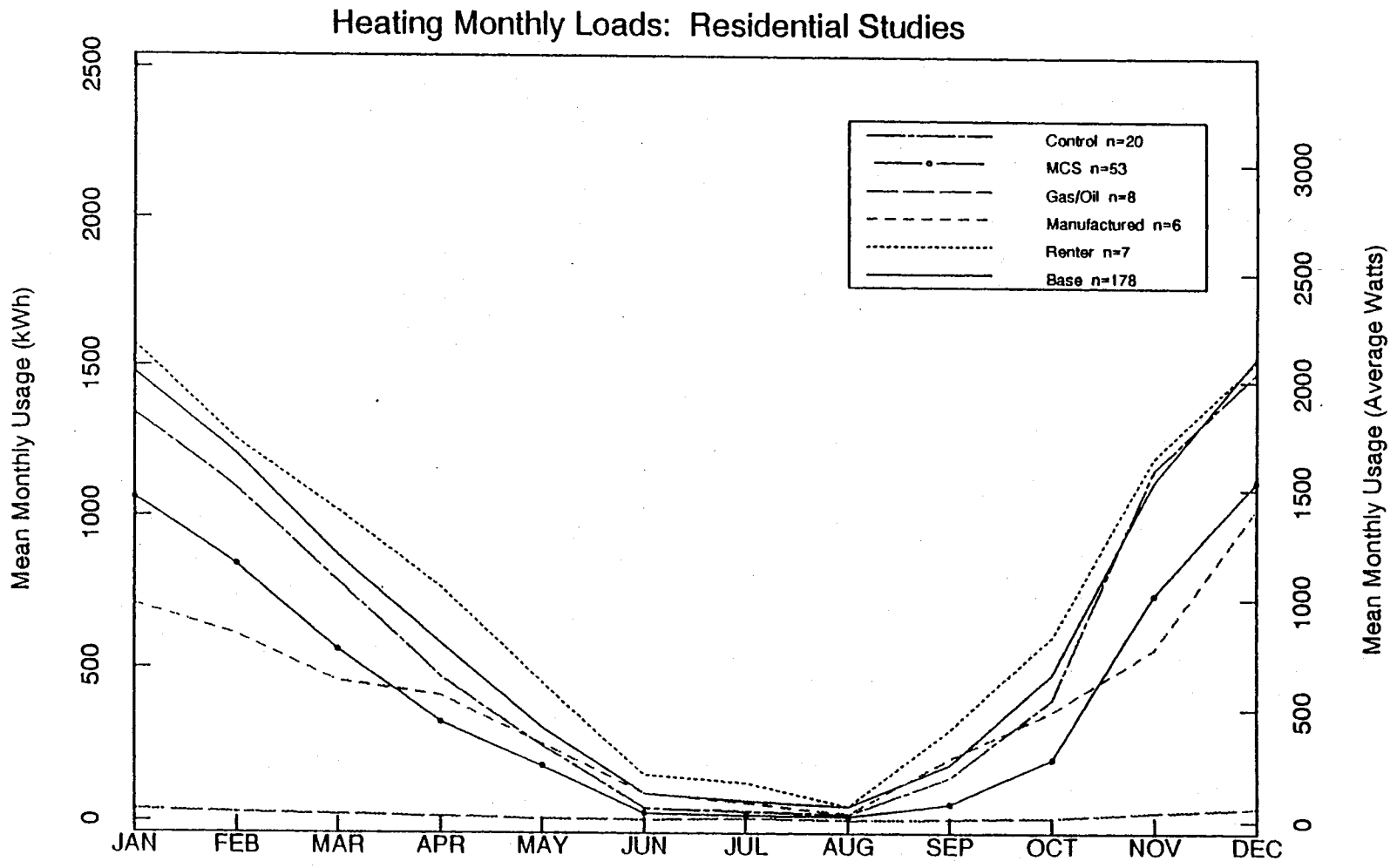
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.2



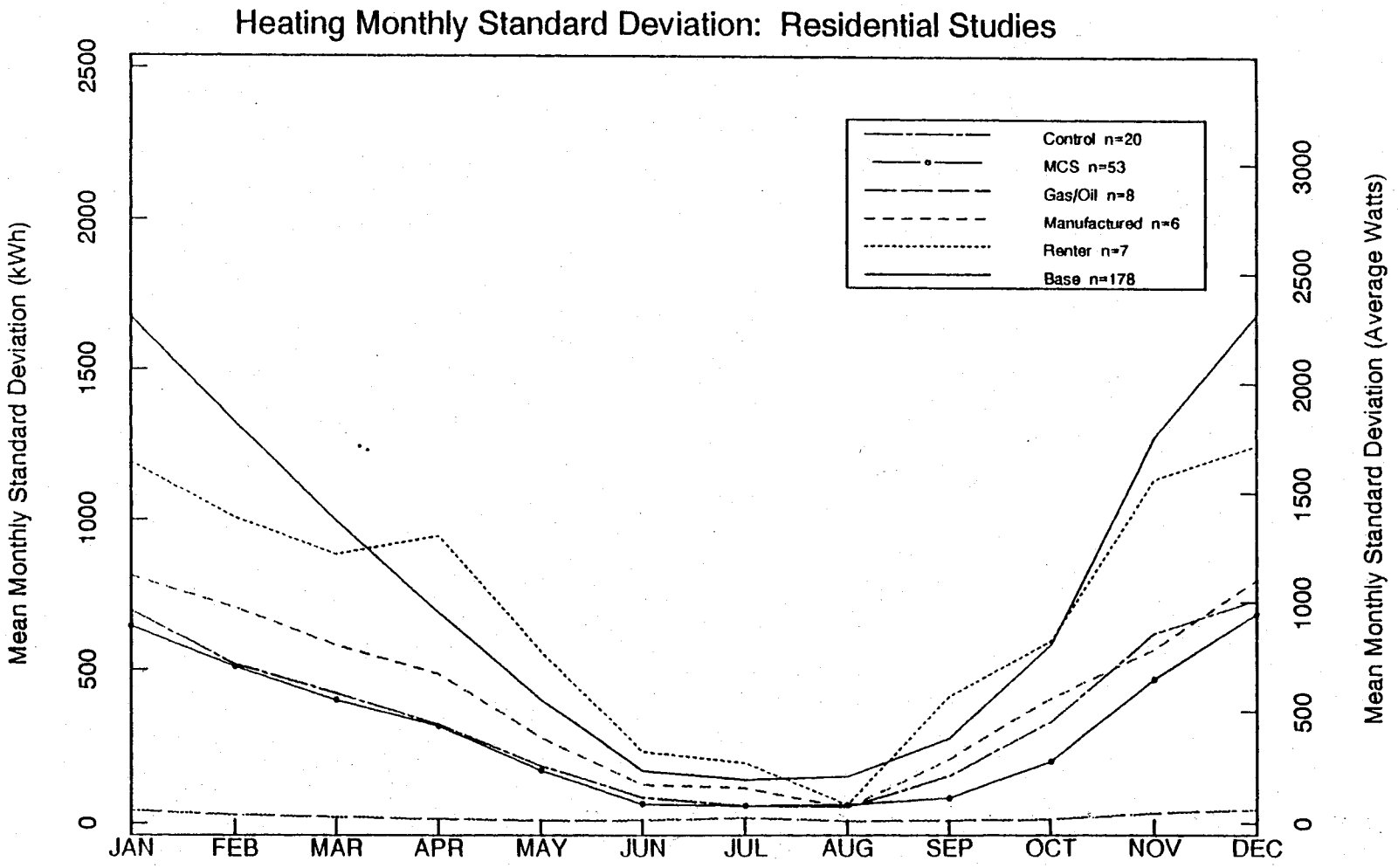
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.3



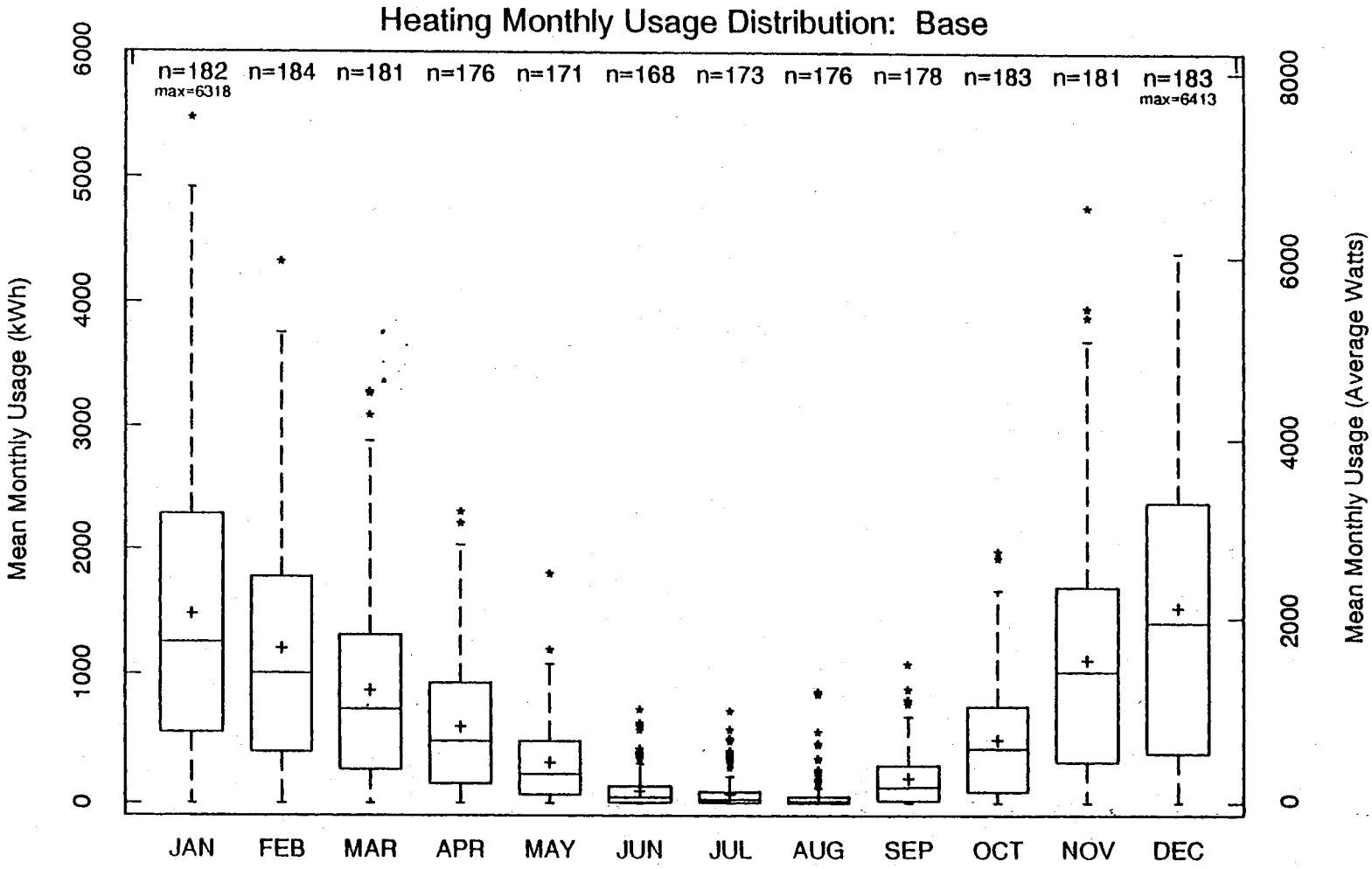
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.4



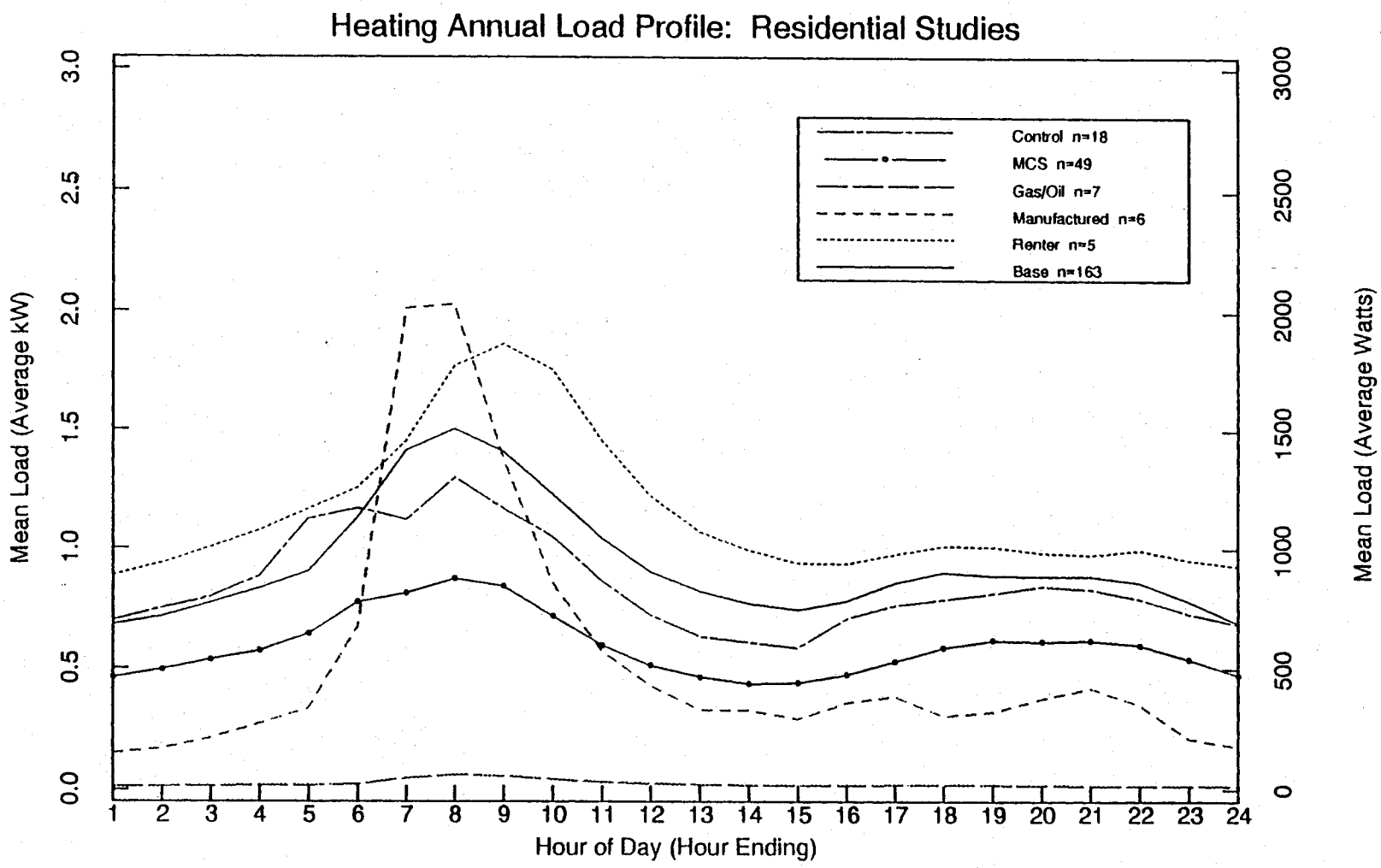
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.5



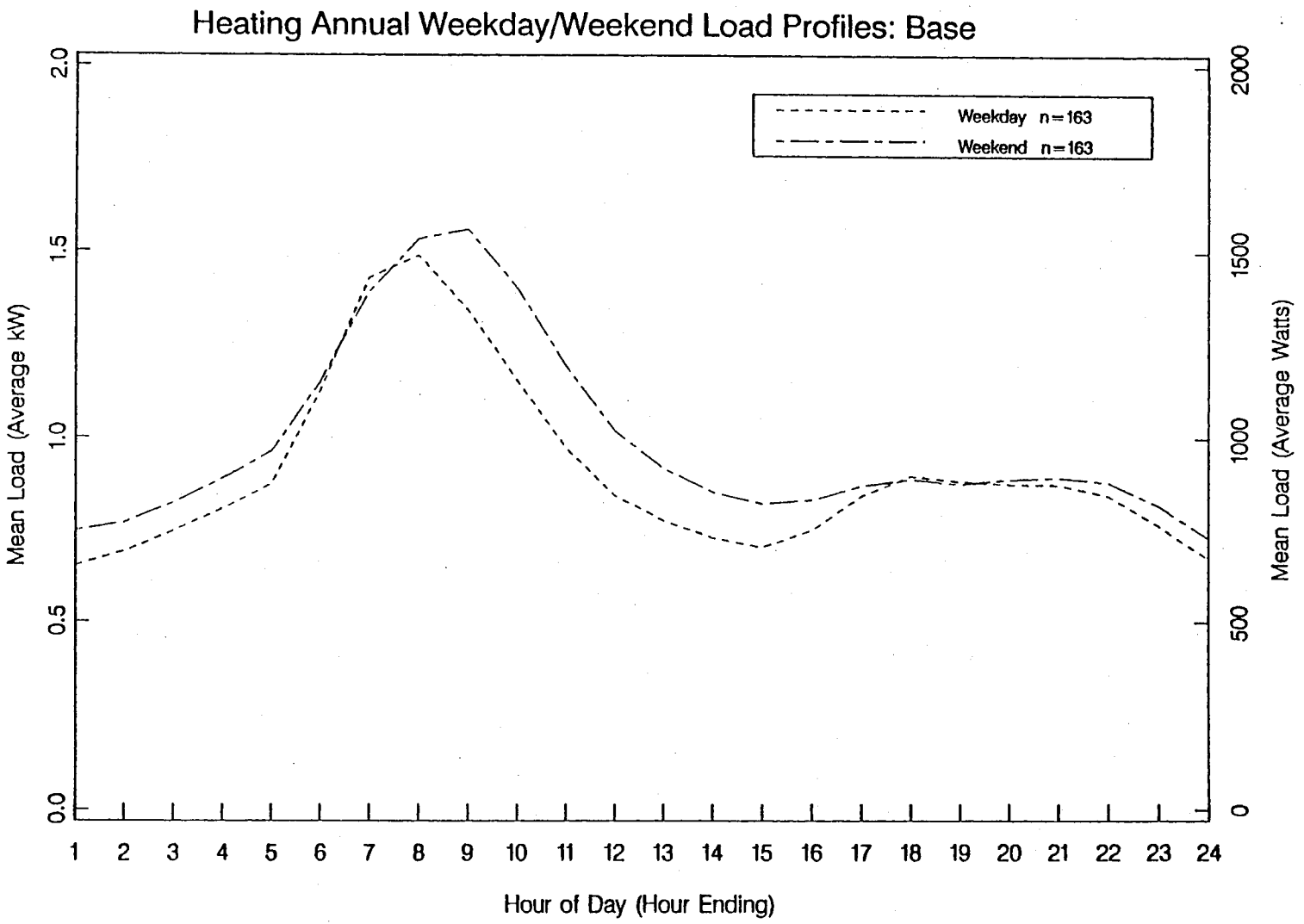
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.6



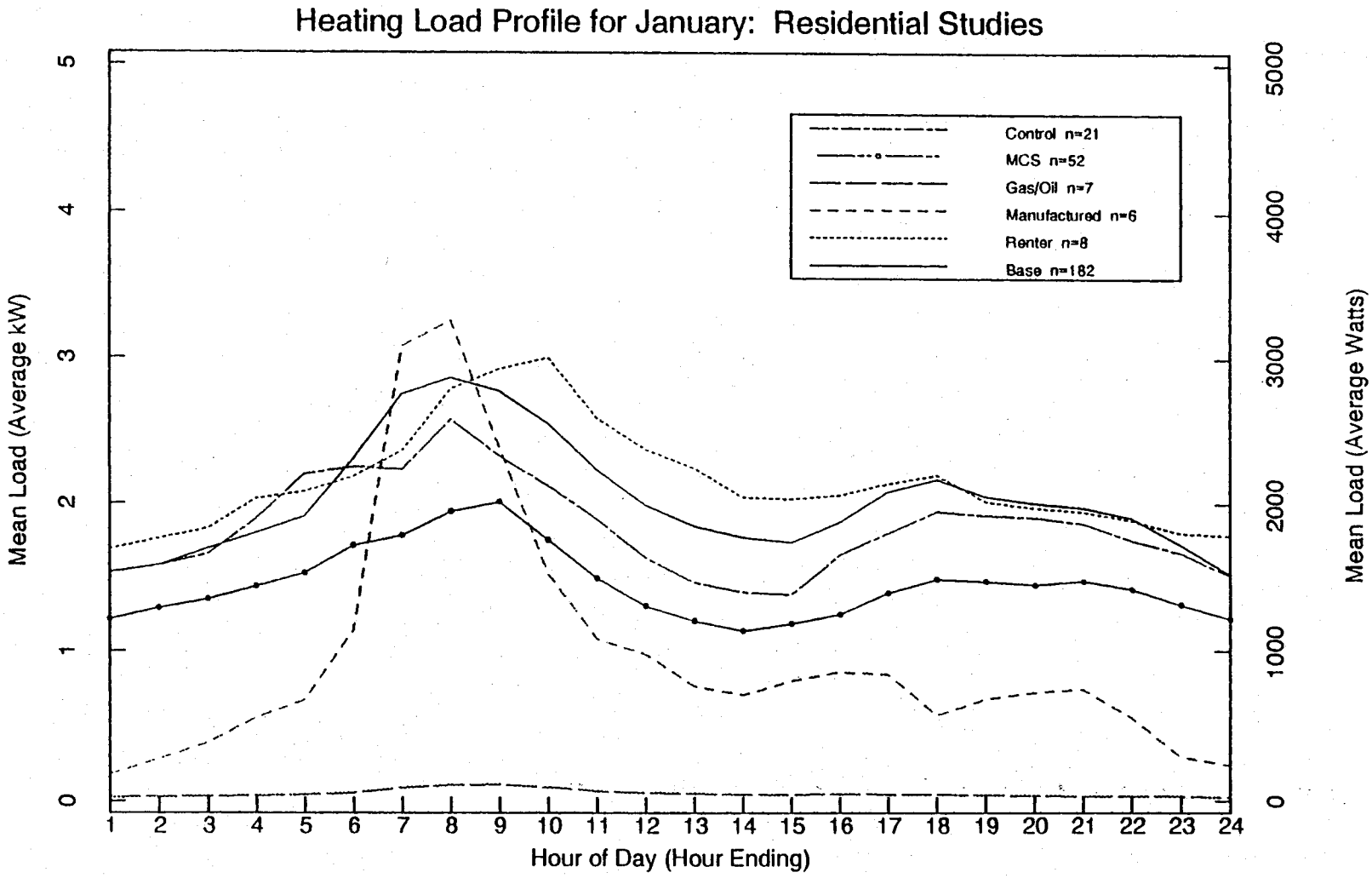
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.7



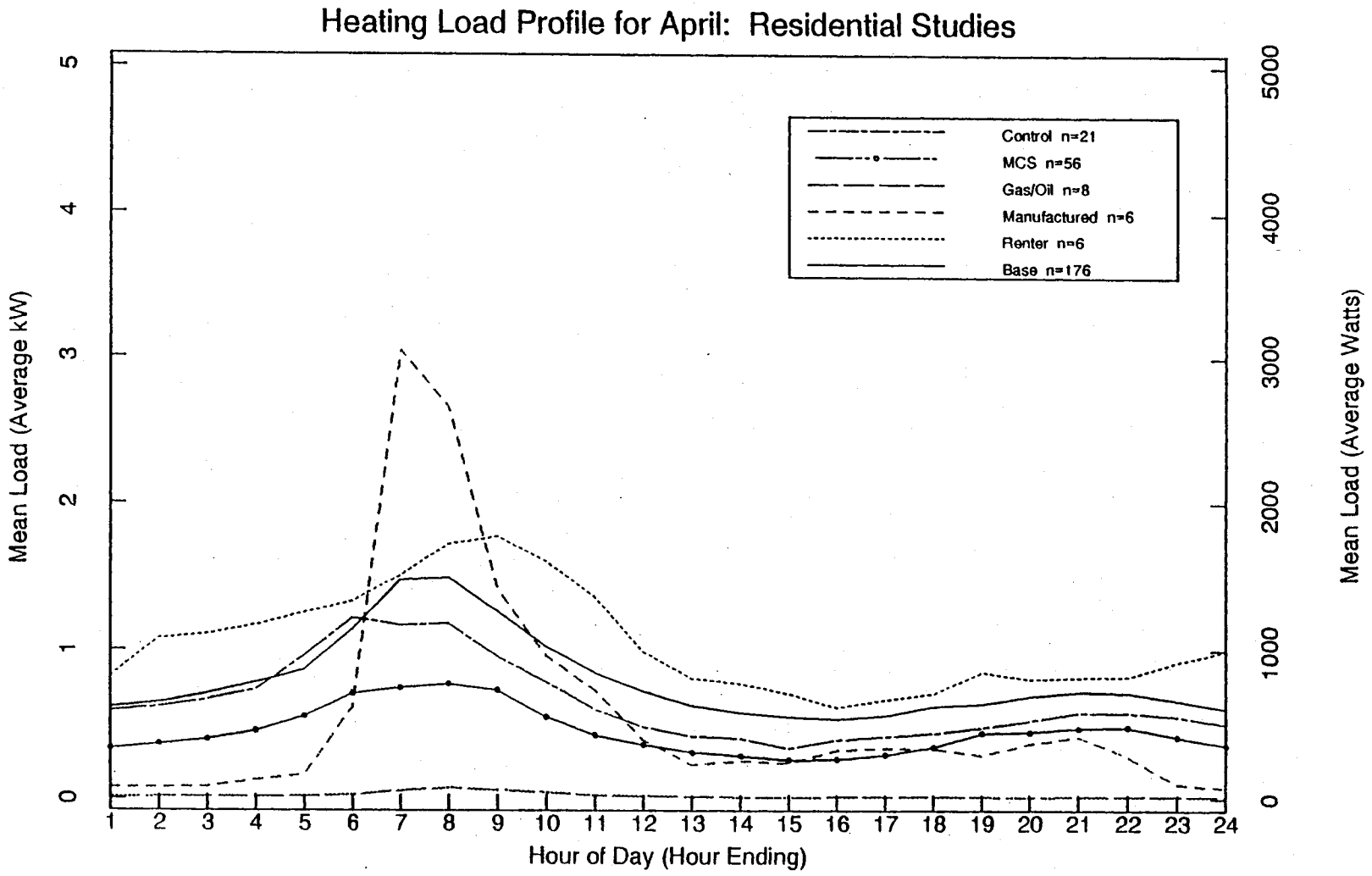
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7D.8(a)



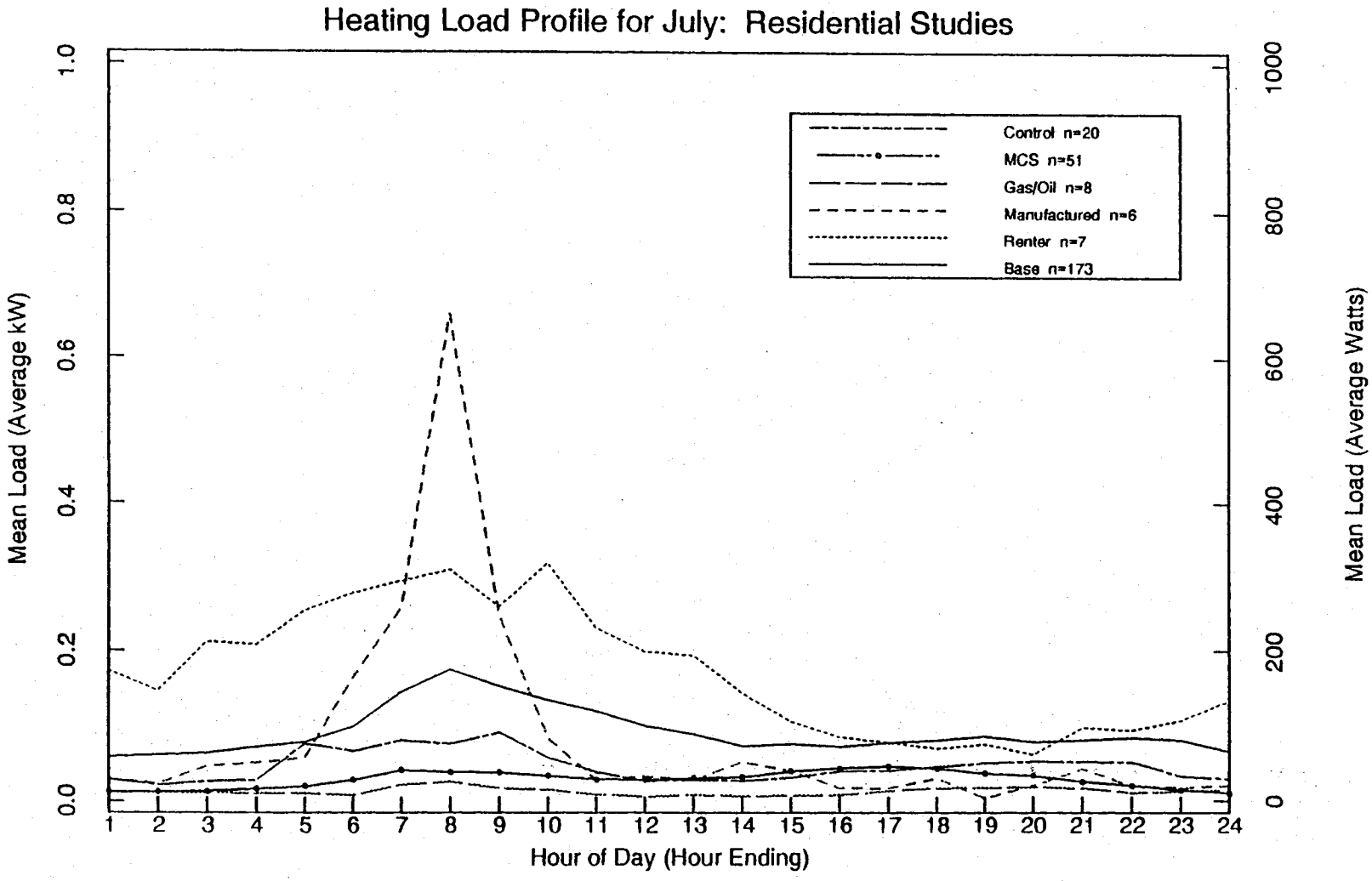
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FIGURE 7D.8(b)



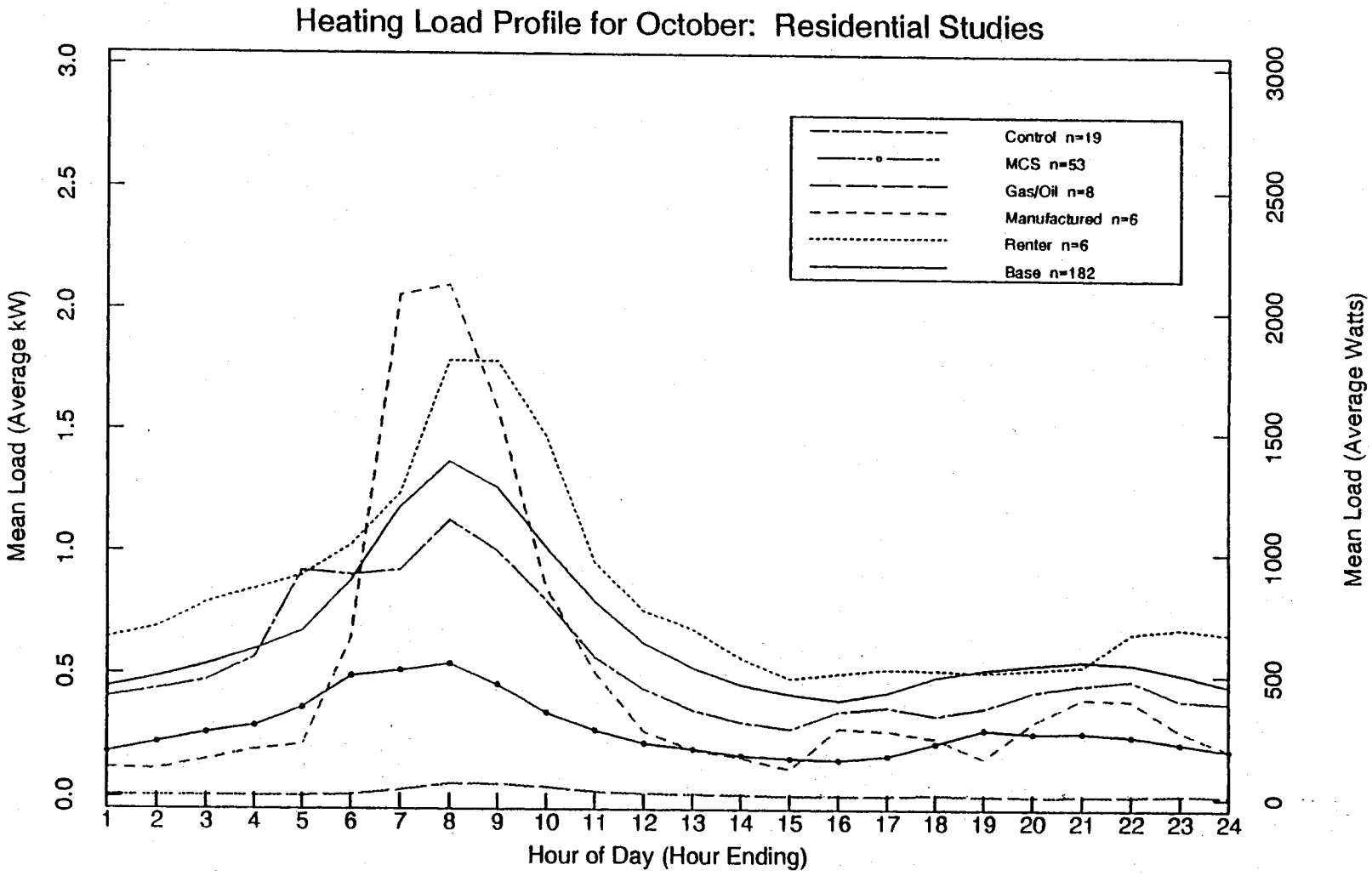
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.8(c)



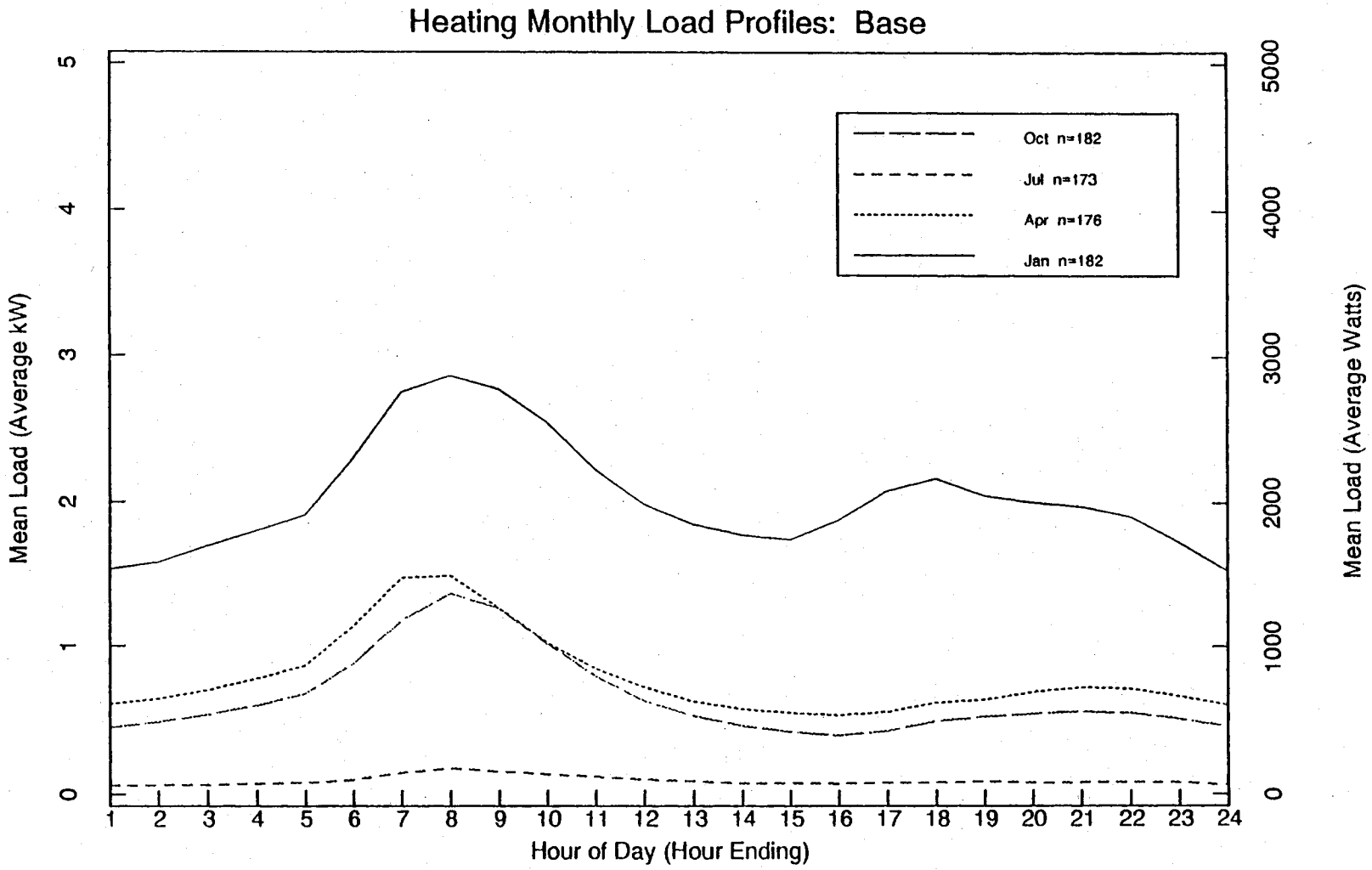
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.8(d)



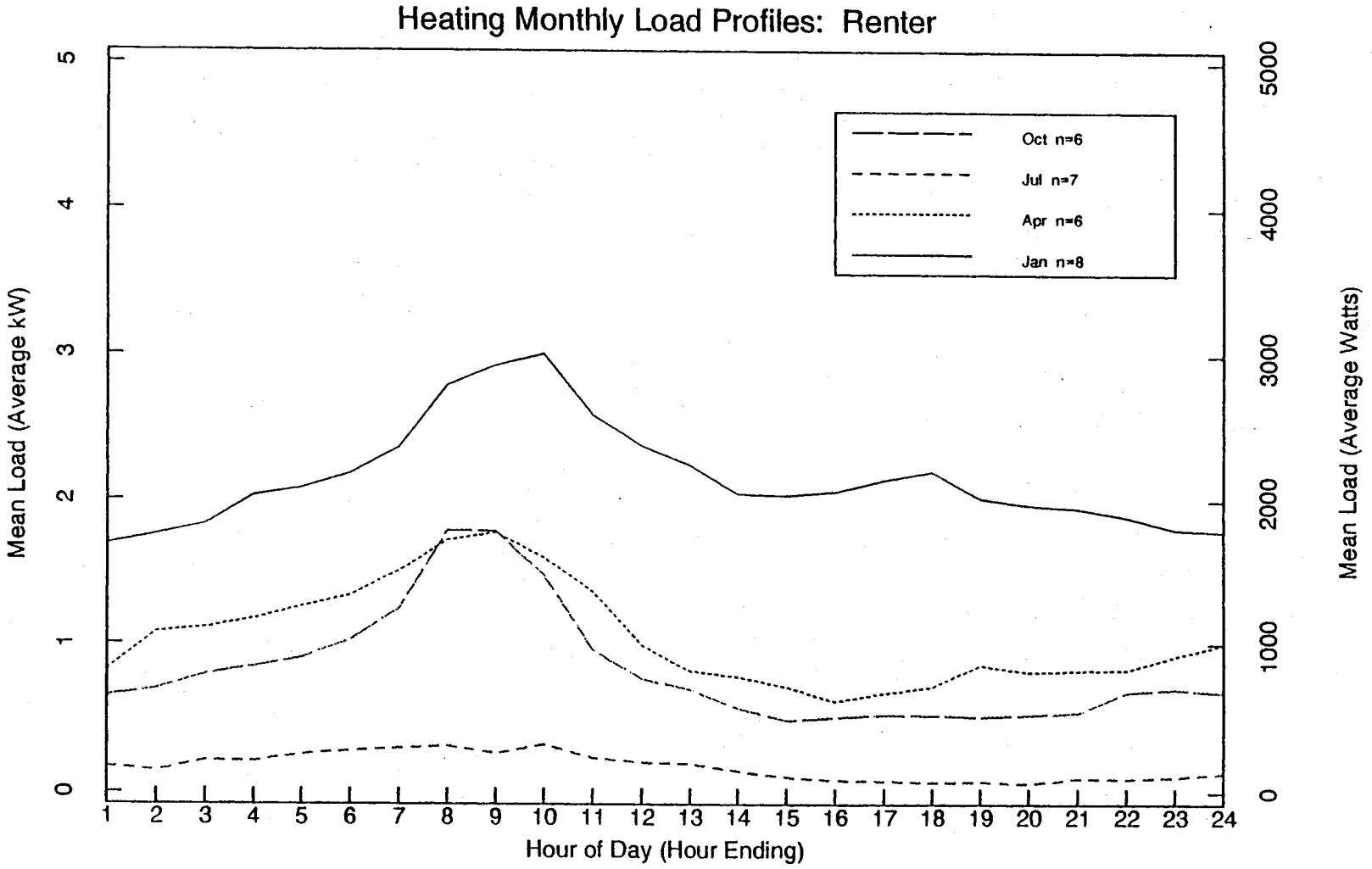
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(a)



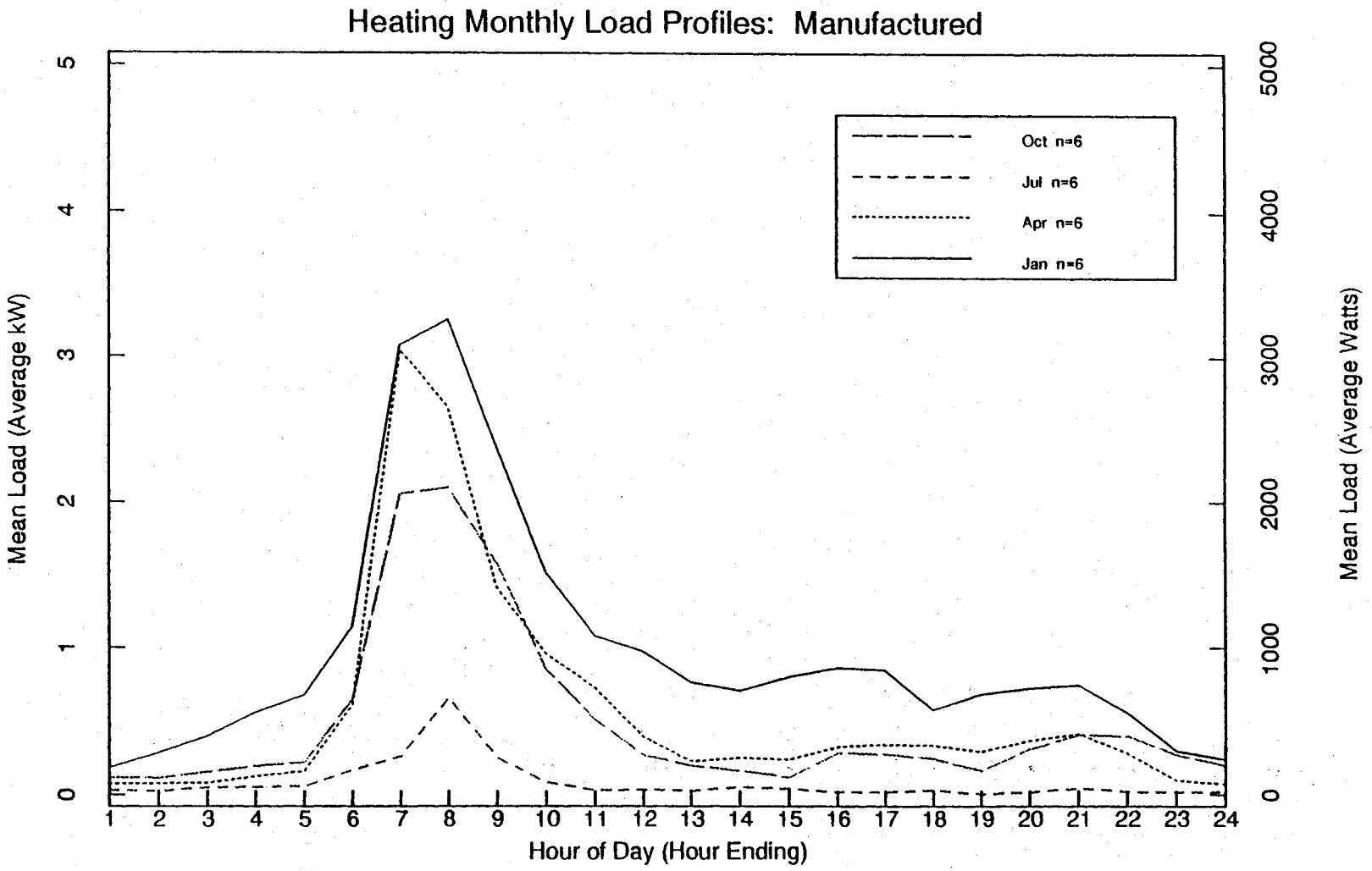
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(b)



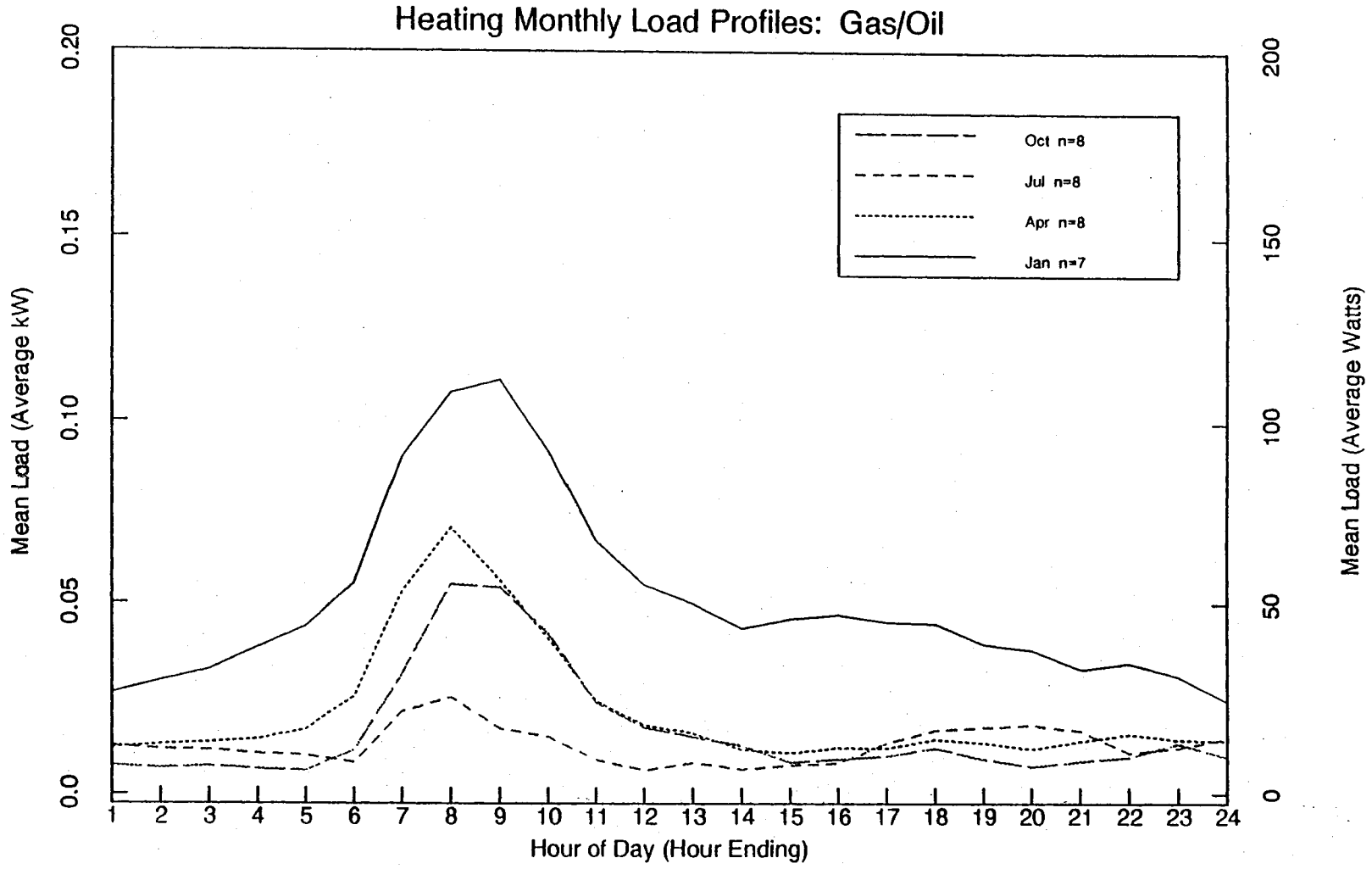
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(c)



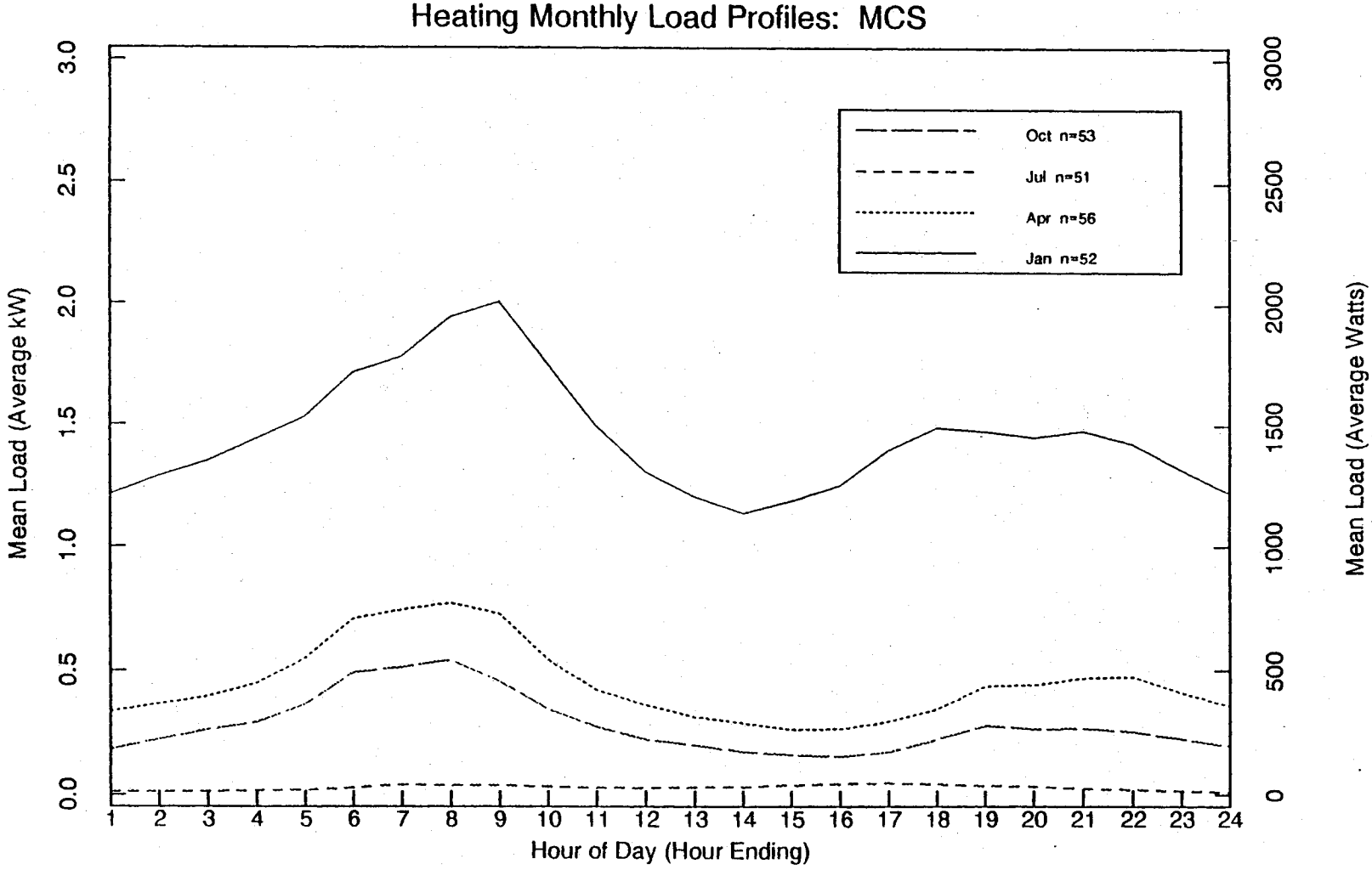
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(d)



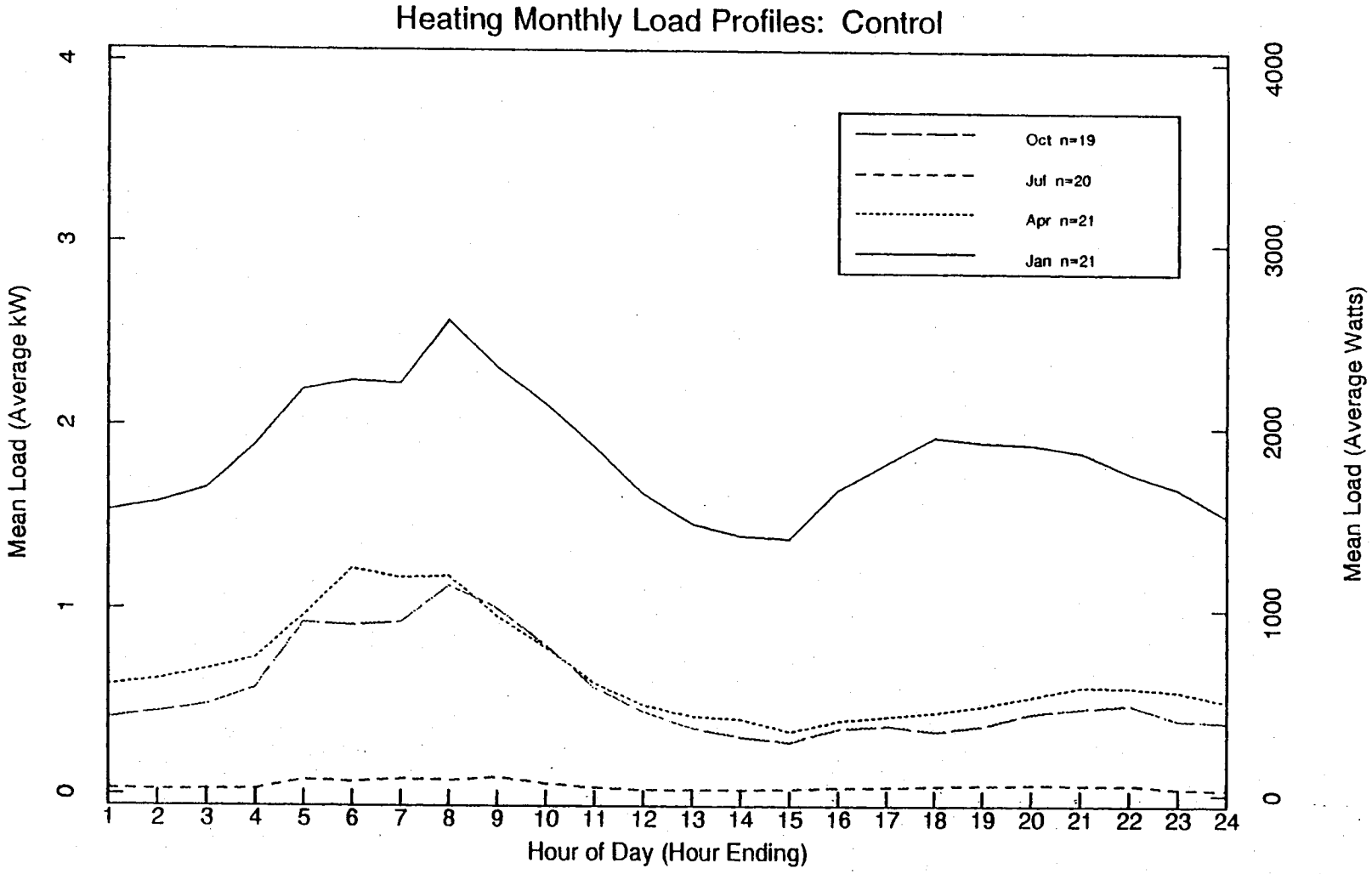
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(e)



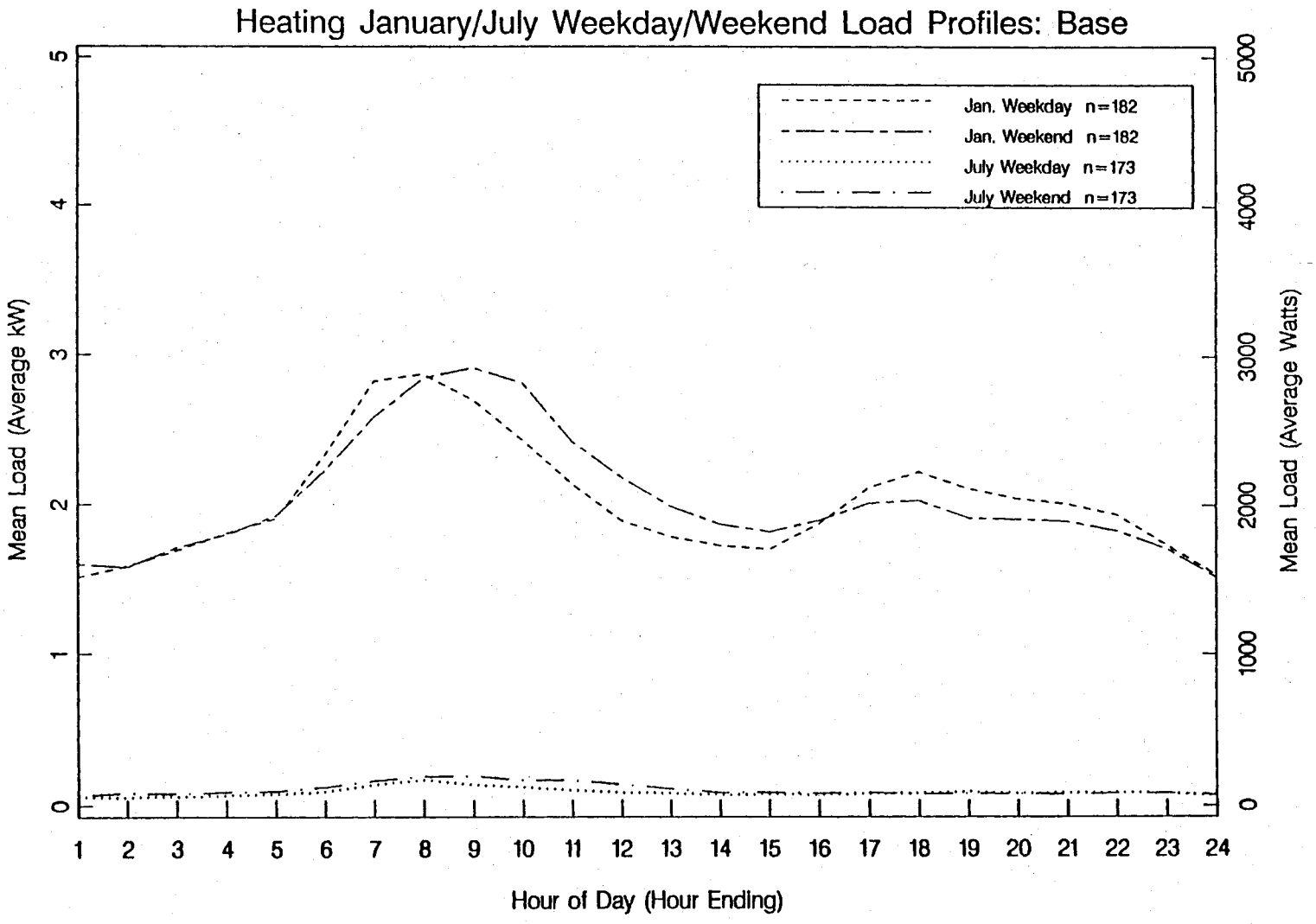
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.9(f)



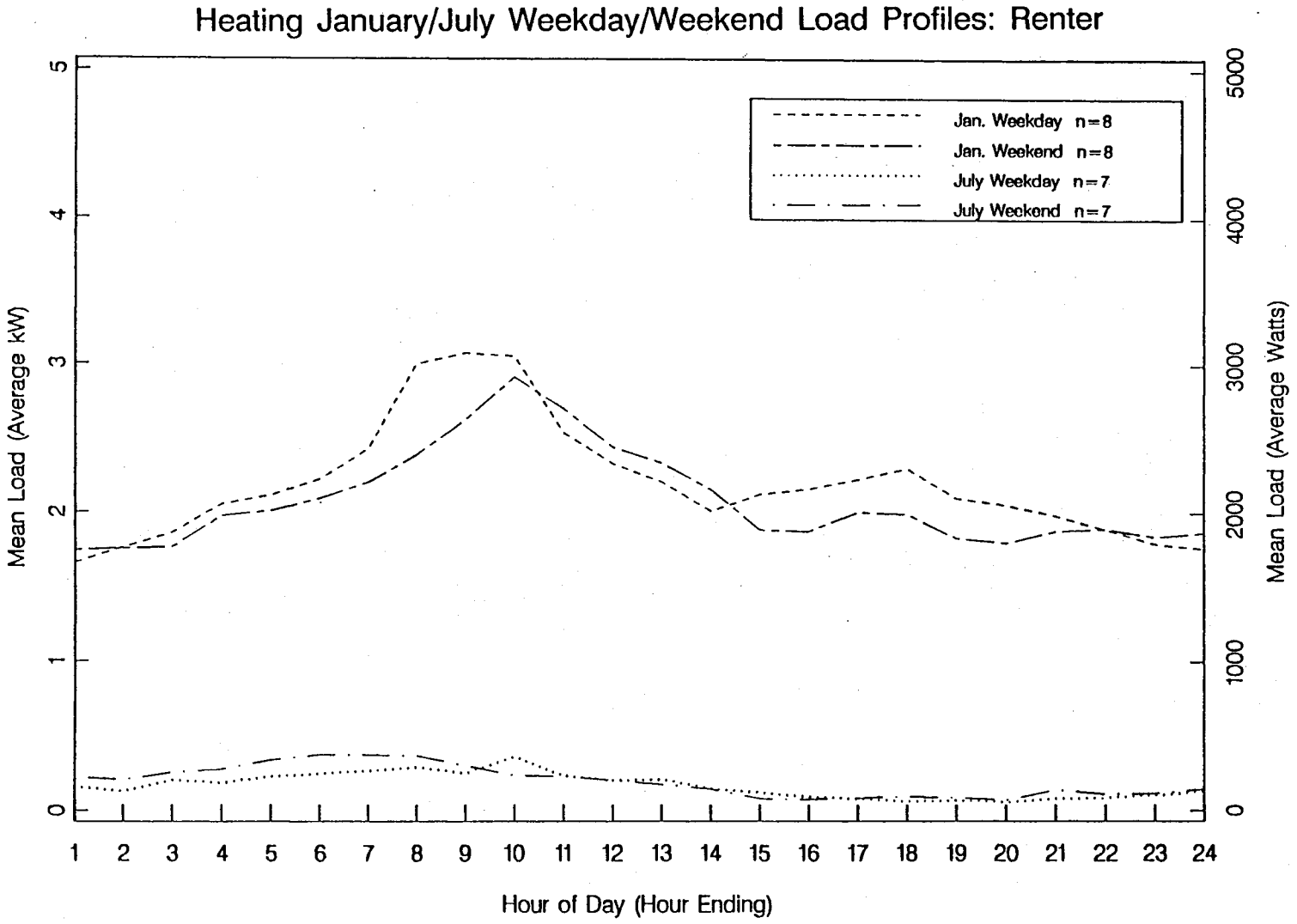
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7D.10(a)



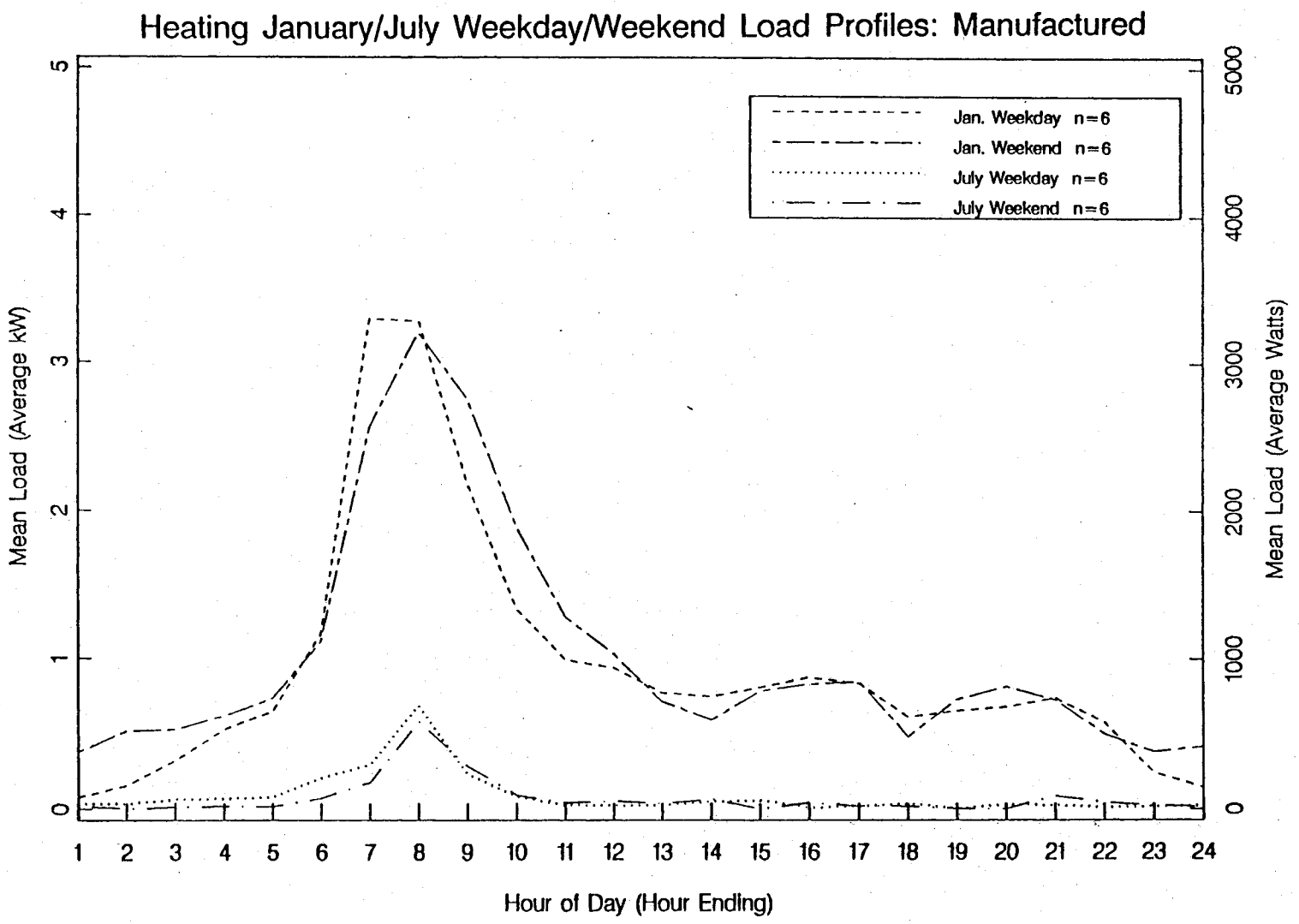
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7D.10(b)



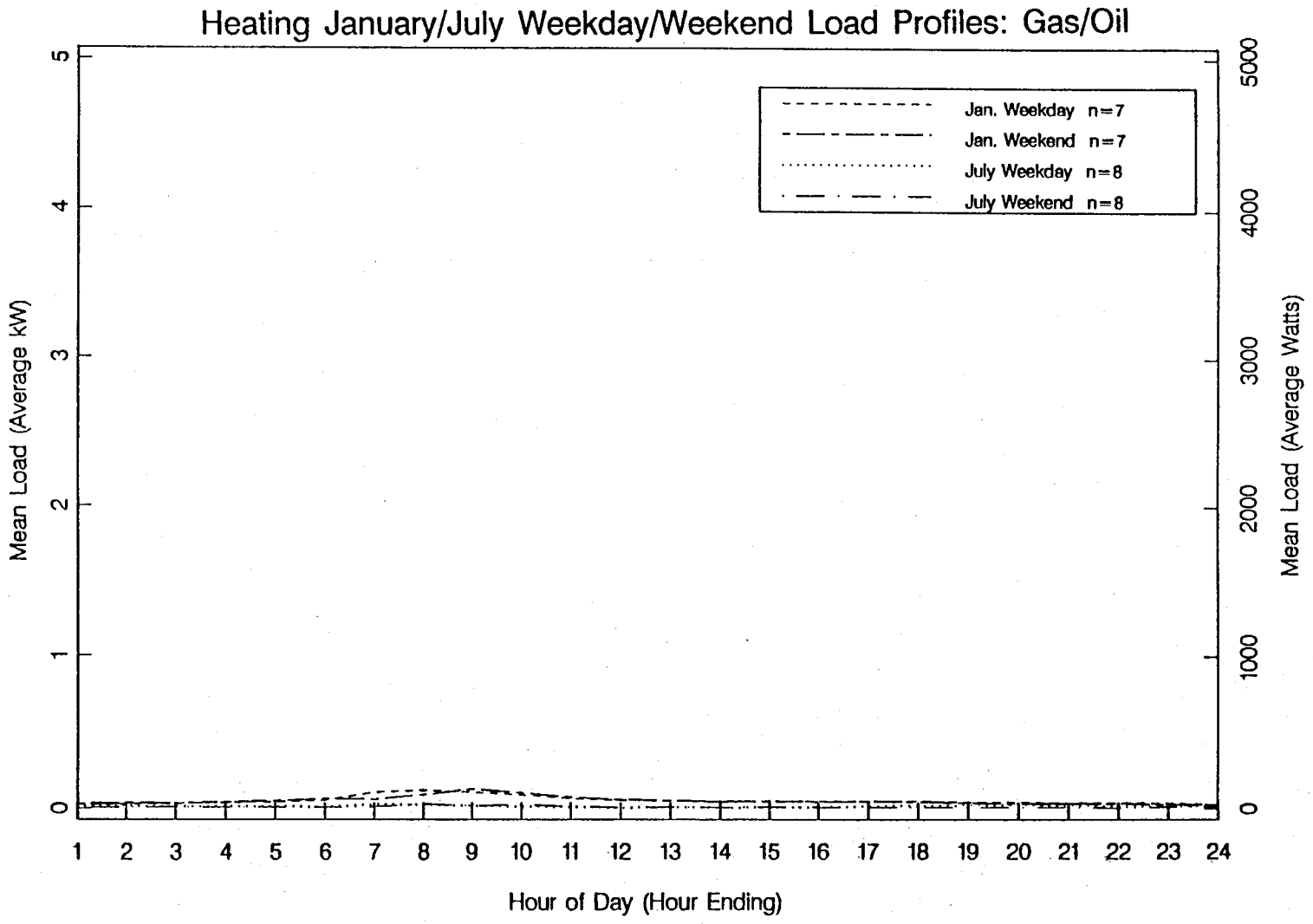
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7D.10(c)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

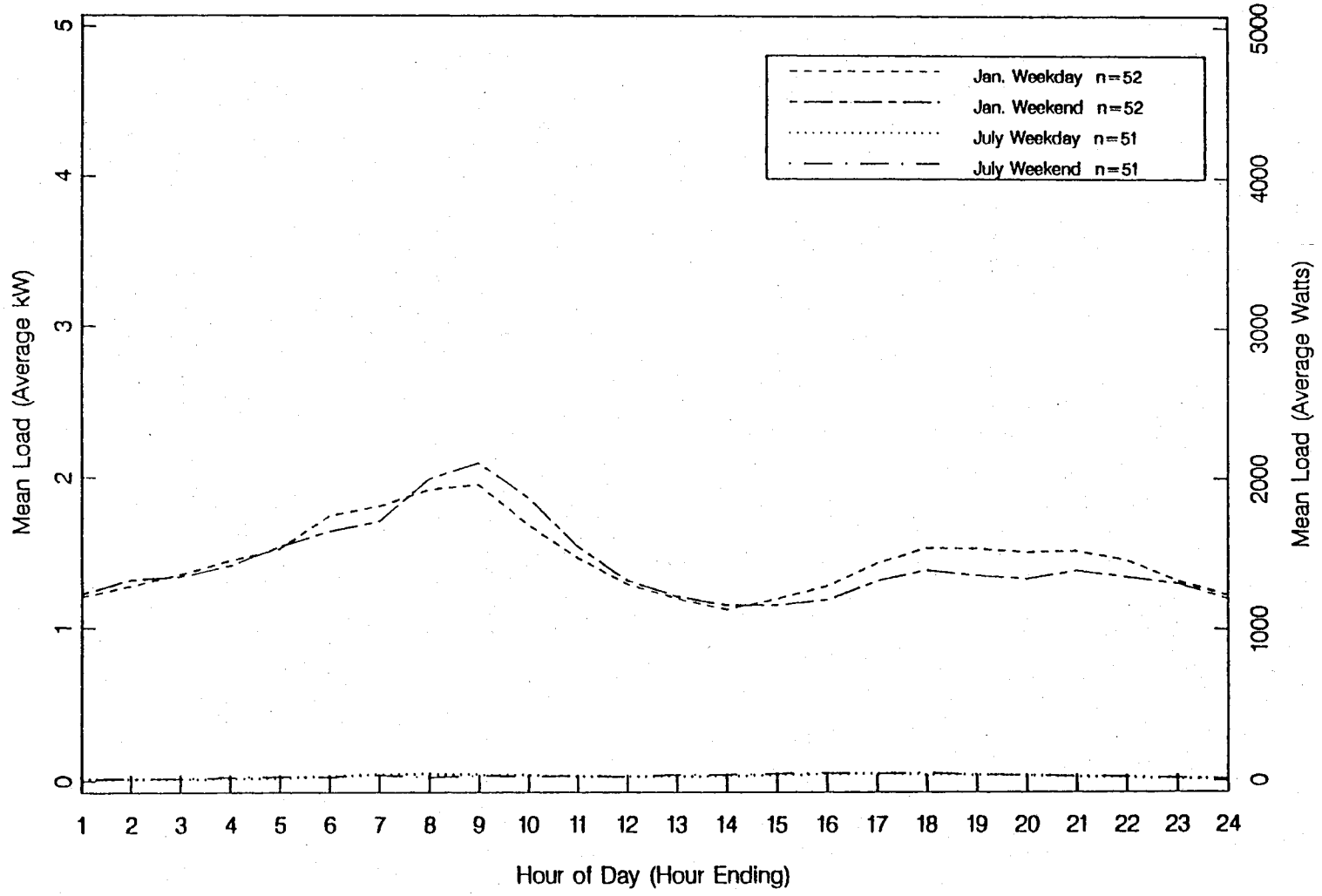
FIGURE 7D.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

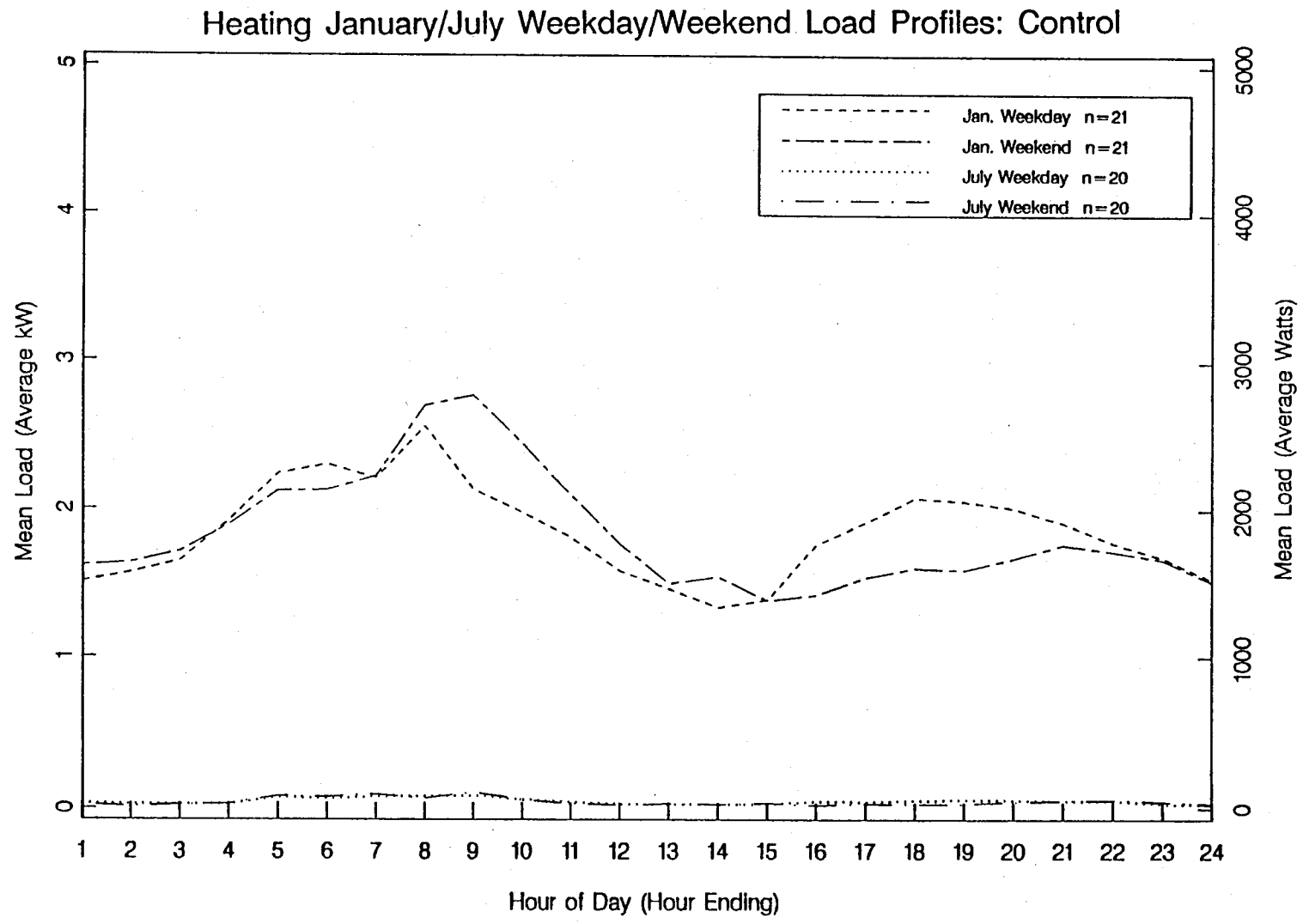
FIGURE 7D.10(e)

Heating January/July Weekday/Weekend Load Profiles: MCS



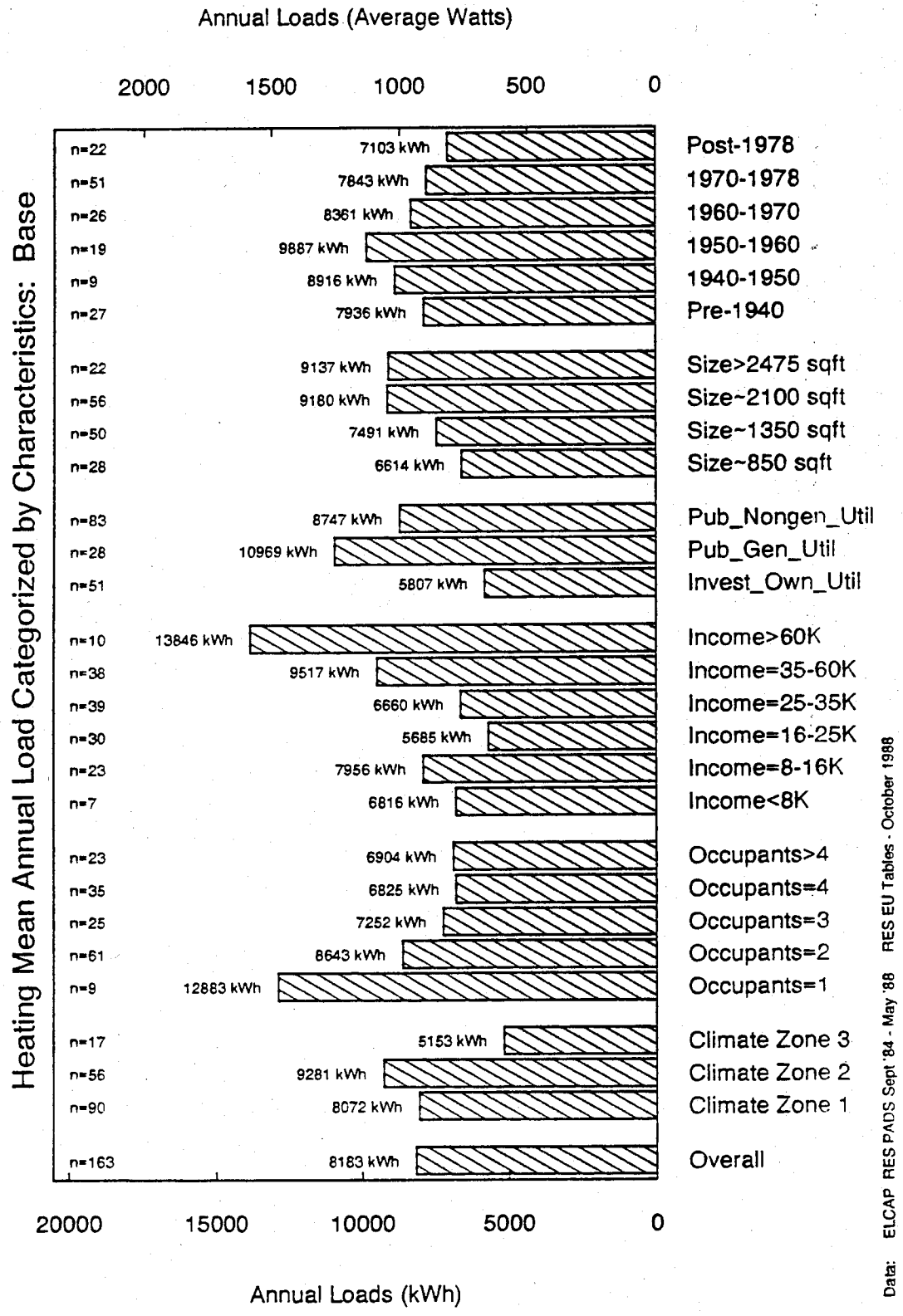
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7D.10(f)



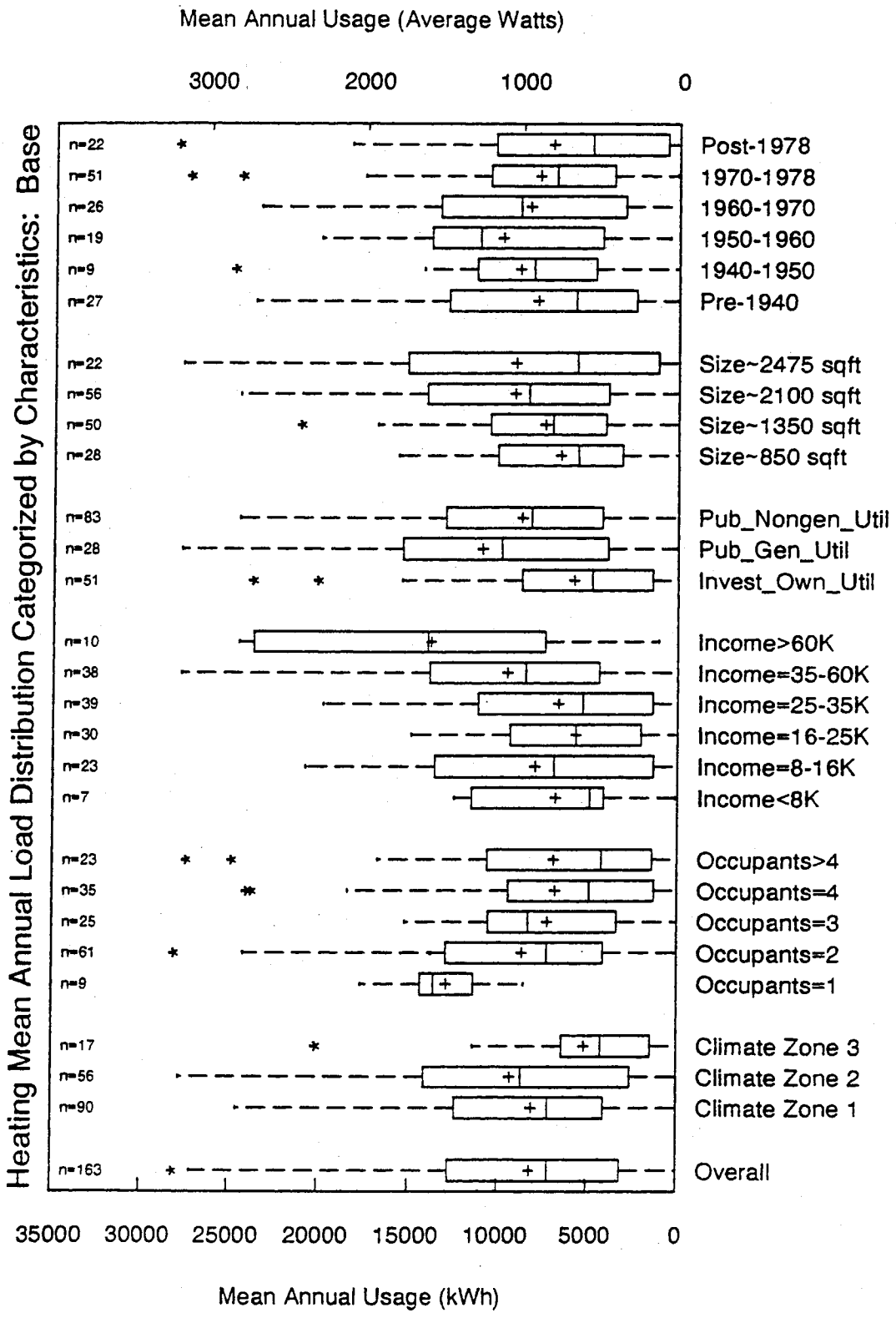
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7D.11



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7D.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7D.1

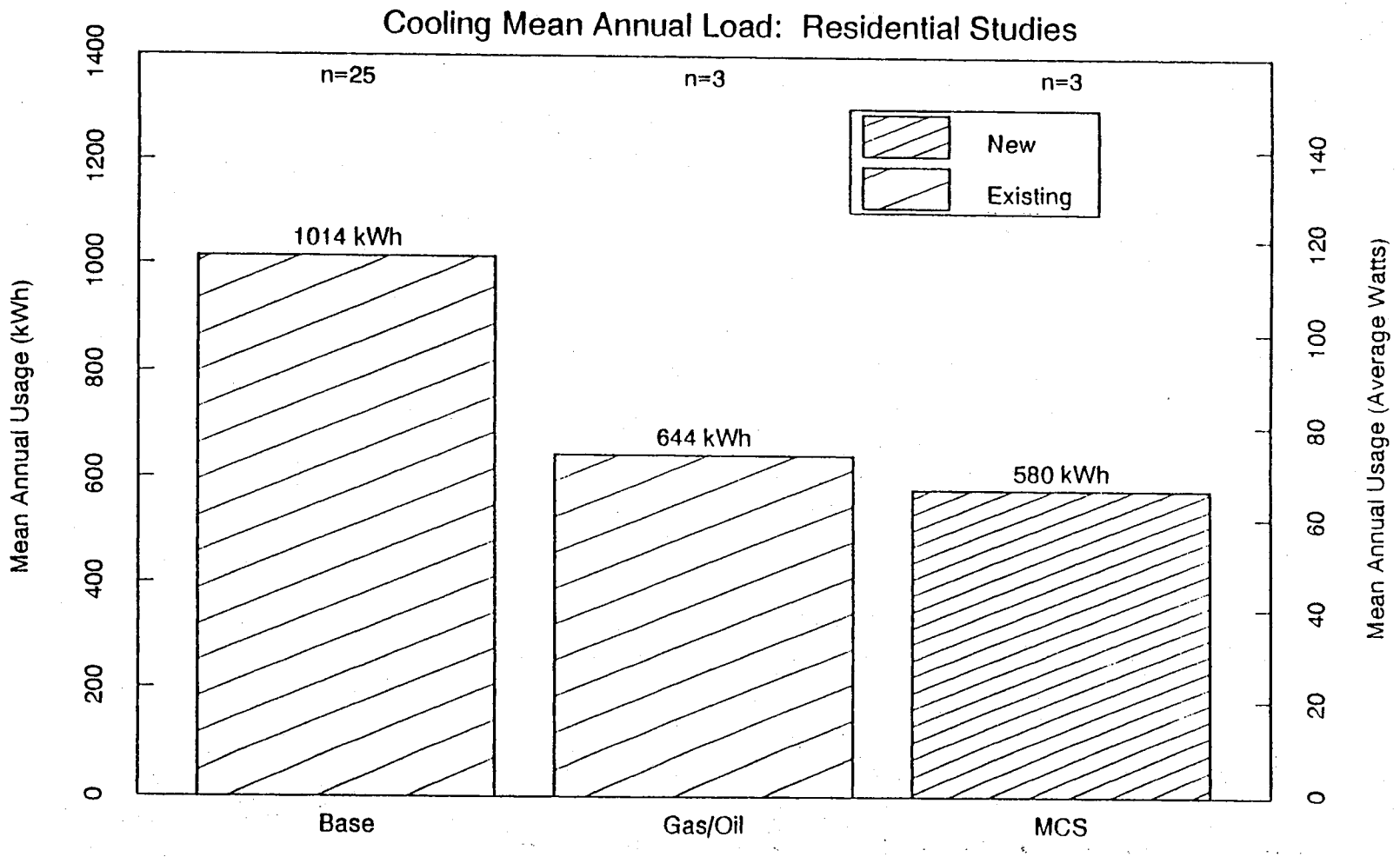
Heating Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	163	8183	6324	18	7462	2149	49	5196	2266	230	7490	5584
Climate Zone 1	90	8072	5741	10	7603	2263	31	5033	2137	131	7317	5061
Climate Zone 2	56	9281	7299	4	7223	2097	14	5547	2659	74	8463	6619
Climate Zone 3	17	5153	4944	4	7348	2501	4	5231	2239	25	5517	4286
Occupants=1	9	12883	2780	0	-	-	2	1657	95	11	10842	5177
Occupants=2	61	8643	6445	6	8582	2892	12	5436	2091	79	8151	5869
Occupants=3	25	7252	4815	3	7203	2550	6	4373	2679	34	6740	4425
Occupants=4	35	6825	6287	2	6906	176	7	5306	1961	44	6587	5667
Occupants>4	23	6904	7521	1	7648	0	4	5174	2430	28	6683	6867
Income<8K	7	6816	4630	0	-	-	1	4429	0	8	6518	4369
Income=8-16K	23	7956	6636	1	9653	0	1	319	0	25	7719	6547
Income=16-25K	30	5685	4211	1	10370	0	7	4818	2443	38	5648	3949
Income=25-35K	39	6660	5491	5	6804	1796	9	4954	1929	53	6384	4825
Income=35-60K	38	9517	6825	3	8292	4014	12	5608	2185	53	8563	6120
Income>60K	10	13846	8855	1	8247	0	1	2262	0	12	12414	8773
Invest_Own_Util	51	5807	5230	7	8346	2590	25	4869	2601	83	5739	4468
Pub_Gen_Util	28	10969	7900	7	6648	1362	10	4861	1029	45	8939	6782
Pub_Nongen_Util	83	8747	5928	4	7339	2380	11	5729	1955	98	8351	5589
Size~850 sqft	28	6614	4677	1	7030	0	1	319	0	30	6418	4659
Size~1350 sqft	50	7491	4977	11	7147	2381	22	4712	1869	83	6709	4225
Size~2100 sqft	56	9180	6602	5	7926	2062	15	5972	1608	76	8464	5858
Size>2475 sqft	22	9137	9272	0	-	-	7	5536	3414	29	8267	8333
Pre-1940	27	7936	6862	0	-	-	0	-	-	27	7936	6862
1940-1950	9	8916	7448	0	-	-	0	-	-	9	8916	7448
1950-1960	19	9887	5630	0	-	-	0	-	-	19	9887	5630
1960-1970	26	8361	5782	0	-	-	0	-	-	26	8361	5782
1970-1978	51	7843	5937	0	-	-	0	-	-	51	7843	5937
Post-1978	22	7103	6982	18	7462	2149	49	5196	2266	89	6126	4051

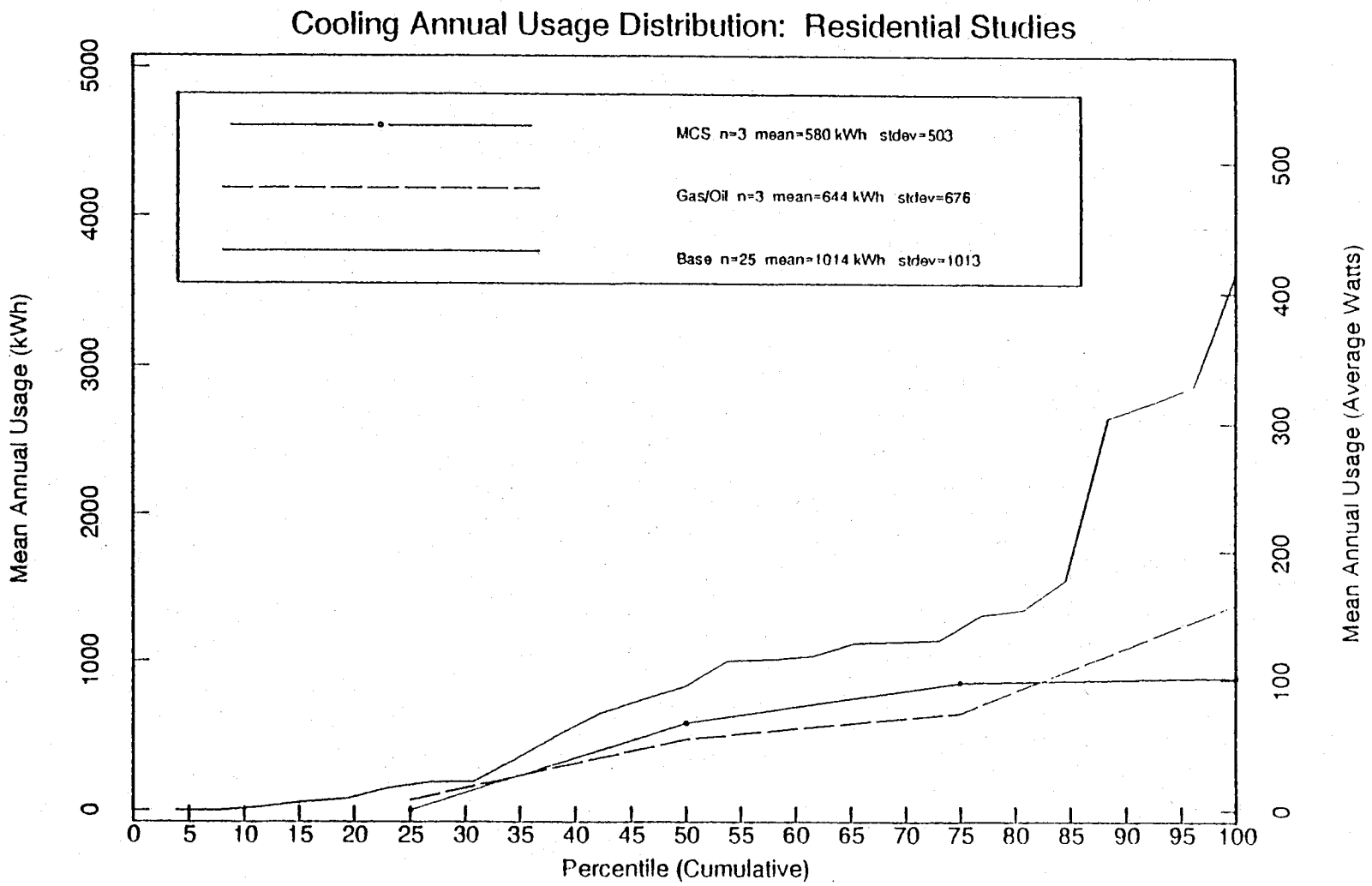
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7E.1



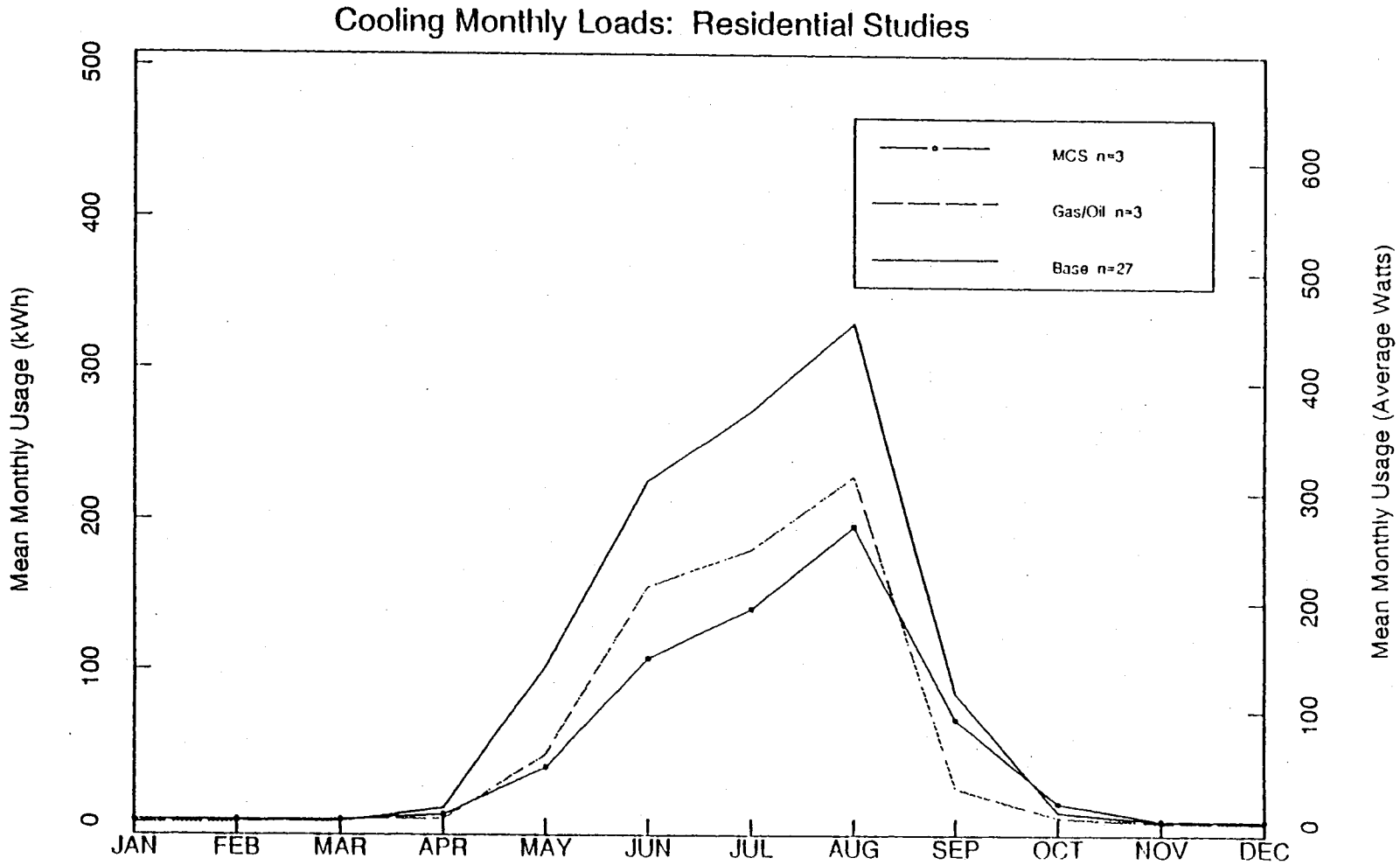
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.2



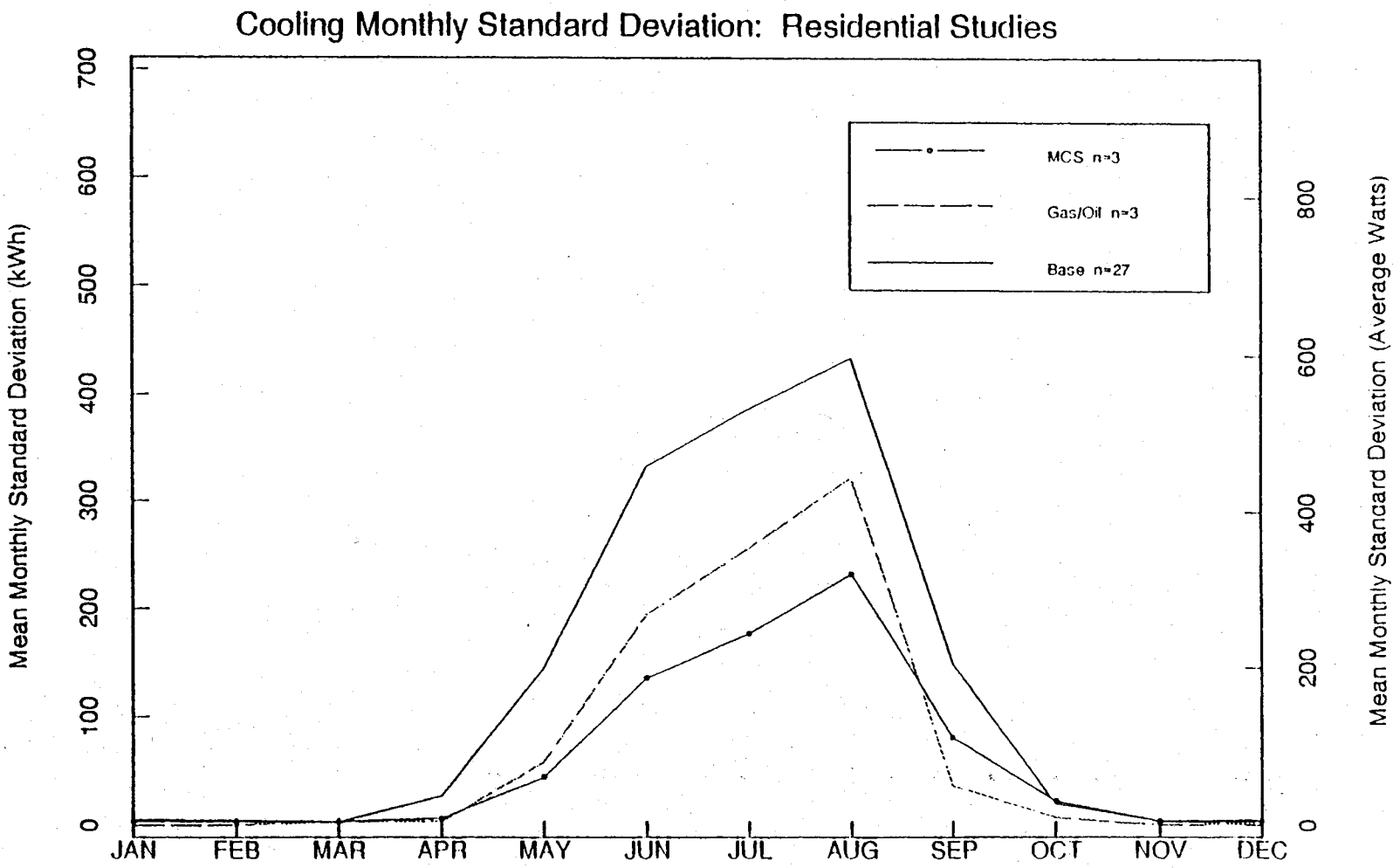
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.3



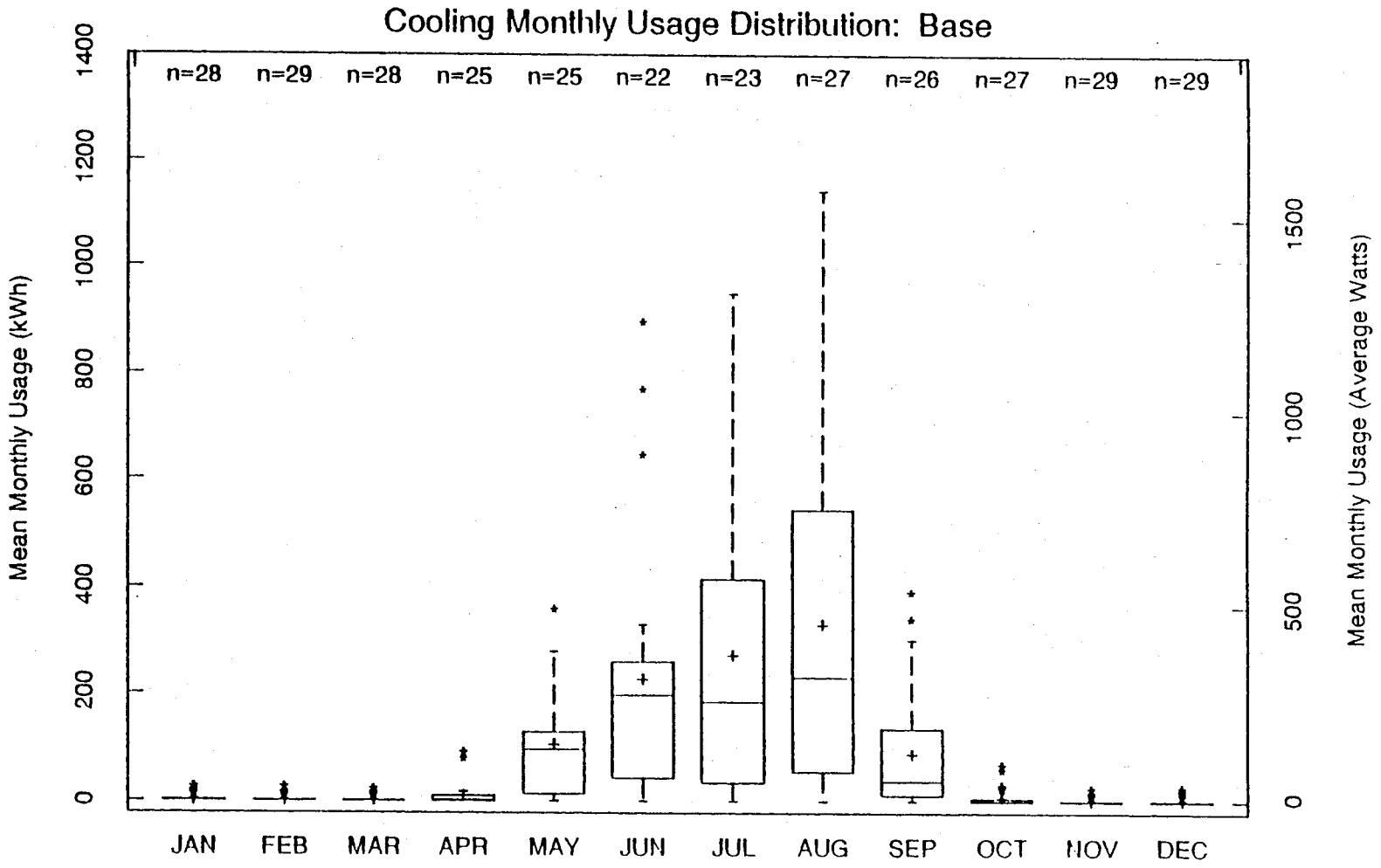
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.4



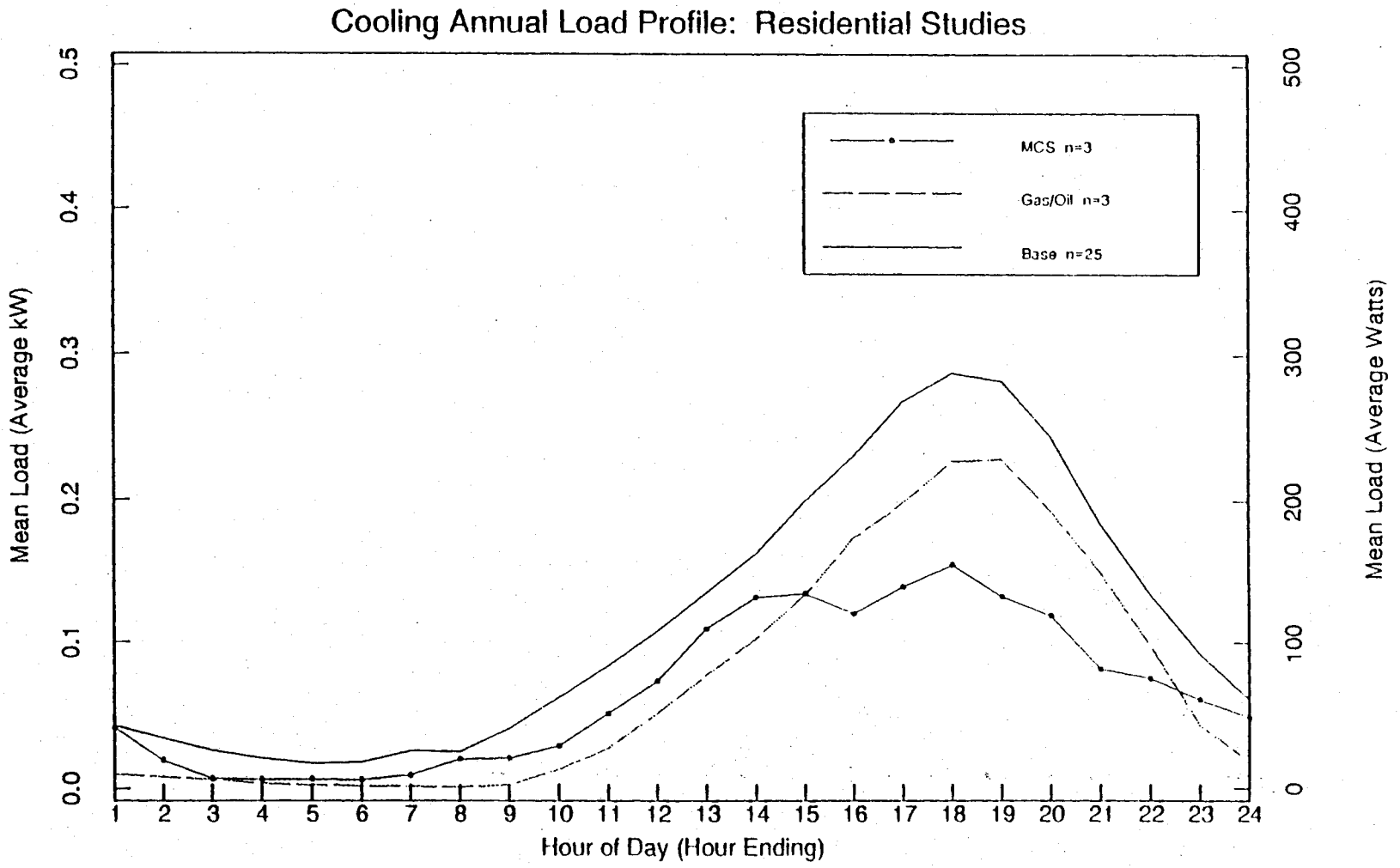
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

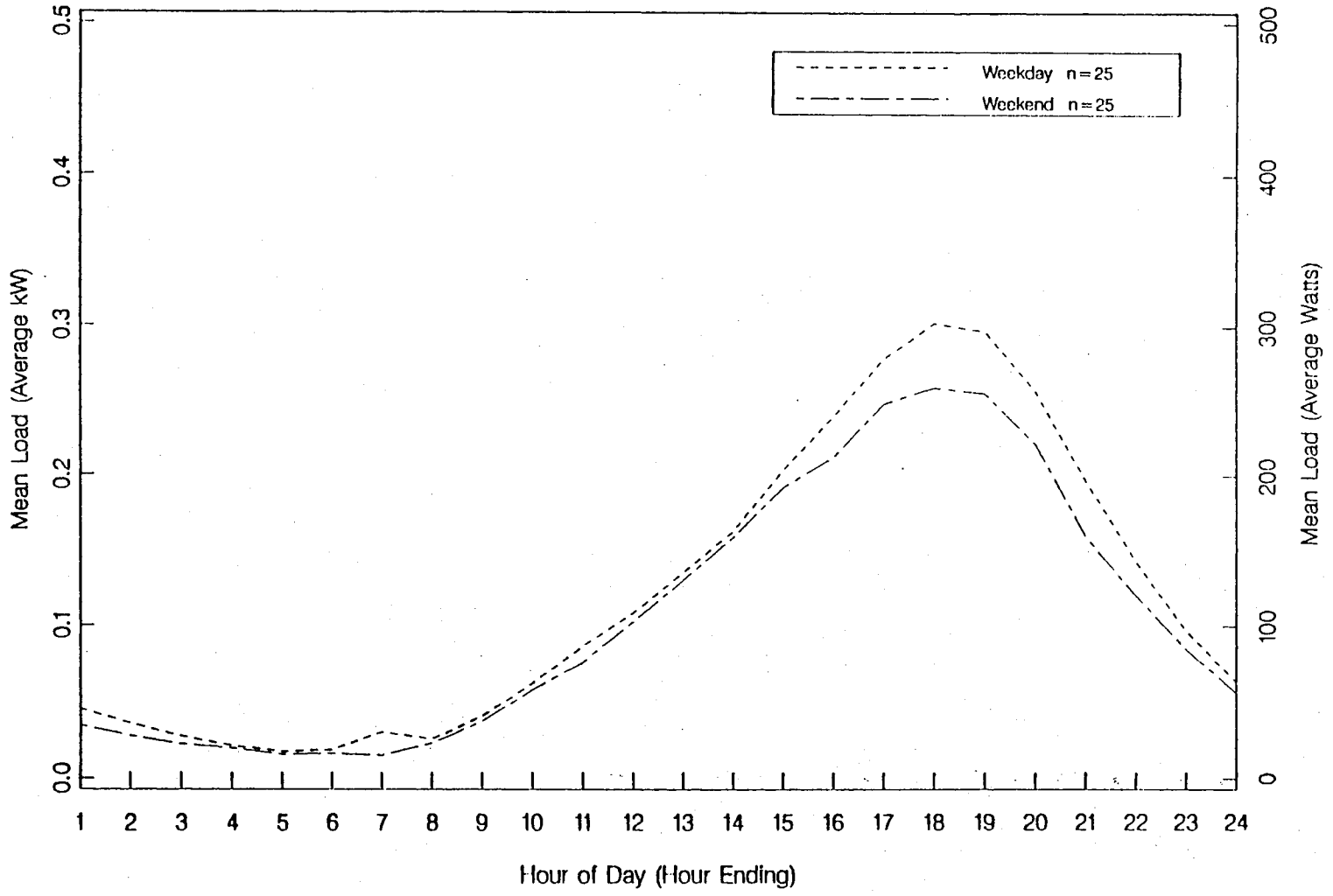
FIGURE 7E.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

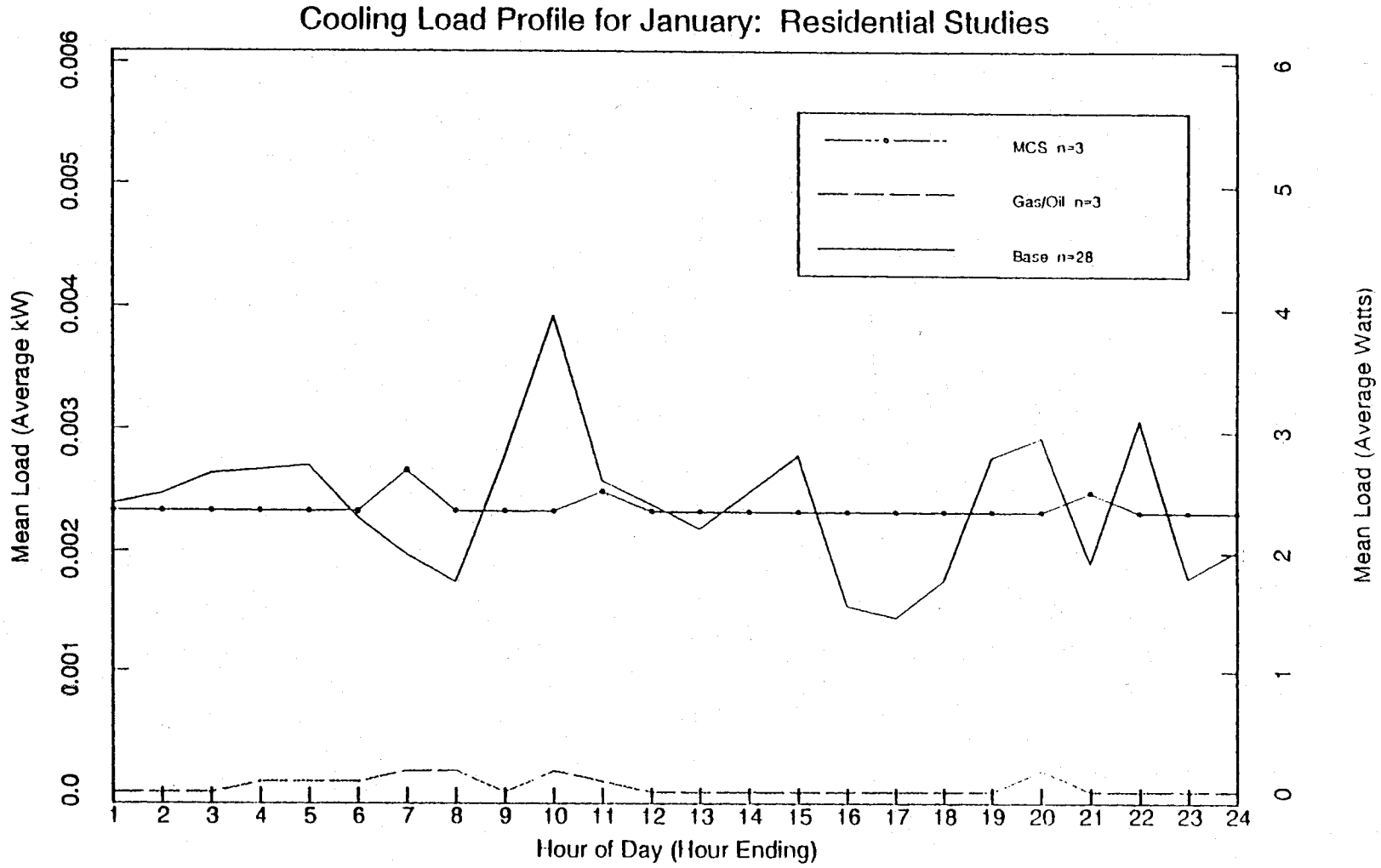
FIGURE 7E.7

Cooling Annual Weekday/Weekend Load Profiles: Base



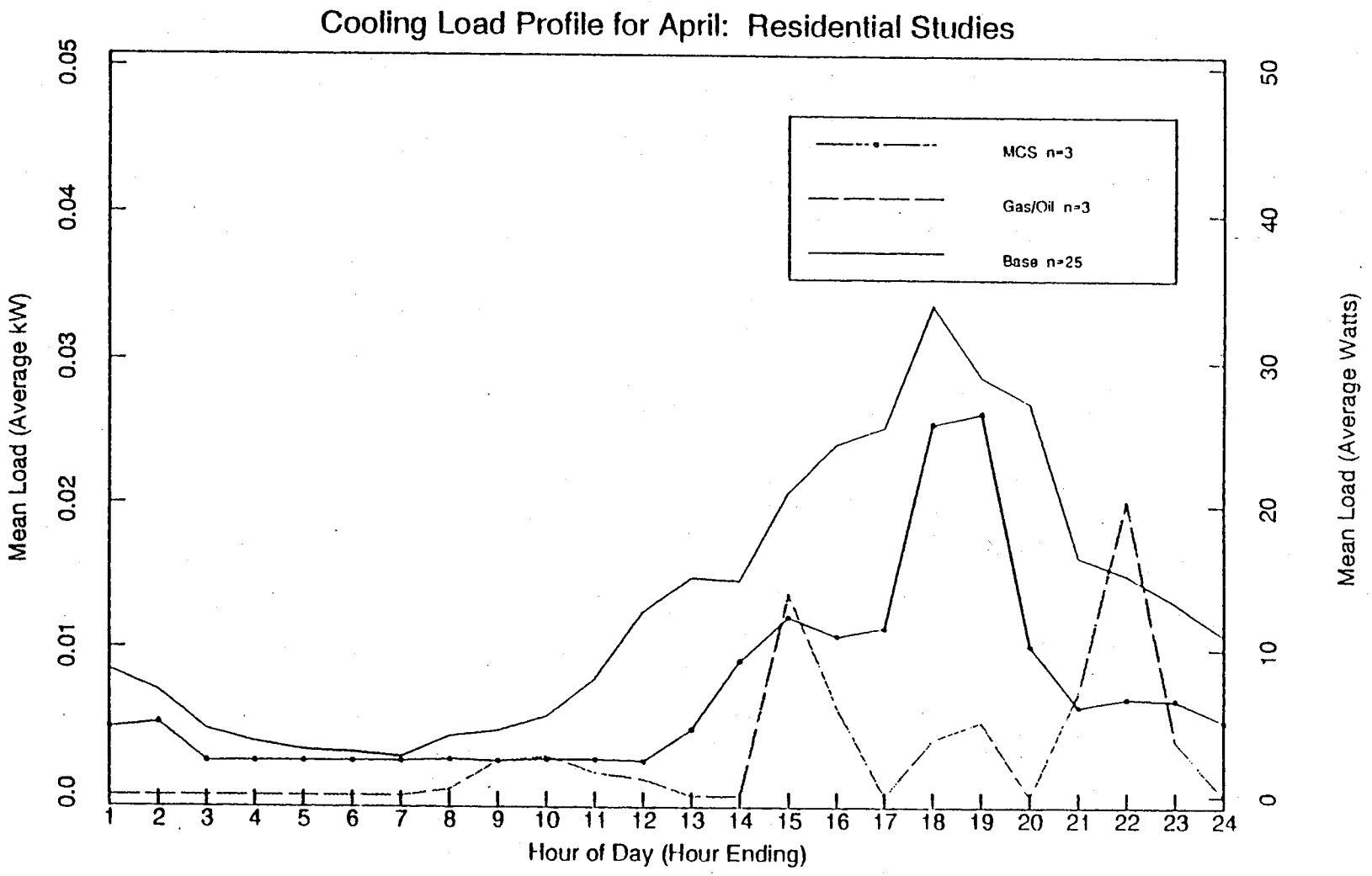
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7E.8(a)



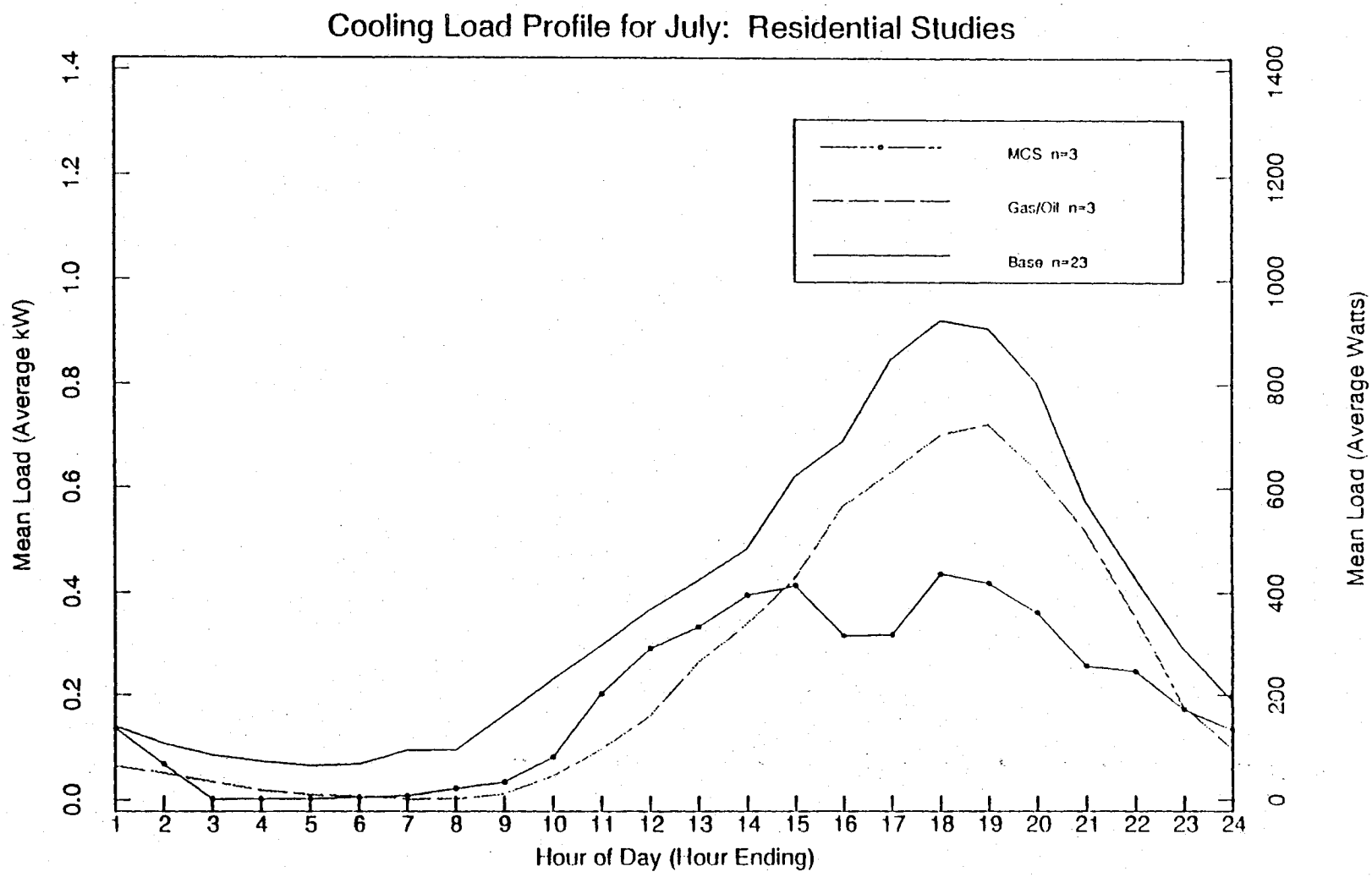
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.8(b)



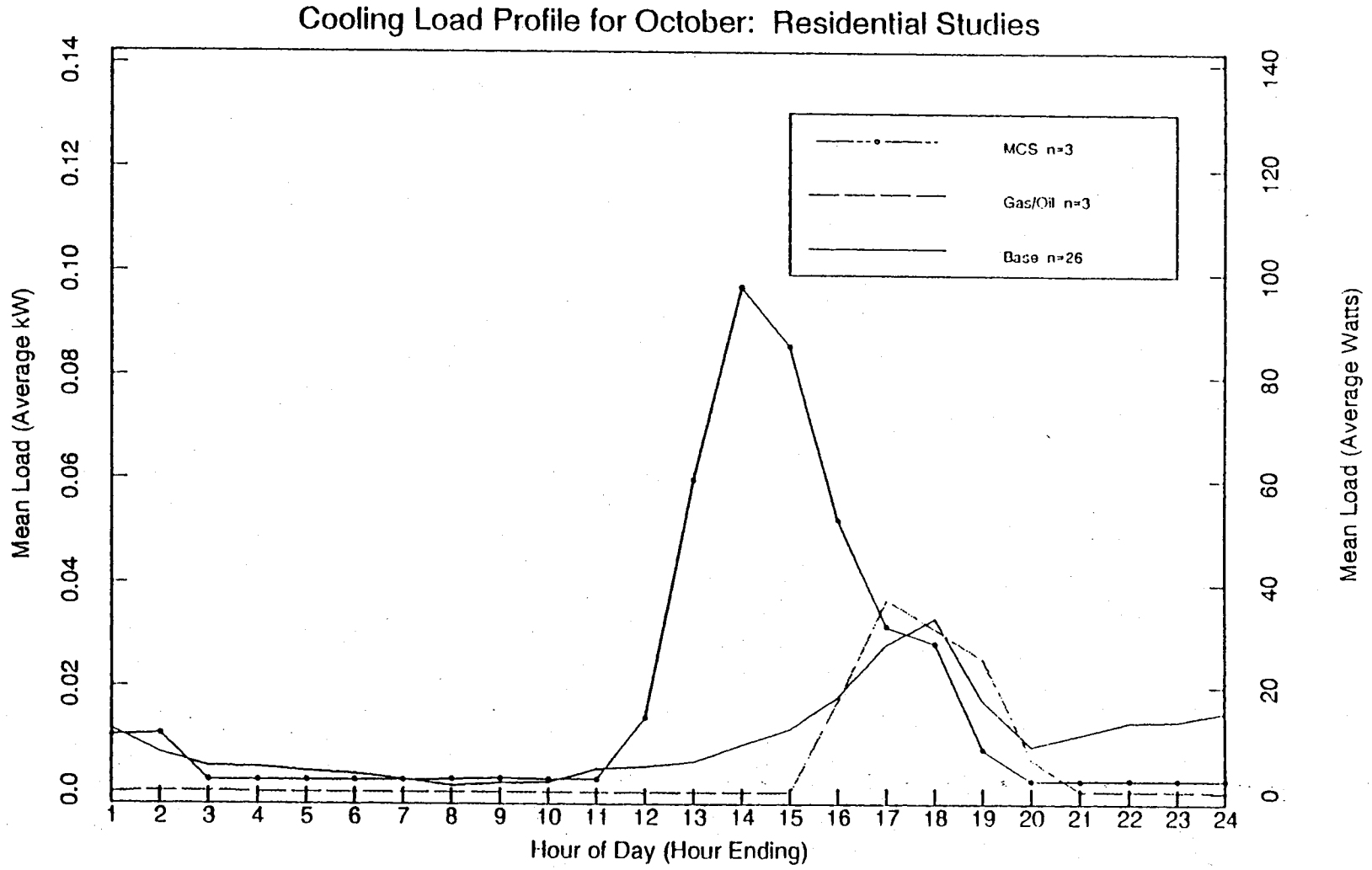
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.8(c)



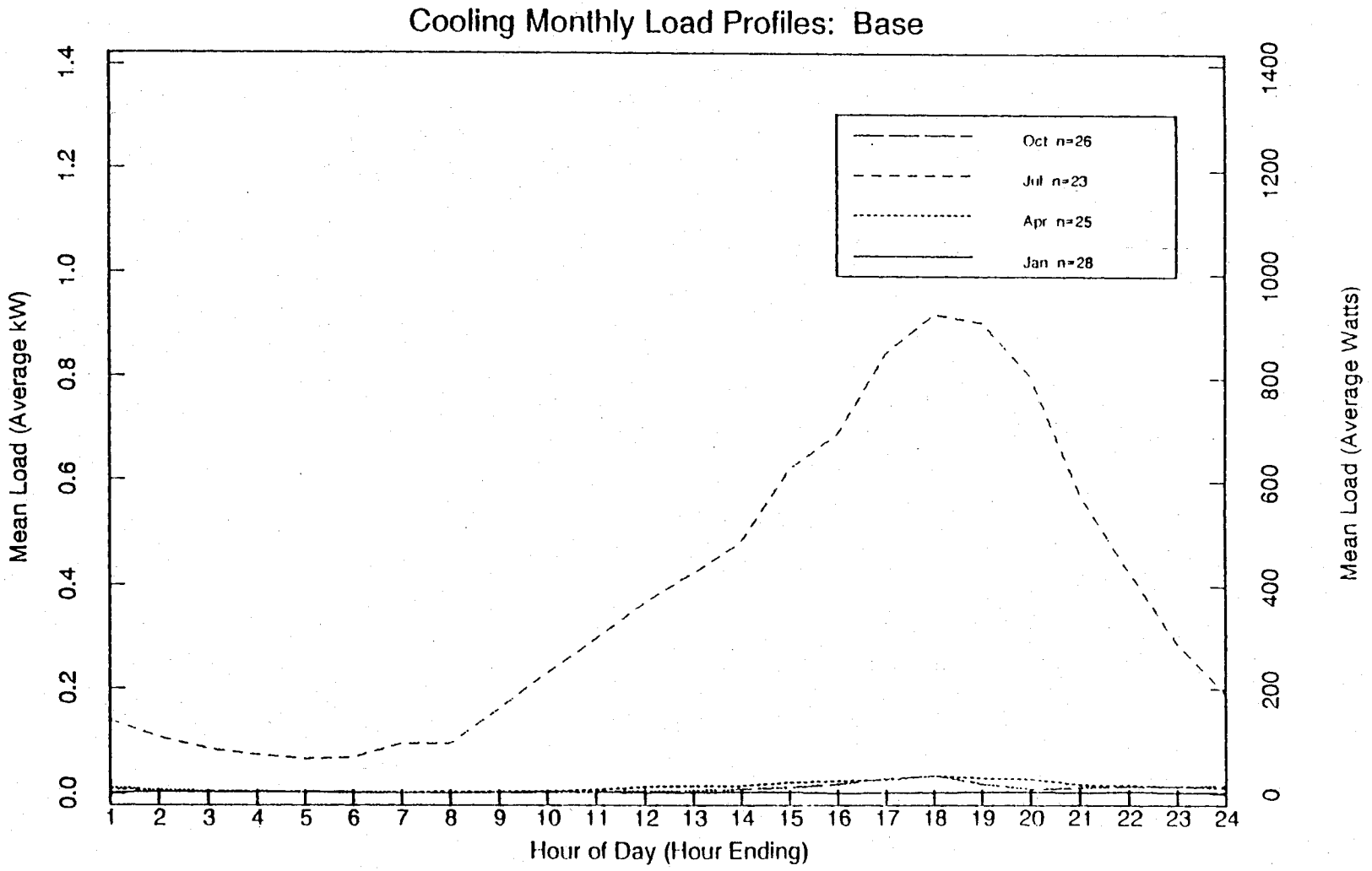
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.8(d)



Data: EICAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.9(a)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.9(b)

Cooling Monthly Load Profiles: Renter

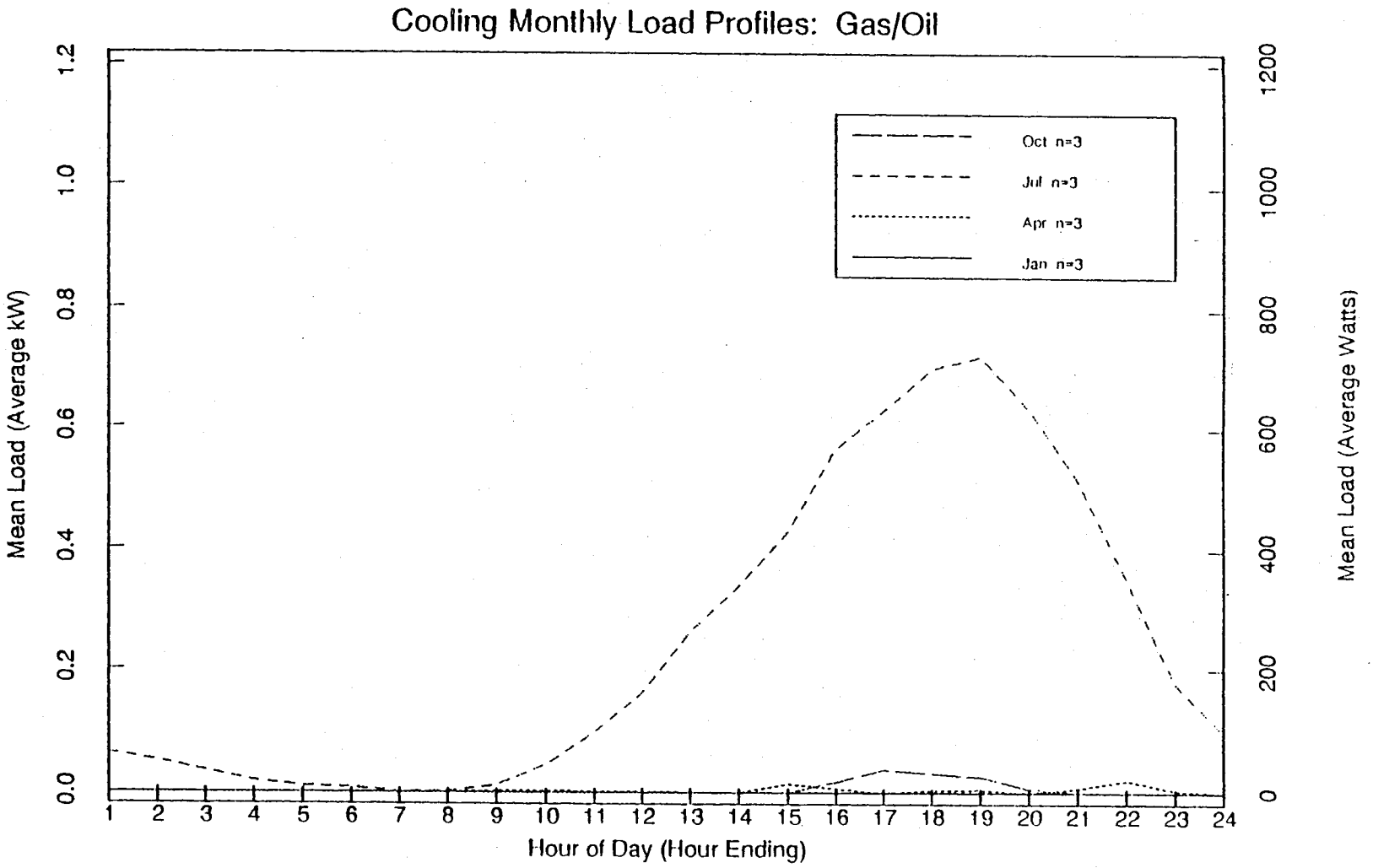
NO DATA TO PLOT

FIGURE 7E.9(c)

Cooling Monthly Load Profiles: Manufactured

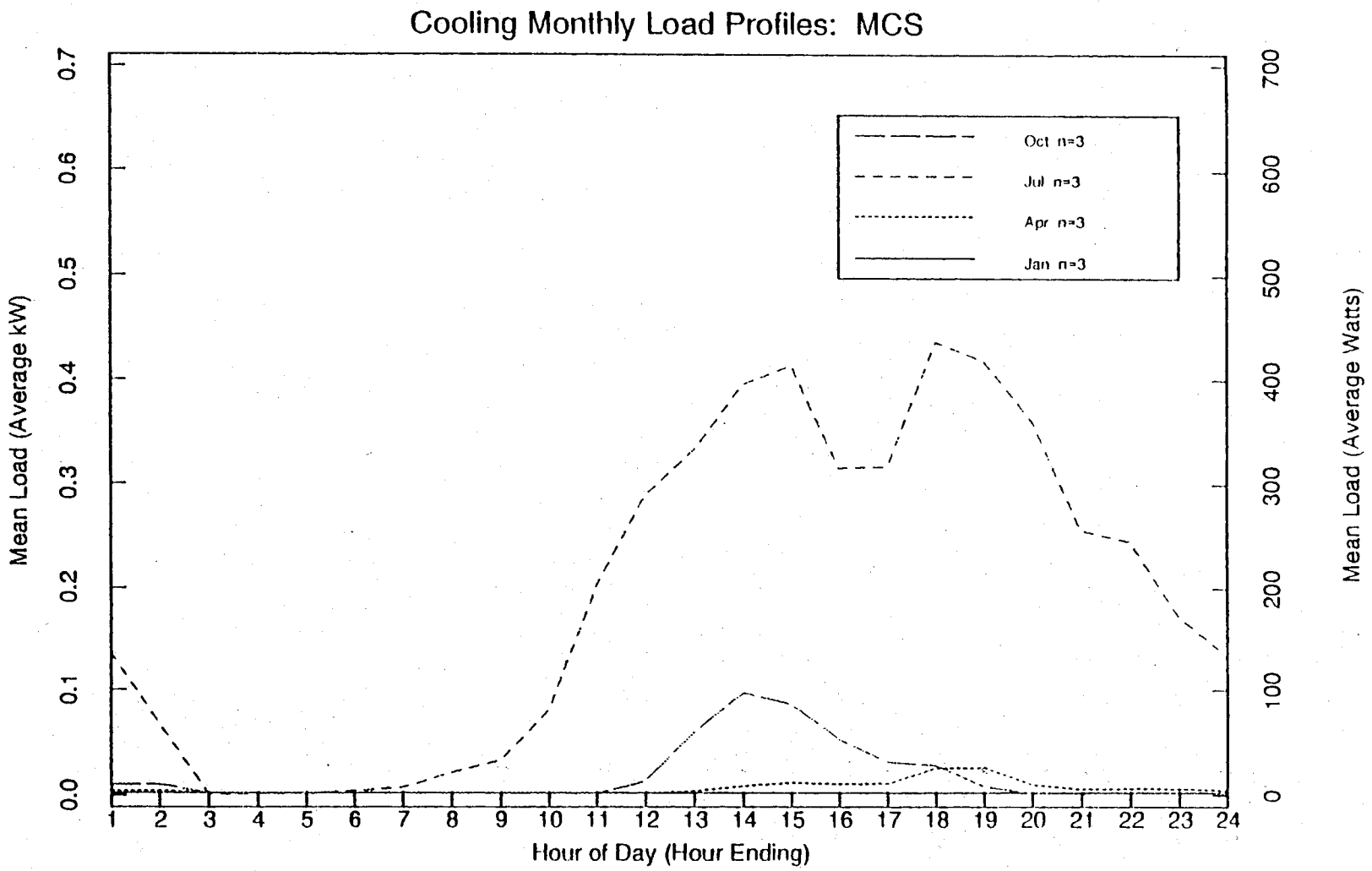
NO DATA TO PLOT

FIGURE 7E.9(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7E.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

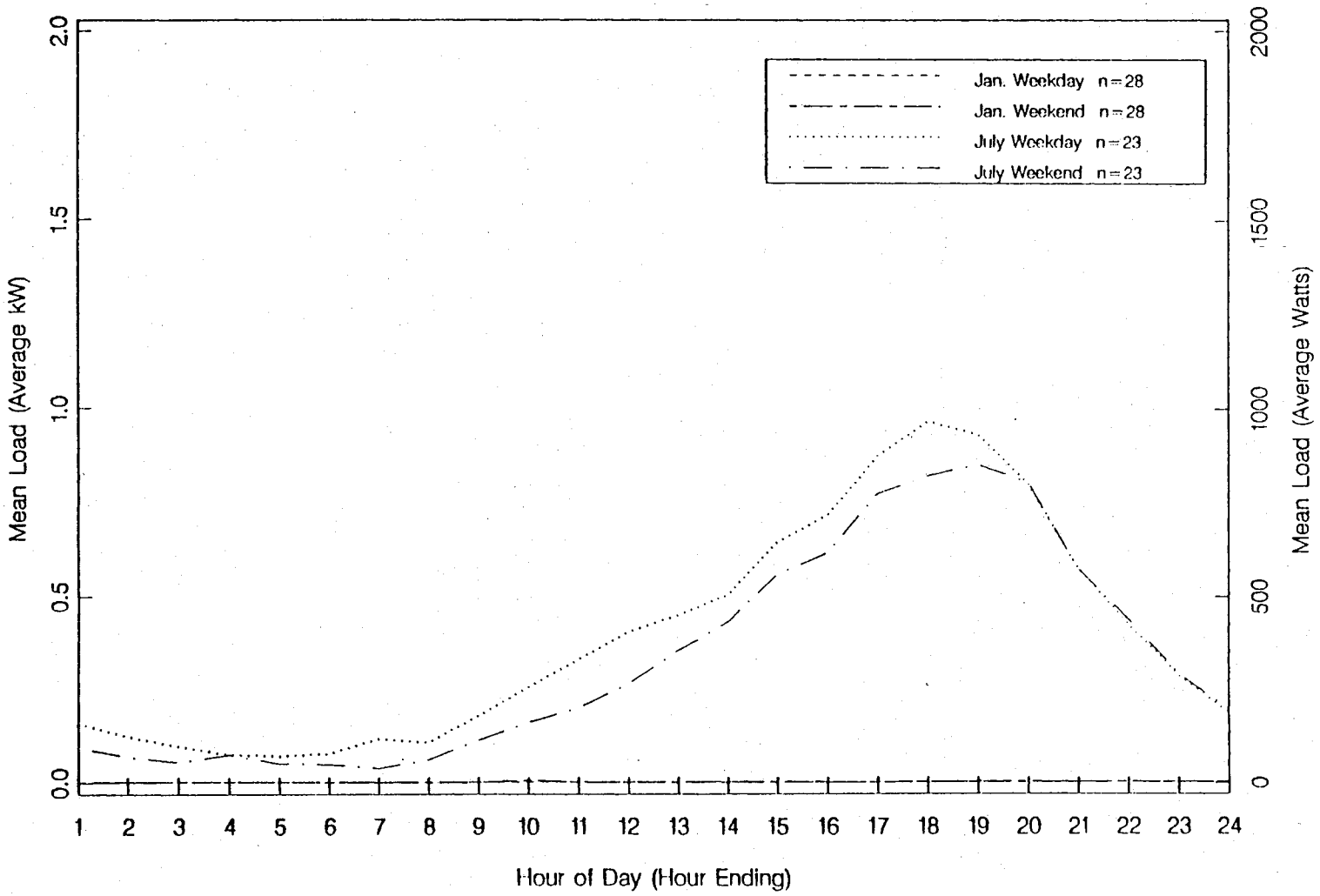
FIGURE 7E.9(f)

Cooling Monthly Load Profiles: Control

NO DATA TO PLOT

FIGURE 7E.10(a)

Cooling January and July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7E.10(b)

Cooling January and July Weekday/Weekend Load Profiles: Renter

NO DATA TO PLOT

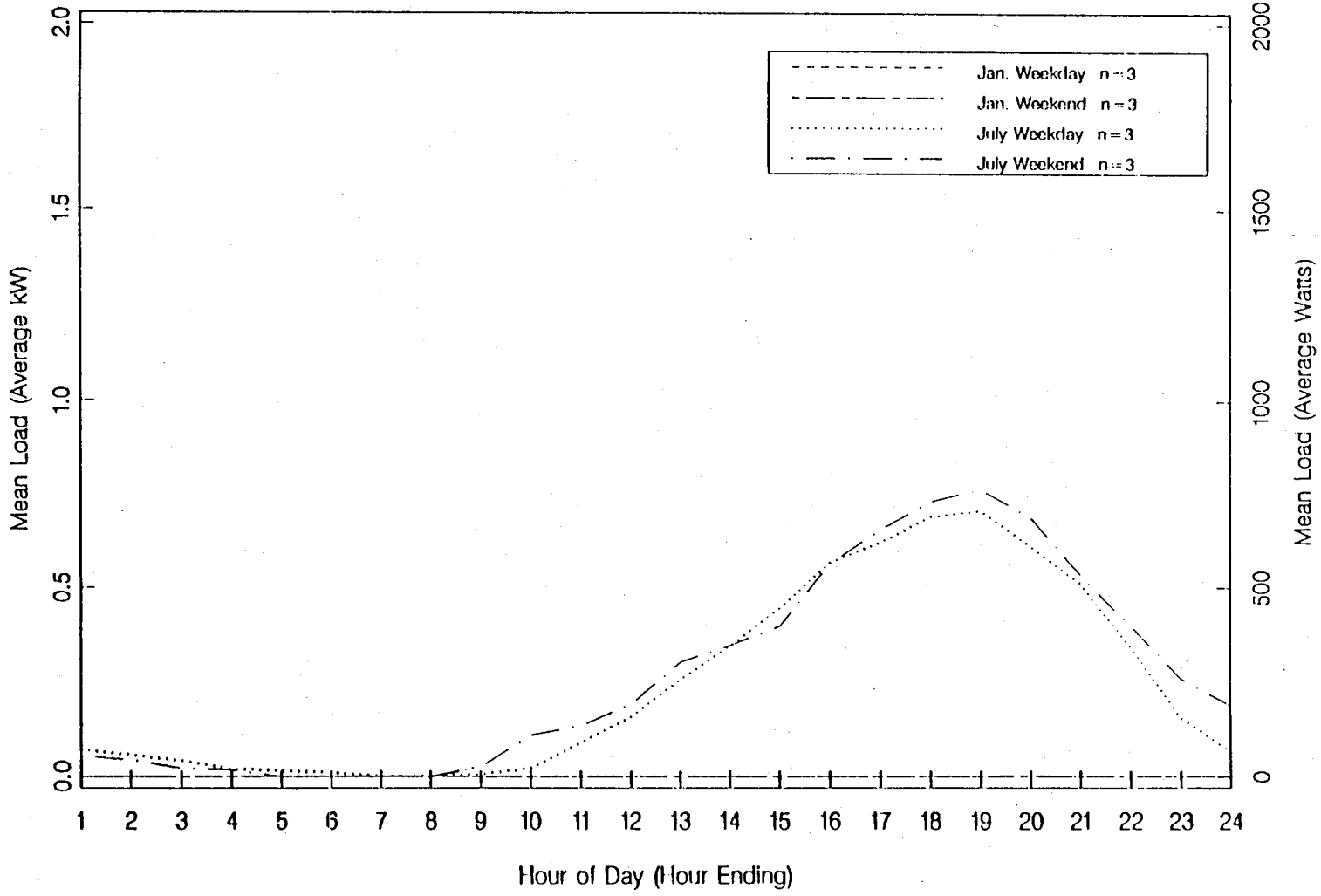
FIGURE 7E.10(c)

Cooling January and July Weekday/Weekend Load Profiles: Manufactured

NO DATA TO PLOT

FIGURE 7E.10(d)

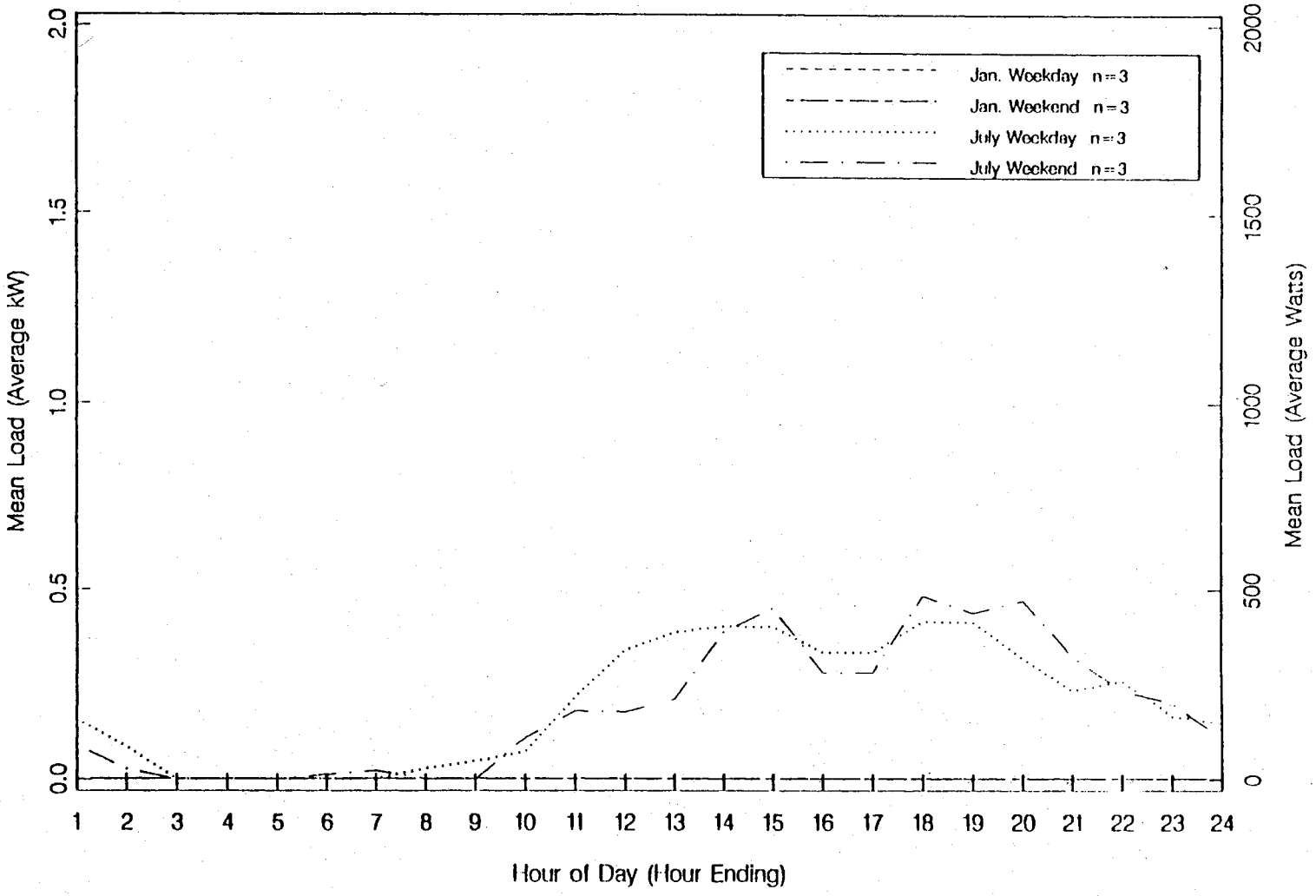
Cooling January and July Weekday/Weekend Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7E.10(e)

Cooling January and July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7E.10(f)

Cooling January and July Weekday/Weekend Load Profiles: Control

NO DATA TO PLOT

FIGURE 7E.11

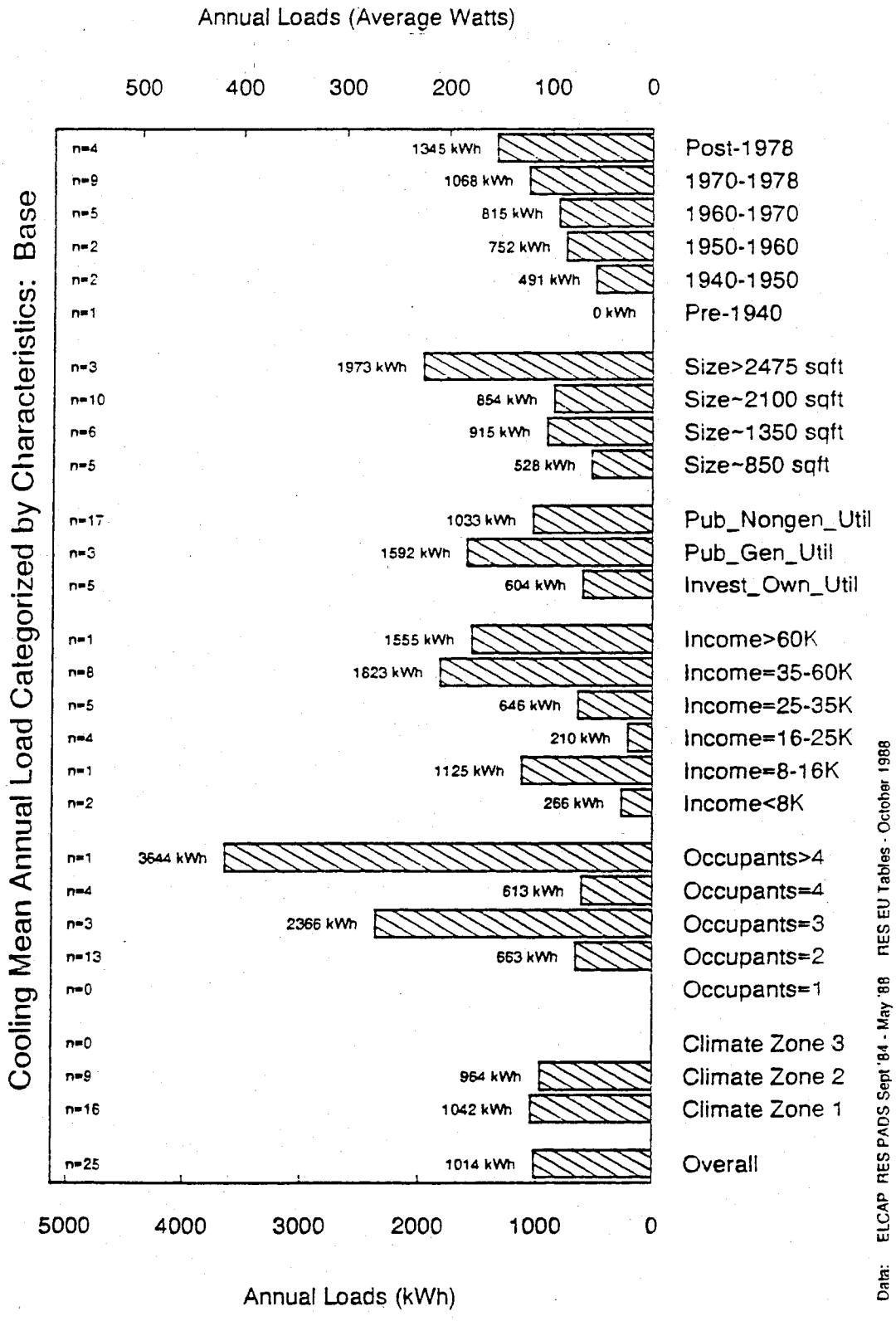
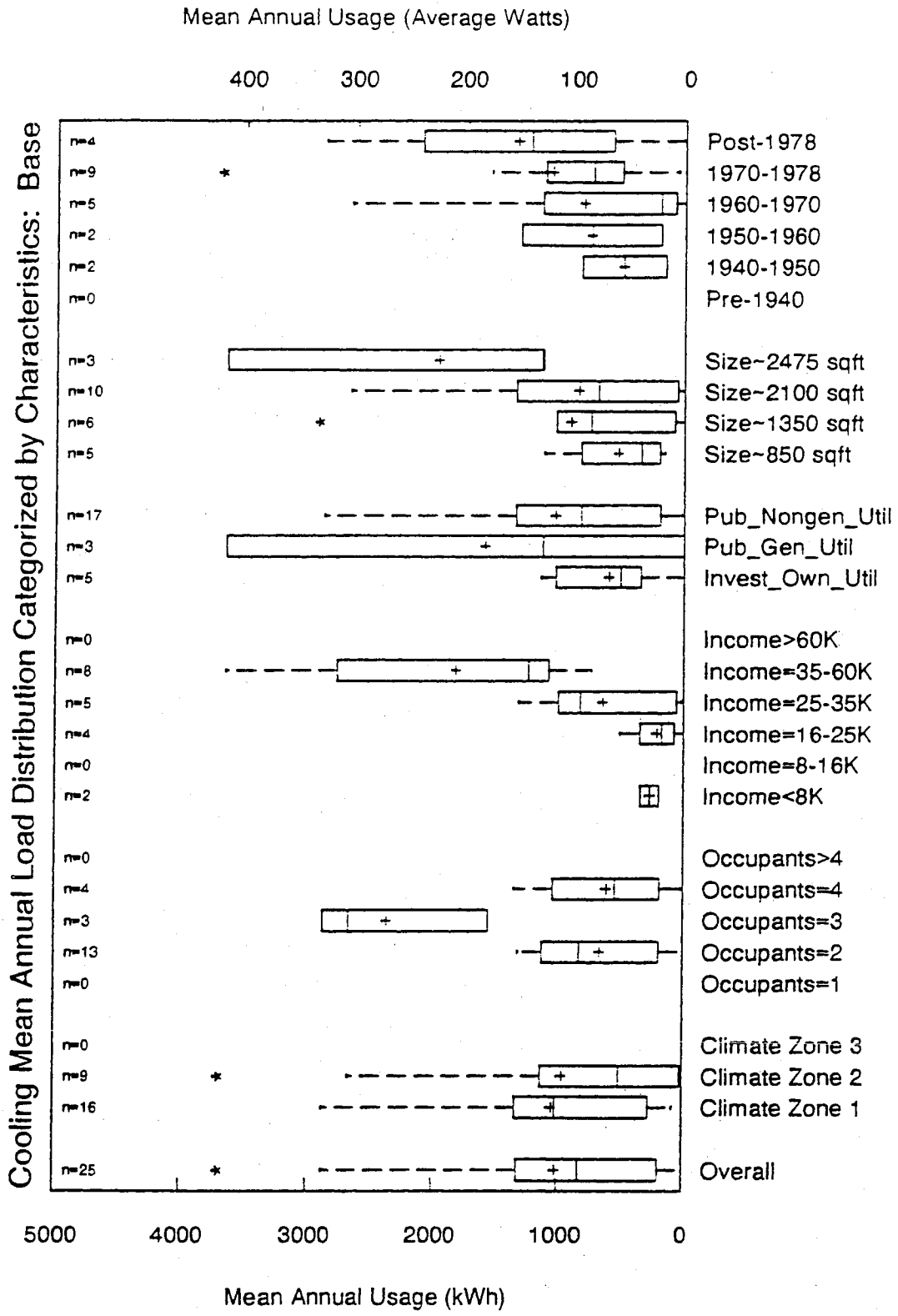

Cooling Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
500
400
300
200
100
0
n=4
1345 kWh
Post-1978
n=9
1068 kWh
1970-1978
n=5
815 kWh
1960-1970
n=2
752 kWh
1950-1960
n=2
491 kWh
1940-1950
n=1
0 kWh
Pre-1940
n=3
1973 kWh
Size>2475 sqft
n=10
854 kWh
Size~2100 sqft
n=6
915 kWh
Size~1350 sqft
n=5
528 kWh
Size~850 sqft
n=17
1033 kWh
Pub_Nongen_Util
n=3
1592 kWh
Pub_Gen_Util
n=5
604 kWh
Invest_Own_Util
n=1
1555 kWh
Income>60K
n=8
1623 kWh
Income=35-60K
n=5
646 kWh
Income=25-35K
n=4
210 kWh
Income=16-25K
n=1
1125 kWh
Income=8-16K
n=2
266 kWh
Income<8K
n=1
3644 kWh
Occupants>4
n=4
613 kWh
Occupants=4
n=3
2366 kWh
Occupants=3
n=13
663 kWh
Occupants=2
n=0
Occupants=1
n=0
Climate Zone 3
n=9
964 kWh
Climate Zone 2
n=16
1042 kWh
Climate Zone 1
n=25
1014 kWh
Overall
5000
4000
3000
2000
1000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7E.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7E.1

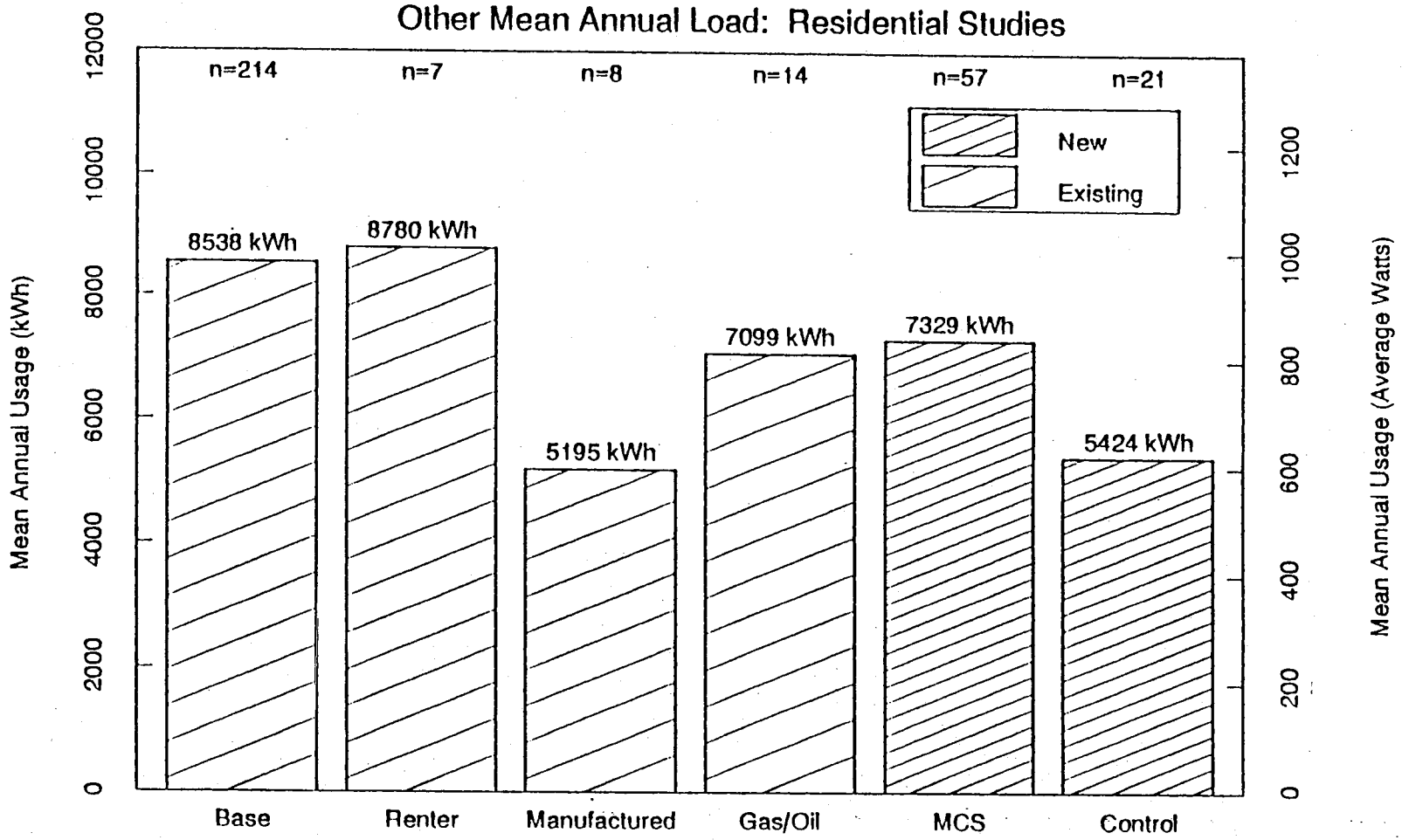
Cooling Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base and MCS

	Base			MCS			Base + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	25	1014	1013	3	580	503	28	968	974
Climate Zone 1	16	1042	840	1	889	0	17	1033	815
Climate Zone 2	9	964	1322	2	426	603	11	868	1217
Climate Zone 3	0	-	-	0	-	-	0	-	-
Occupants=1	0	-	-	1	852	0	1	852	0
Occupants=2	13	663	499	2	445	629	15	634	497
Occupants=3	3	2366	710	0	-	-	3	2366	710
Occupants=4	4	613	571	0	-	-	4	613	571
Occupants>4	1	3644	0	0	-	-	1	3644	0
Income<8K	2	266	108	0	-	-	2	266	108
Income=8-16K	1	1125	0	1	0	0	2	563	796
Income=16-25K	4	210	212	0	-	-	4	210	212
Income=25-35K	5	648	580	1	852	0	6	680	525
Income=35-60K	8	1823	1076	1	889	0	9	1719	1053
Income>60K	1	1555	0	0	-	-	1	1555	0
Invest_Own_Util	5	604	478	2	426	603	7	553	470
Pub_Gen_Util	3	1592	1865	0	-	-	3	1592	1865
Pub_Nongen_Util	17	1033	965	1	889	0	18	1025	937
Size~850 sqft	5	528	430	1	0	0	6	440	441
Size~1350 sqft	6	915	1056	2	871	28	8	904	893
Size~2100 sqft	10	854	868	0	-	-	10	854	868
Size>2475 sqft	3	1973	1447	0	-	-	3	1973	1447
Pre-1940	1	0	0	0	-	-	1	0	0
1940-1950	2	491	483	0	-	-	2	491	483
1950-1960	2	752	796	0	-	-	2	752	796
1960-1970	5	815	1133	0	-	-	5	815	1133
1970-1978	9	1068	1062	0	-	-	9	1068	1062
Post-1978	4	1345	1174	3	580	503	7	1017	970

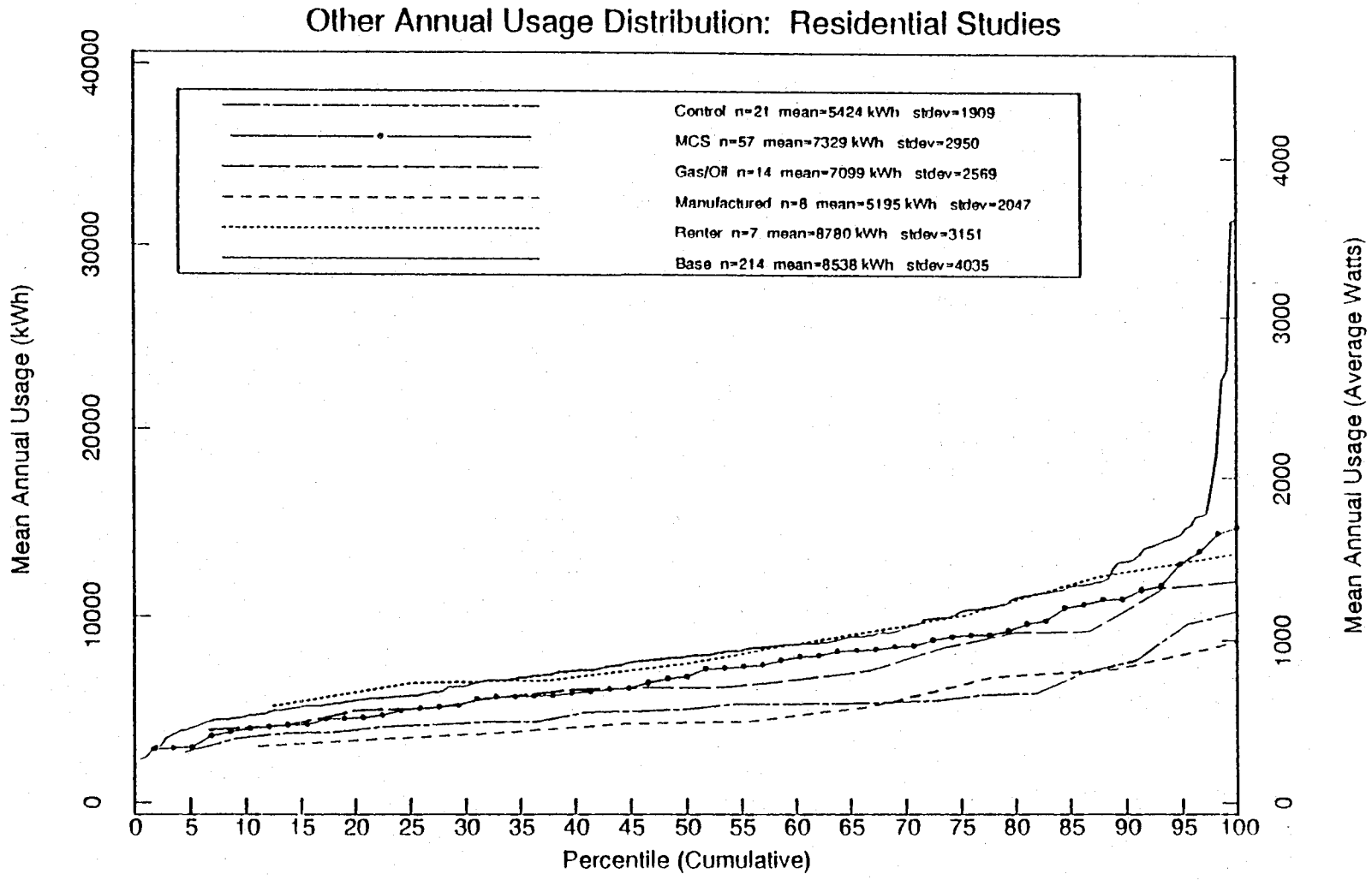
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7F.1



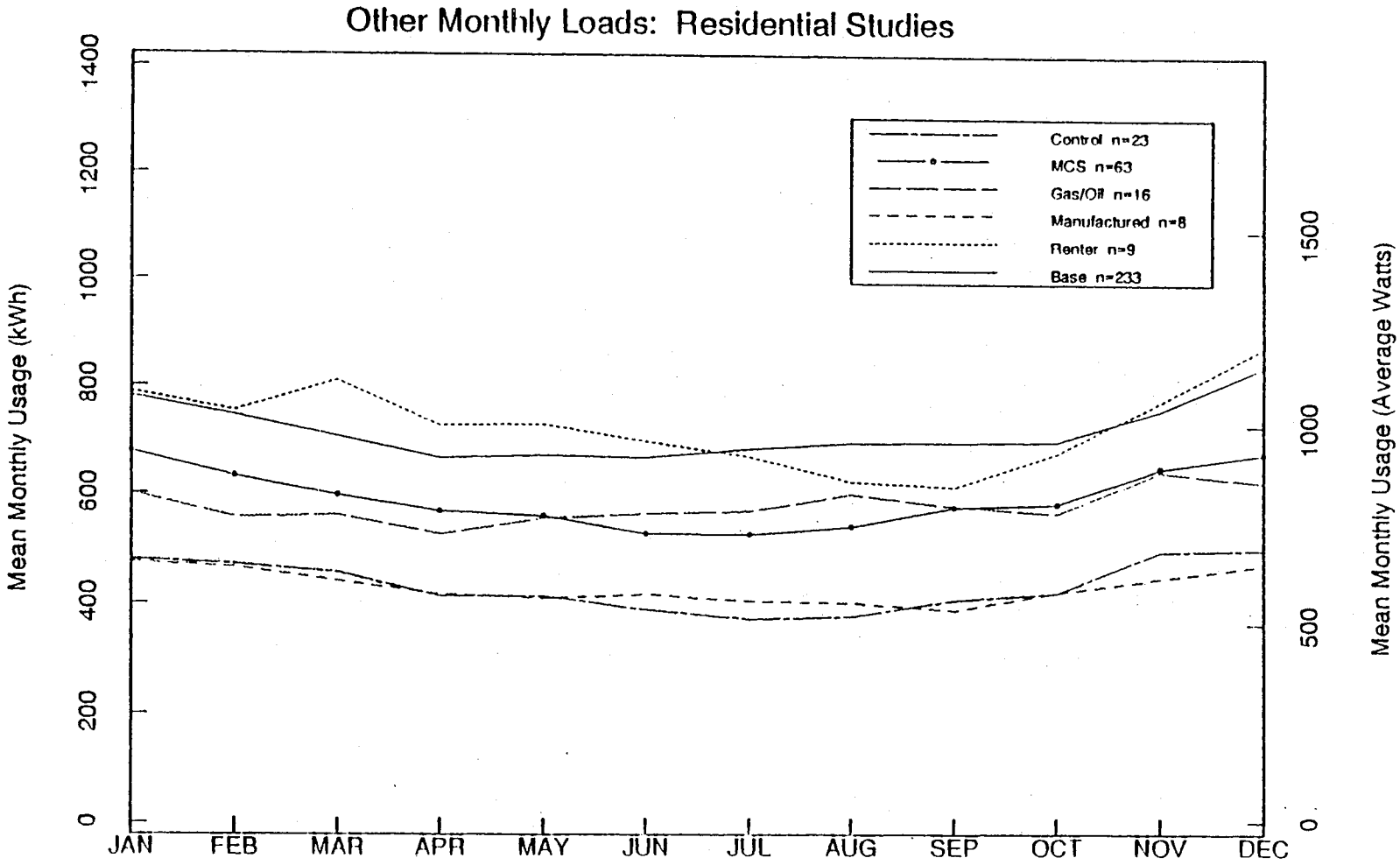
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.2



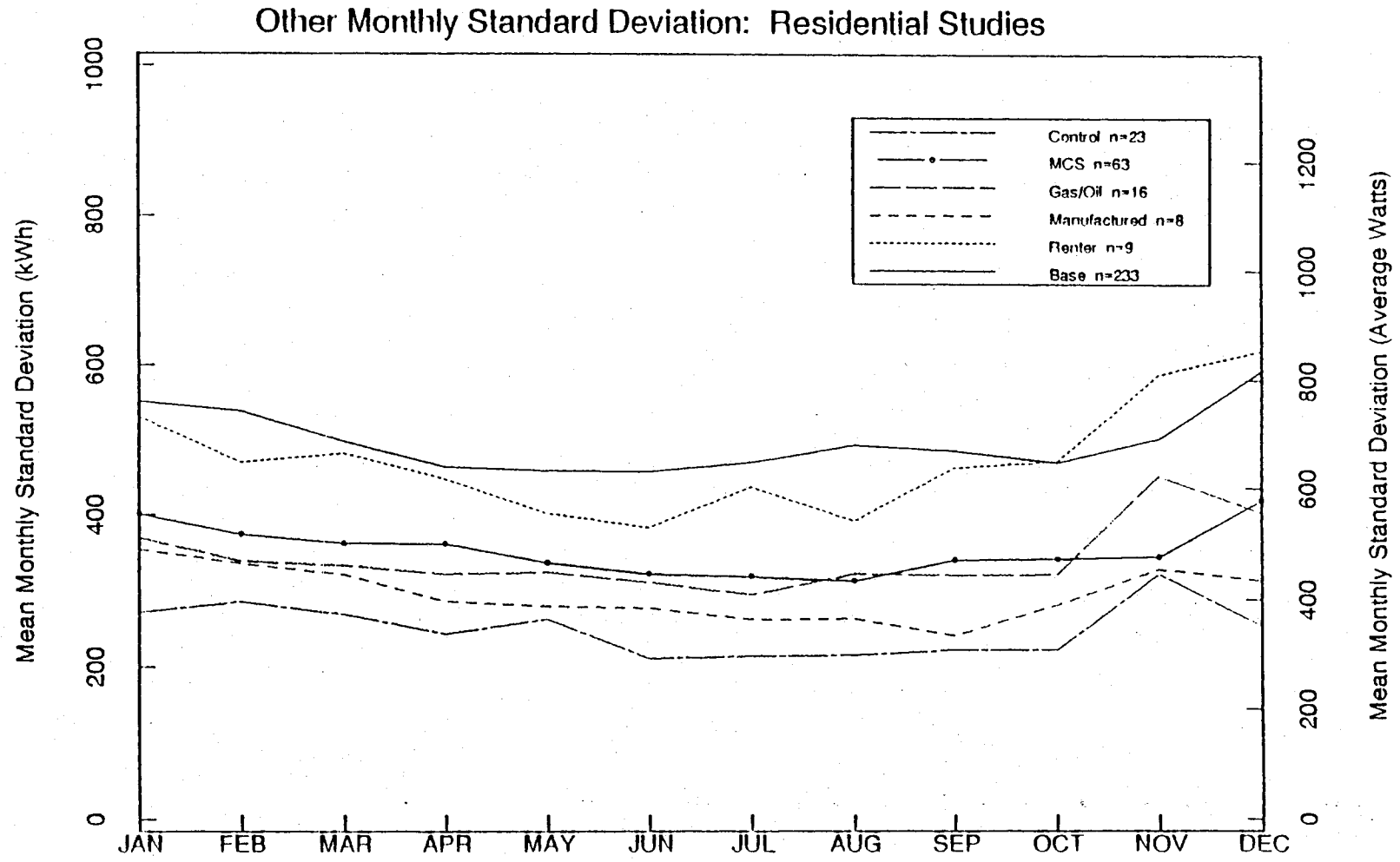
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.3



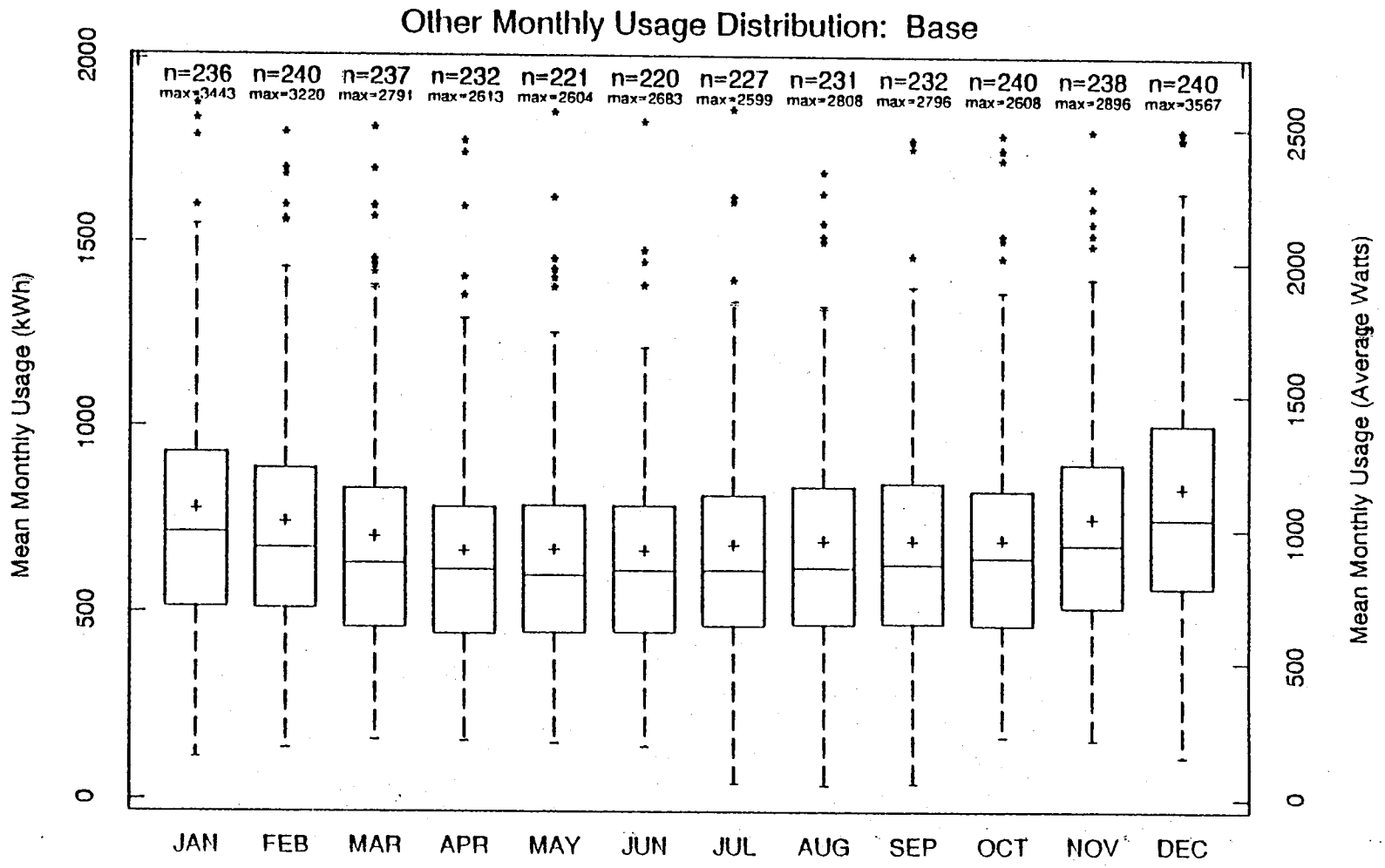
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.4



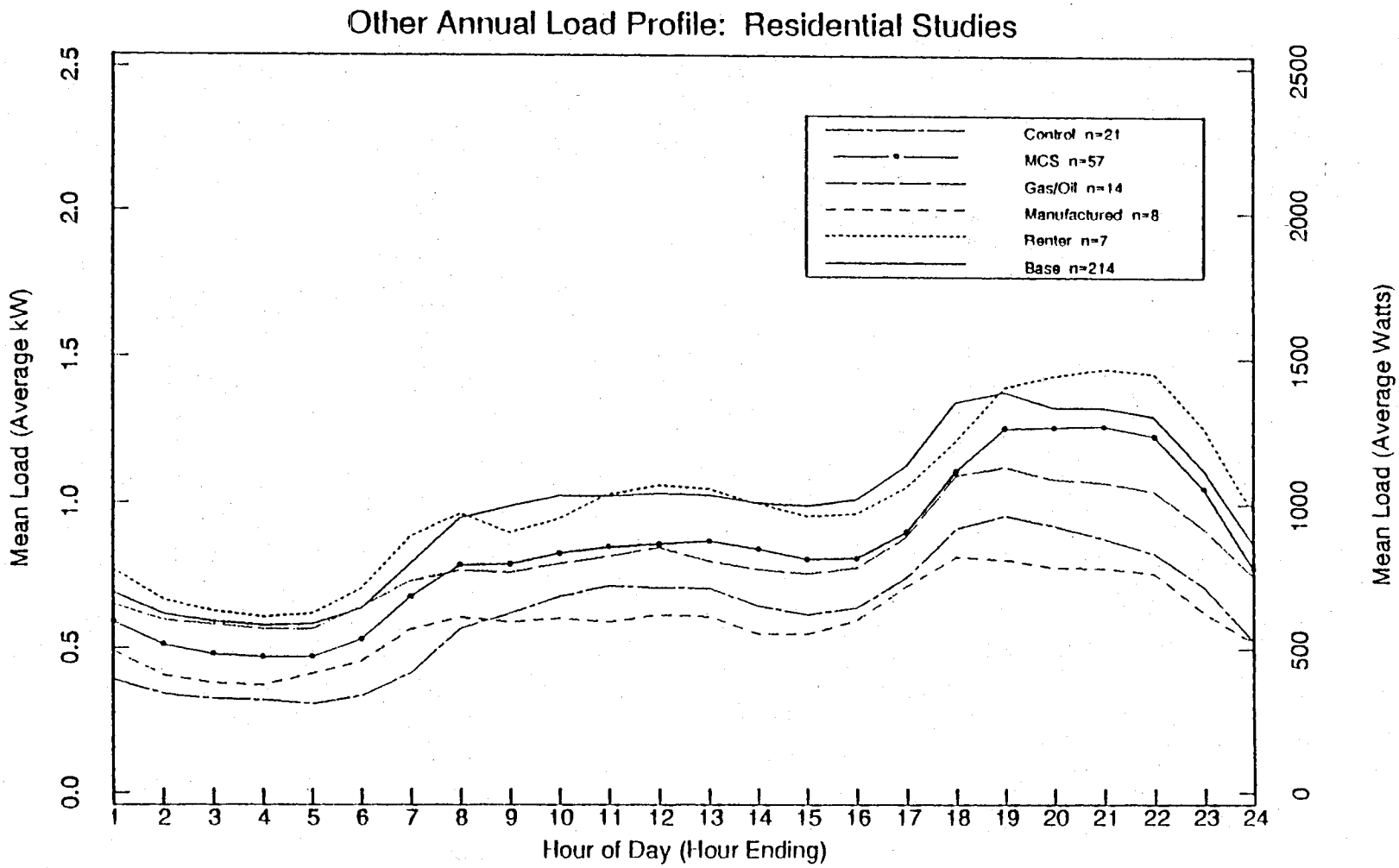
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

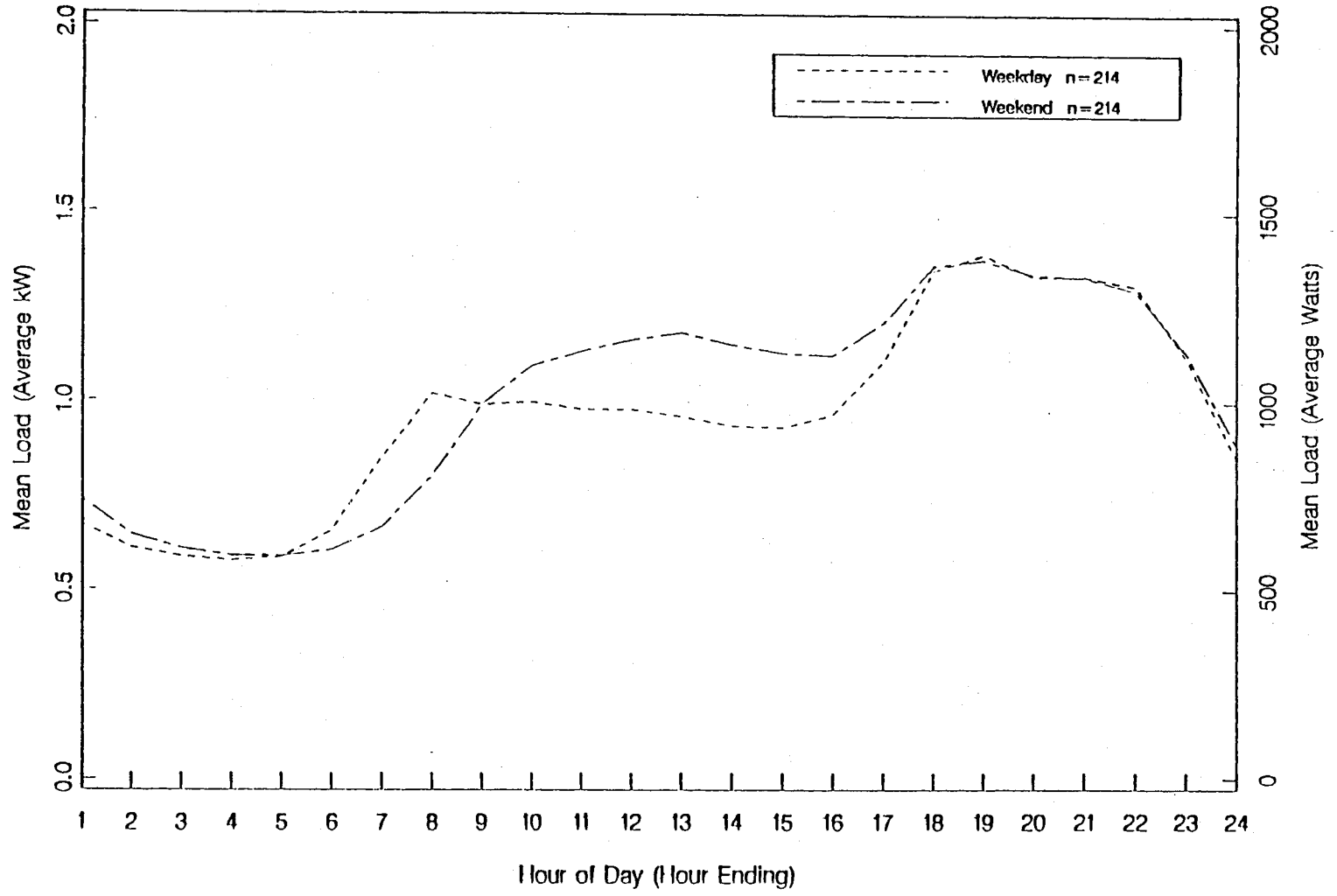
FIGURE 7F.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

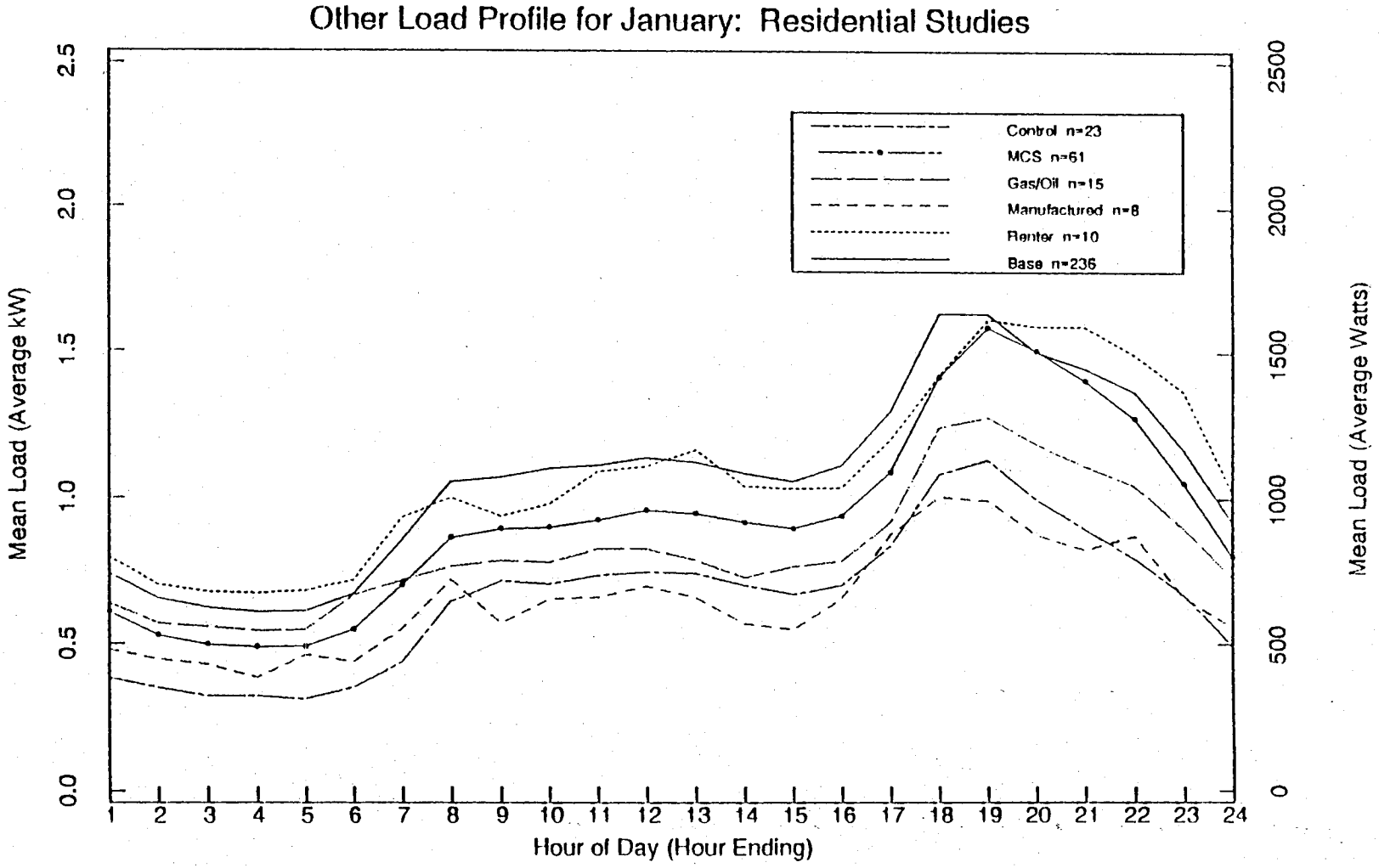
FIGURE 7F.7

Other Annual Weekday/Weekend Load Profiles: Base



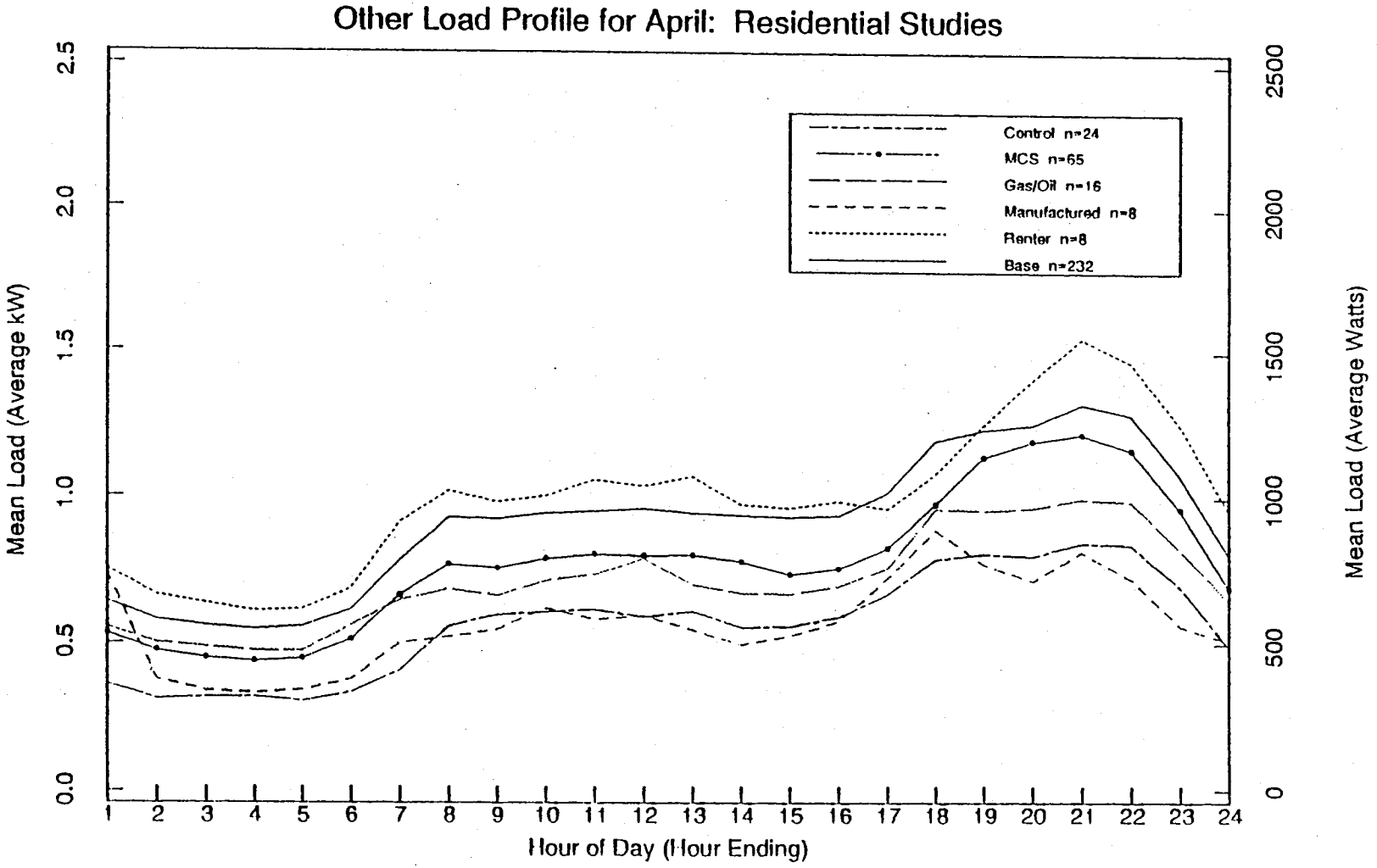
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.8(a)



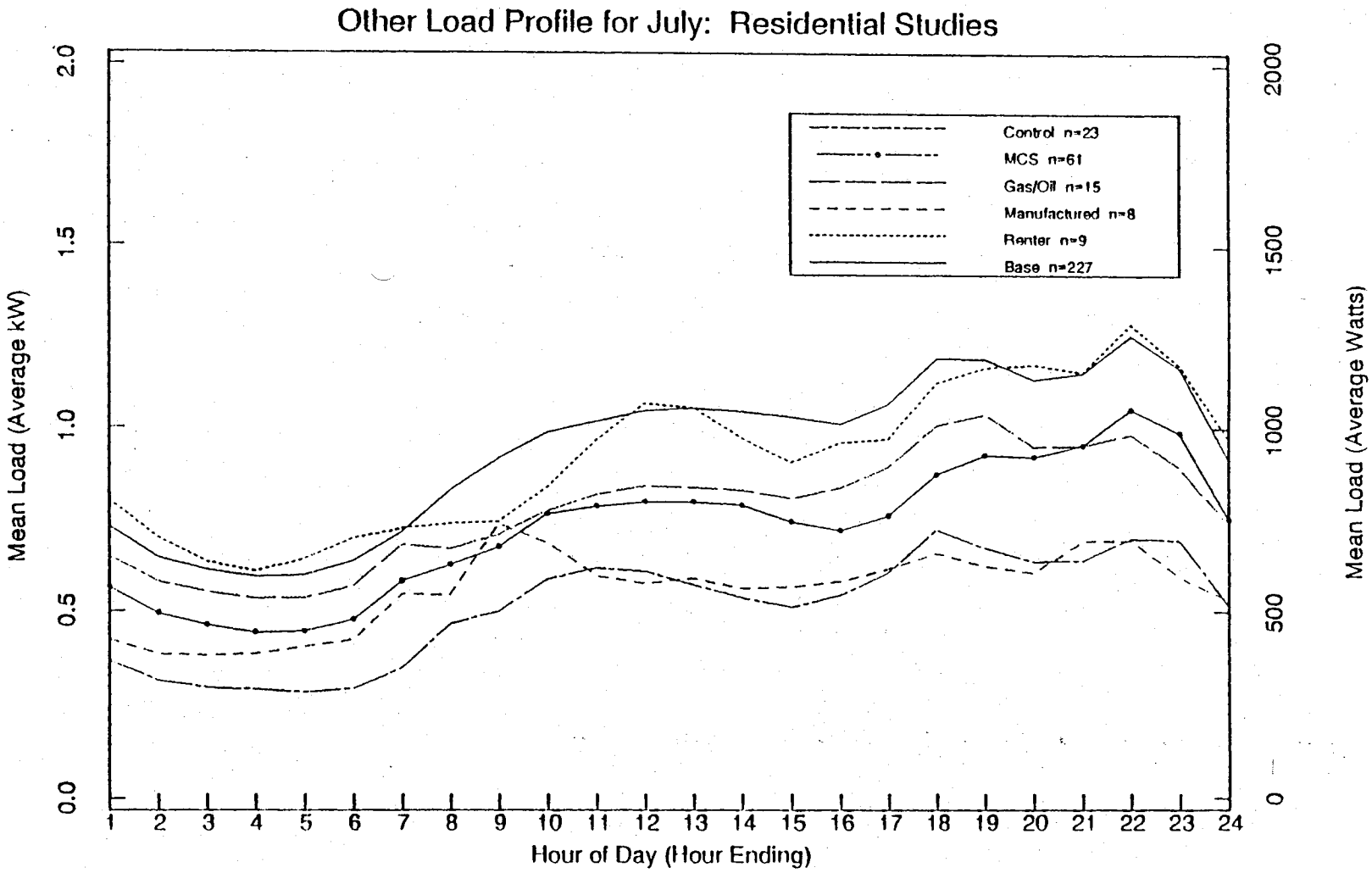
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.8(b)



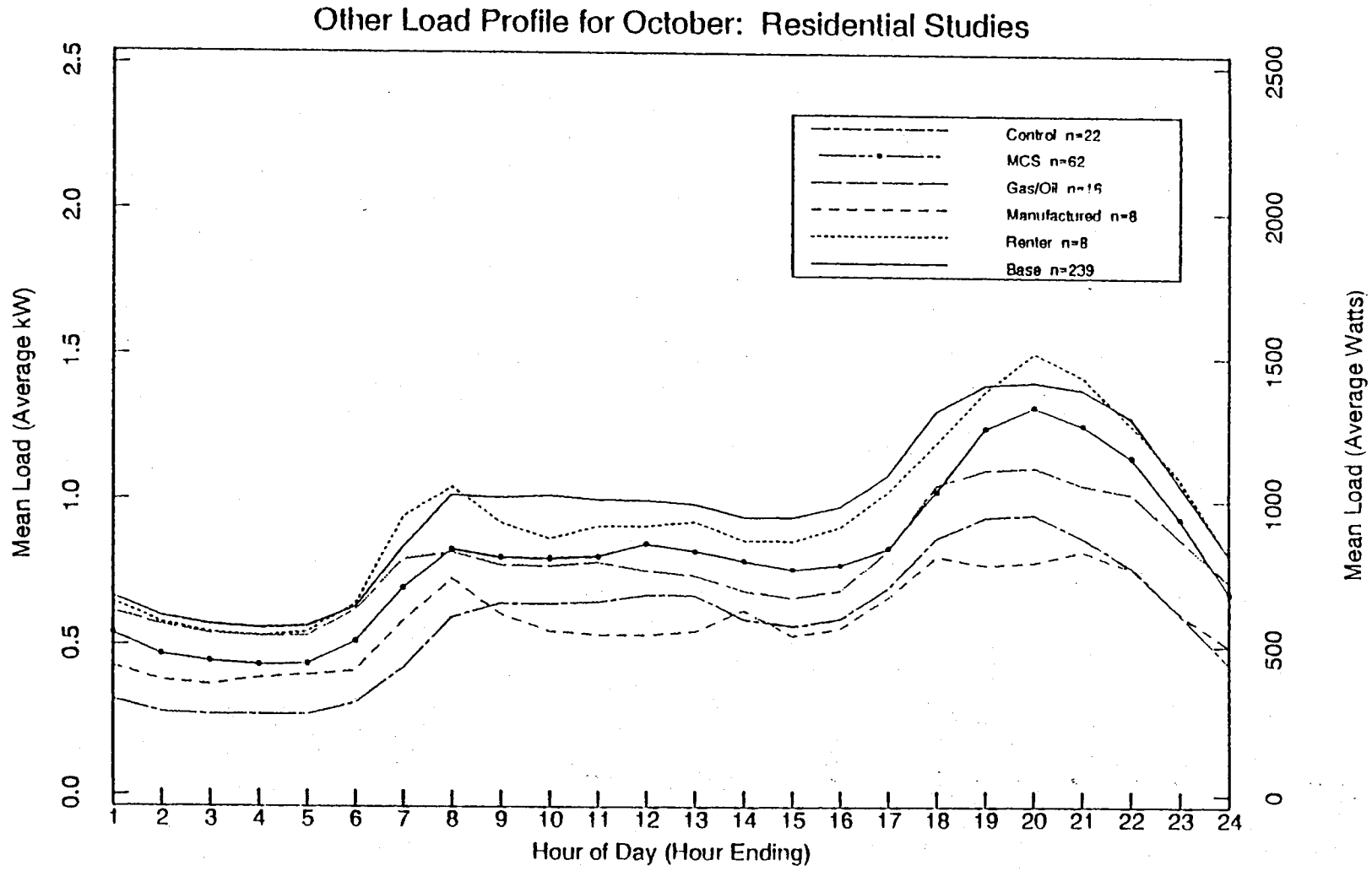
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.8(c)



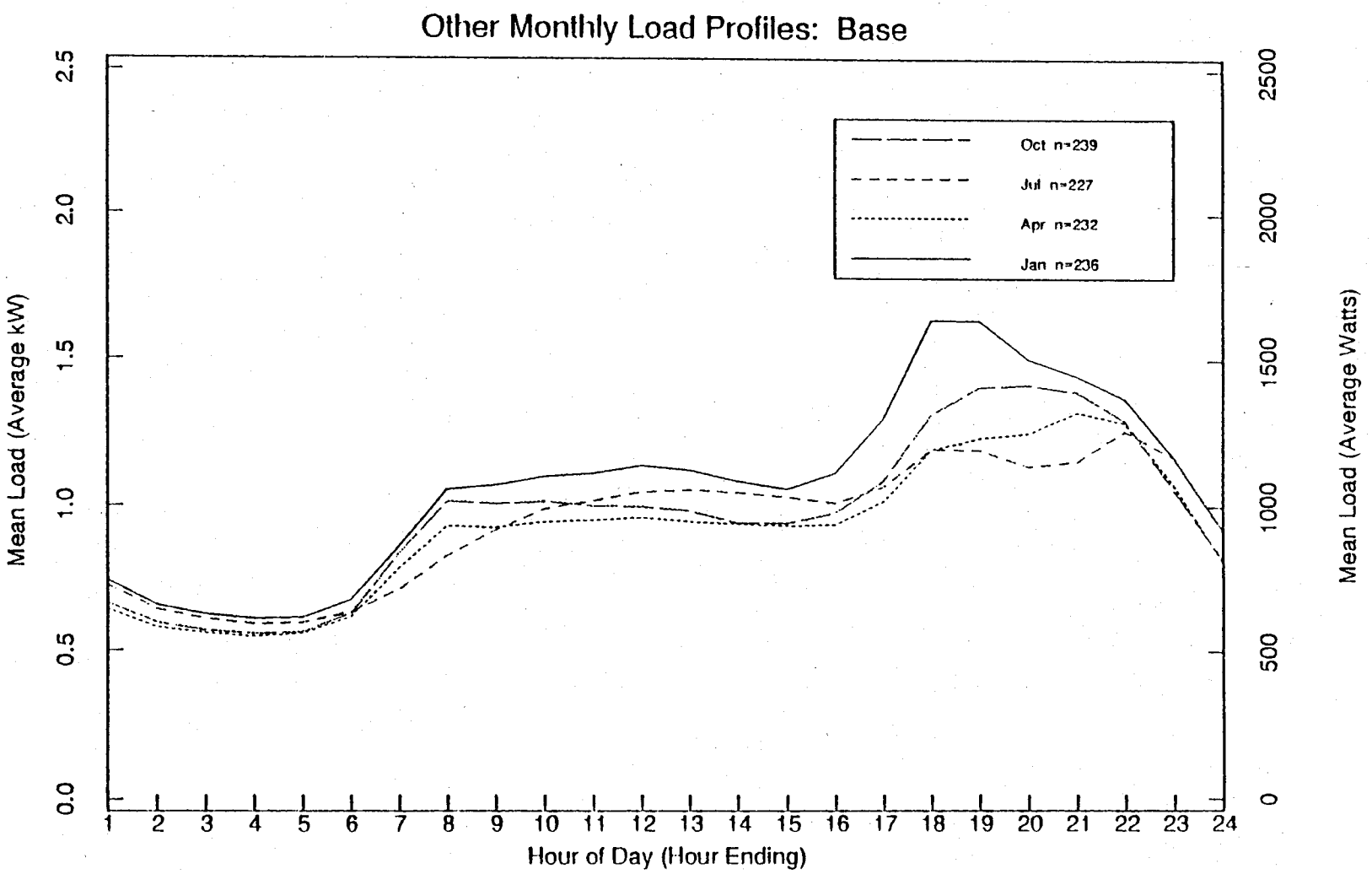
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.8(d)



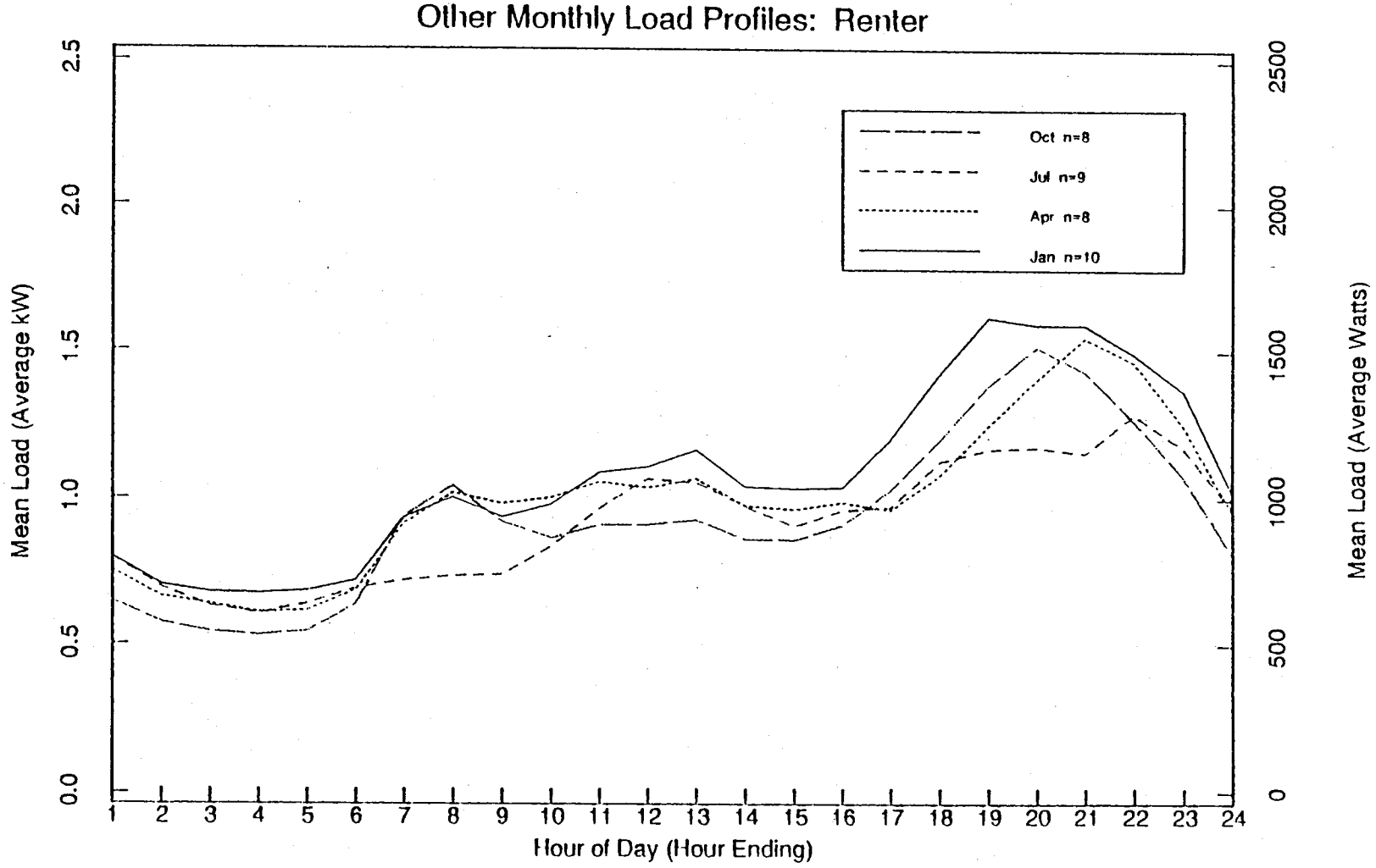
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.9(a)



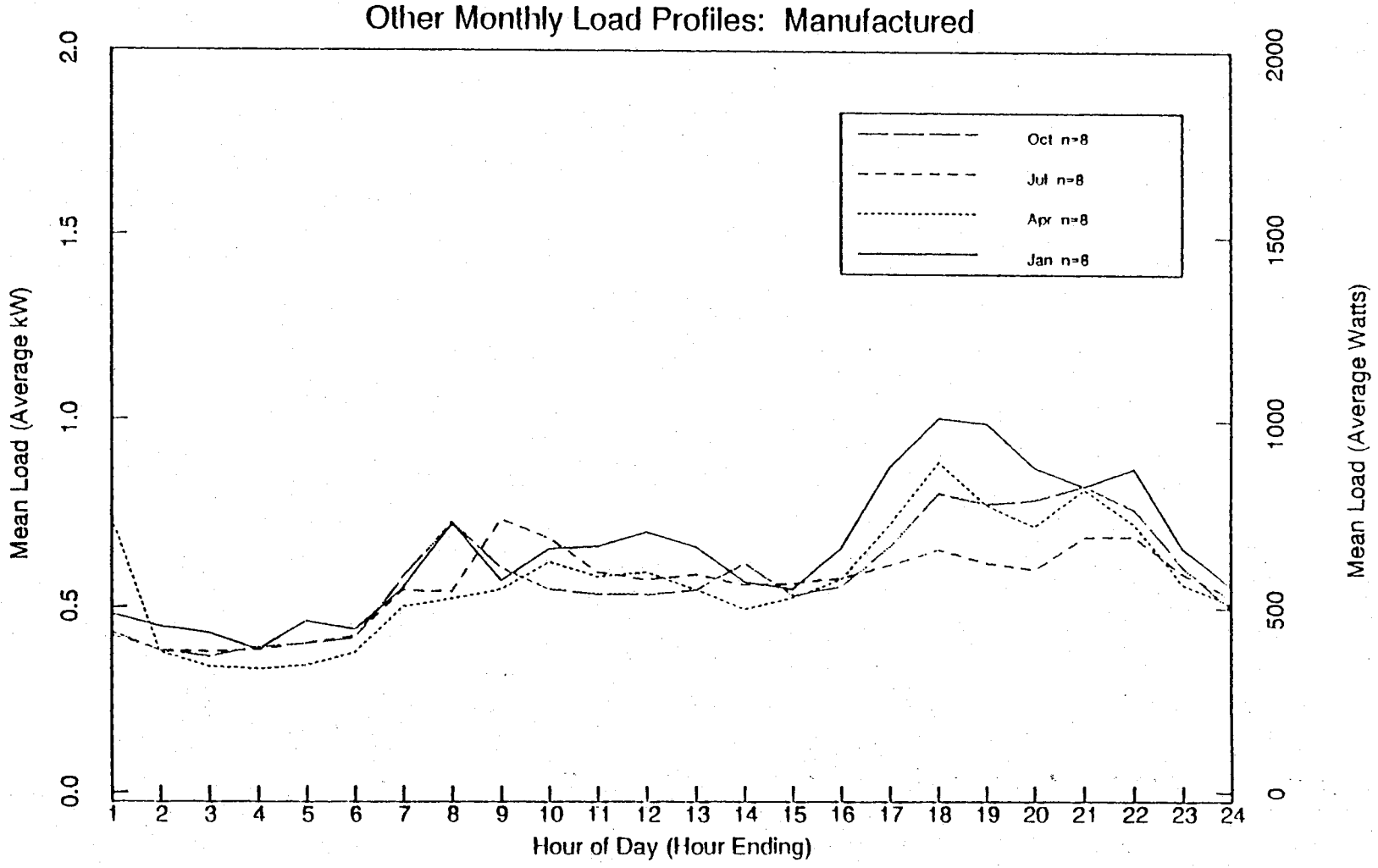
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.9(b)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

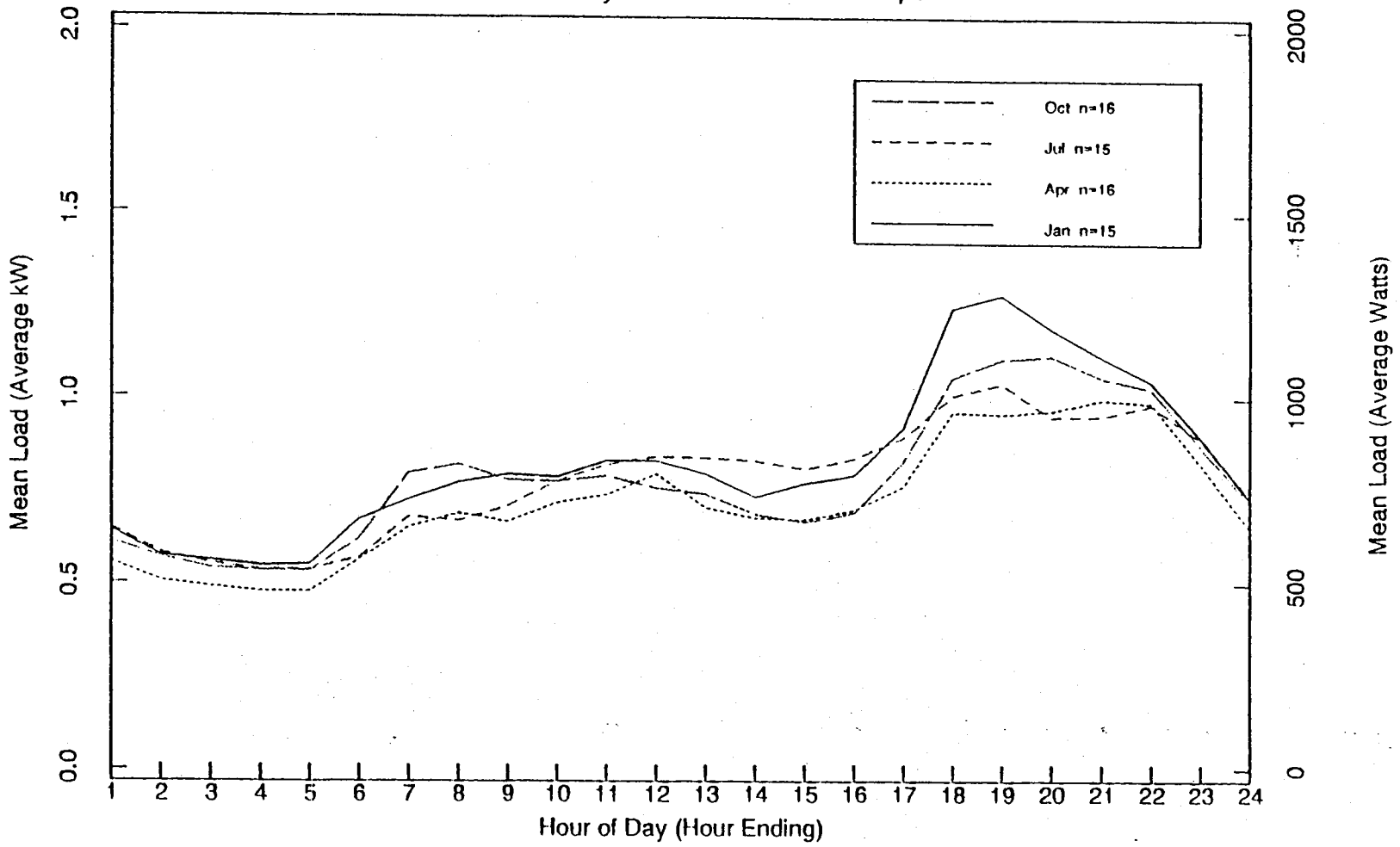
FIGURE 7F.9(c)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

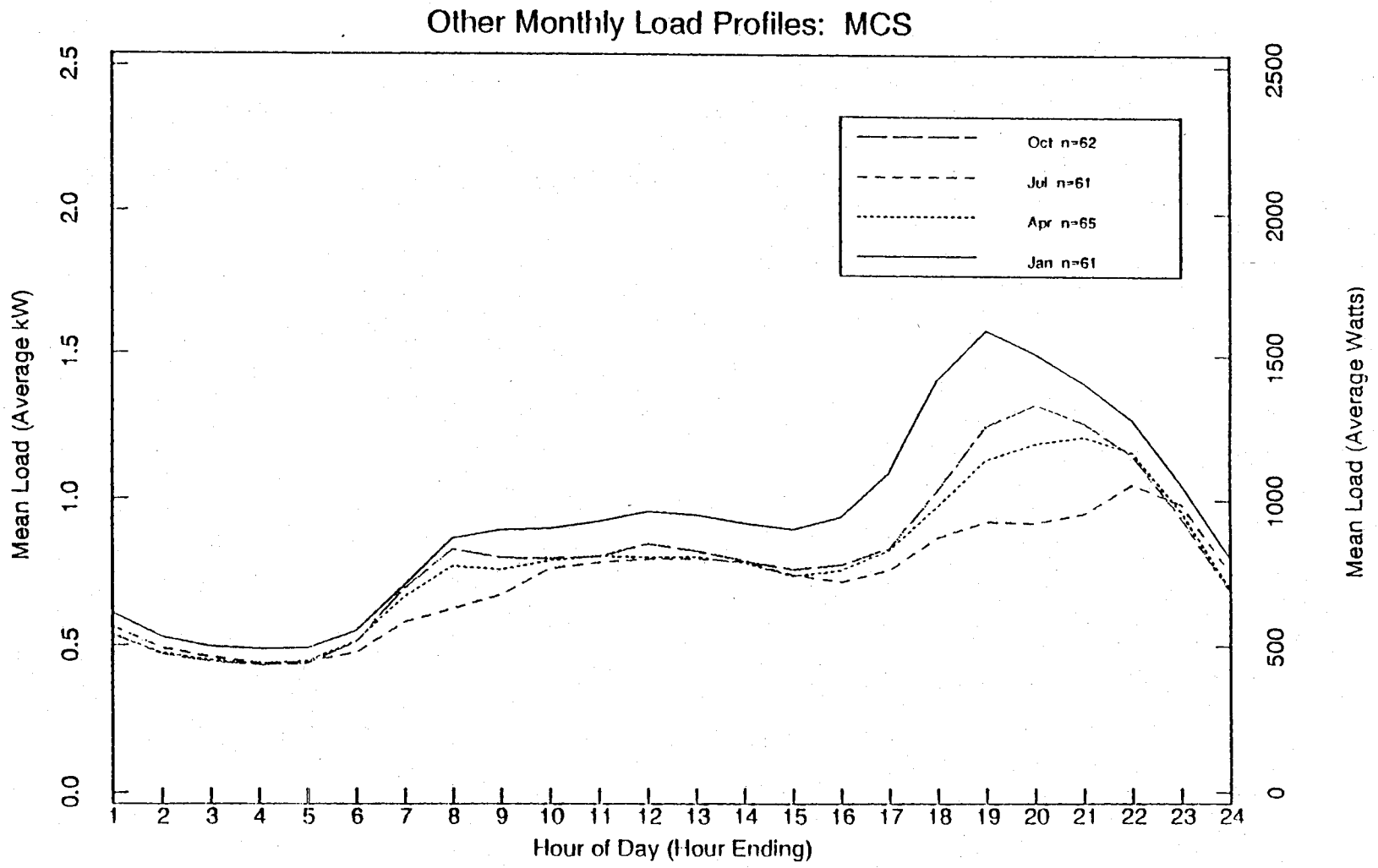
FIGURE 7F.9(d)

Other Monthly Load Profiles: Gas/Oil



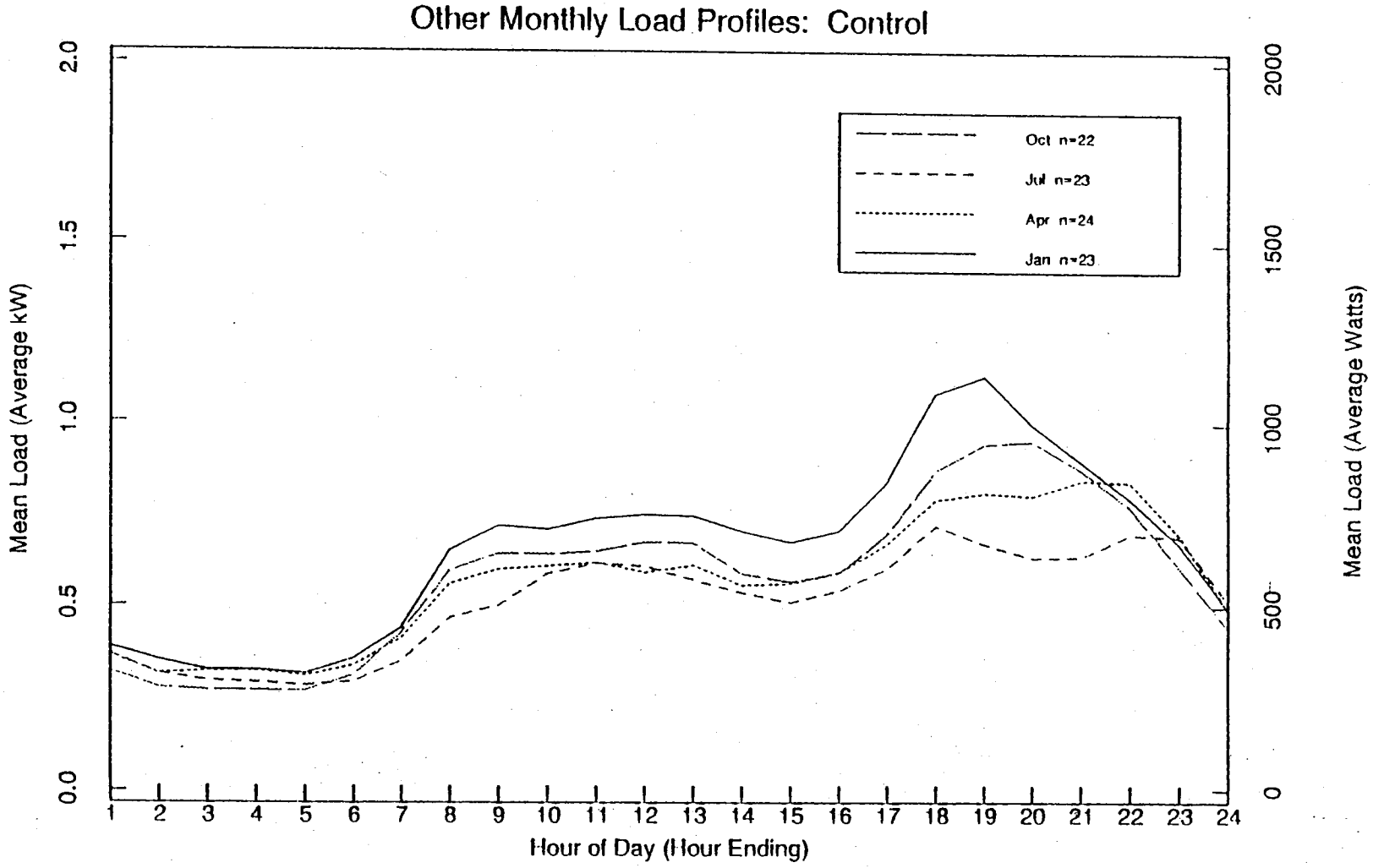
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

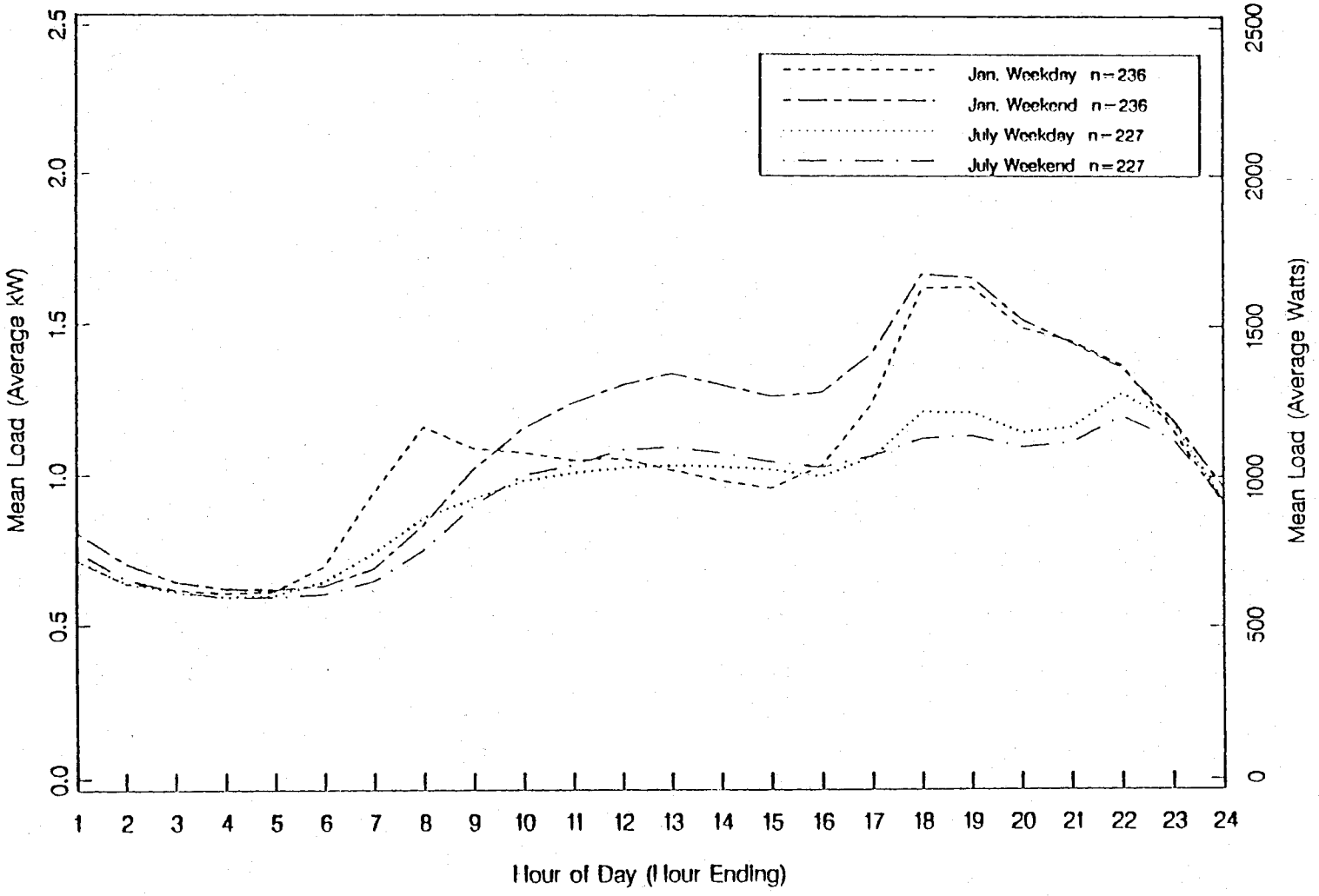
FIGURE 7F.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7F.10(a)

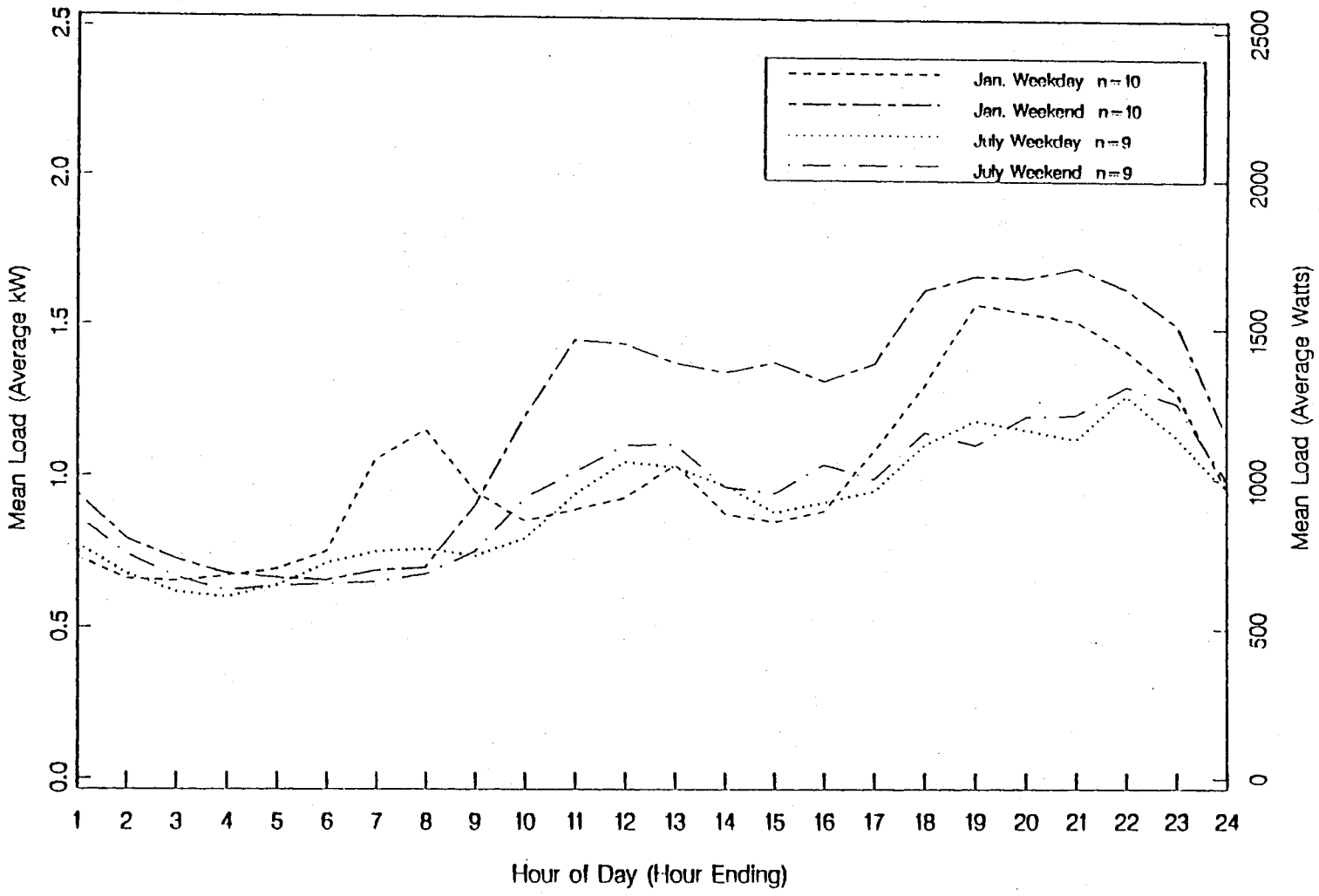
Other January/July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.10(b)

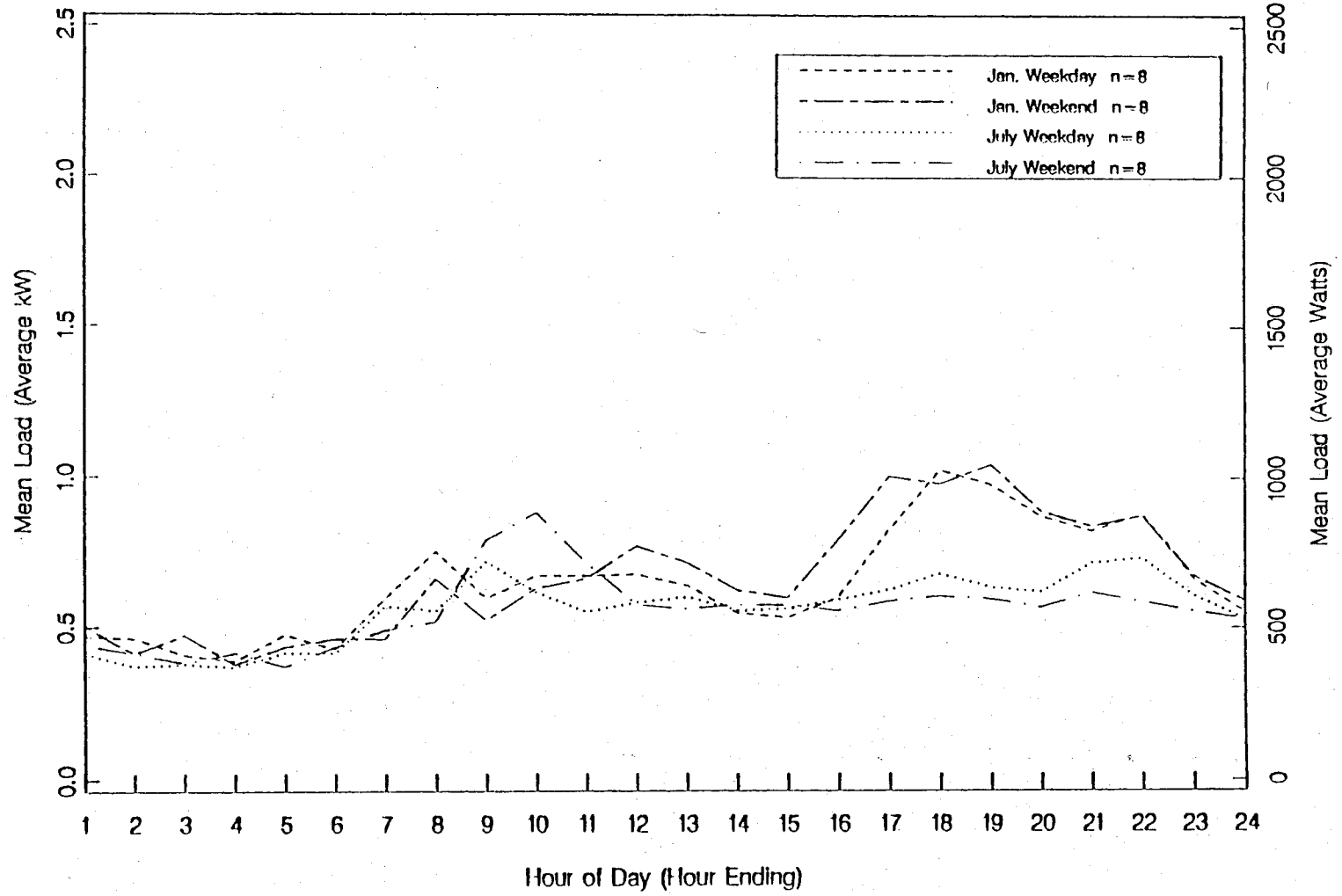
Other January/July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.10(c)

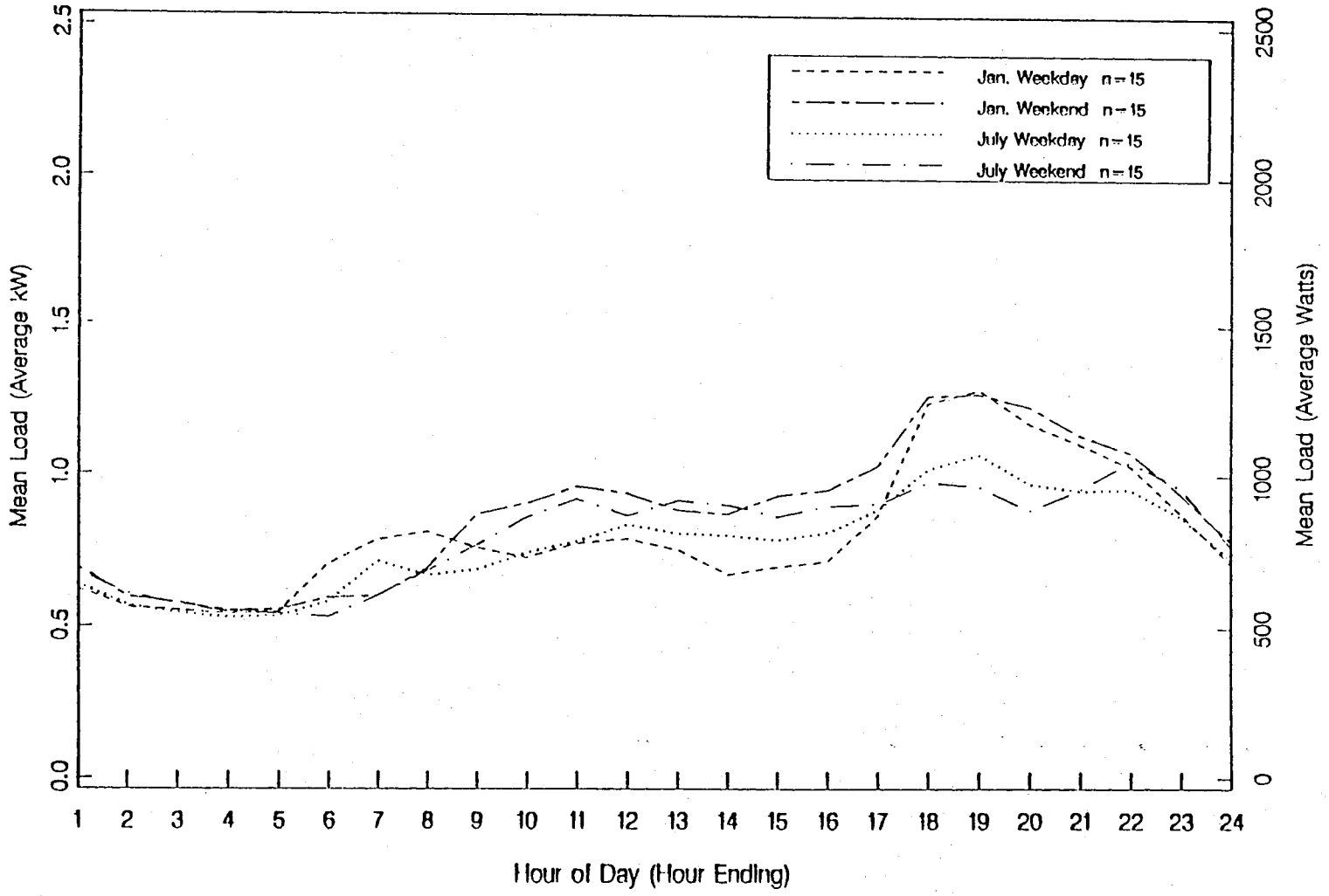
Other January/July Weekday/Weekend Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.10(d)

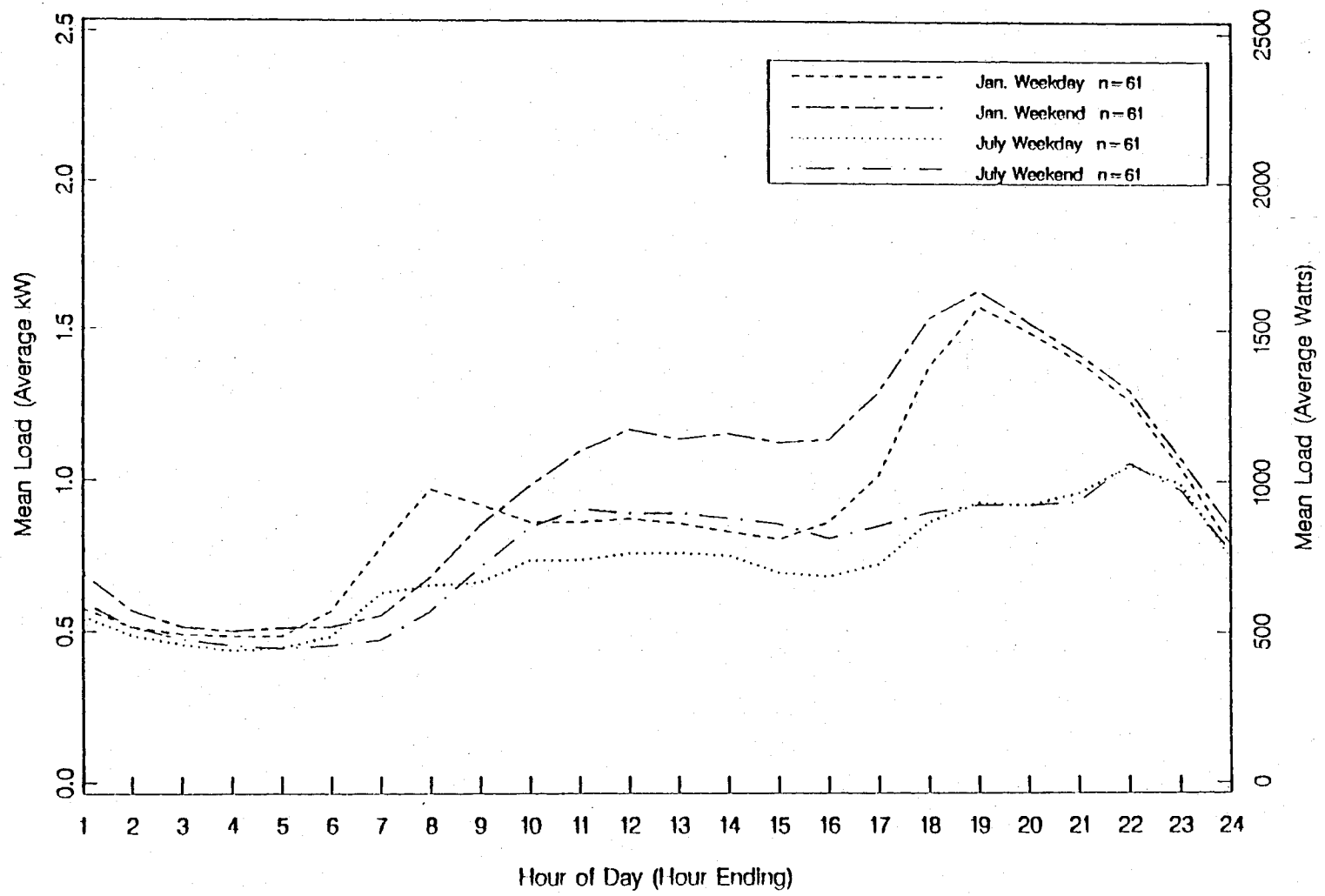
Other January/July Weekday/Weekend Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.10(e)

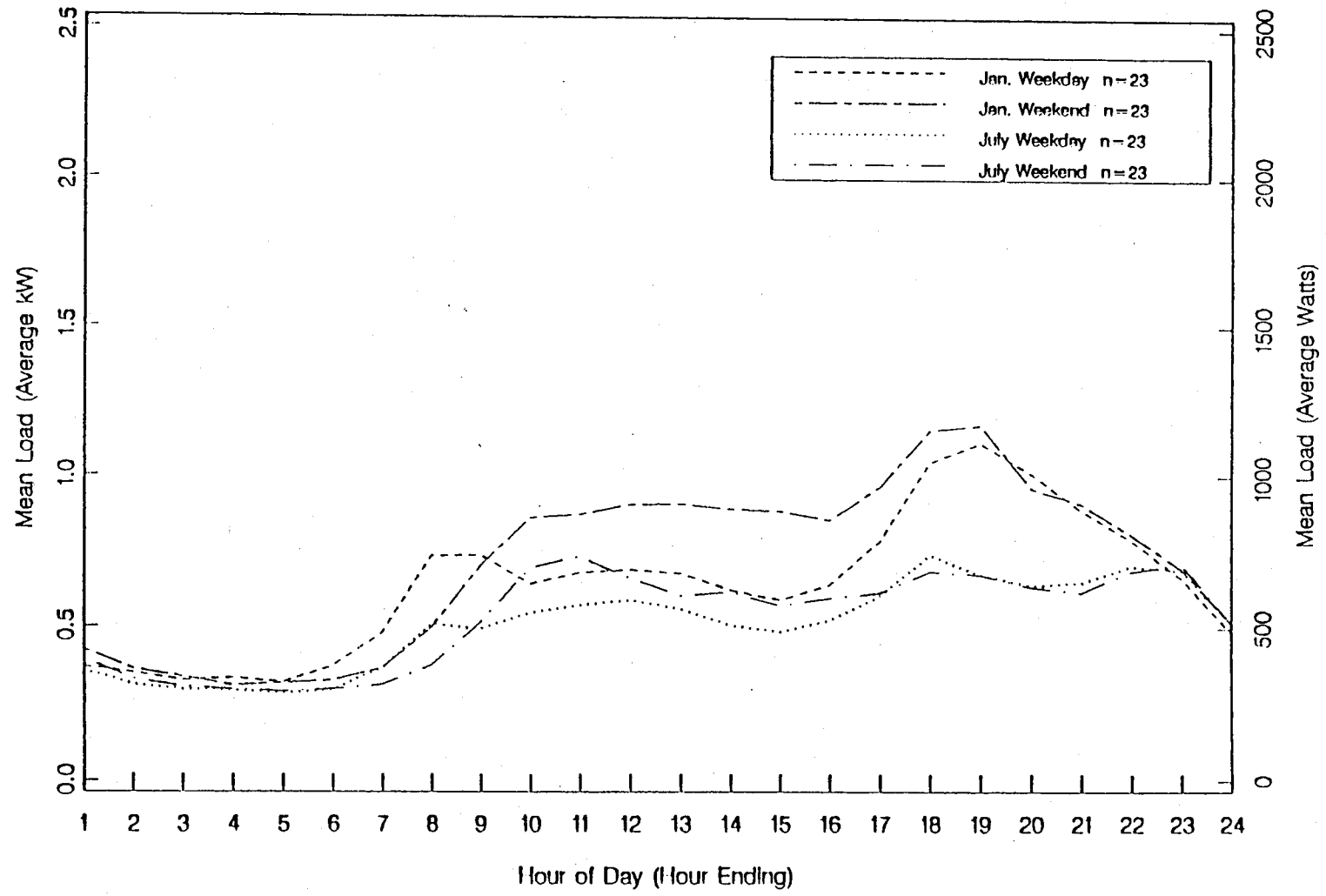
Other January/July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7F.10(f)

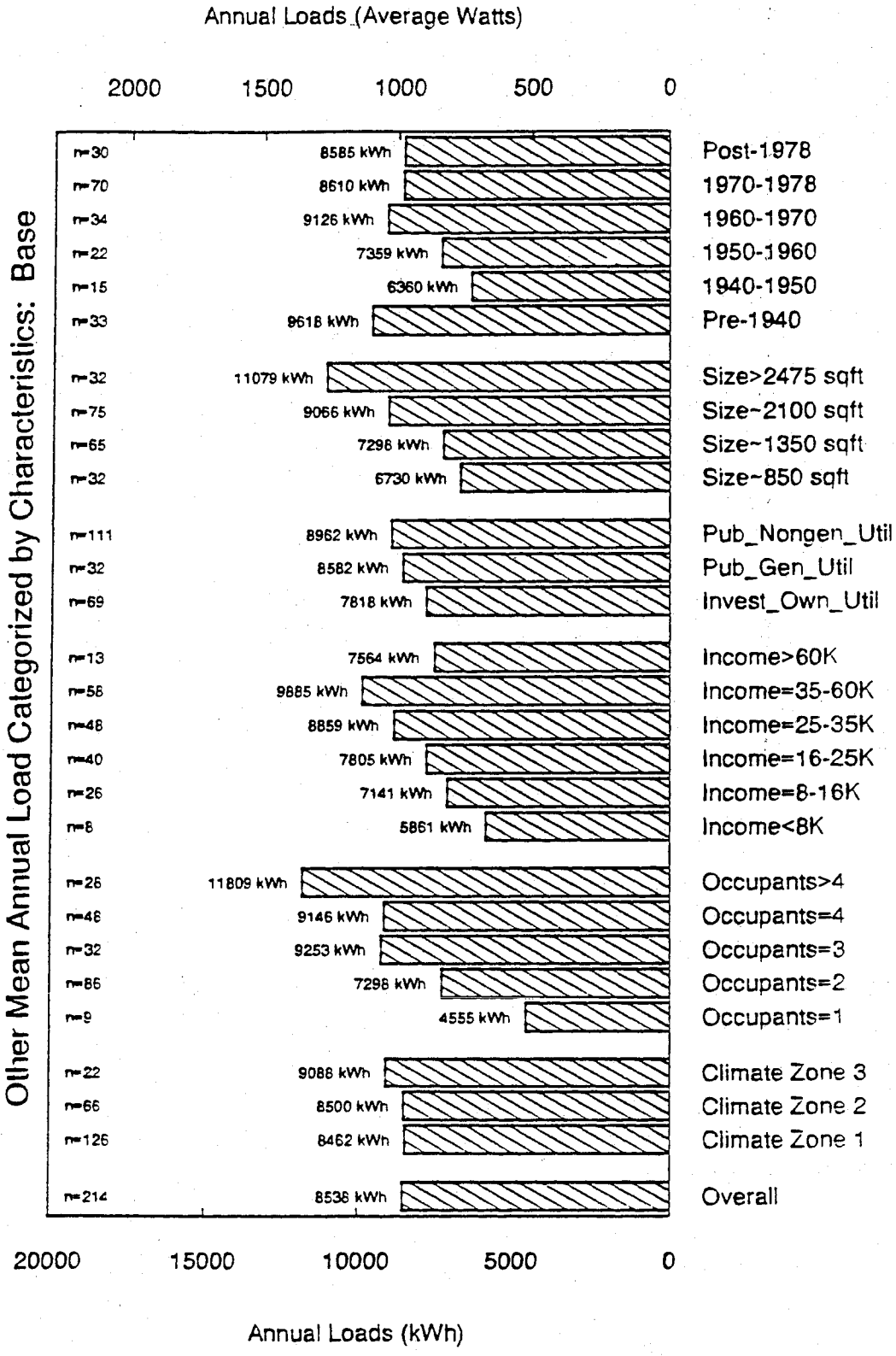
Other January/July Weekday/Weekend Load Profiles: Control



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

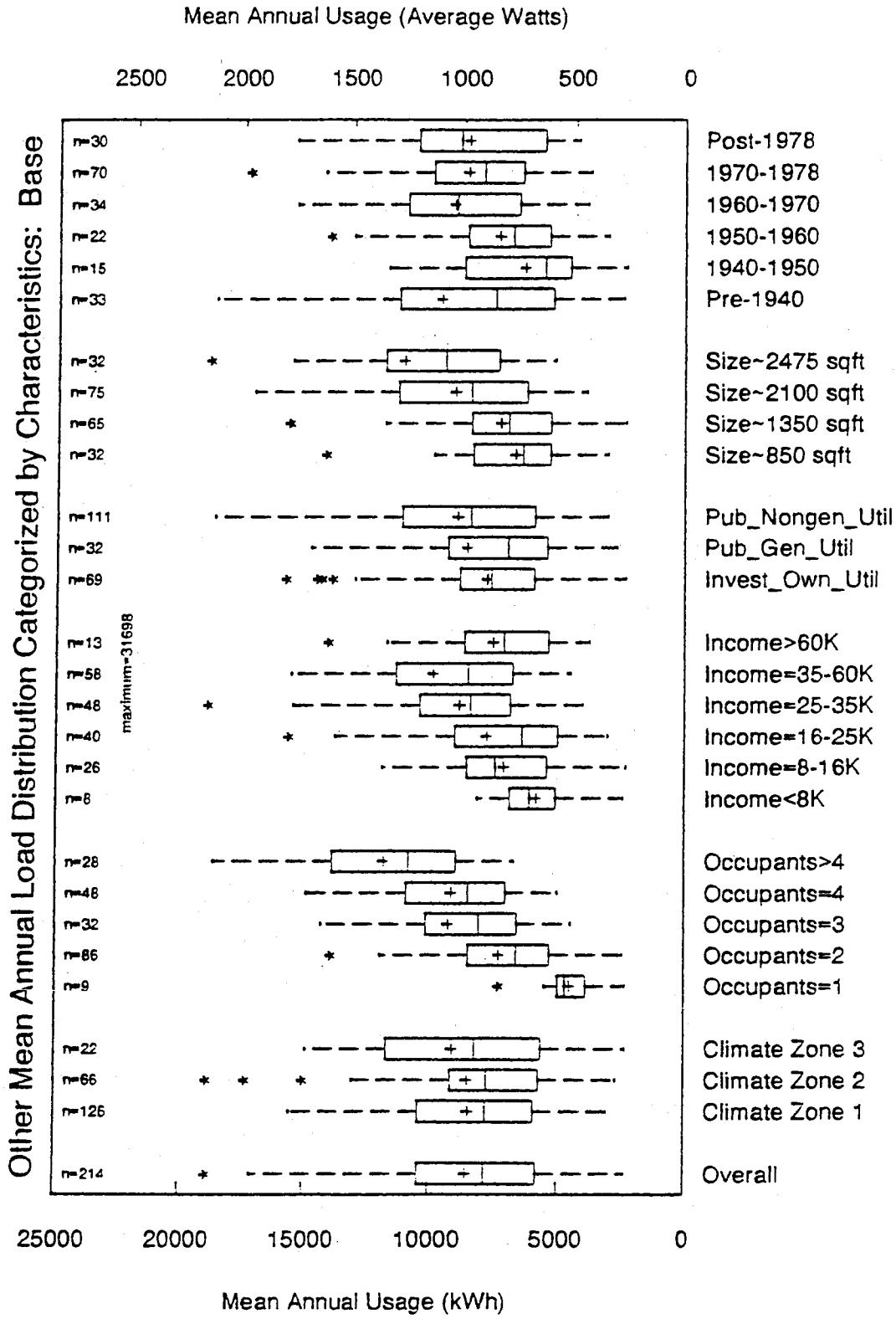
FIGURE 7F.11

Other Mean Annual Load Categorized by Characteristics: Base



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7F.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7F.1

Other Mean Annual End-Use Loads and Standard Deviations (kWh)

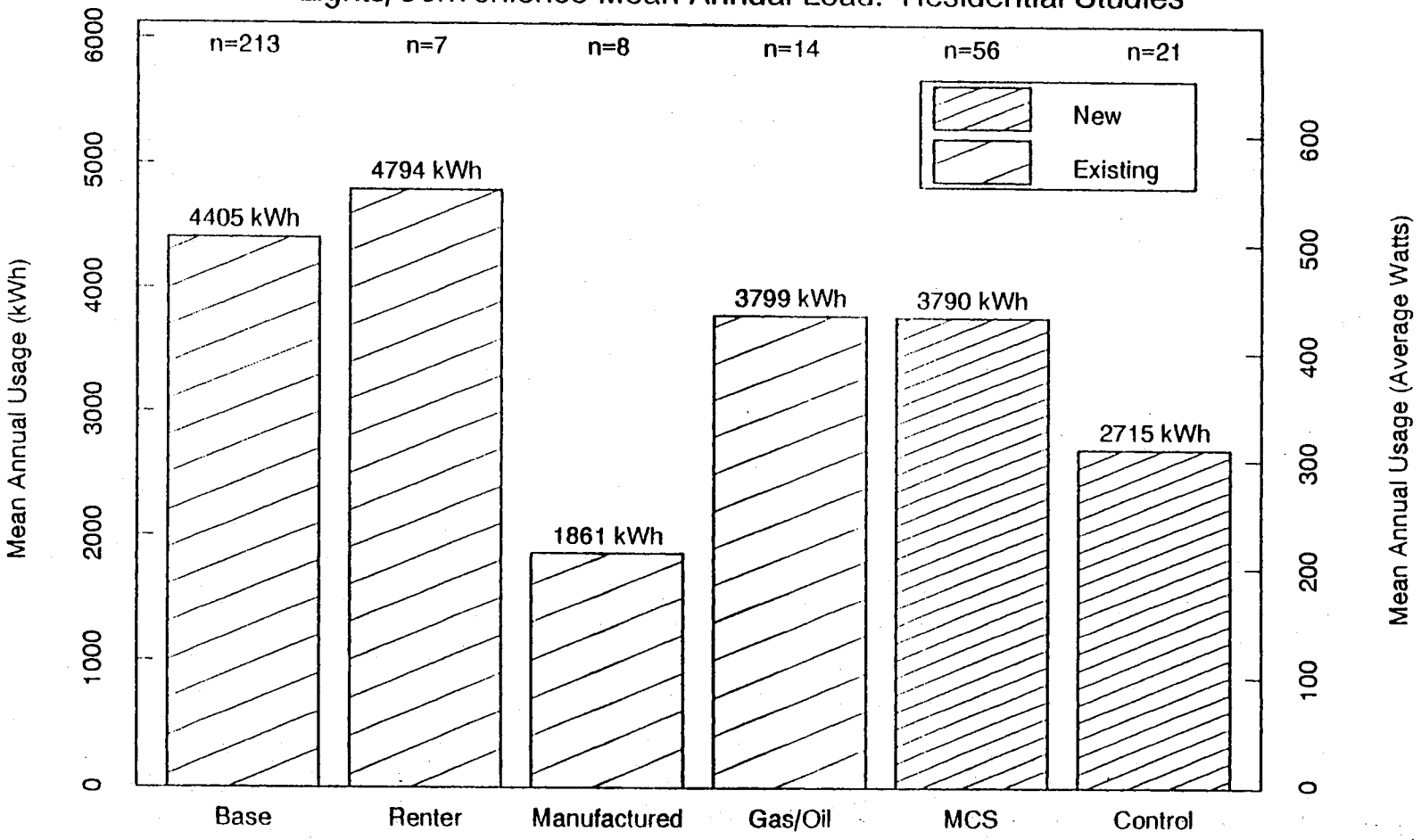
Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	214	8538	4035	21	5424	1909	57	7329	2950	292	8078	3823
Climate Zone 1	126	8462	3625	13	5168	1336	36	6778	2579	175	7871	3456
Climate Zone 2	66	8500	4582	4	7328	3197	17	8658	3381	87	8477	4292
Climate Zone 3	22	9088	4644	4	4350	538	4	6636	3103	30	8130	4429
Occupants=1	9	4655	1375	1	4401	0	2	7681	2776	12	5063	1890
Occupants=2	86	7298	3593	7	4389	619	14	5962	2286	107	6933	3417
Occupants=3	32	9253	4863	3	3996	1431	8	7458	2567	43	8552	4554
Occupants=4	48	9146	2766	3	7515	1963	7	7890	2229	58	8910	2691
Occupants>4	28	11809	4310	1	10356	0	5	10051	4439	34	11508	4245
Income<8K	8	5861	1739	0	-	-	1	4734	0	9	5736	1670
Income=8-16K	26	7141	2537	1	3754	0	1	2933	0	28	6869	2639
Income=16-25K	40	7805	4803	1	5078	0	8	5829	2353	49	7427	4495
Income=25-35K	48	8859	3069	8	5768	1853	12	7276	2556	68	8216	3035
Income=35-60K	58	9885	4860	3	6070	3740	13	8765	3075	74	9534	4591
Income>60K	13	7564	2771	1	4128	0	1	8430	0	15	7392	2729
Invest_Own_Util	69	7818	2710	10	5120	2098	32	7621	3106	111	7518	2864
Pub_Gen_Util	32	8582	5901	7	5674	1034	10	6175	1738	49	7675	4979
Pub_Nongen_Util	111	8962	4081	4	5746	2898	11	7103	3576	126	8698	4055
Size<850 sqft	32	6730	2314	1	9671	0	1	2933	0	34	6704	2393
Size=1350 sqft	65	7298	2765	13	5015	1367	26	6317	2538	104	6767	2673
Size=2100 sqft	75	9066	4069	6	5524	2449	17	8210	2620	98	8700	3853
Size>2475 sqft	32	11079	5858	0	-	-	9	9380	3135	41	10706	5391
Pre-1940	33	9618	6871	0	-	-	0	-	-	33	9618	6871
1940-1950	15	6360	2690	0	-	-	0	-	-	15	6360	2690
1950-1960	22	7359	2904	0	-	-	0	-	-	22	7359	2904
1960-1970	34	9126	3159	0	-	-	0	-	-	34	9126	3159
1970-1978	70	8610	3621	0	-	-	0	-	-	70	8610	3621
Post-1978	30	8585	2841	21	5424	1909	57	7329	2950	108	7307	2929

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

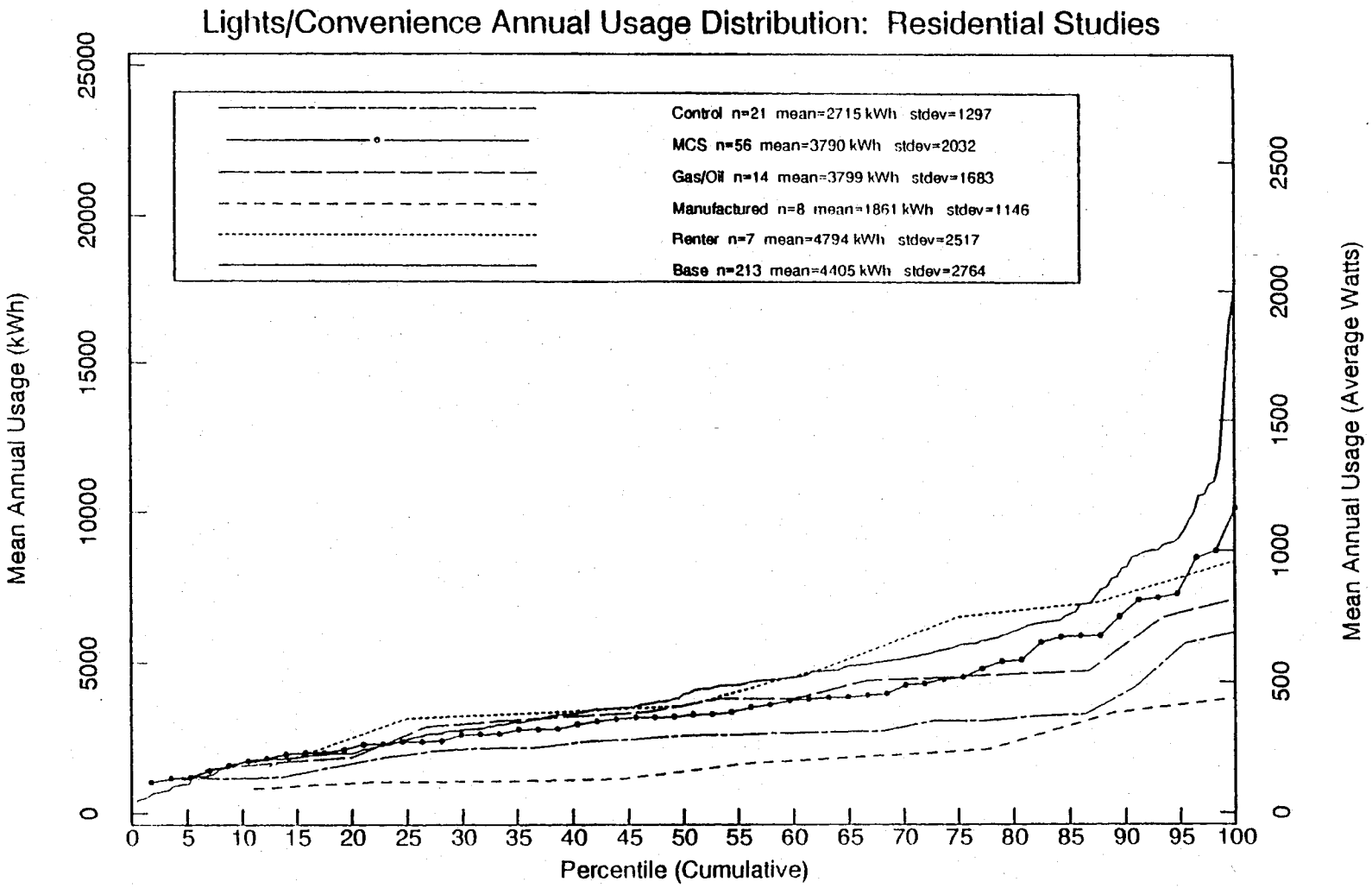
FIGURE 7G.1

Lights/Convenience Mean Annual Load: Residential Studies



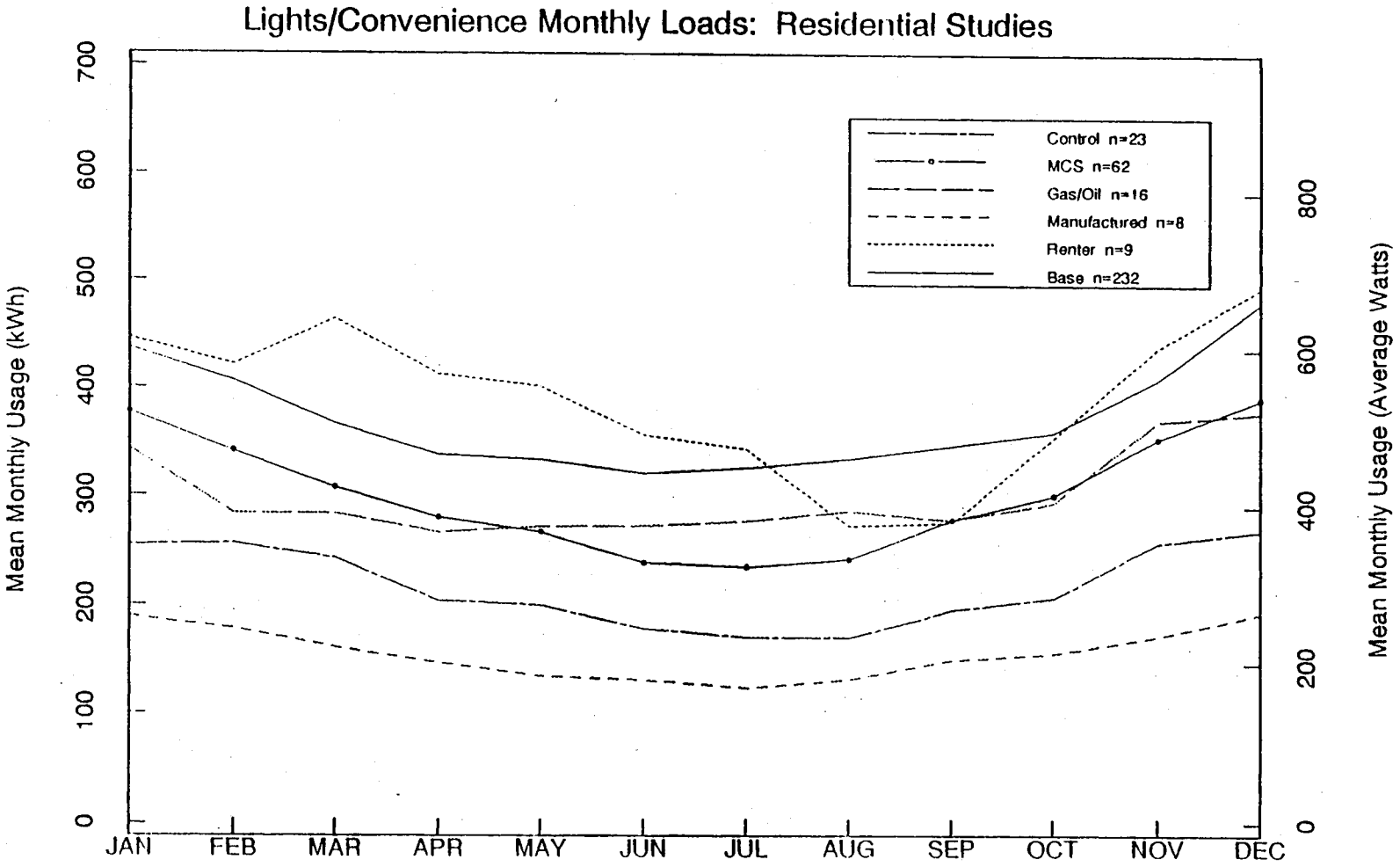
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.2



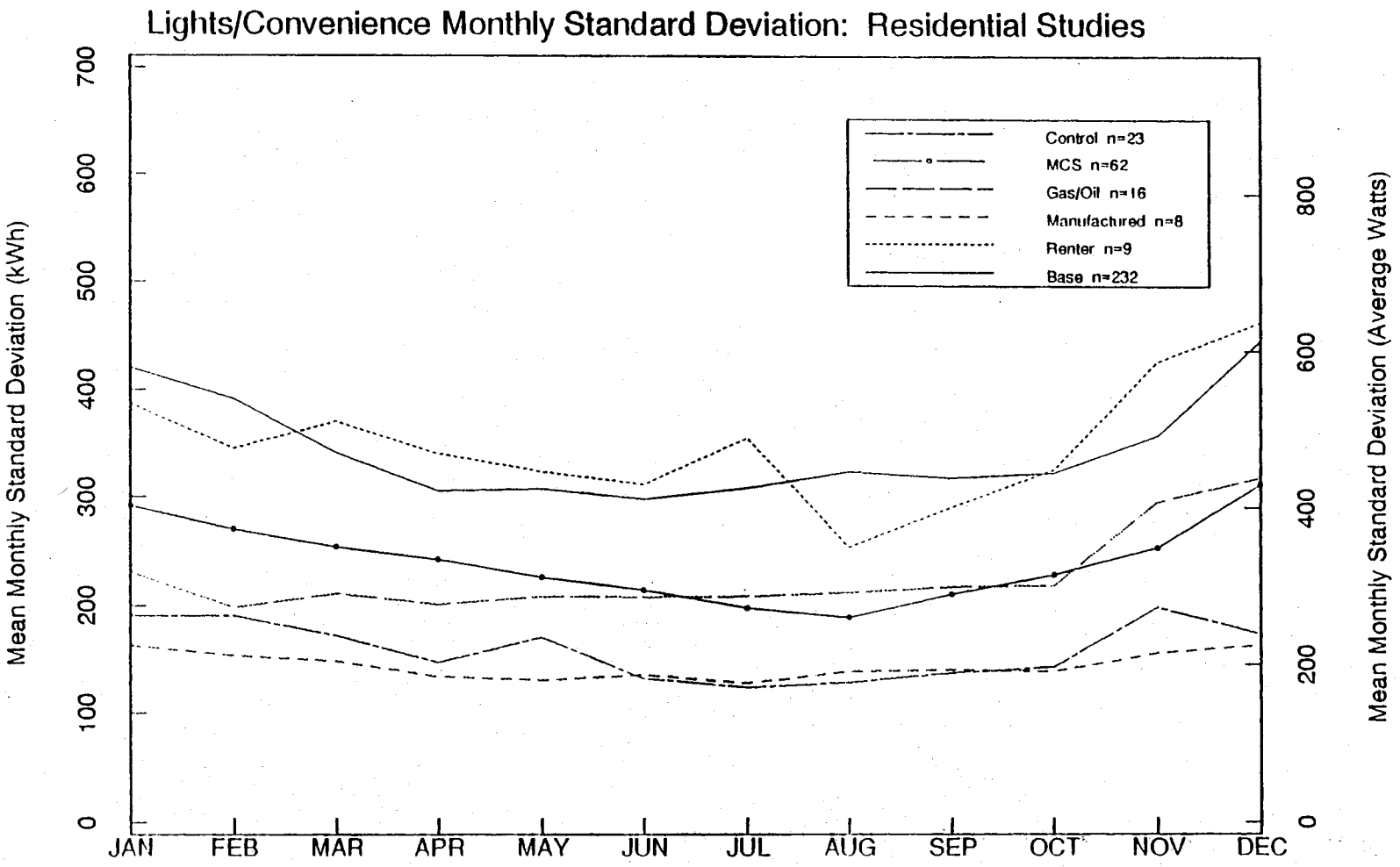
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.3



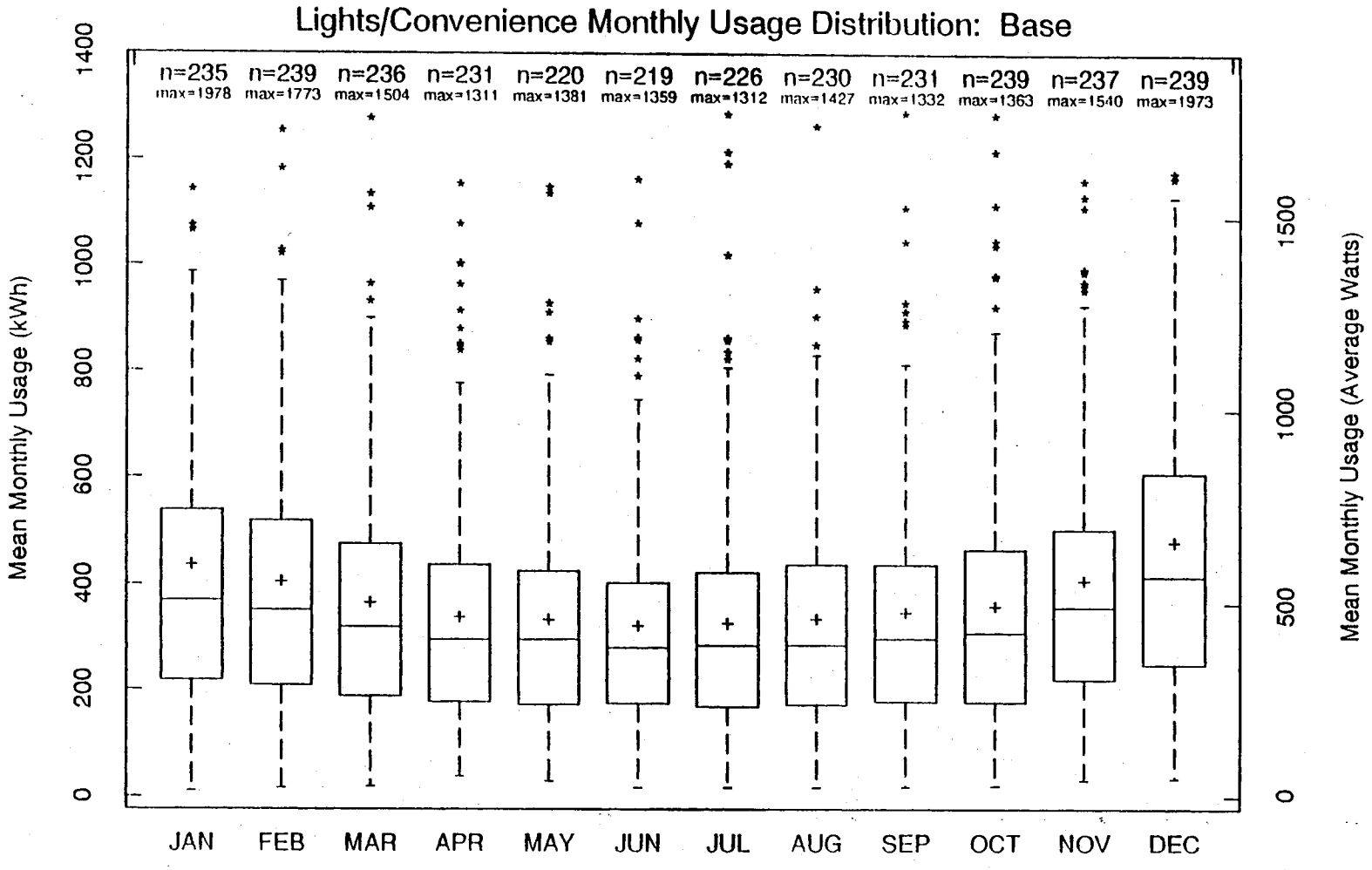
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.4



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

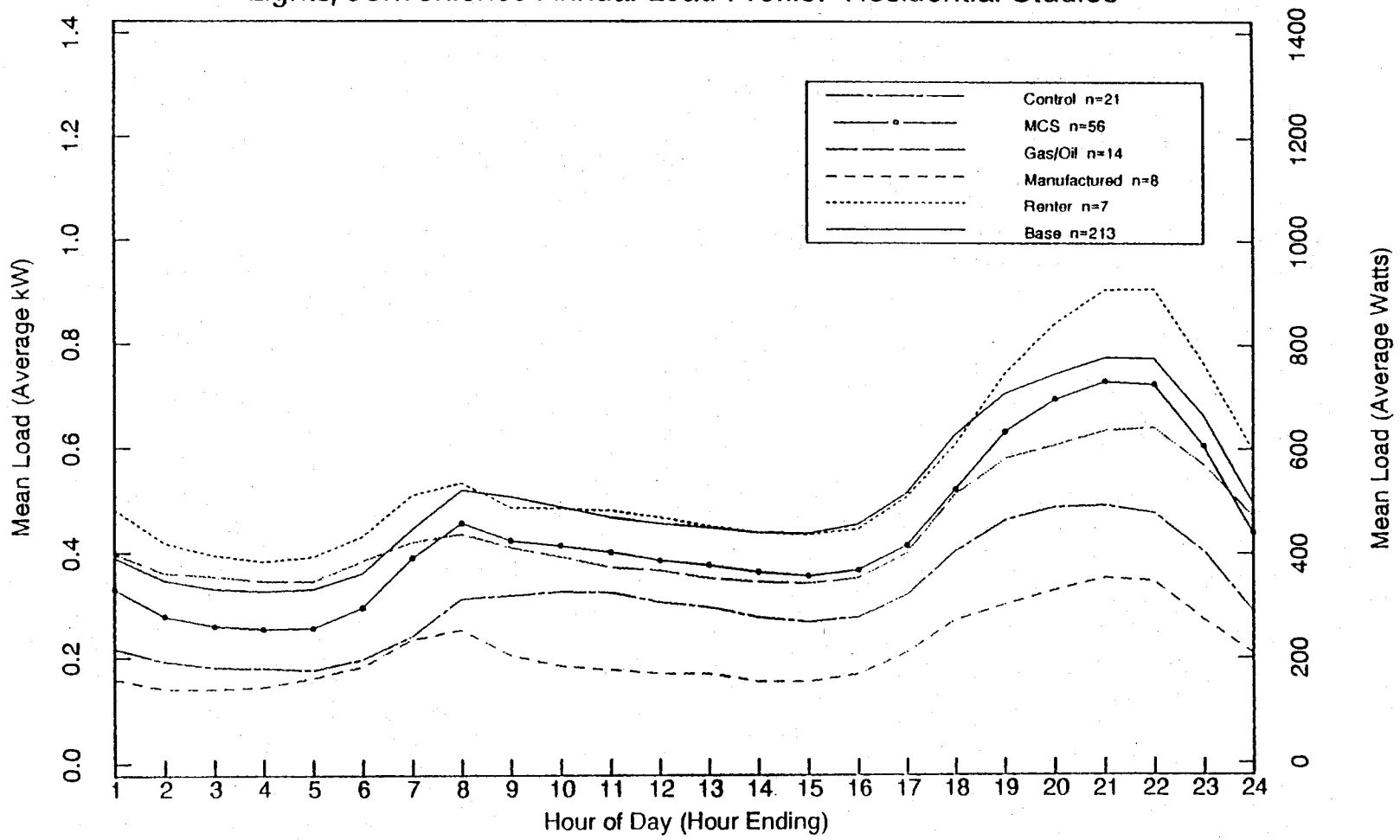
FIGURE 7G.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

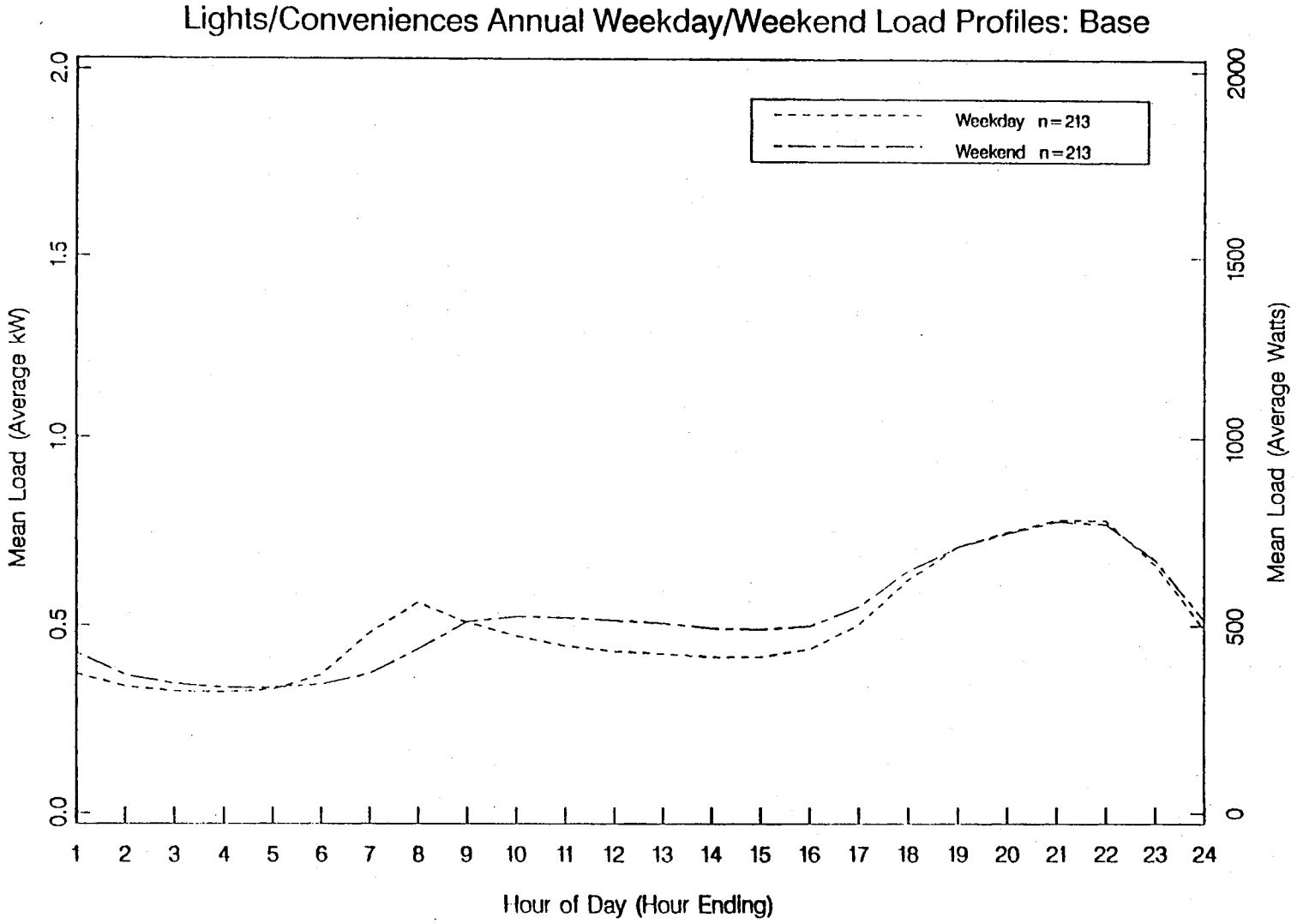
FIGURE 7G.6

Lights/Convenience Annual Load Profile: Residential Studies



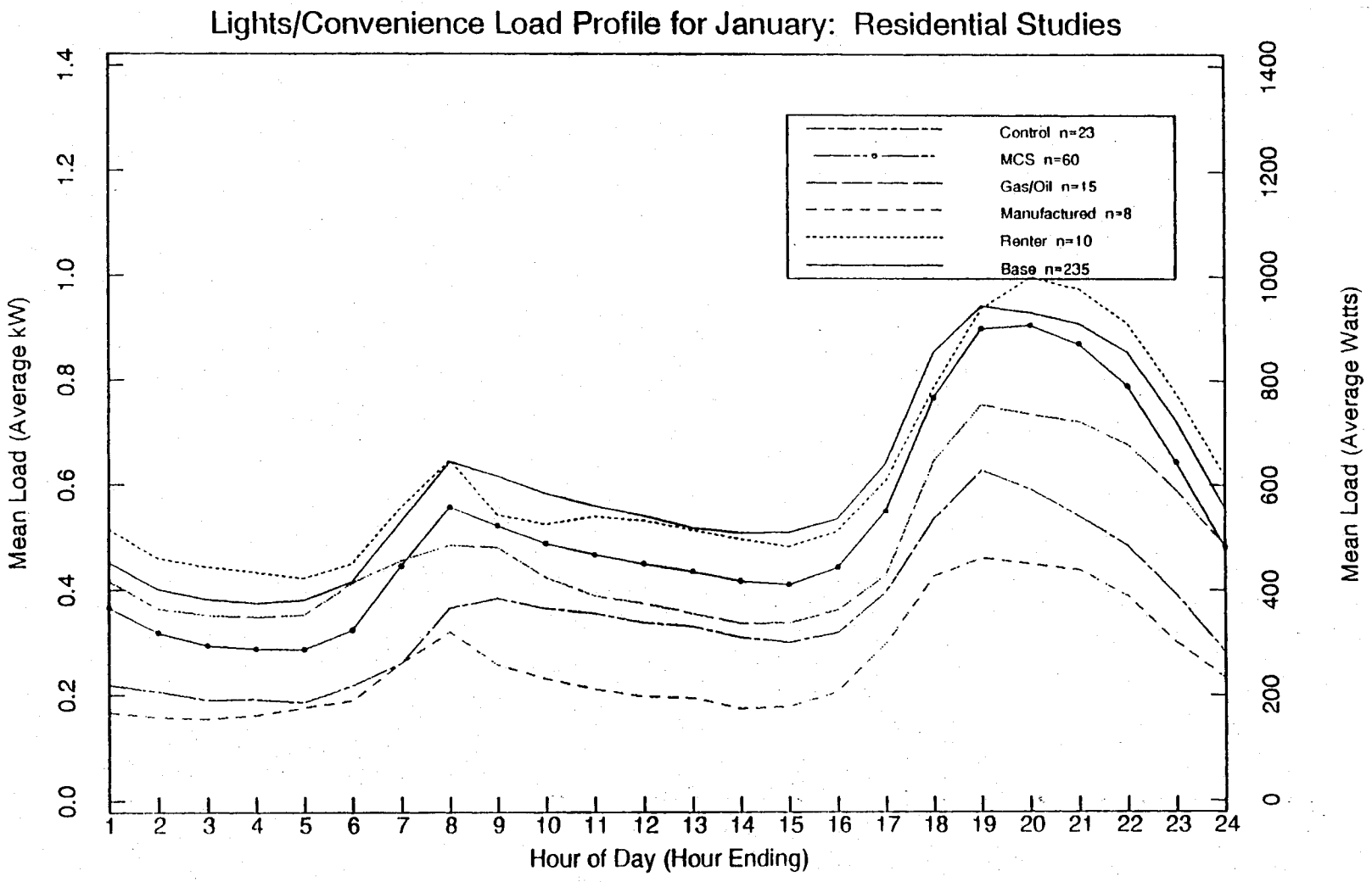
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.7



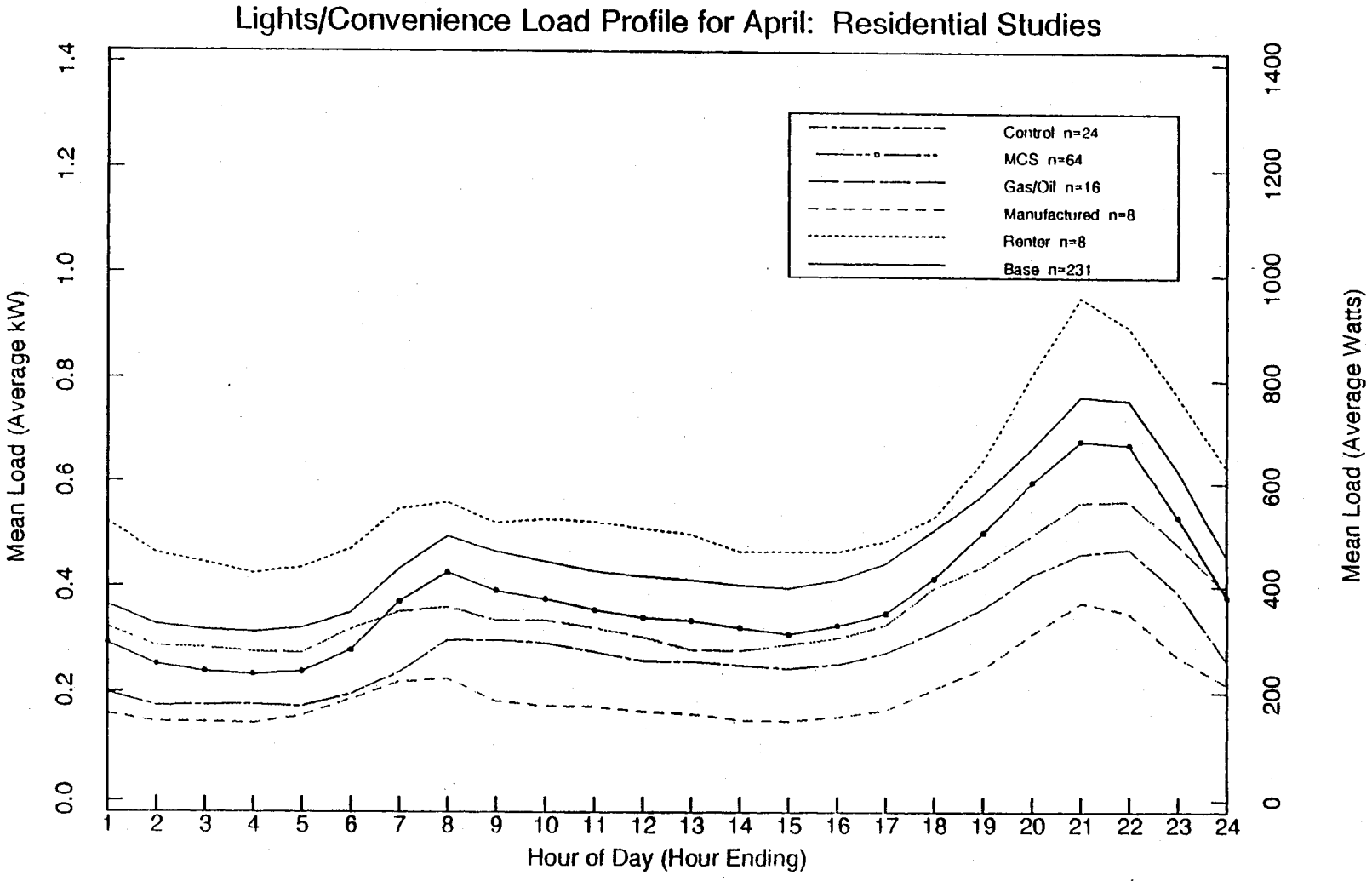
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7G.8(a)



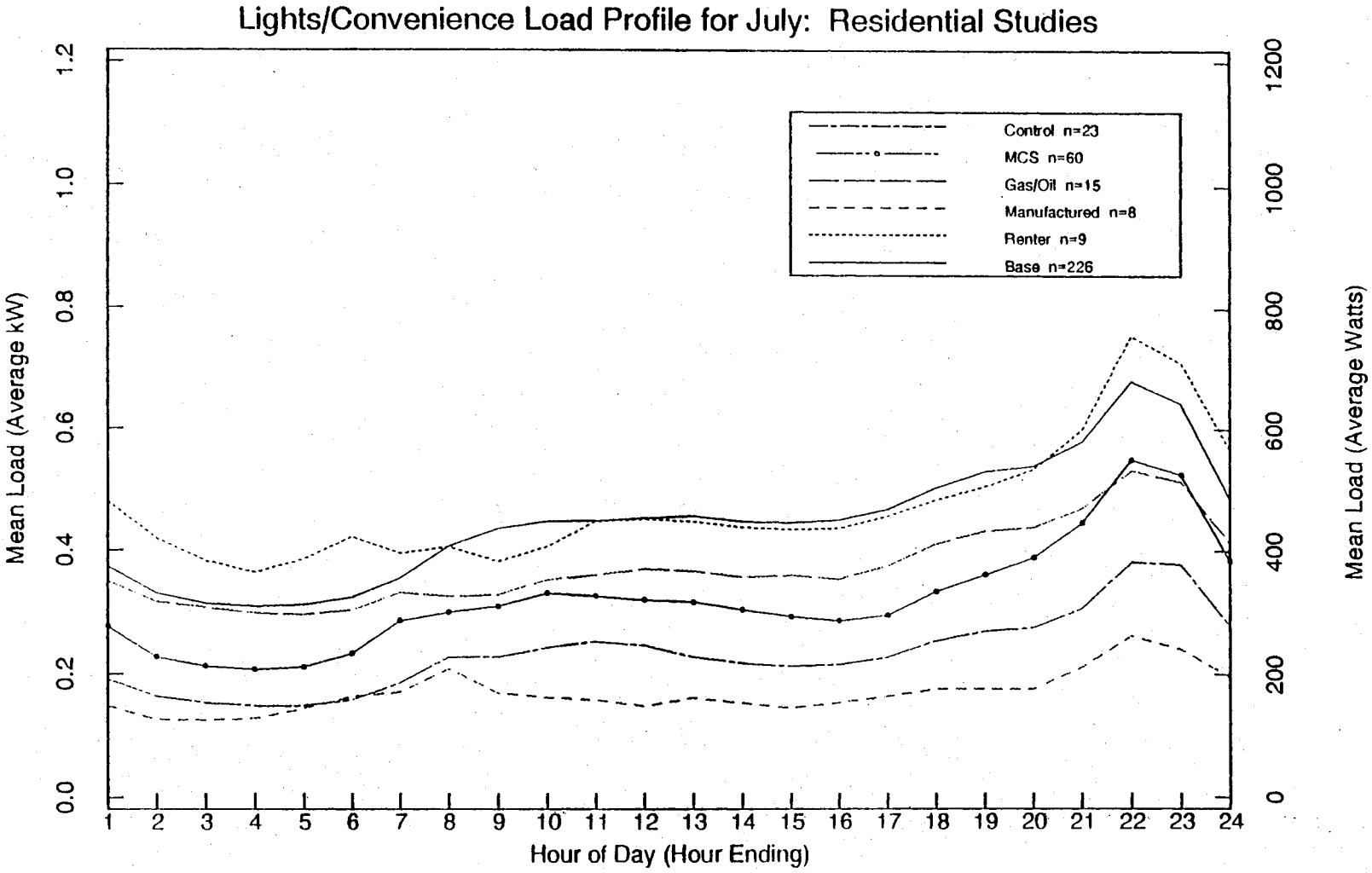
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.8(b)



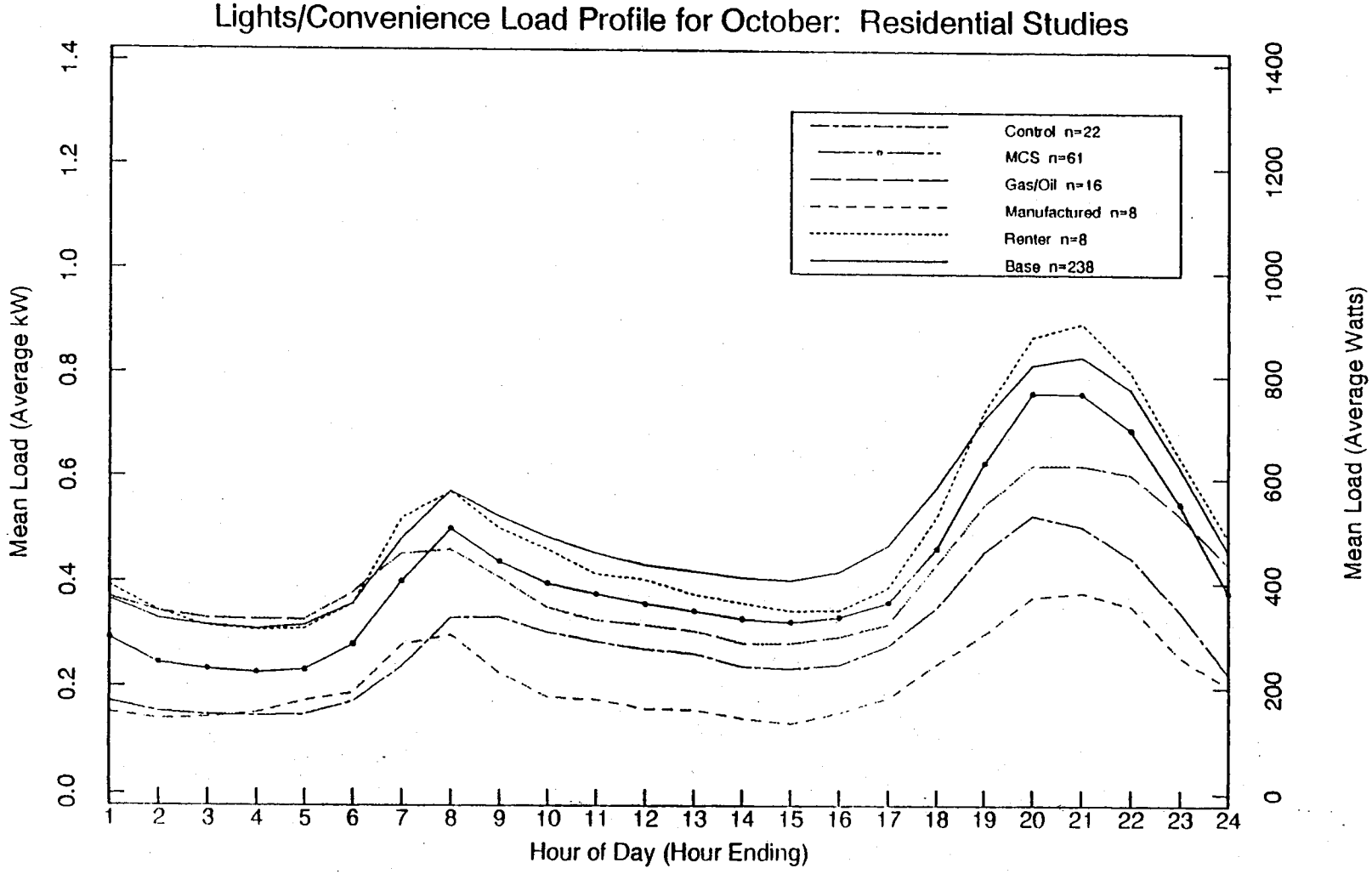
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.8(c)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

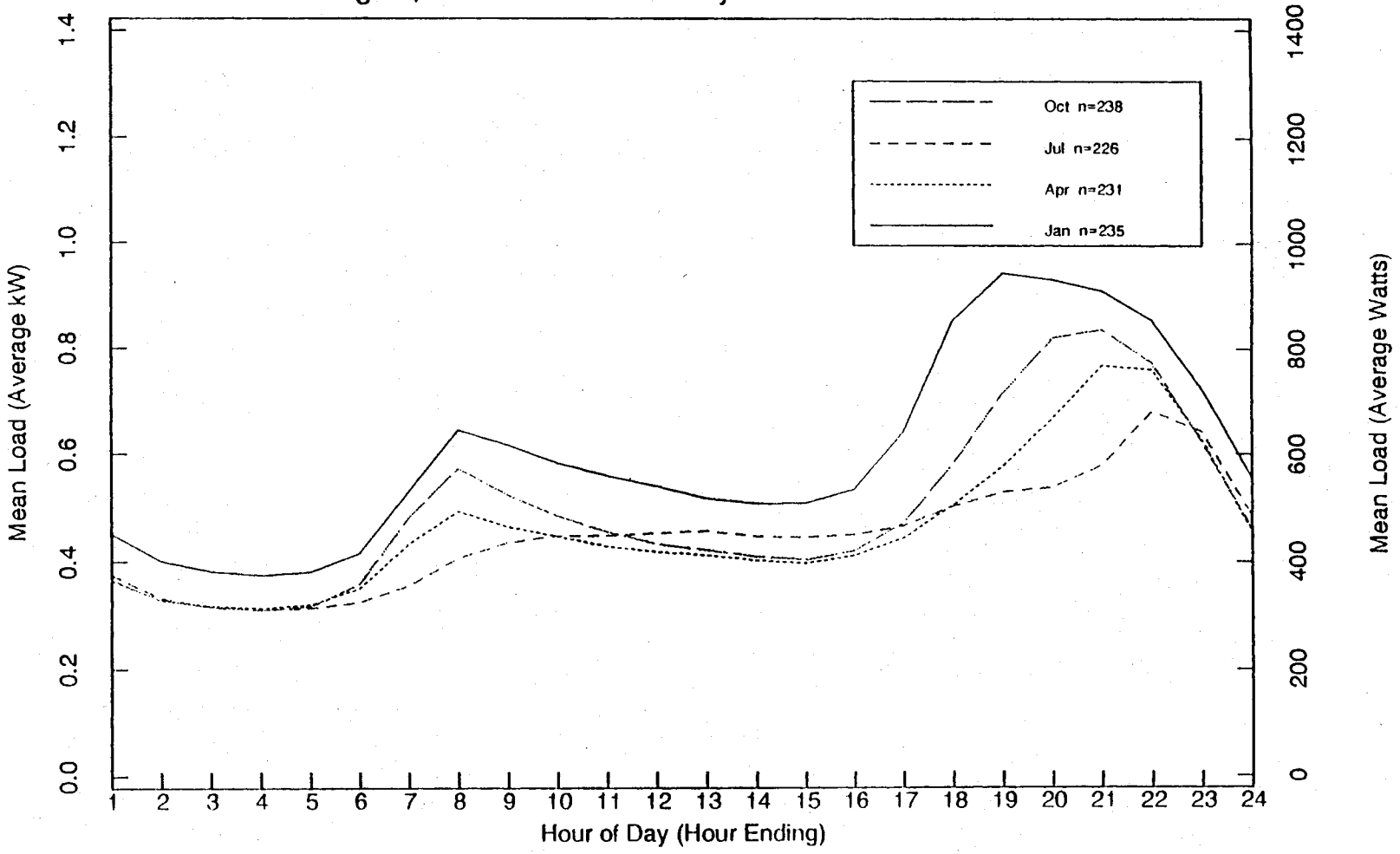
FIGURE 7G.8(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

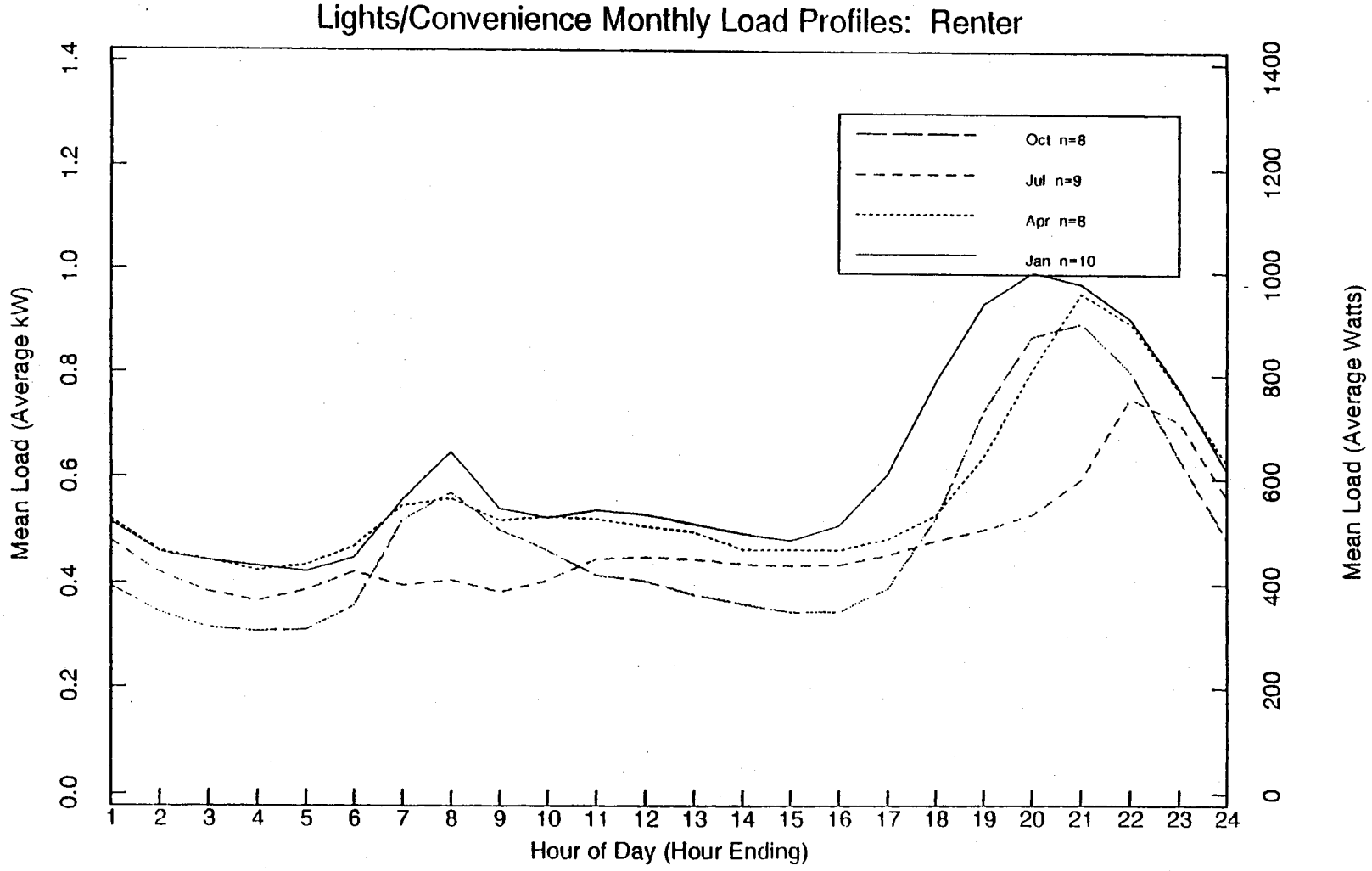
FIGURE 7G.9(a)

Lights/Convenience Monthly Load Profiles: Base



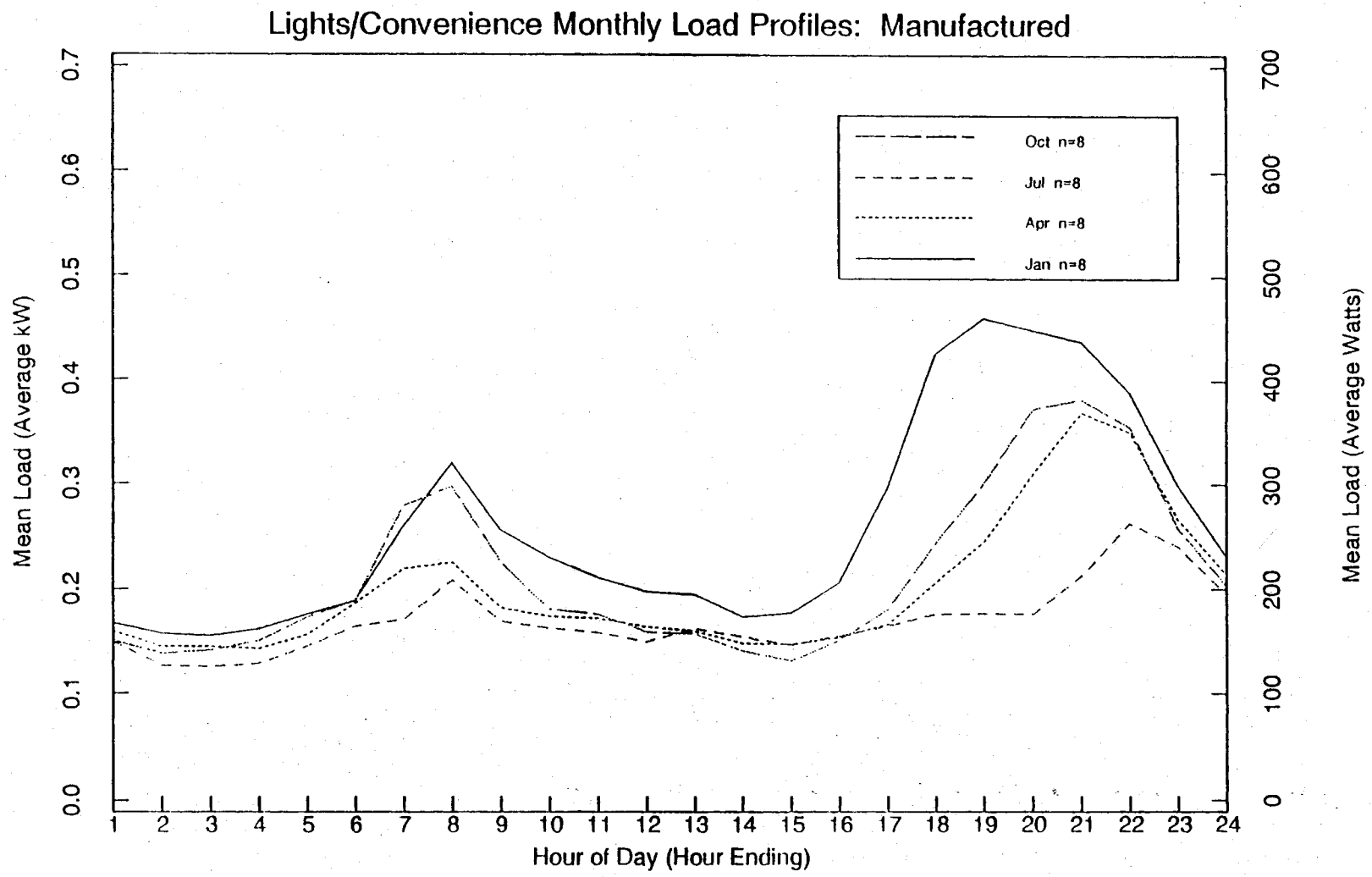
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.9(b)



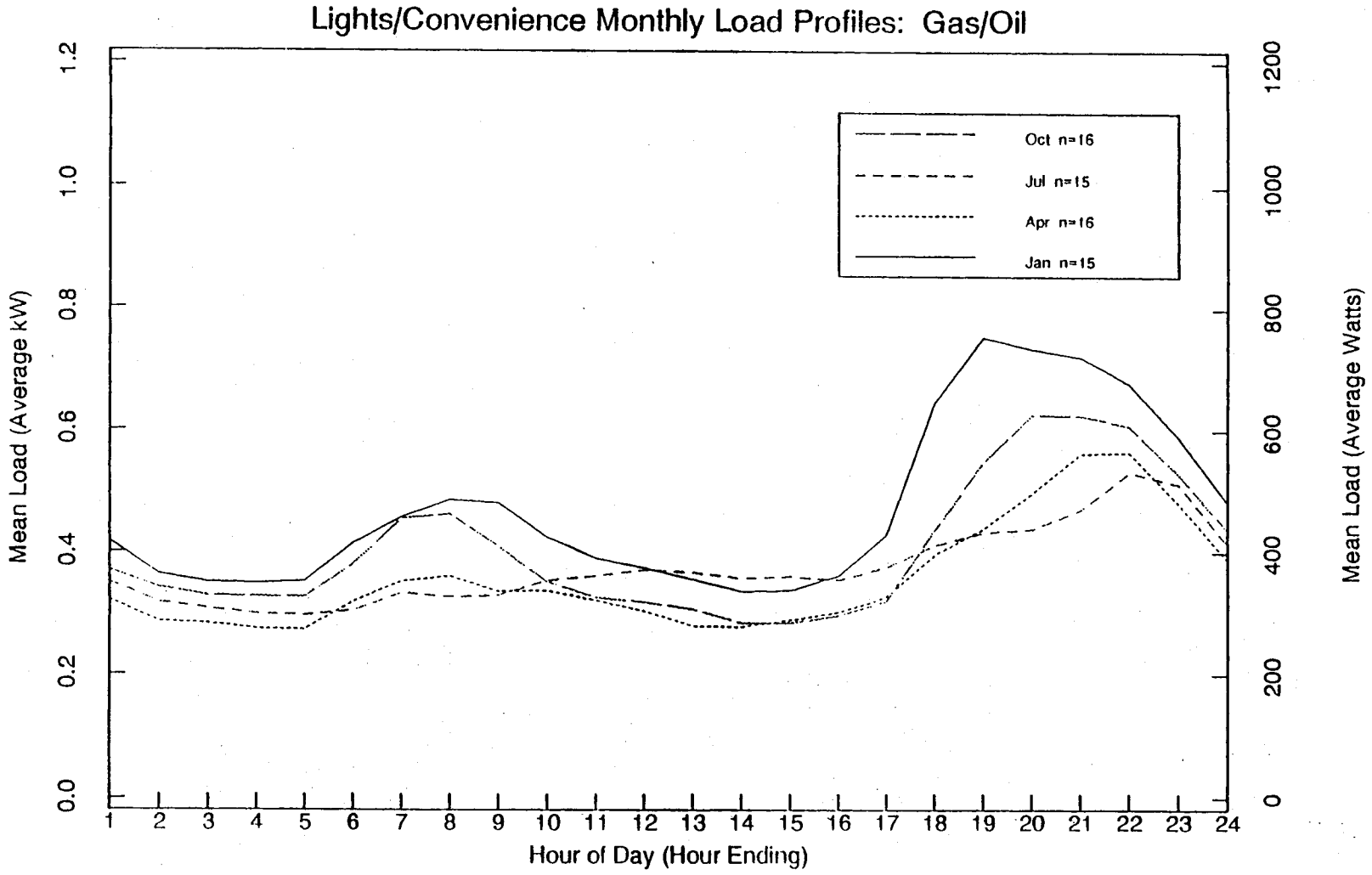
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.9(c)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

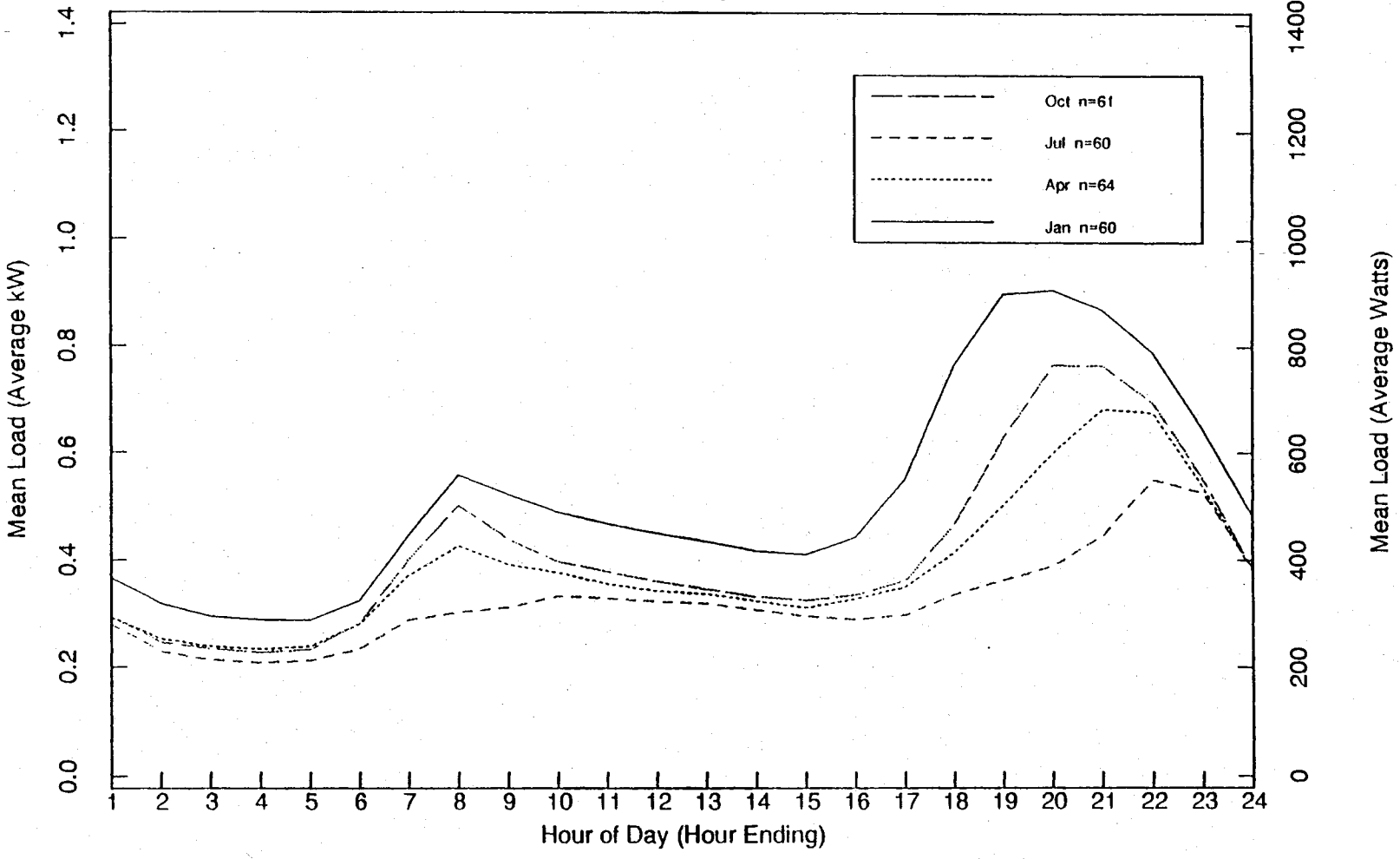
FIGURE 7G.9(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

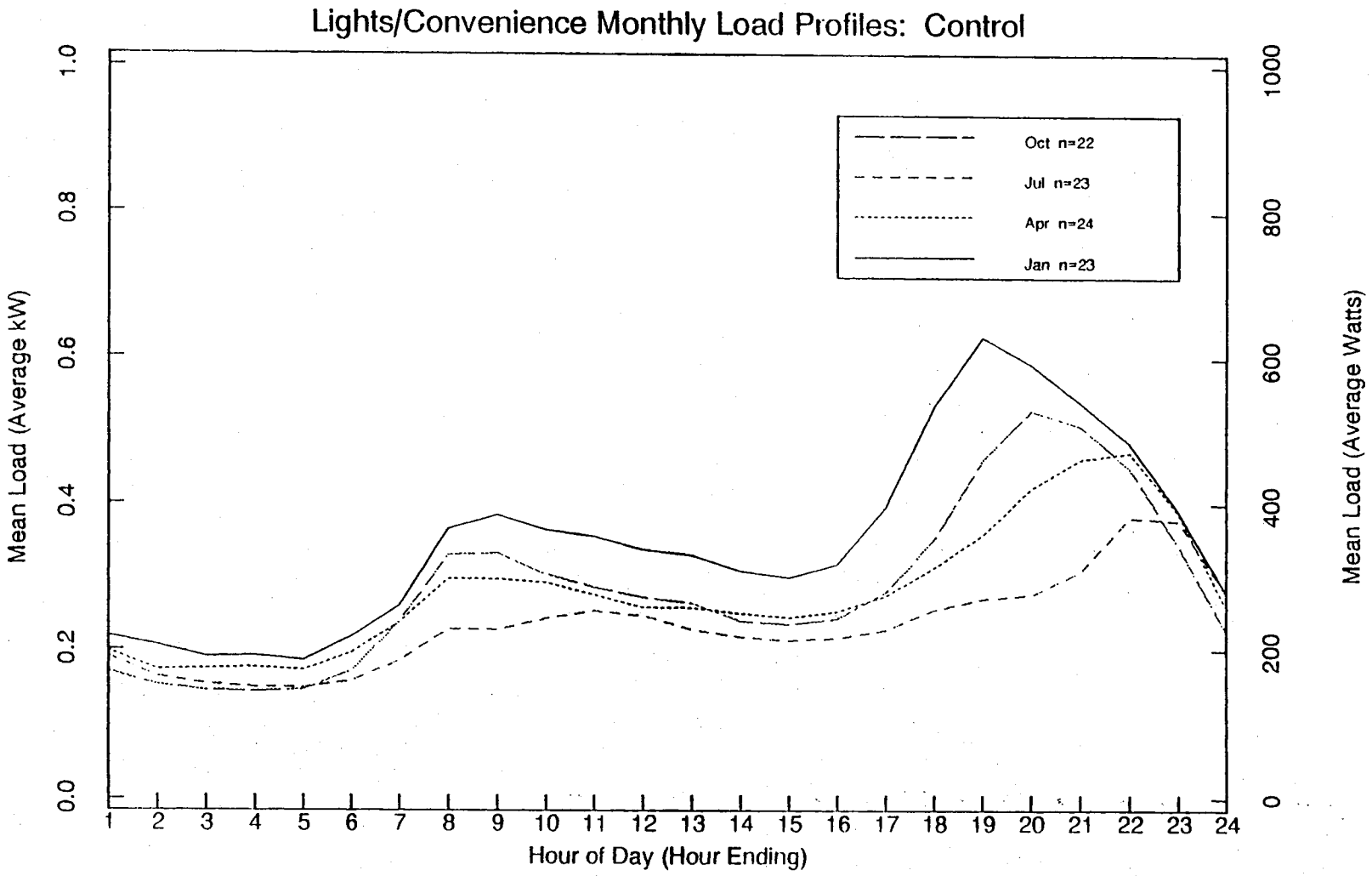
FIGURE 7G.9(e)

Lights/Convenience Monthly Load Profiles: MCS



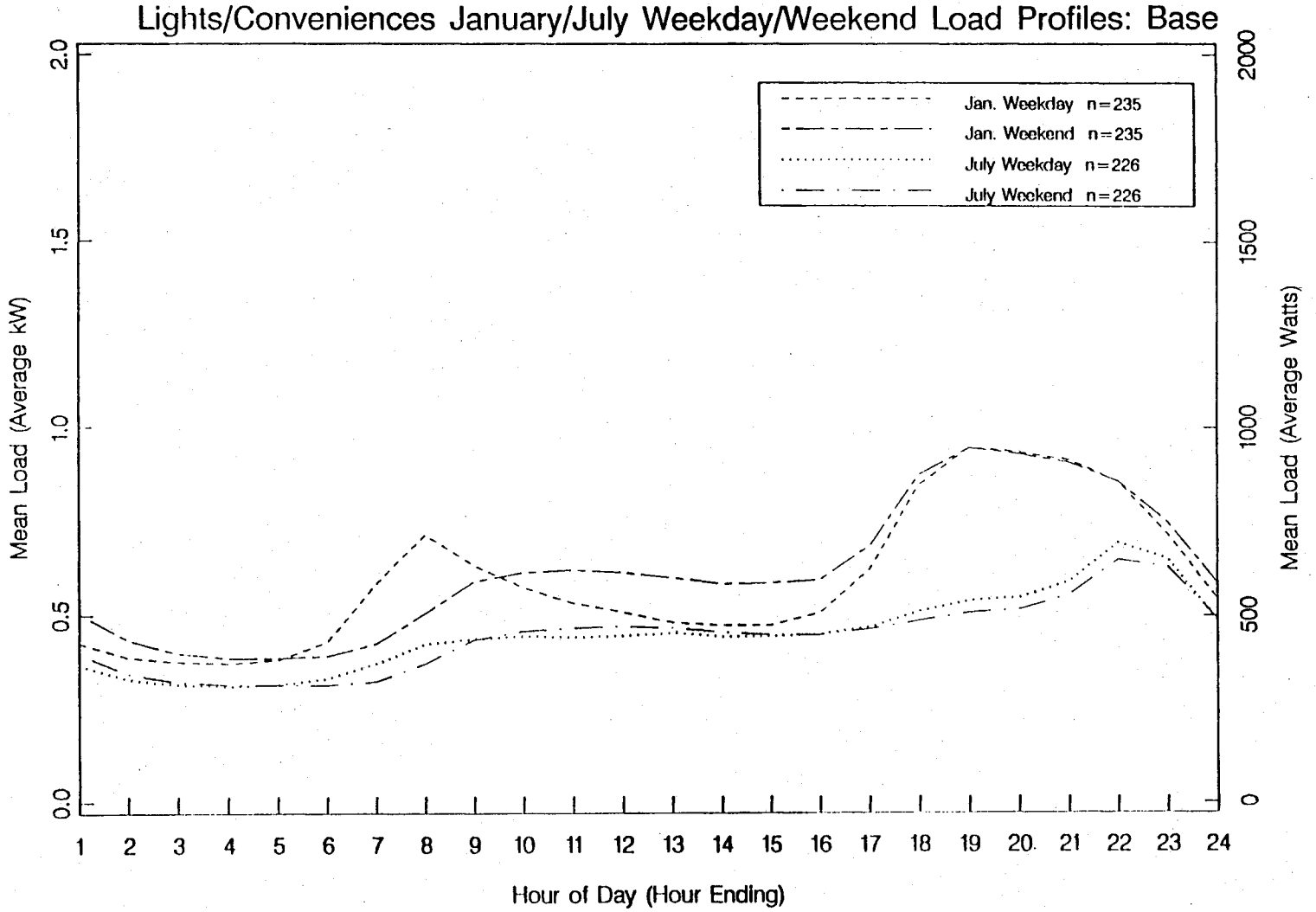
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7G.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

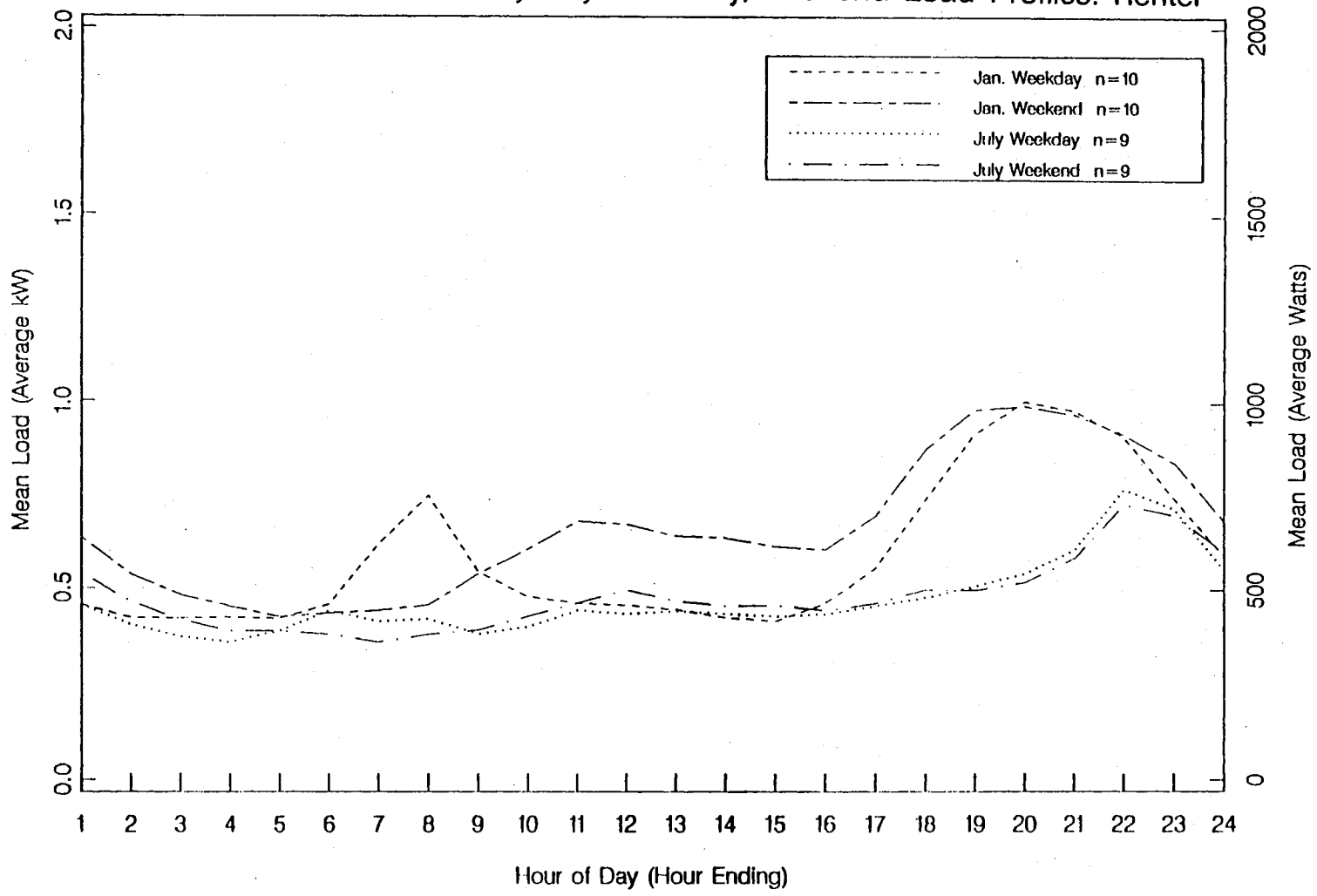
FIGURE 7G.10(a)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

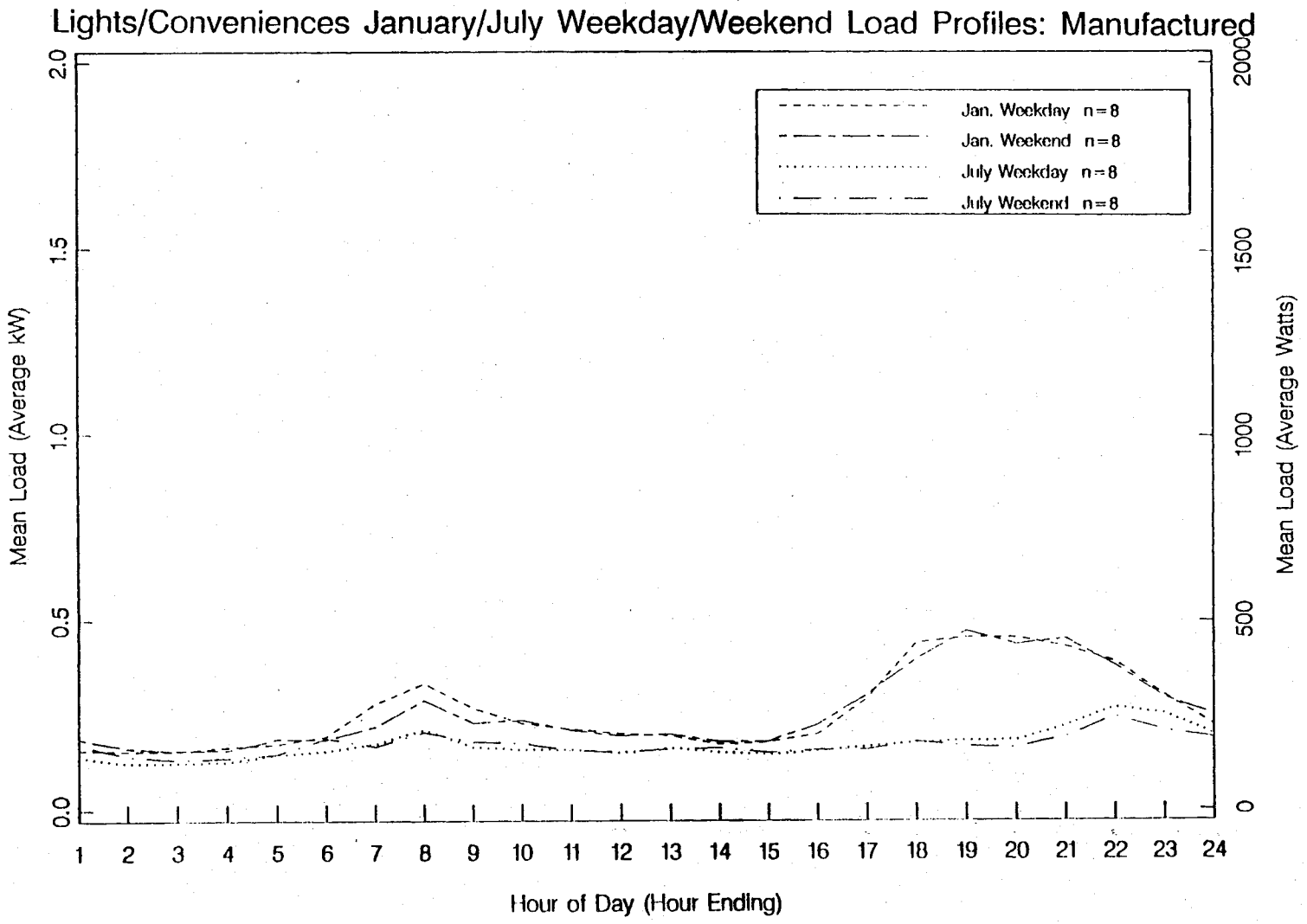
FIGURE 7G.10(b)

Lights/Conveniences January/July Weekday/Weekend Load Profiles: Renter



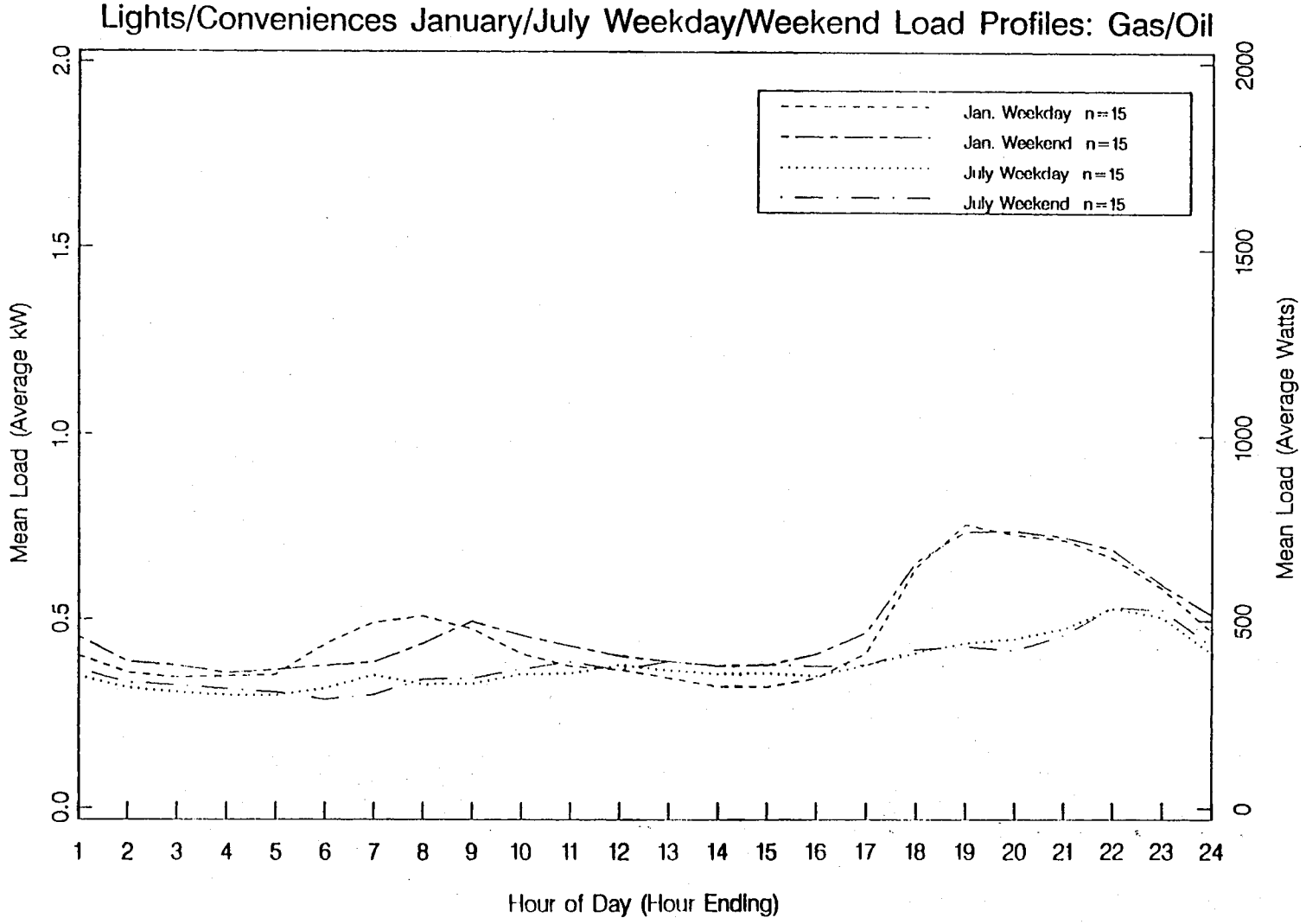
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7G.10(c)



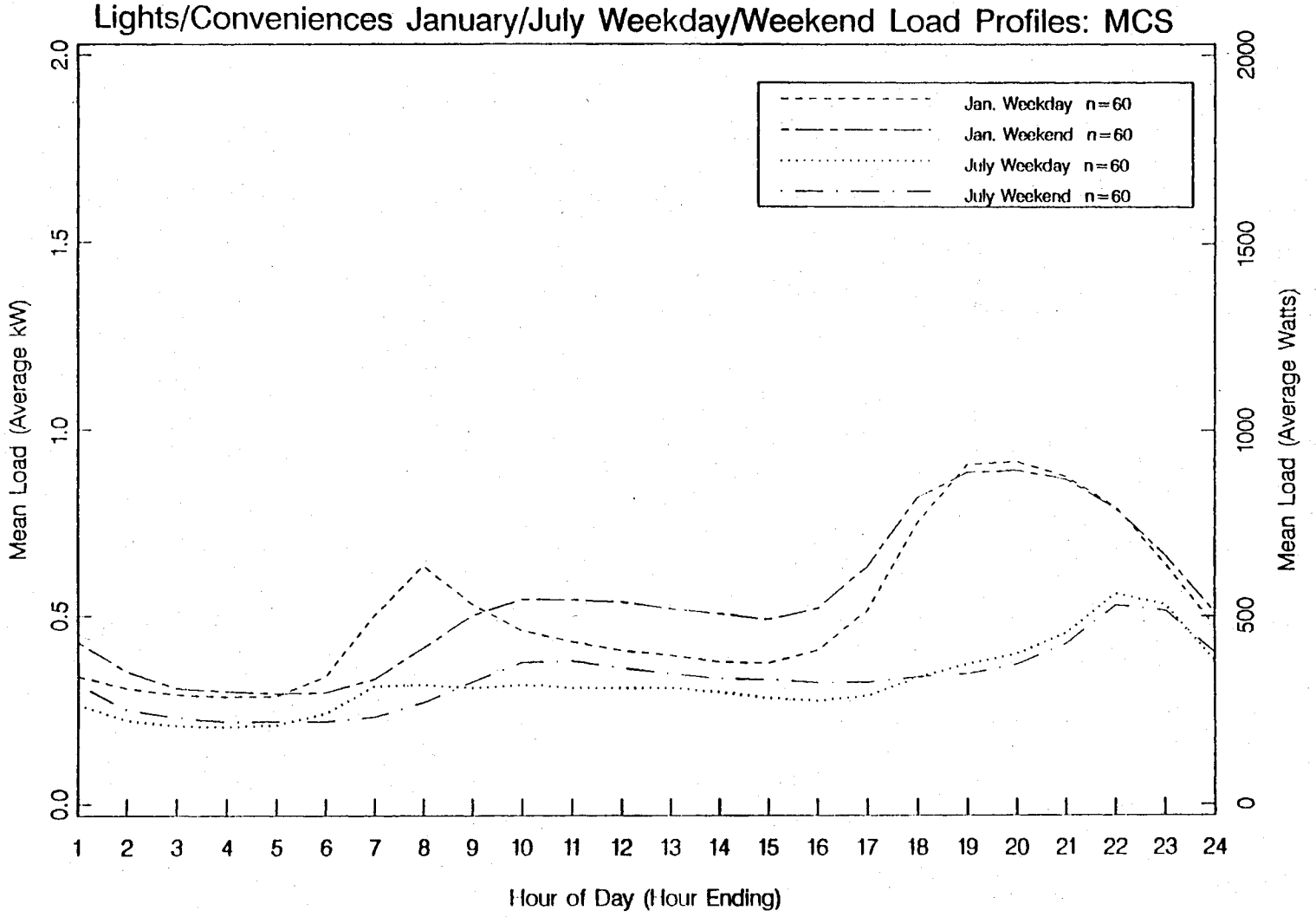
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7G.10(d)



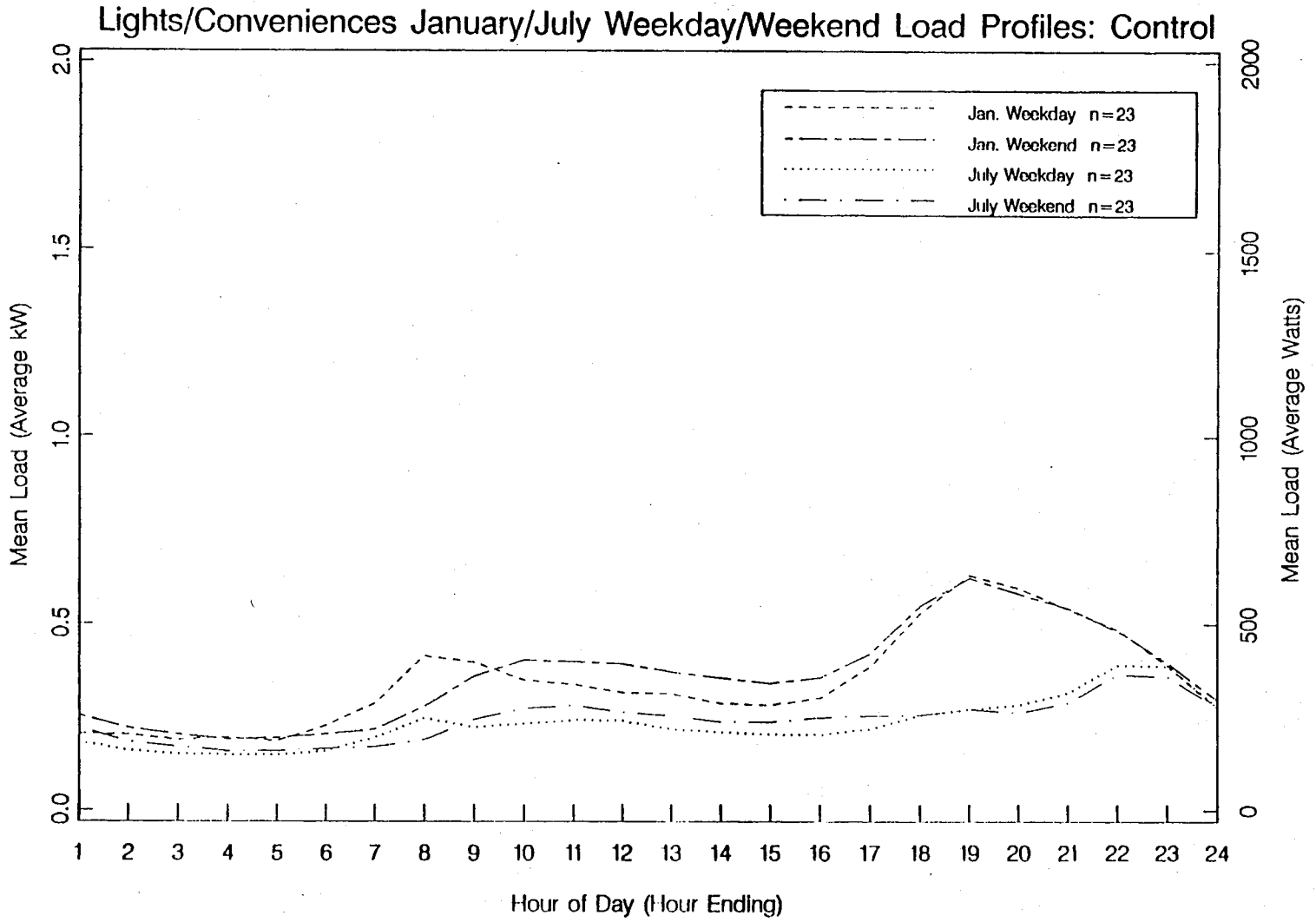
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7G.10(e)



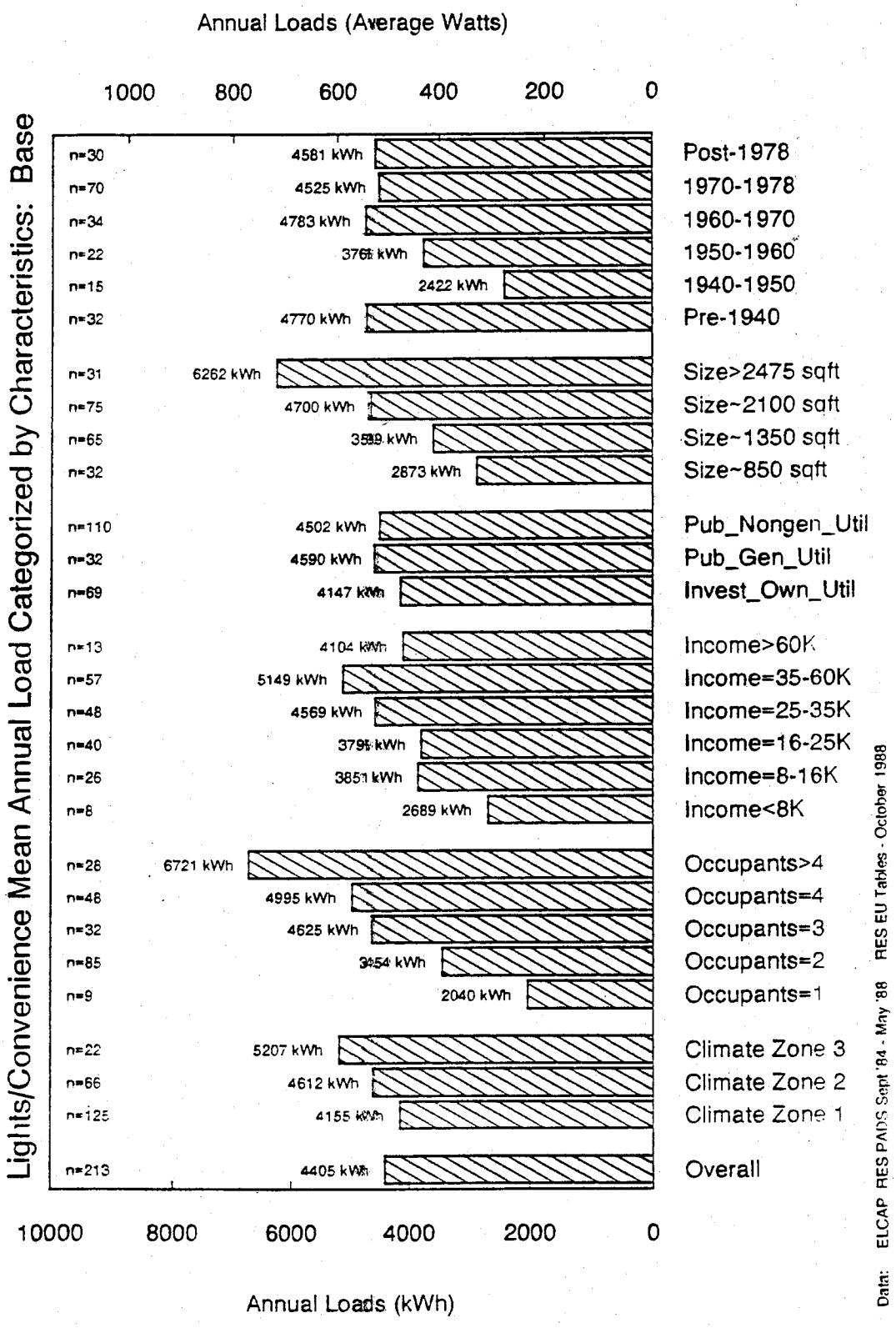
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7G.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

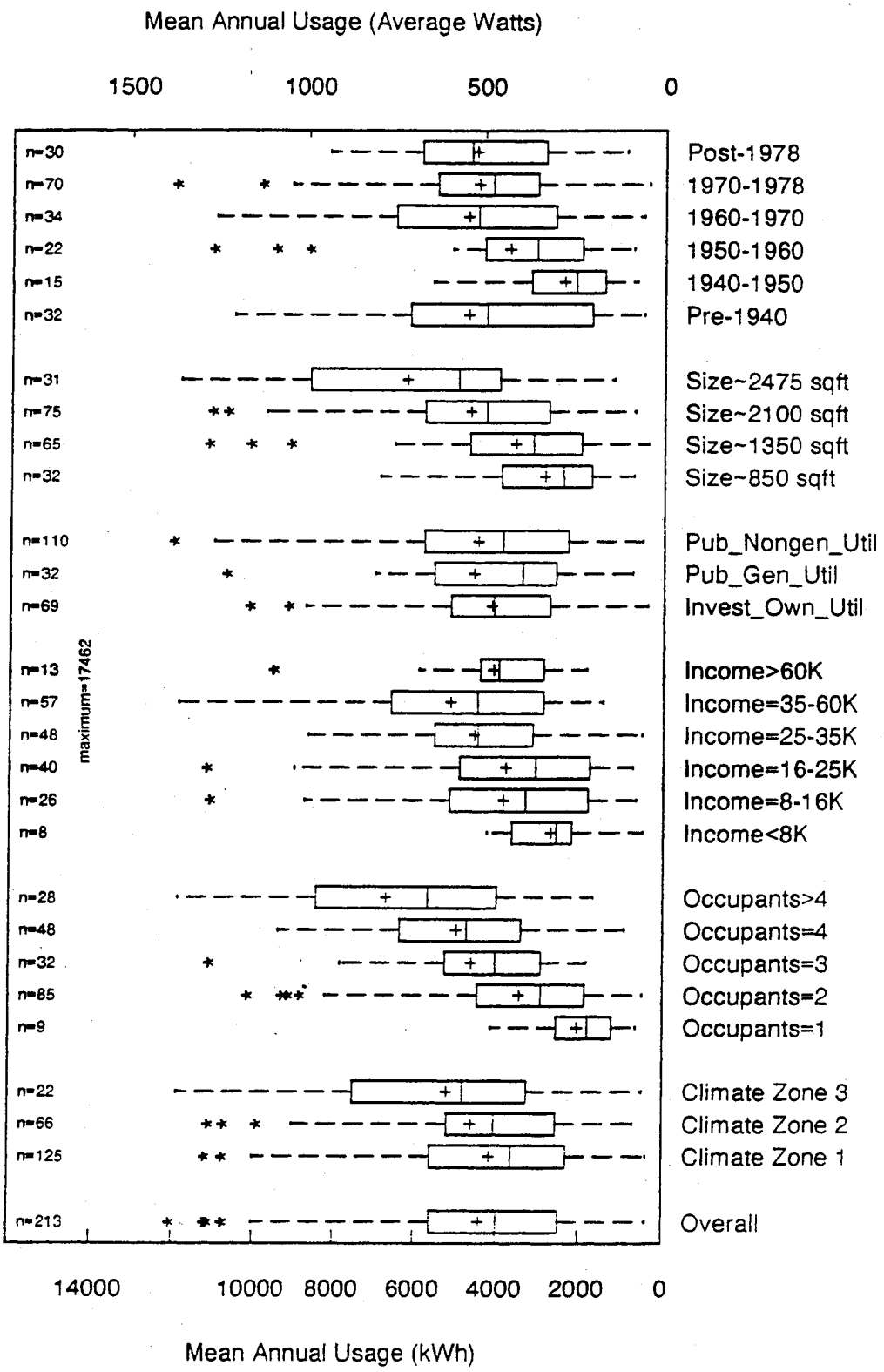
FIGURE 7G.11



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7G.12

Lights/Convenience Mean Annual Load Distribution Categorized by Characteristics: Base



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7G.1

Lights/Convenience Mean Annual End-Use Loads and Standard Deviations (kWh)

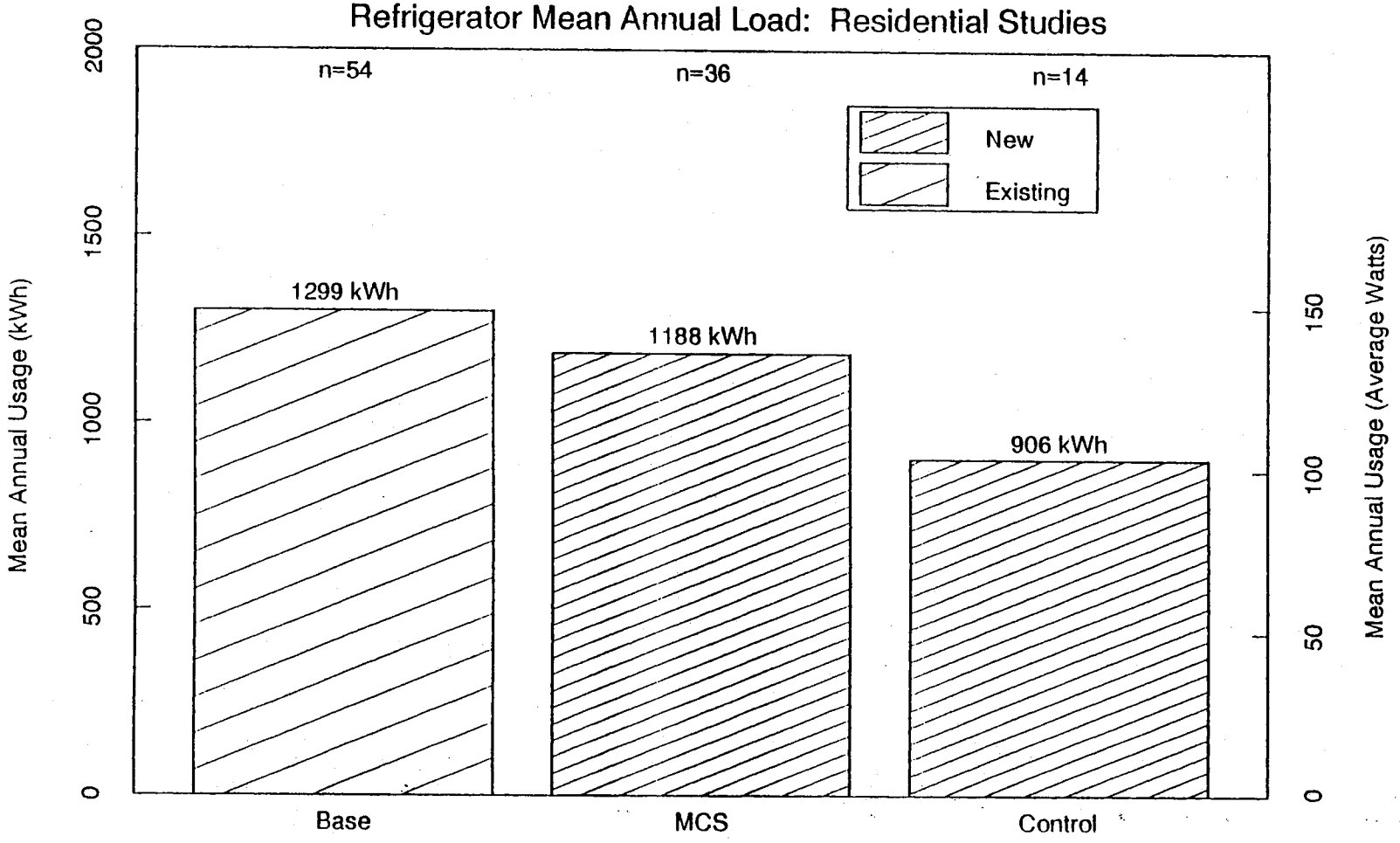
Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	213	4405	2764	21	2715	1297	56	3790	2032	290	4164	2594
Climate Zone 1	125	4155	2288	13	2518	836	35	3492	1817	173	3898	2168
Climate Zone 2	66	4612	3412	4	3745	2468	17	4382	2391	87	4527	3180
Climate Zone 3	22	5207	3001	4	2327	745	4	3876	2185	30	4646	2852
Occupants=1	9	2040	1149	1	2163	0	2	3063	946	12	2221	1094
Occupants=2	85	3454	2148	7	2321	777	14	2979	1588	106	3316	2033
Occupants=3	32	4625	2561	3	1465	591	7	4760	1911	42	4422	2491
Occupants=4	48	4995	2159	3	3848	1603	7	3970	1625	58	4812	2092
Occupants>4	28	6721	3882	1	6027	0	5	4684	2309	34	6401	3676
Income<8K	8	2689	1221	0	-	-	1	2938	0	9	2717	1145
Income=8-16K	26	3851	2622	1	1135	0	1	1578	0	28	3673	2608
Income=16-25K	40	3796	2986	1	3285	0	7	3234	1382	48	3703	2772
Income=25-35K	48	4569	2664	8	2956	1177	12	3971	2083	68	4274	2474
Income=35-60K	57	5149	2881	3	3223	2509	13	4039	1918	73	4872	2747
Income>60K	13	4104	1987	1	1516	0	1	5045	0	15	3995	1978
Invest_Own_Util	69	4147	2270	10	2549	1419	31	4028	2178	110	3968	2212
Pub_Gen_Util	32	4590	3513	7	2758	742	10	3045	808	49	4013	2968
Pub_Nongen_Util	110	4502	2839	4	3053	1957	11	3331	2229	125	4352	2783
Size<850 sqft	32	2873	1644	1	5669	0	1	1578	0	34	2917	1681
Size=1350 sqft	65	3599	2179	13	2517	854	25	3010	1404	103	3320	1919
Size=2100 sqft	75	4700	2545	6	2676	1769	17	4010	2049	98	4458	2464
Size>2475 sqft	31	6262	3713	0	-	-	9	5517	2145	40	6095	3413
Pre-1940	32	4770	3960	0	-	-	0	-	-	32	4770	3960
1940-1950	15	2422	1346	0	-	-	0	-	-	15	2422	1346
1950-1960	22	3766	2693	0	-	-	0	-	-	22	3766	2693
1960-1970	34	4783	2699	0	-	-	0	-	-	34	4783	2699
1970-1978	70	4525	2512	0	-	-	0	-	-	70	4525	2512
Post-1978	30	4581	1905	21	2715	1297	56	3790	2032	107	3801	1965

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

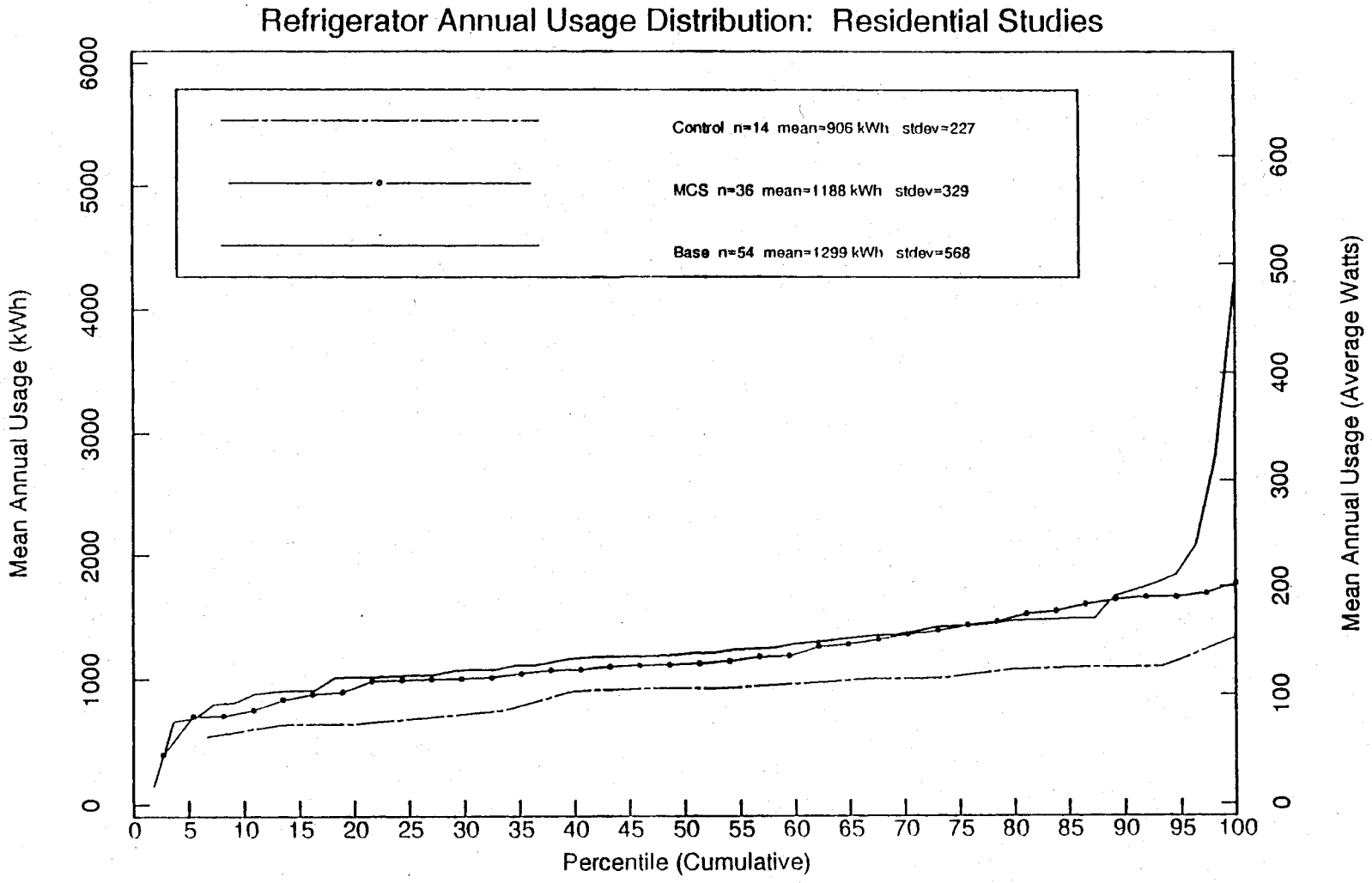
FIGURE 7H.1

Refrigerator Mean Annual Load: Residential Studies



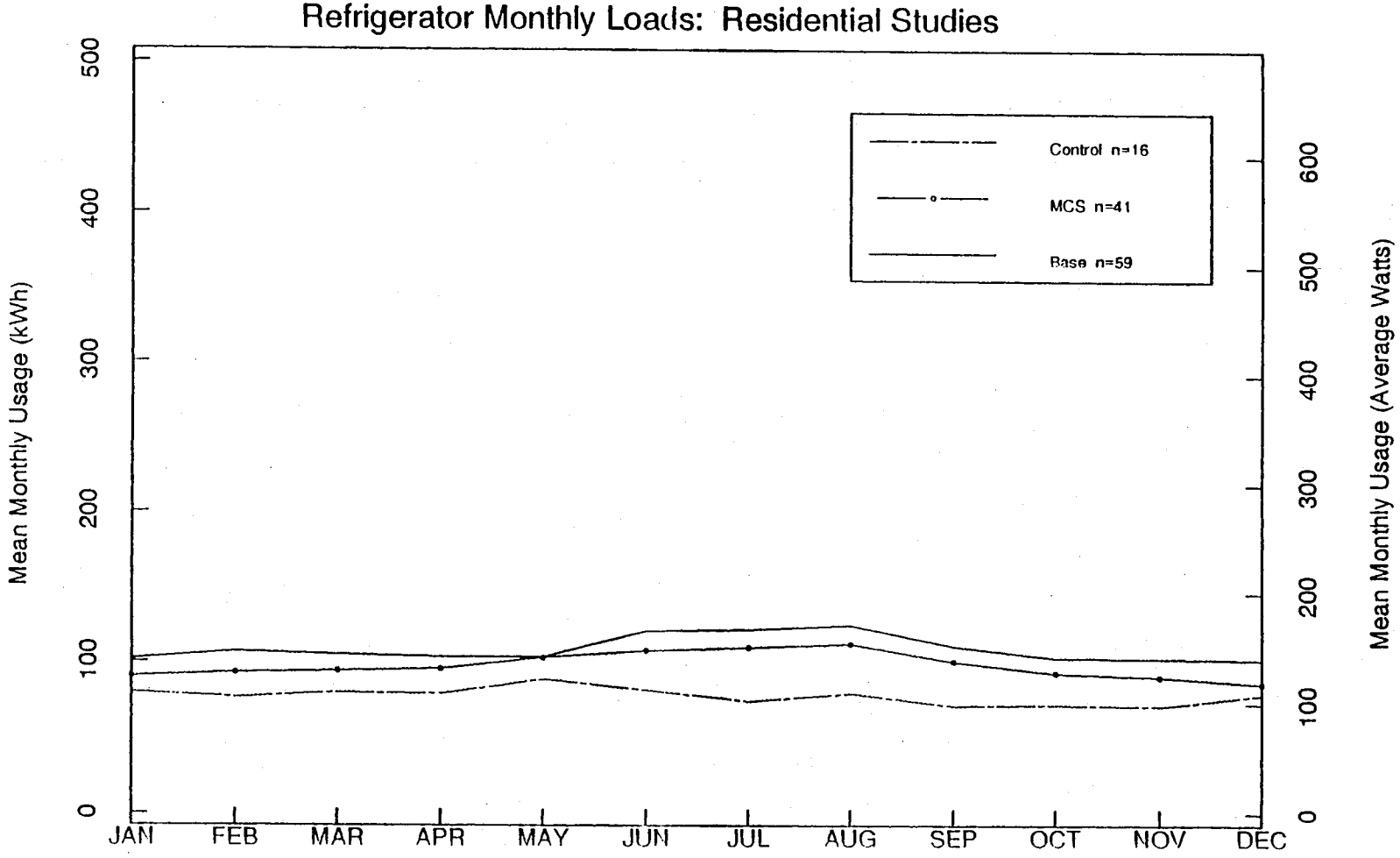
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.2



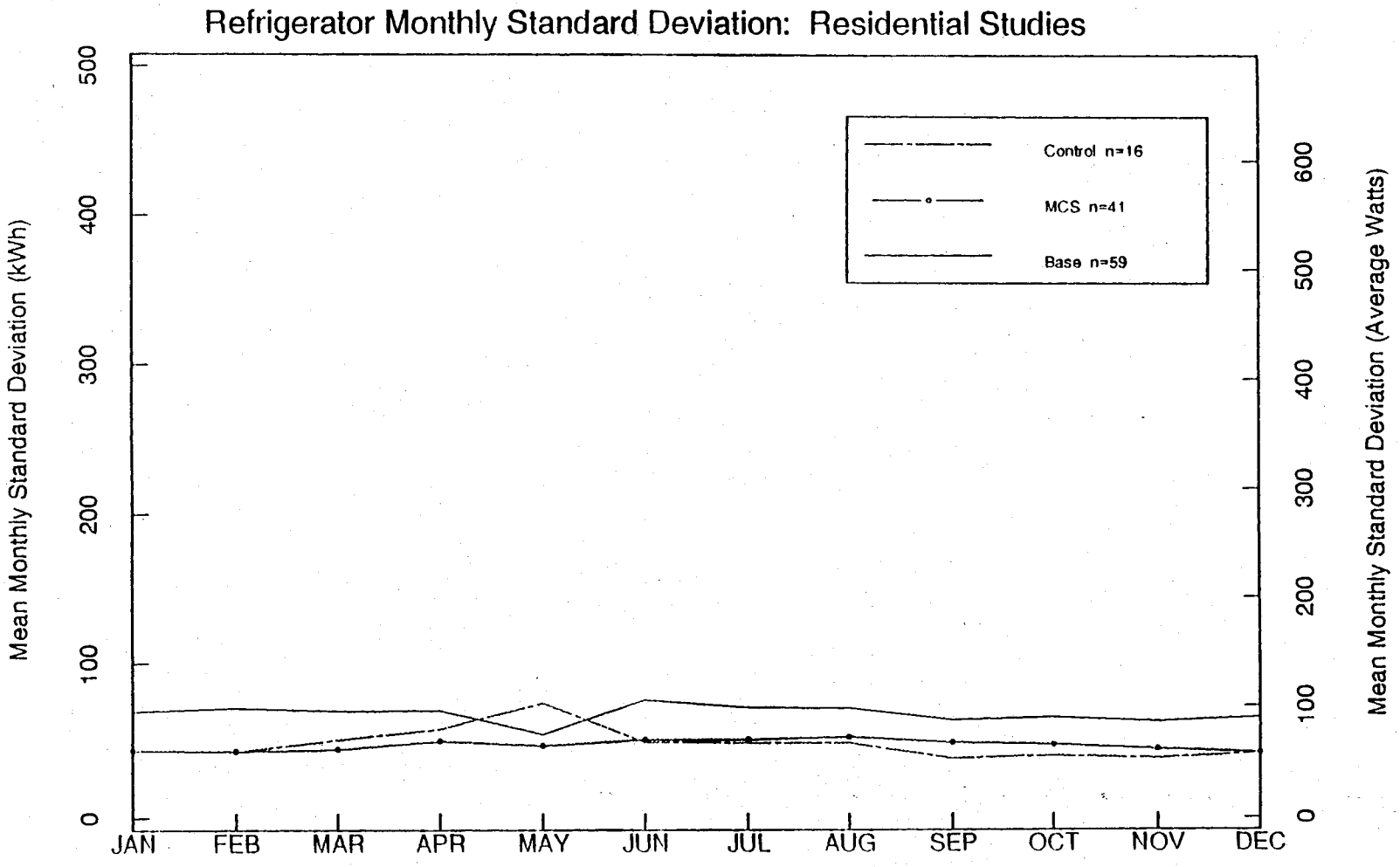
Data: ELCAP RES PADS Sept'84 - May'88 - RES EU Tables - October 1988

FIGURE 7H.3



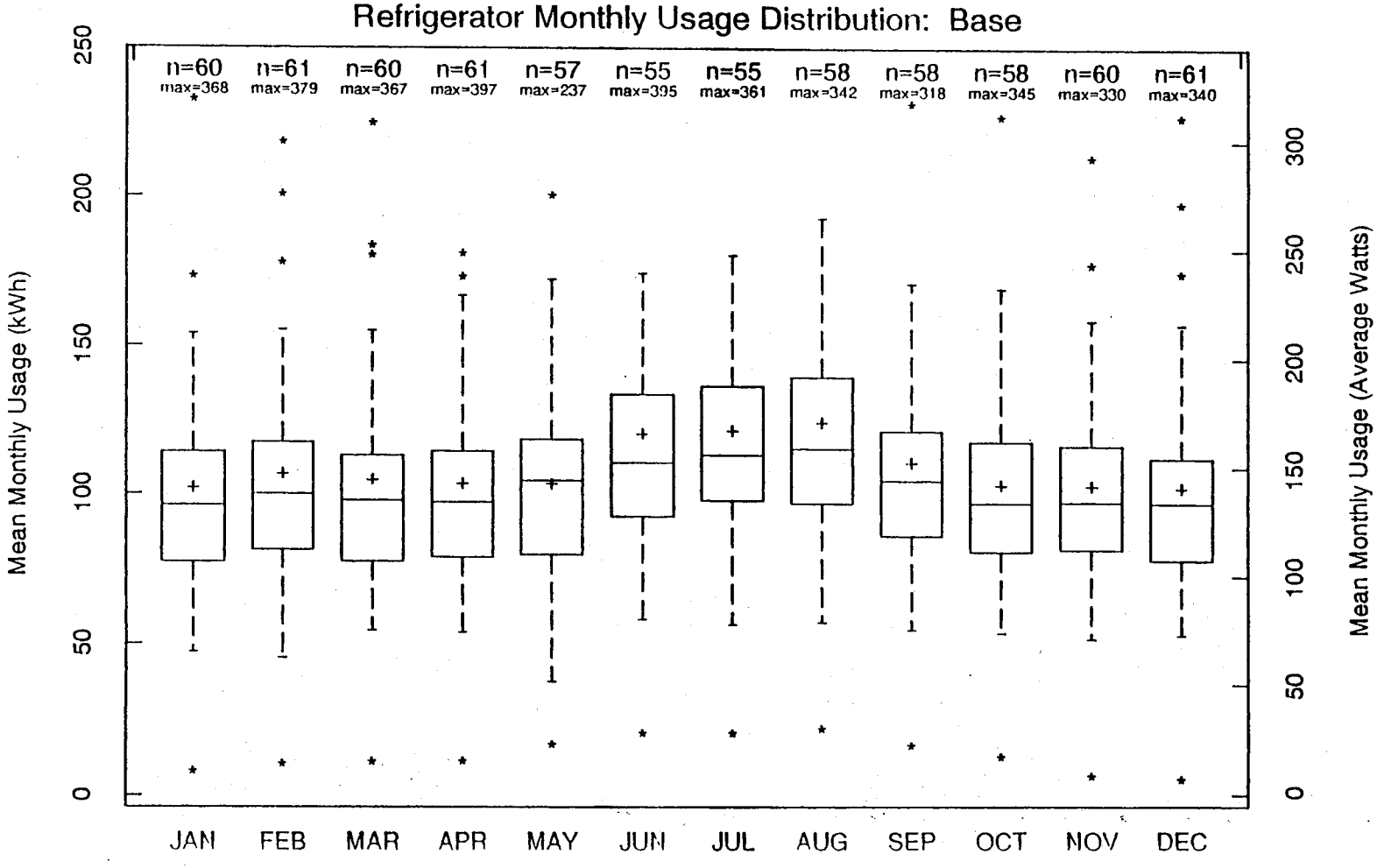
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.4



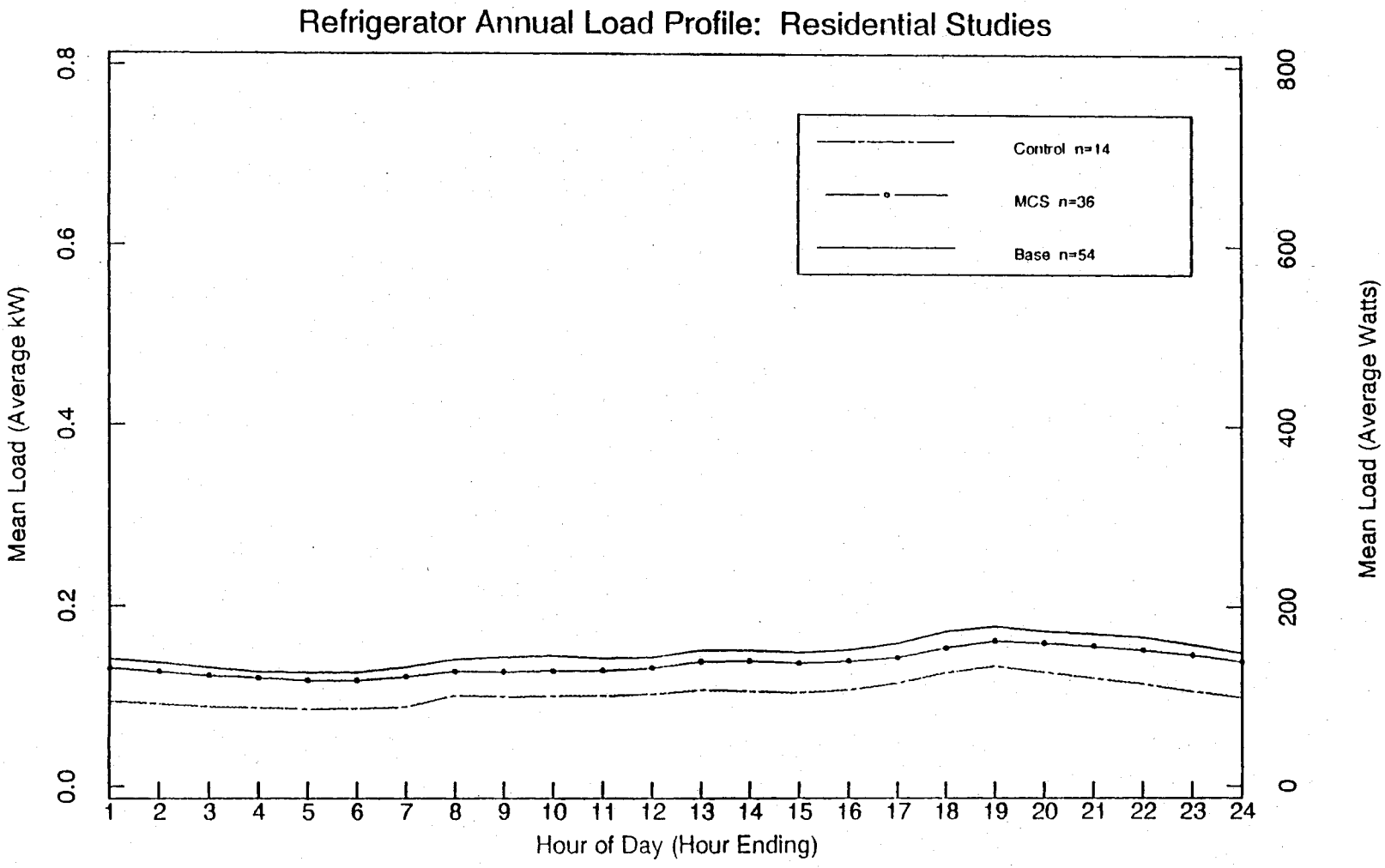
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

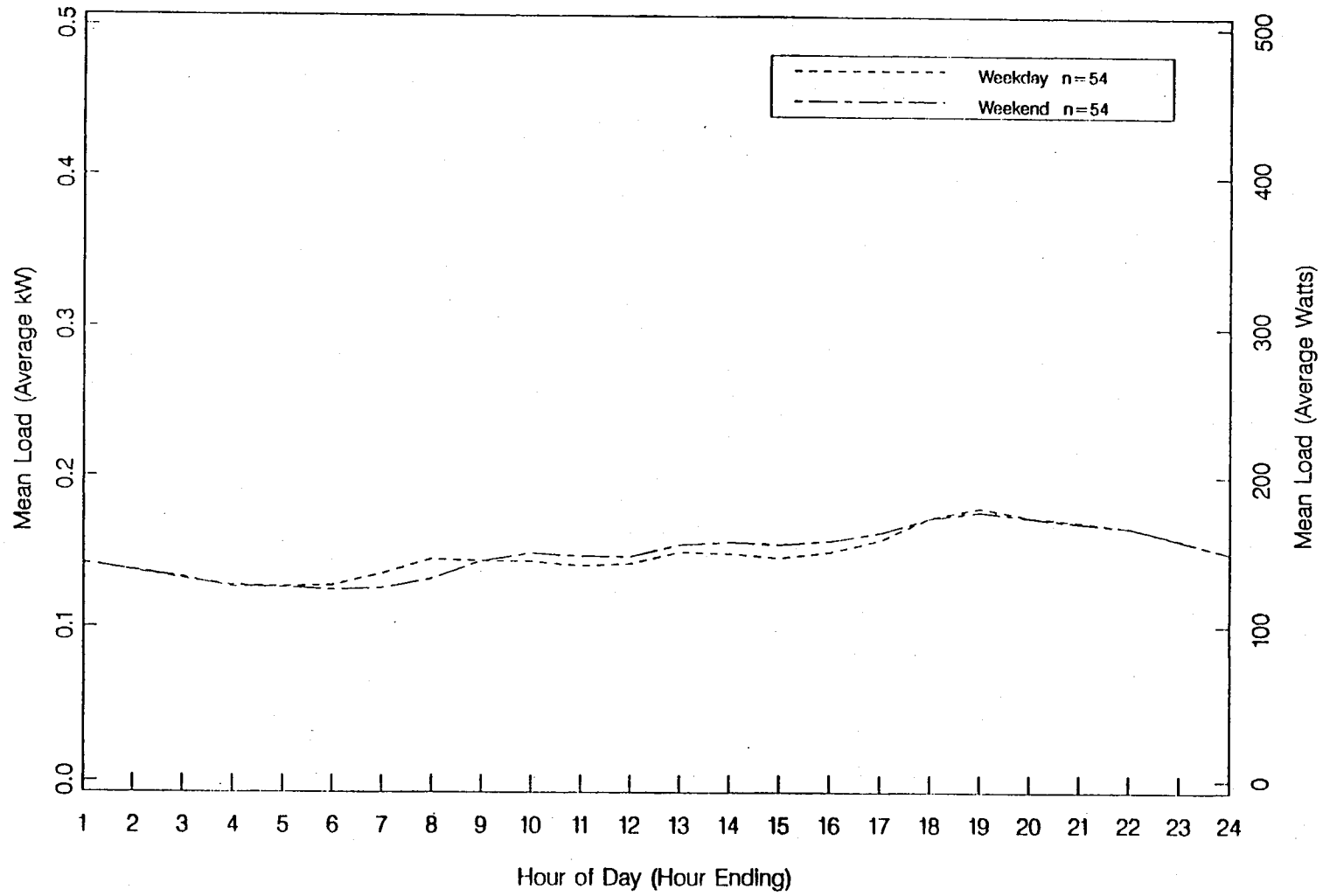
FIGURE 7H.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

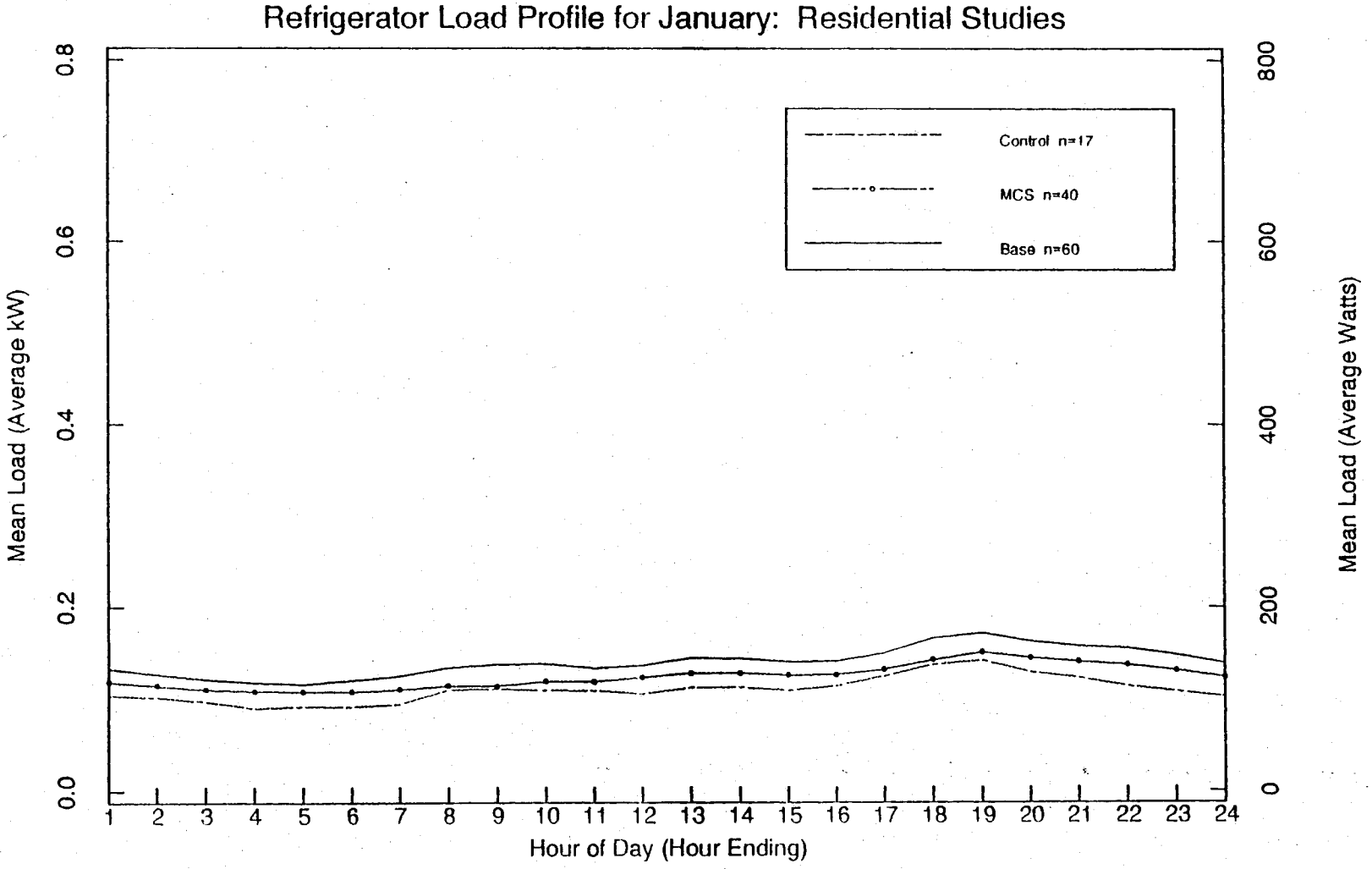
FIGURE 7H.7

Refrigerator Annual Weekday/Weekend Load Profiles: Base



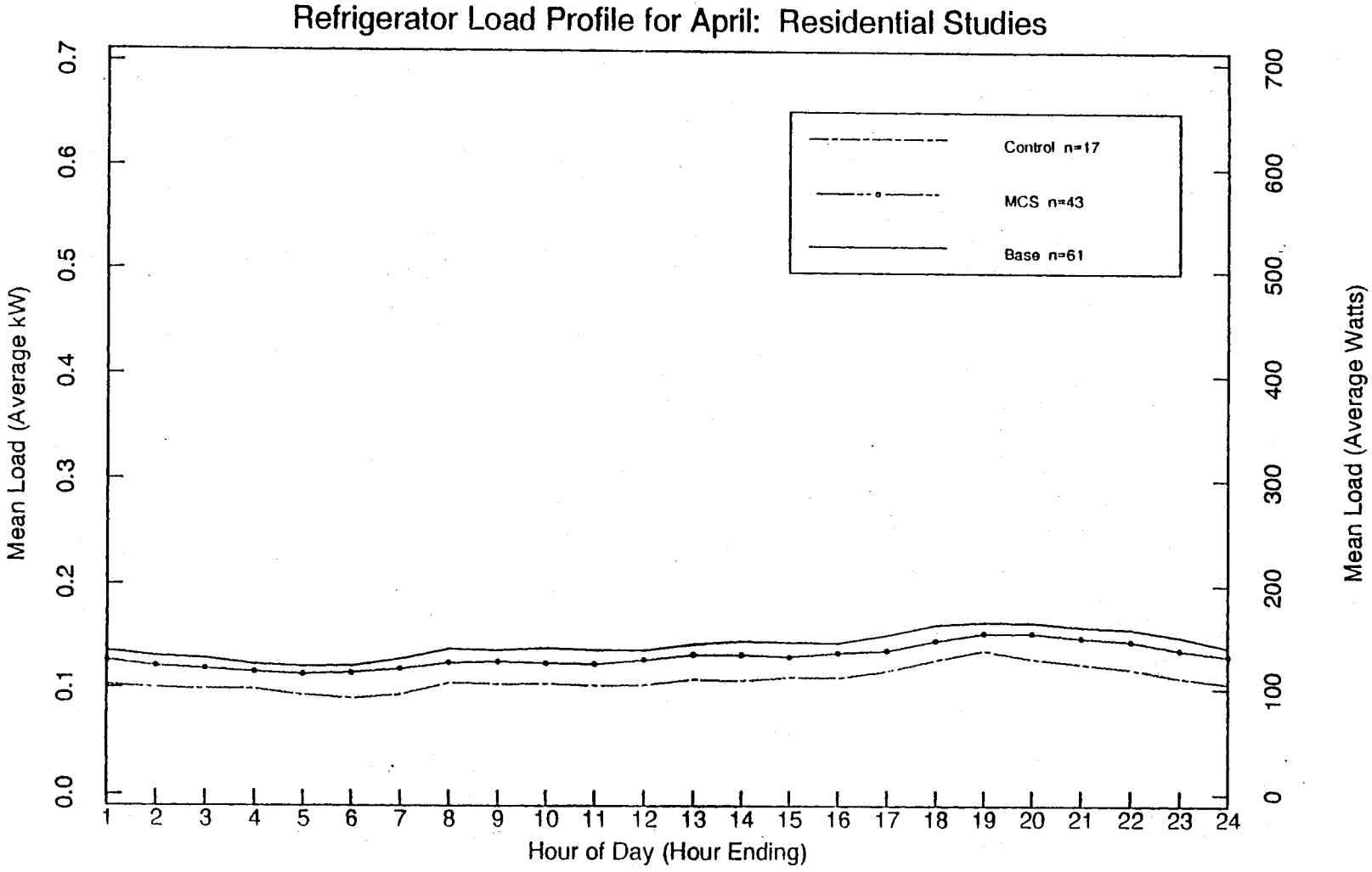
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7H.8(a)



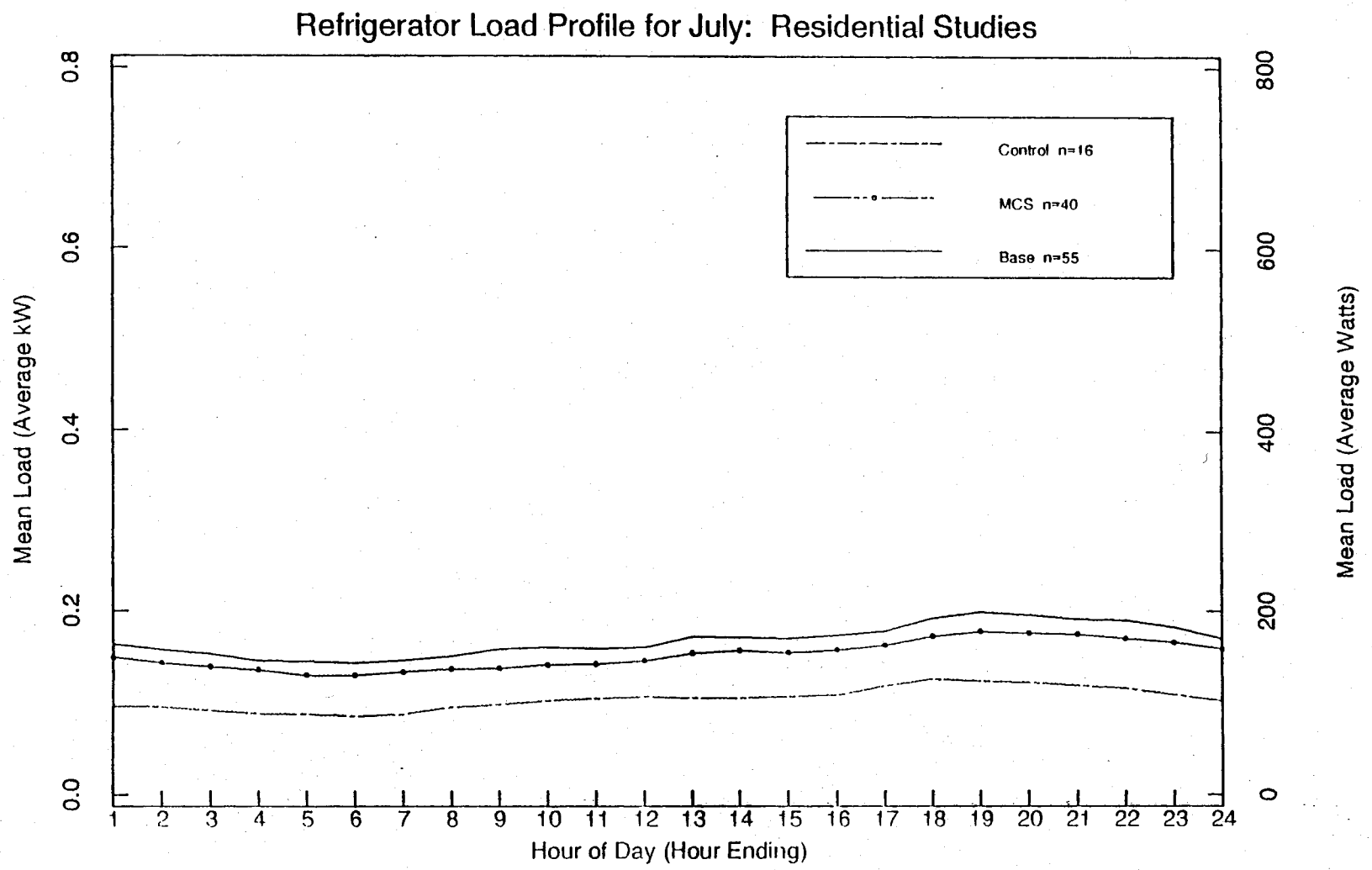
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.8(b)



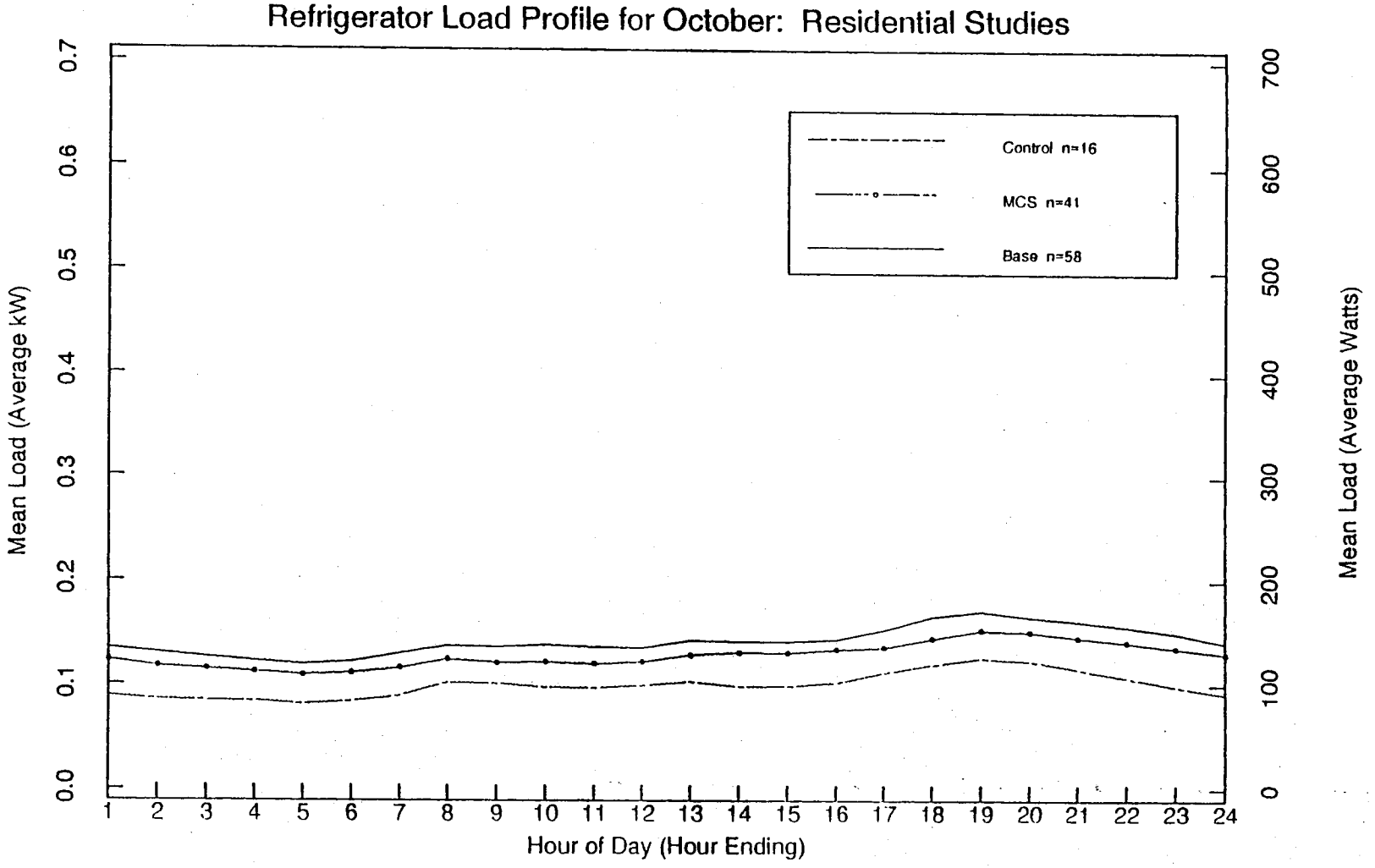
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.8(c)



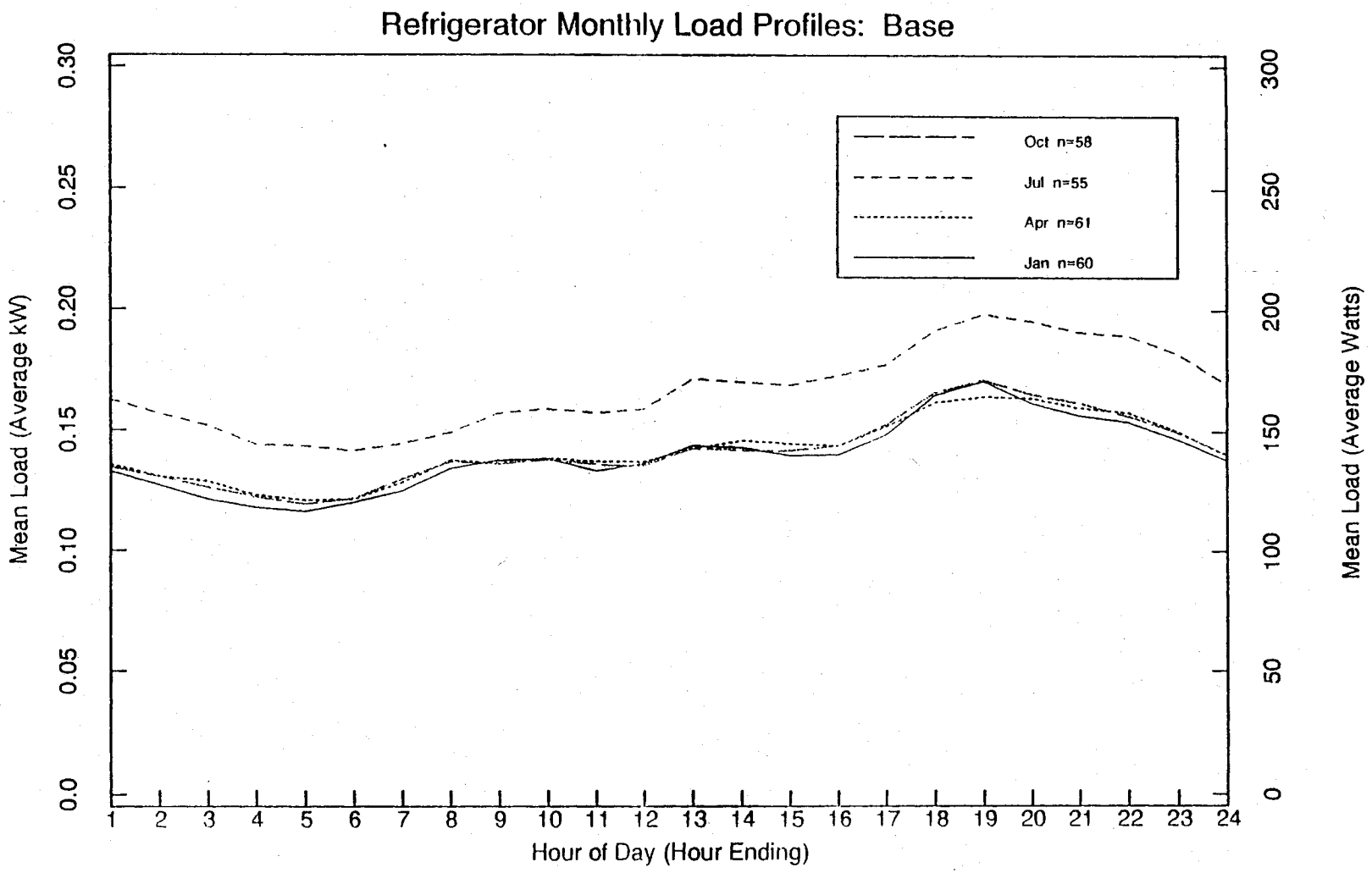
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.8(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.9(a)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.9(b)

Refrigerator Monthly Load Profiles: Renter

NO DATA TO PLOT

FIGURE 7H.9(c)

Refrigerator Monthly Load Profiles: Manufactured

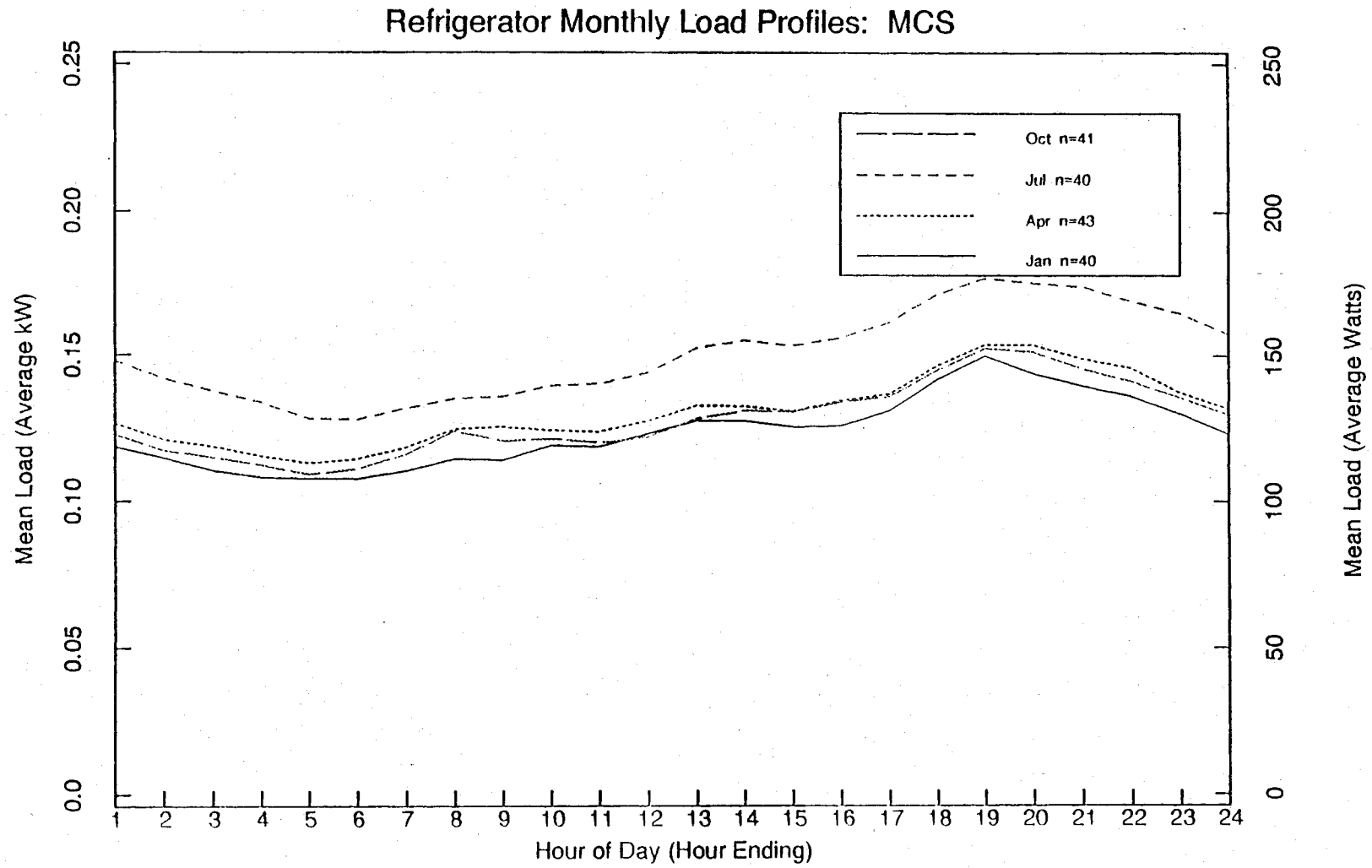
NO DATA TO PLOT

FIGURE 7H.9(d)

Refrigerator Monthly Load Profiles: Gas/Oil

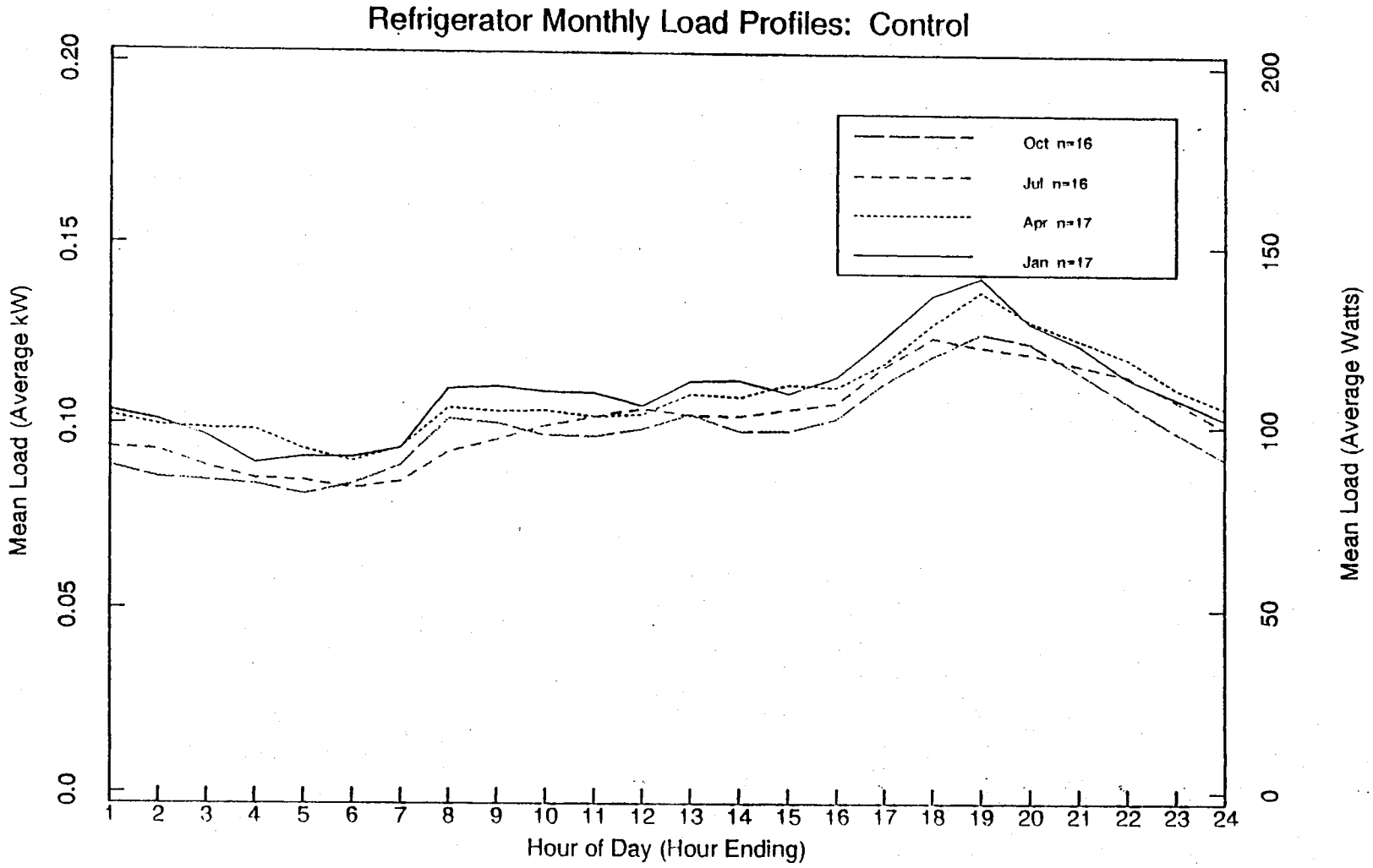
NO DATA TO PLOT

FIGURE 7H.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

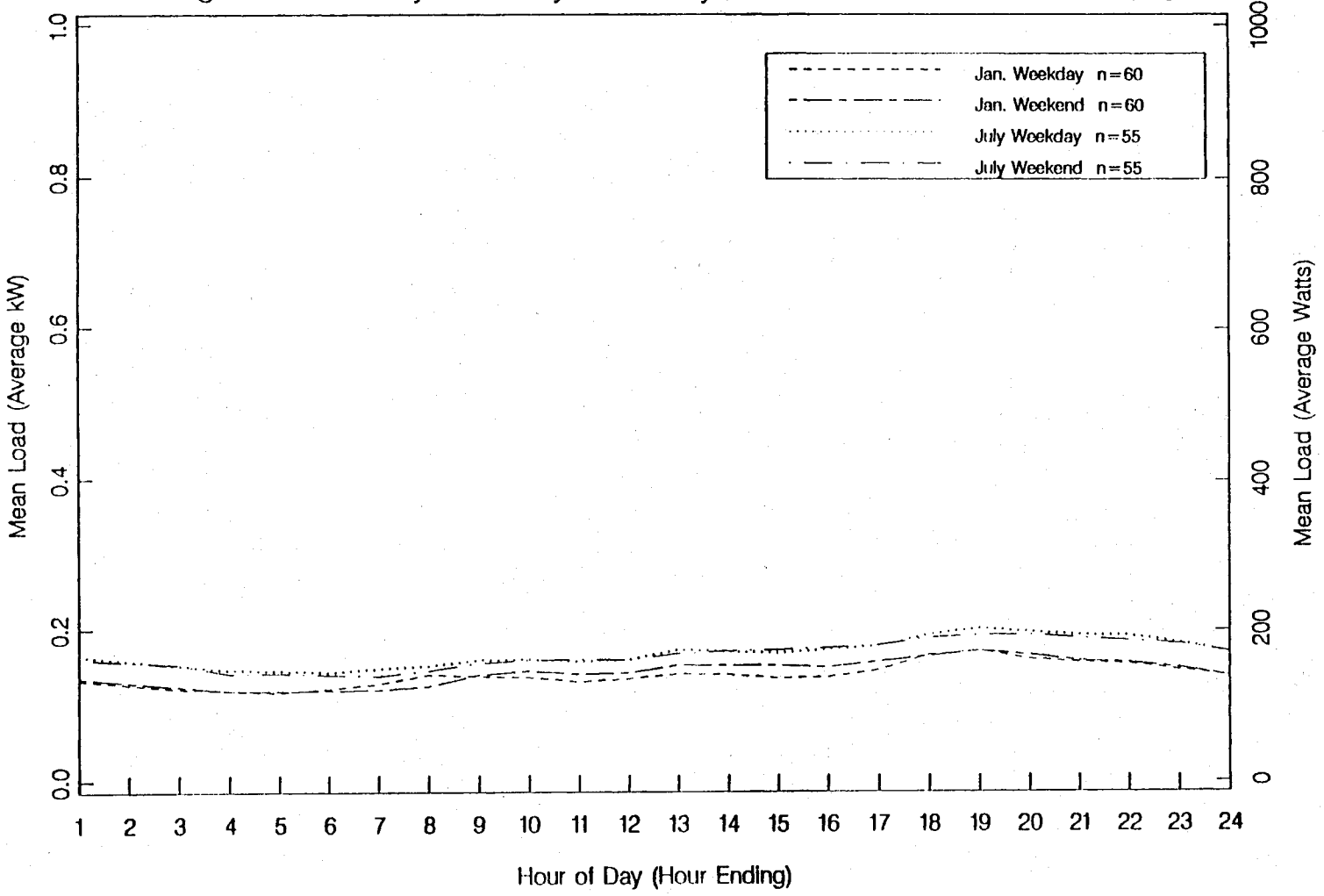
FIGURE 7H.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7H.10(a)

Refrigerator January and July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7H.10(b)

Refrigerator January and July Weekday/Weekend Load Profiles: Renter

NO DATA TO PLOT

FIGURE 7H.10(c)

Refrigerator January and July Weekday/Weekend Load Profiles: Manufactured

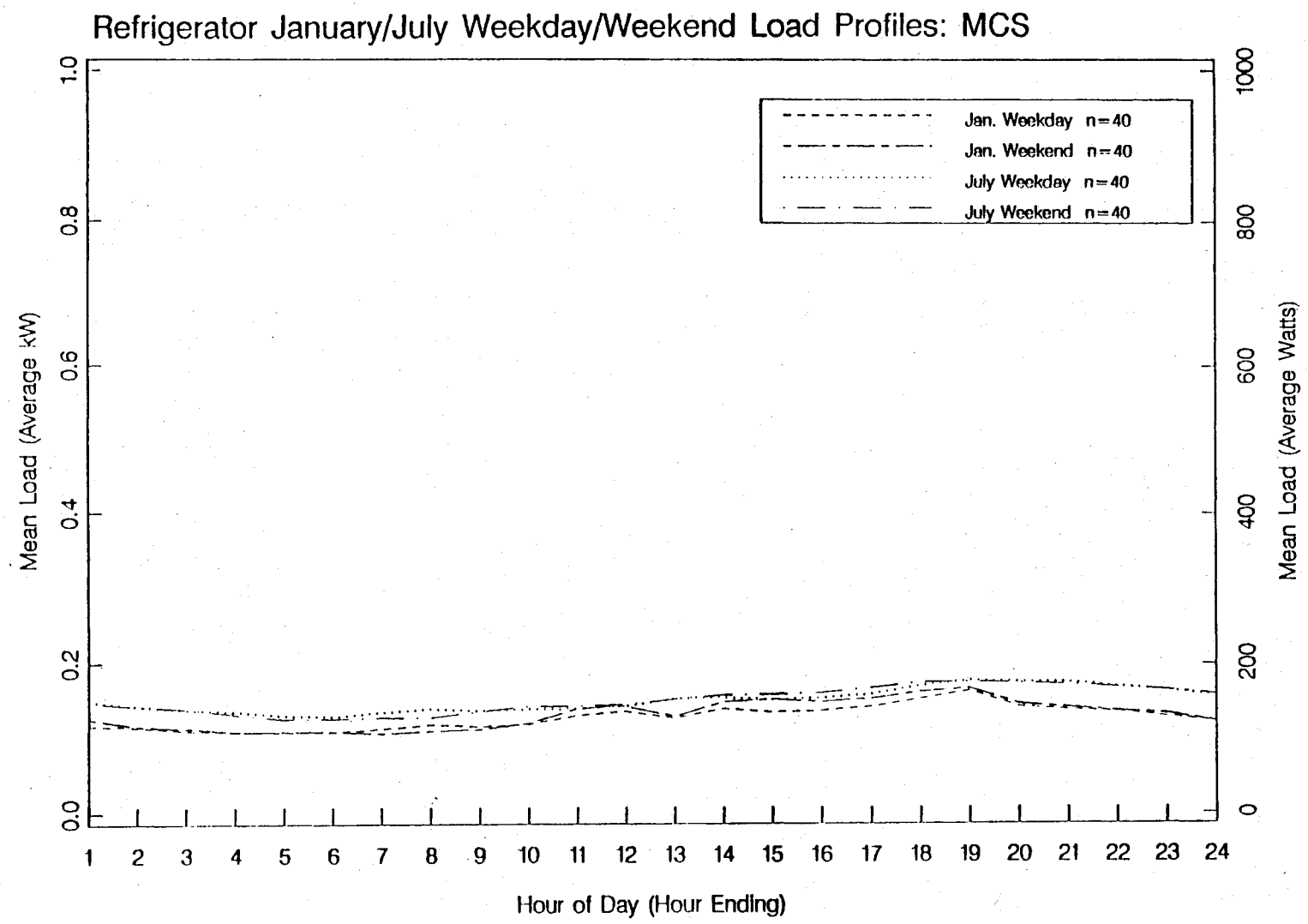
NO DATA TO PLOT

FIGURE 7H.10(d)

Refrigerator January and July Weekday/Weekend Load Profiles: Gas/Oil

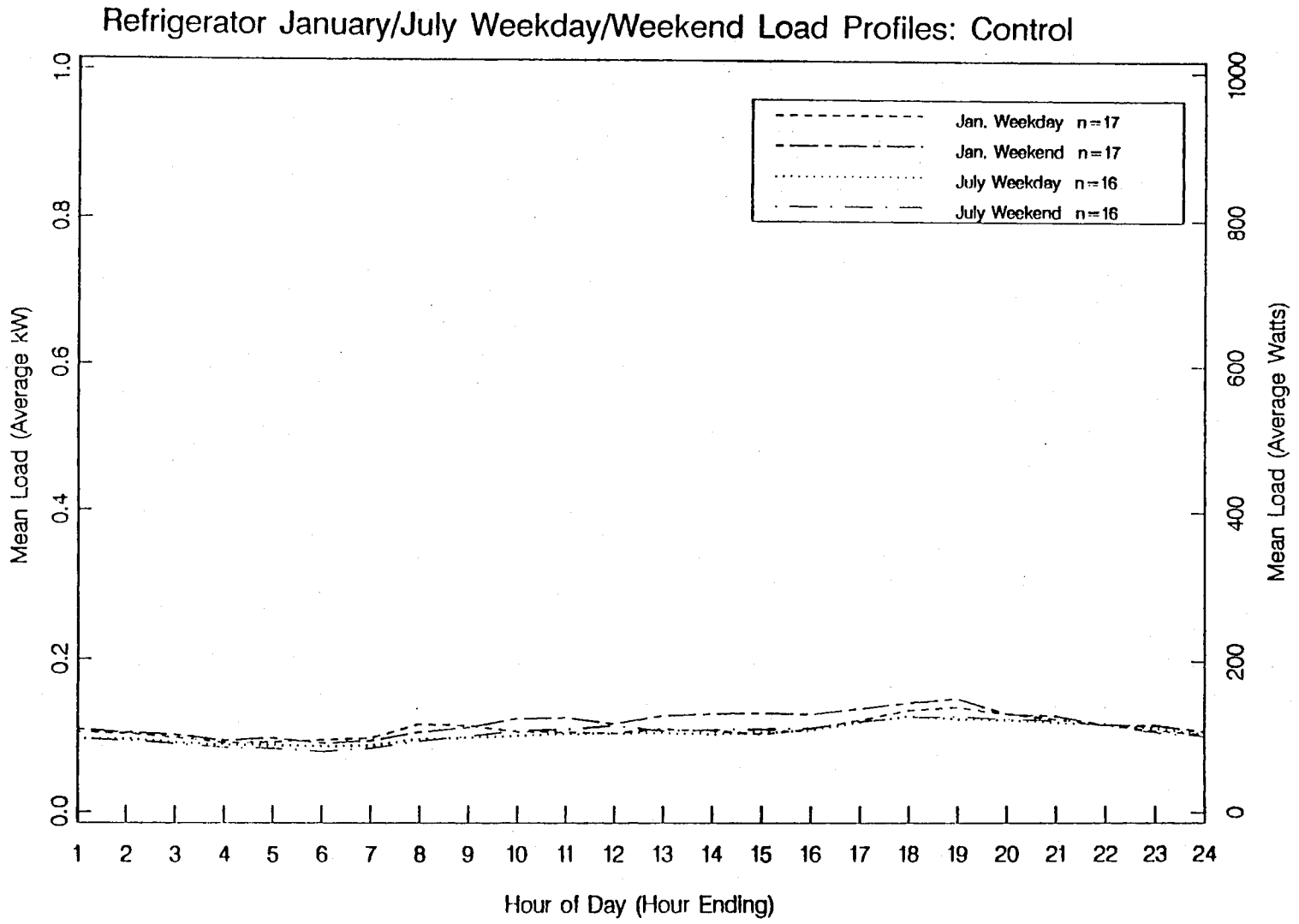
NO DATA TO PLOT

FIGURE 7H.10(e)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7H.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7H.11

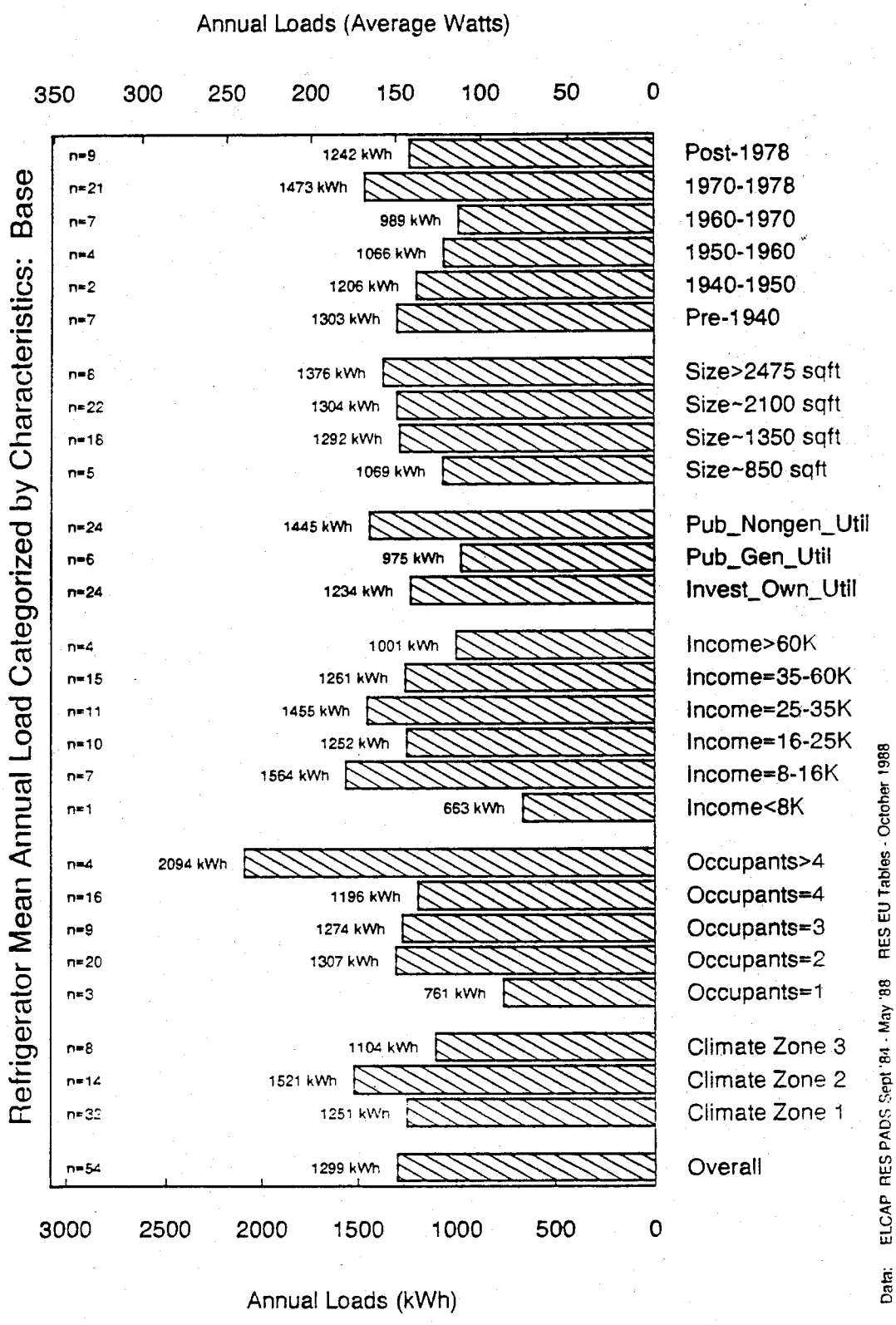
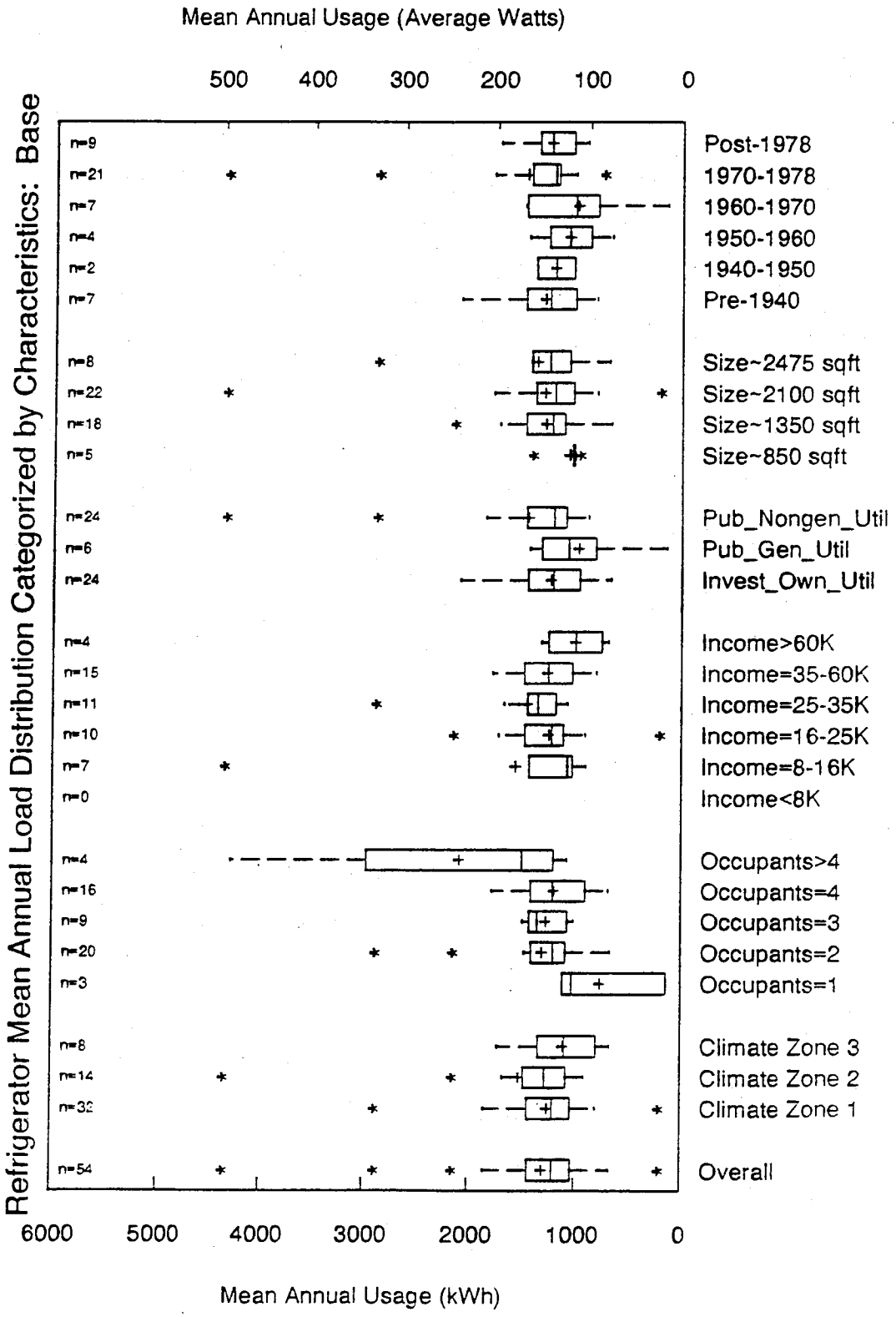

Refrigerator Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
350 300 250 200 150 100 50 0
n=9 1242 kWh Post-1978
n=21 1473 kWh 1970-1978
n=7 989 kWh 1960-1970
n=4 1066 kWh 1950-1960
n=2 1206 kWh 1940-1950
n=7 1303 kWh Pre-1940
n=6 1376 kWh Size>2475 sqft
n=22 1304 kWh Size~2100 sqft
n=16 1292 kWh Size~1350 sqft
n=5 1069 kWh Size~850 sqft
n=24 1445 kWh Pub_Nongen_Util
n=6 975 kWh Pub_Gen_Util
n=24 1234 kWh Invest_Own_Util
n=4 1001 kWh Income>60K
n=15 1261 kWh Income=35-60K
n=11 1455 kWh Income=25-35K
n=10 1252 kWh Income=16-25K
n=7 1564 kWh Income=8-16K
n=1 663 kWh Income<8K
n=4 2094 kWh Occupants>4
n=16 1196 kWh Occupants=4
n=9 1274 kWh Occupants=3
n=20 1307 kWh Occupants=2
n=3 761 kWh Occupants=1
n=8 1104 kWh Climate Zone 3
n=14 1521 kWh Climate Zone 2
n=32 1251 kWh Climate Zone 1
n=54 1299 kWh Overall
3000 2500 2000 1500 1000 500 0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7H.12



Data: ELCAP RES DADS Sept84 - May'88 RES EU Tables - October 1988

TABLE 7H.1

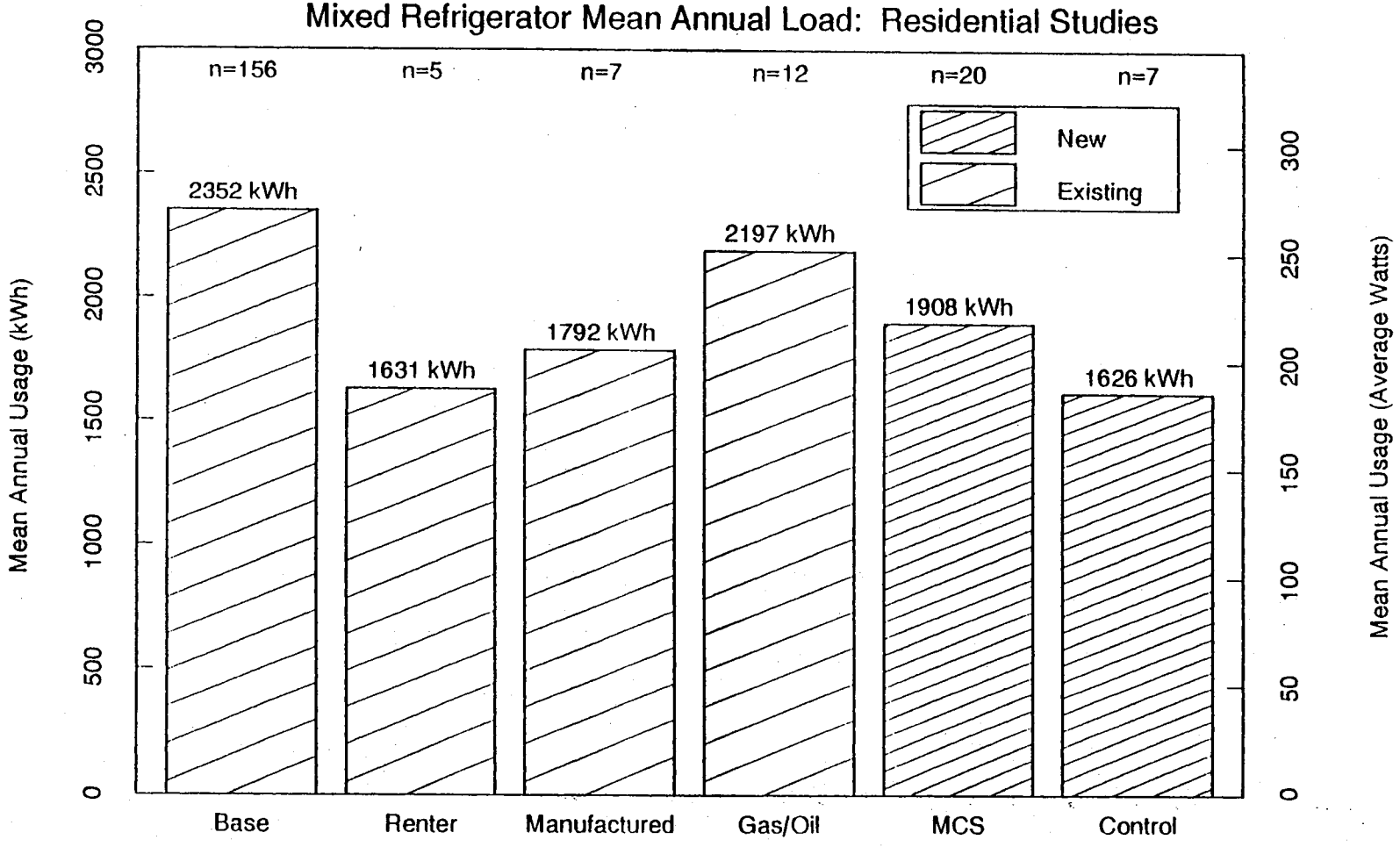
Refrigerator Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	54	1299	568	14	906	227	36	1188	329	104	1208	475
Climate Zone 1	32	1251	426	9	965	247	25	1114	297	66	1160	370
Climate Zone 2	14	1521	853	1	691	0	9	1424	308	24	1450	688
Climate Zone 3	8	1104	364	4	828	167	2	1047	486	14	1017	334
Occupants=1	3	761	538	1	1339	0	1	1605	0	5	1045	553
Occupants=2	20	1307	455	7	922	172	8	1260	284	35	1219	401
Occupants=3	9	1274	204	2	810	168	5	1007	186	16	1133	254
Occupants=4	16	1196	326	1	1098	0	4	1313	617	21	1214	374
Occupants>4	4	2094	1485	0	-	-	3	1139	438	7	1685	1194
Income<8K	1	663	0	0	-	-	0	-	-	1	663	0
Income=8-16K	7	1564	1214	1	691	0	0	-	-	8	1455	1166
Income=16-25K	10	1252	518	1	745	0	6	1144	365	17	1184	456
Income=25-35K	11	1455	485	5	1028	257	8	1120	438	24	1254	457
Income=35-60K	15	1261	262	2	1004	109	6	1398	267	23	1275	267
Income>60K	4	1001	302	1	1002	0	1	1180	0	6	1031	245
Invest_Own_Util	24	1234	358	8	968	226	20	1248	335	52	1199	341
Pub_Gen_Util	6	975	464	4	819	276	6	850	286	16	889	345
Pub_Nongen_Util	24	1445	718	2	837	129	8	1233	231	34	1359	630
Size~850 sqft	5	1089	168	0	-	-	0	-	-	5	1069	168
Size~1350 sqft	18	1292	337	9	854	221	17	1141	344	44	1144	353
Size~2100 sqft	22	1304	743	4	999	268	10	1313	368	36	1273	618
Size>2475 sqft	8	1376	637	0	-	-	6	1230	144	14	1313	482
Pre-1940	7	1303	423	0	-	-	0	-	-	7	1303	423
1940-1950	2	1206	251	0	-	-	0	-	-	2	1206	251
1950-1960	4	1066	322	0	-	-	0	-	-	4	1066	322
1960-1970	7	989	461	0	-	-	0	-	-	7	989	461
1970-1978	21	1473	767	0	-	-	0	-	-	21	1473	767
Post-1978	9	1242	268	14	906	227	36	1188	329	59	1129	321

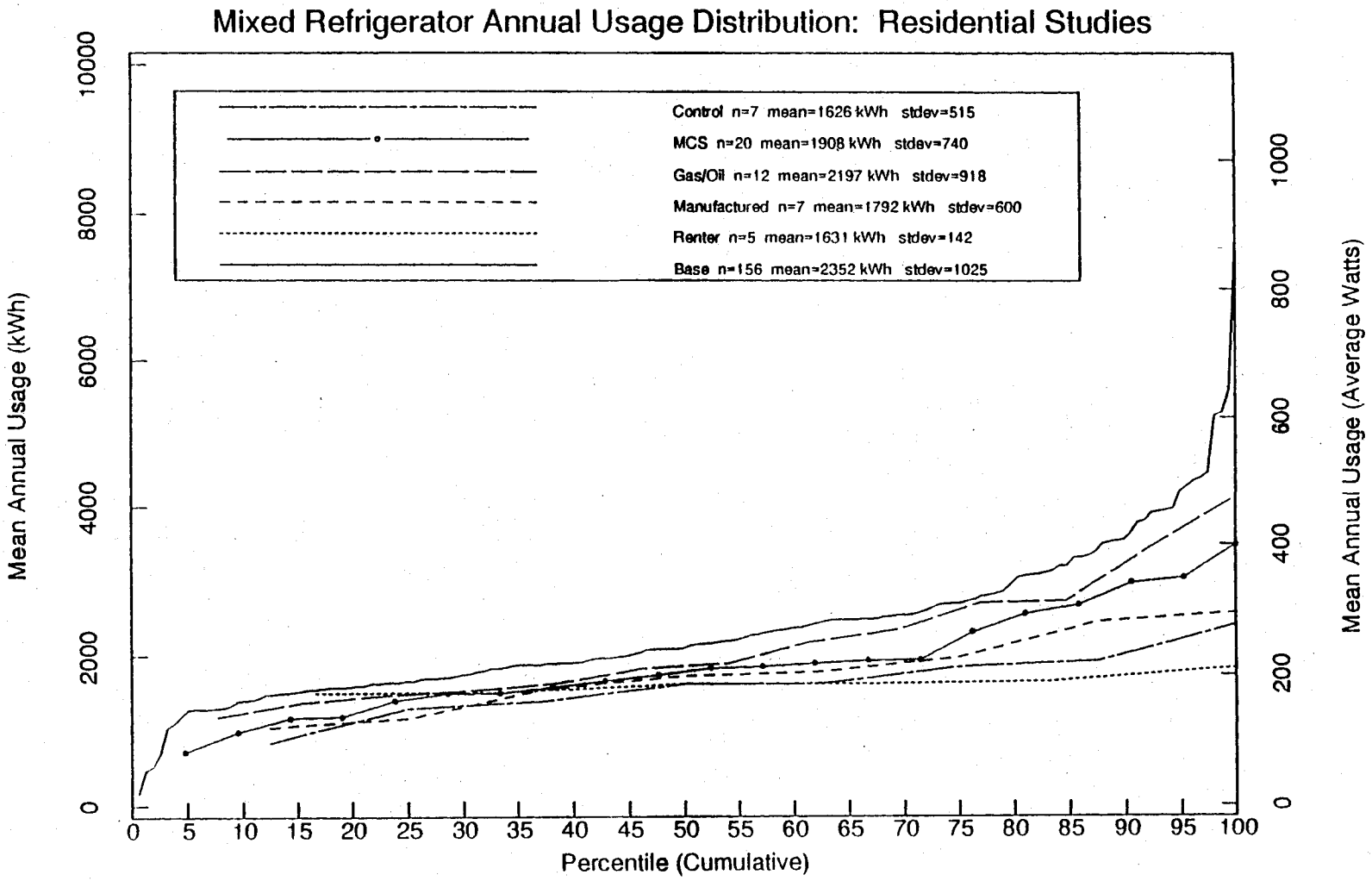
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7I.1
Mixed Refrigerator Mean Annual Load: Residential Studies



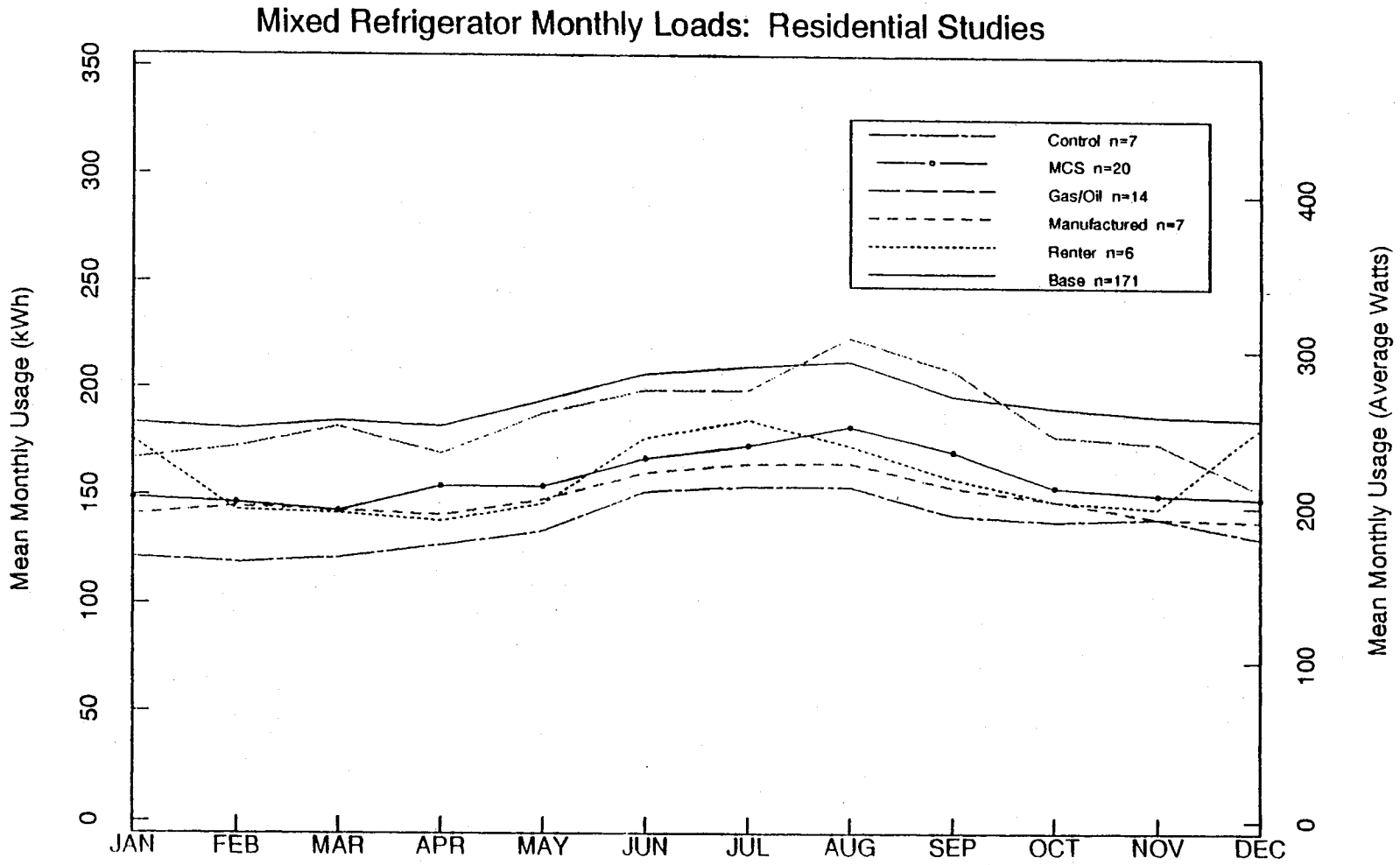
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.2



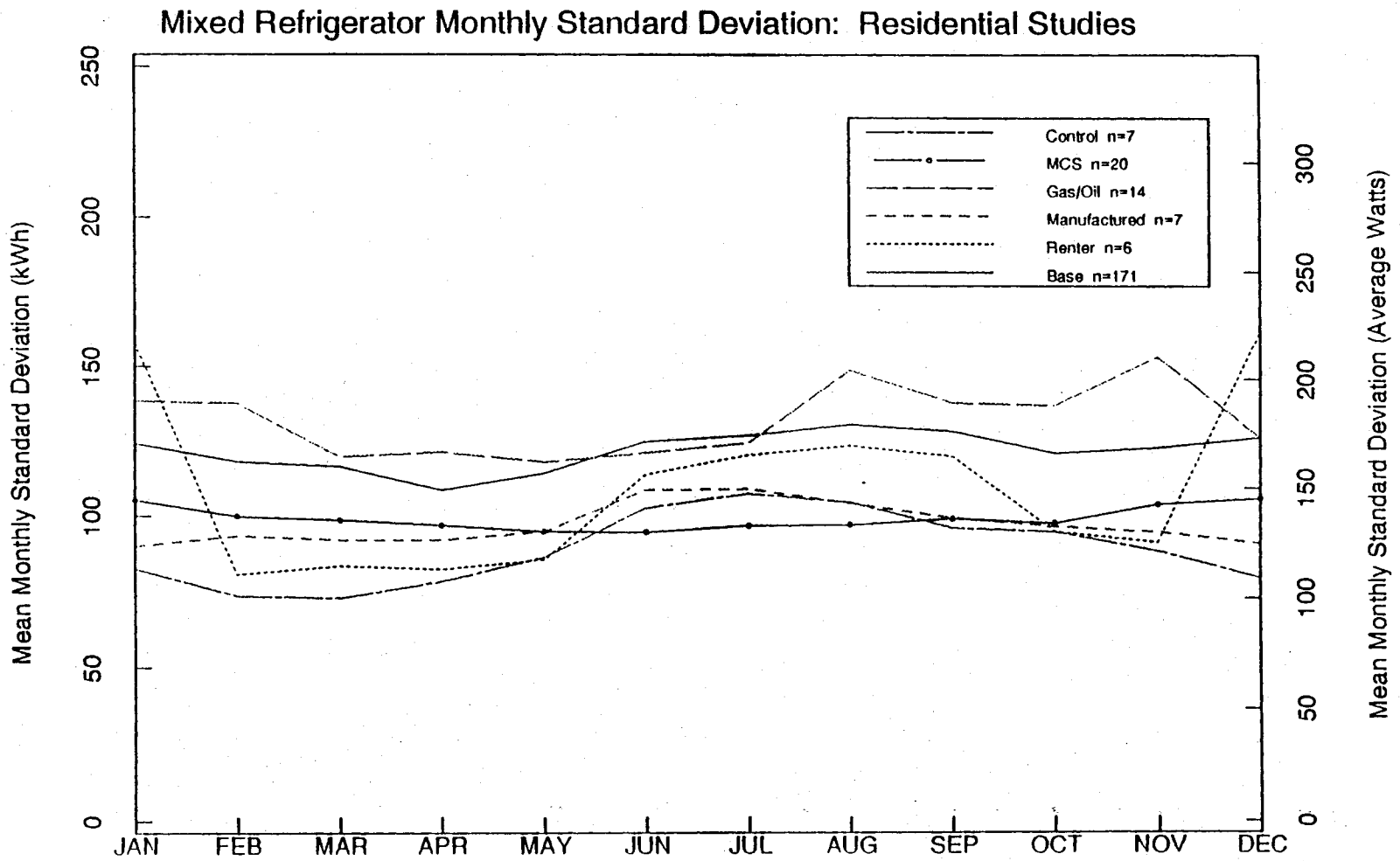
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.3



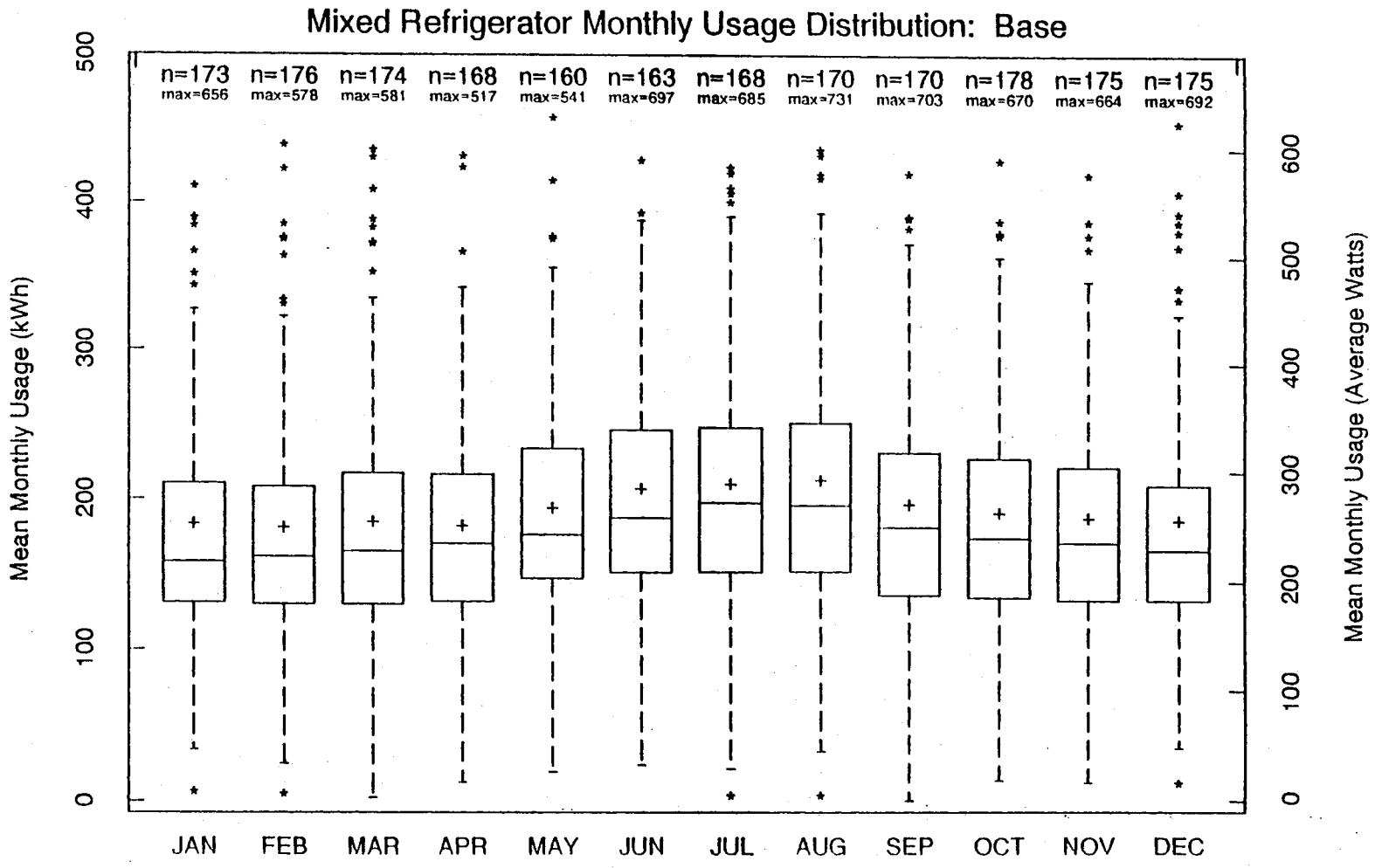
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.4



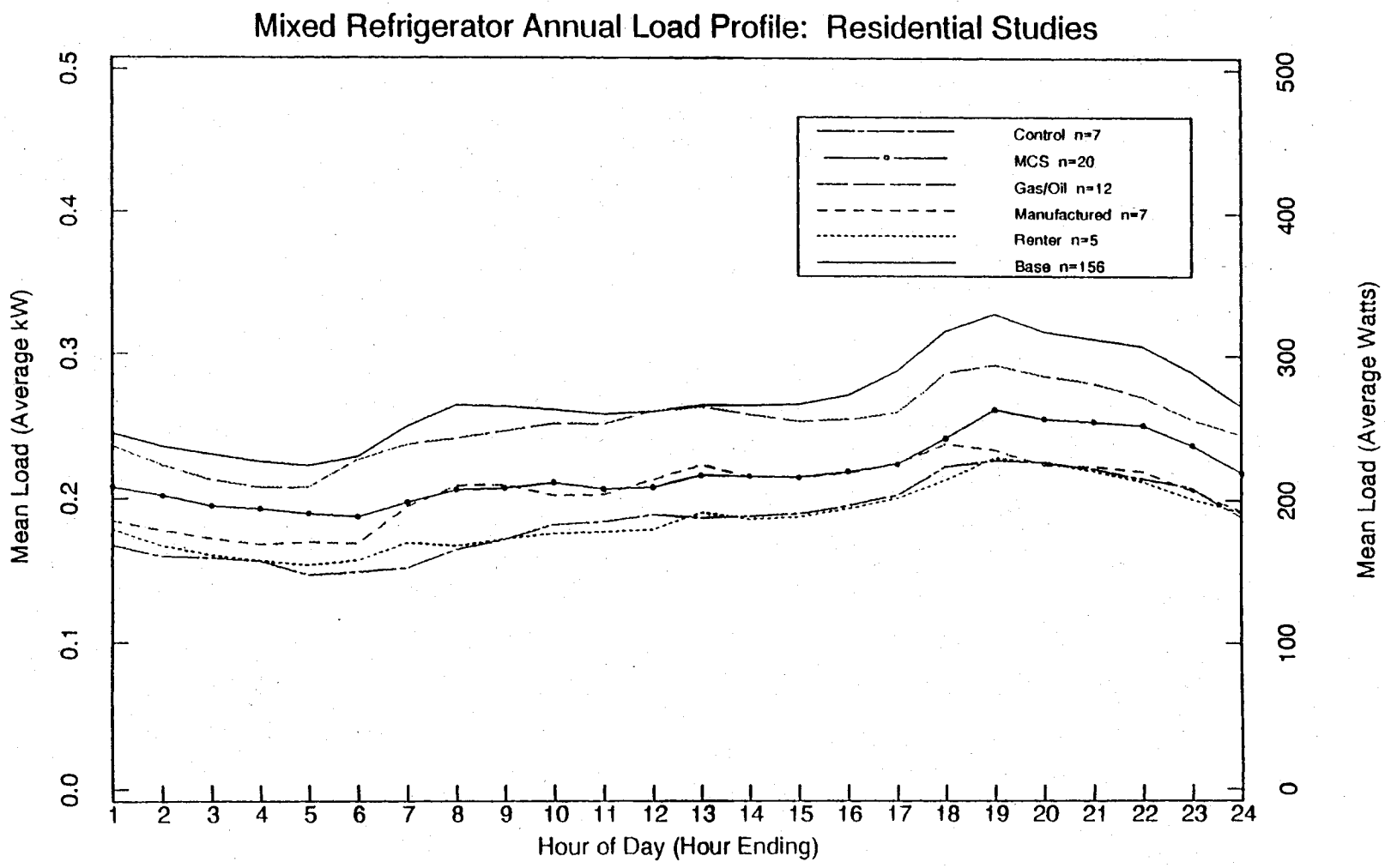
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

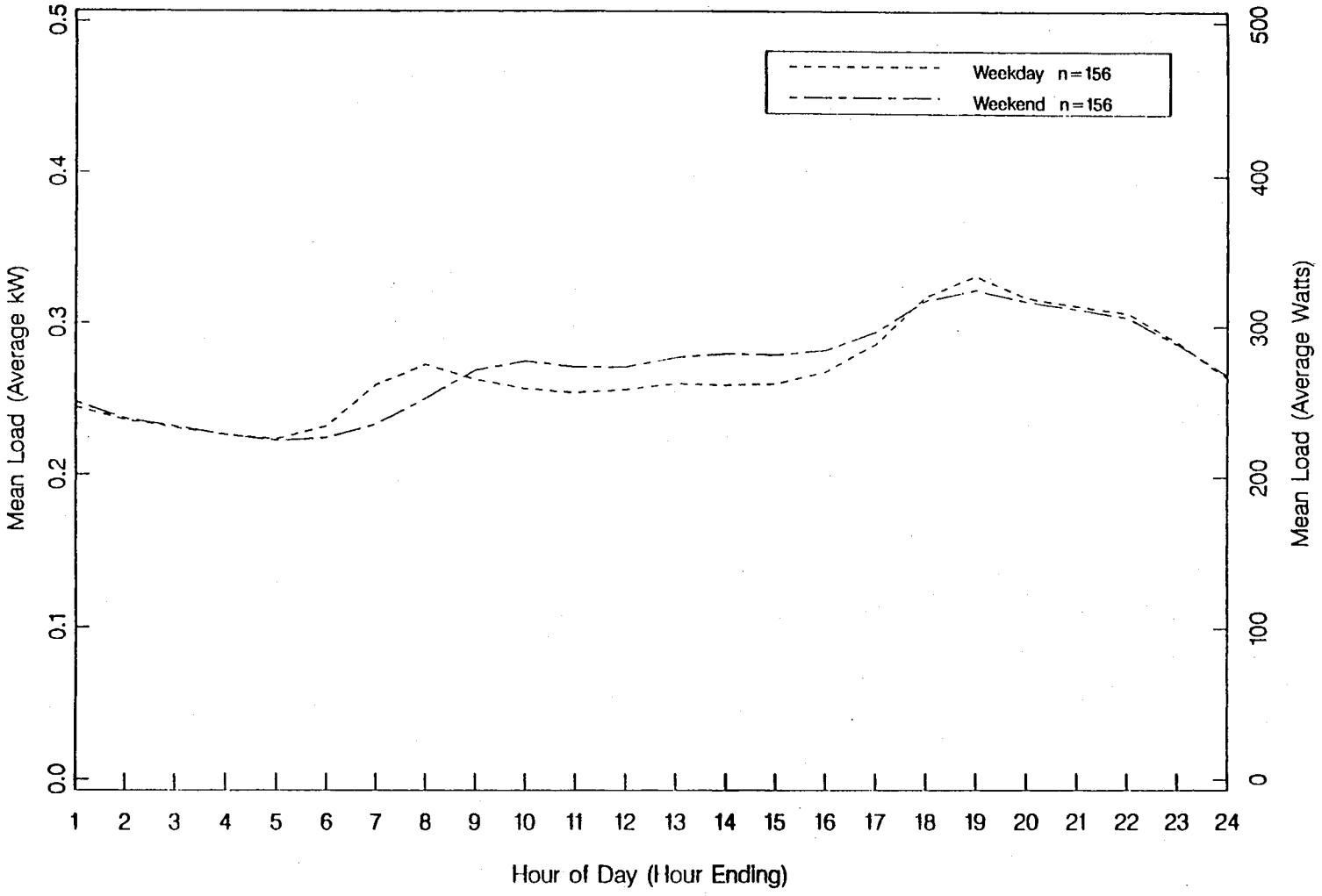
FIGURE 7I.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

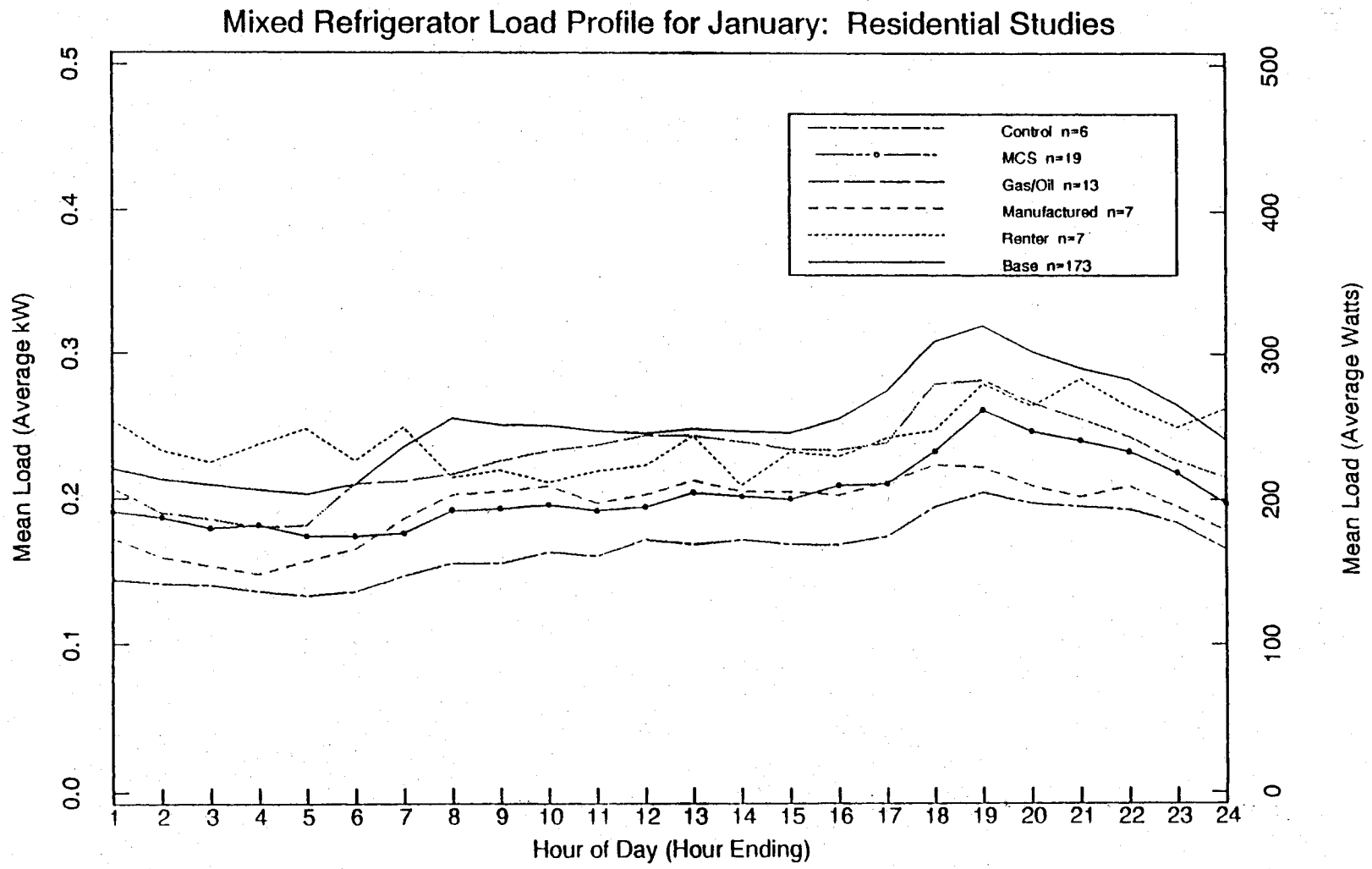
FIGURE 7I.7

Mixed Refrigerator Annual Weekday/Weekend Load Profiles: Base



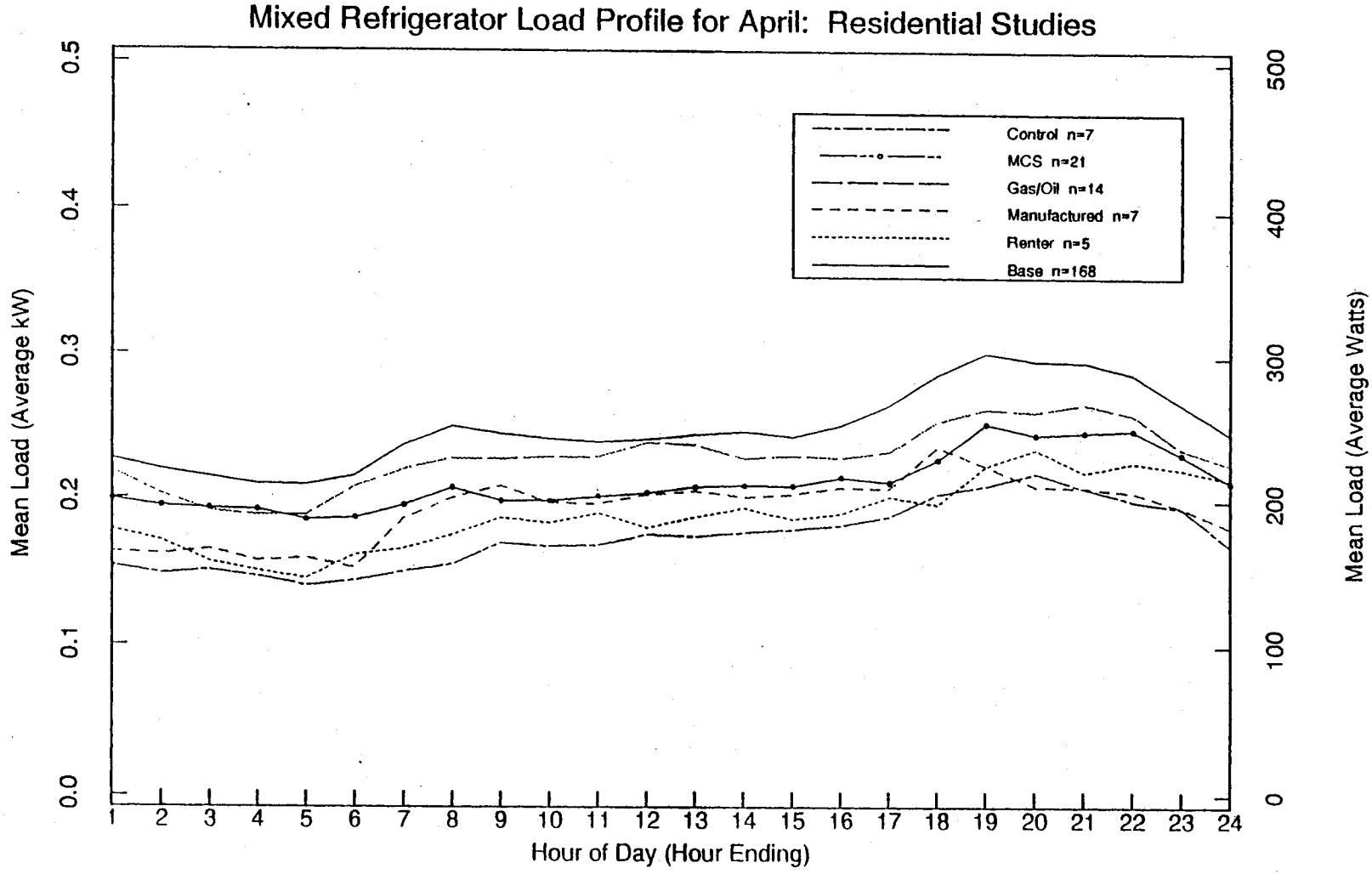
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.8(a)



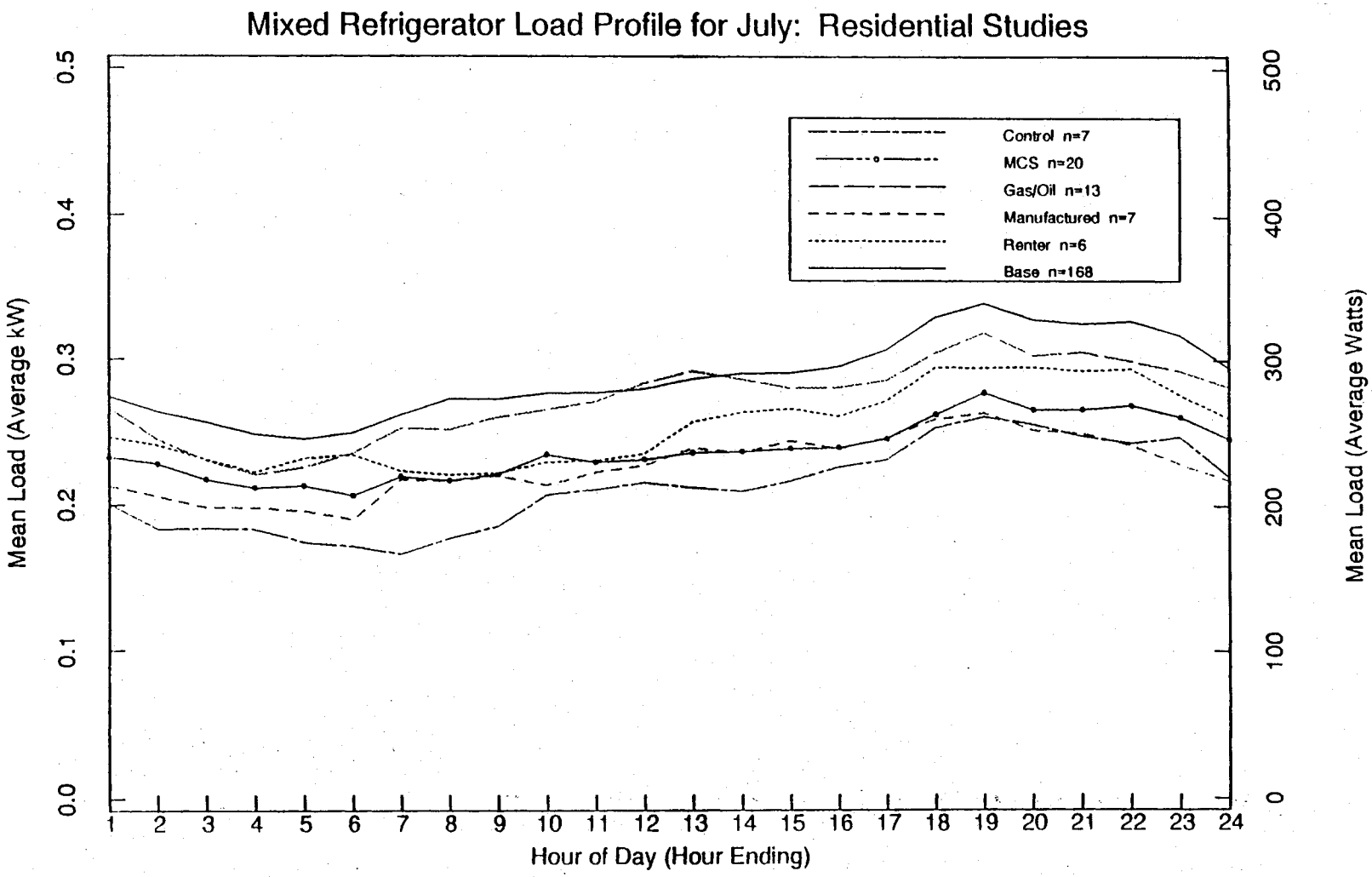
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.8(b)



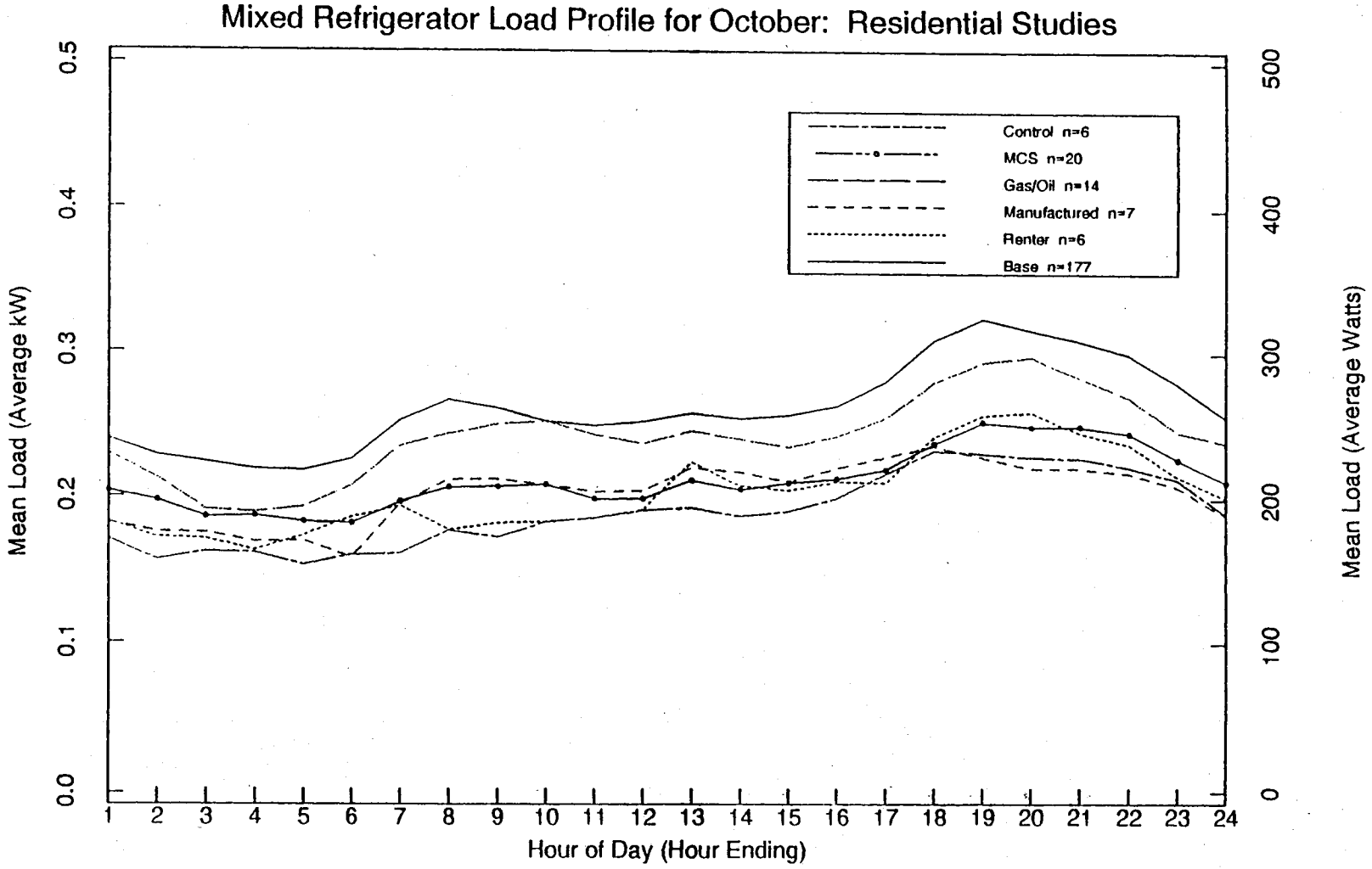
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.8(c)



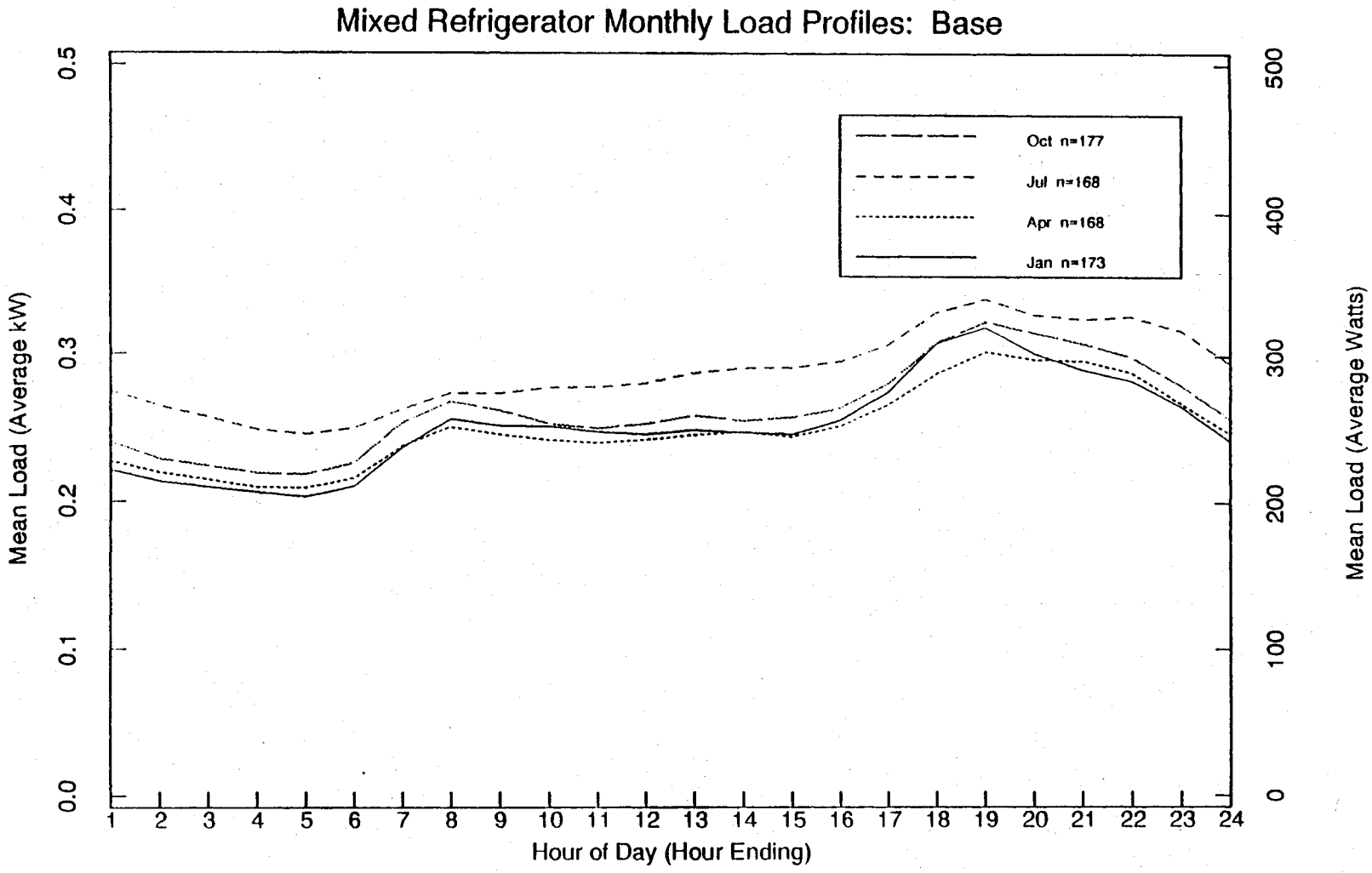
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.8(d)



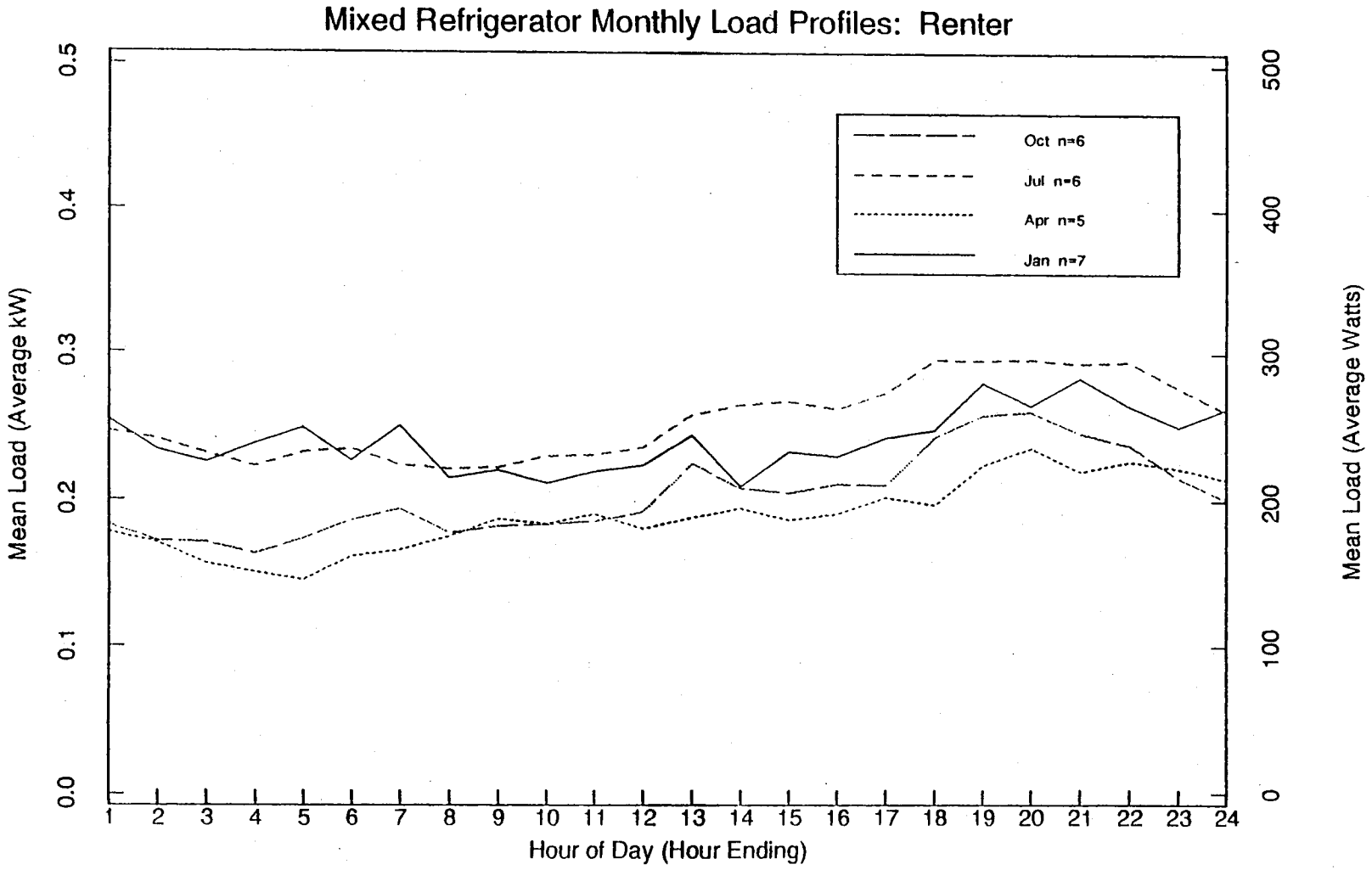
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.9(a)



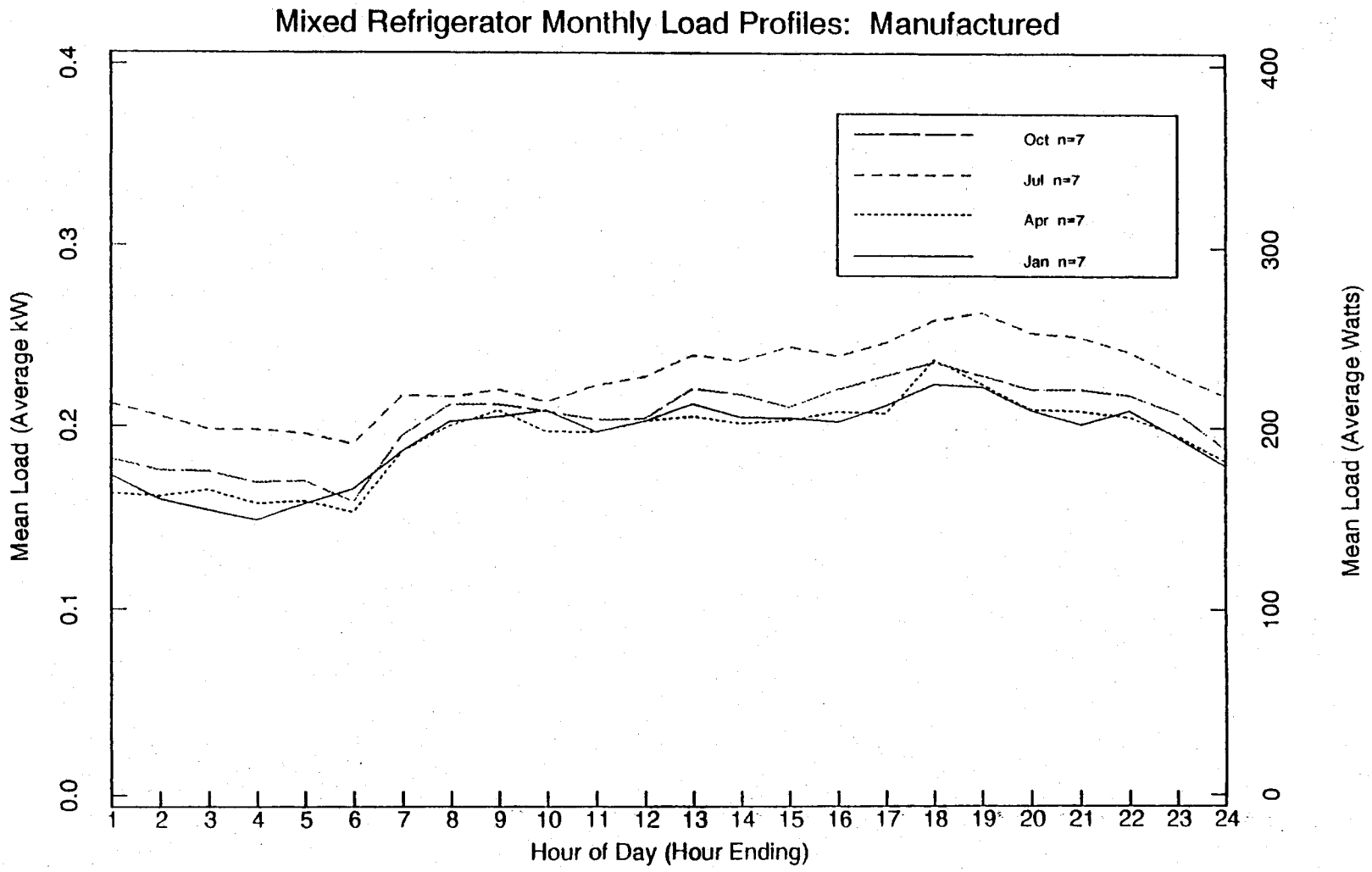
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.9(b)



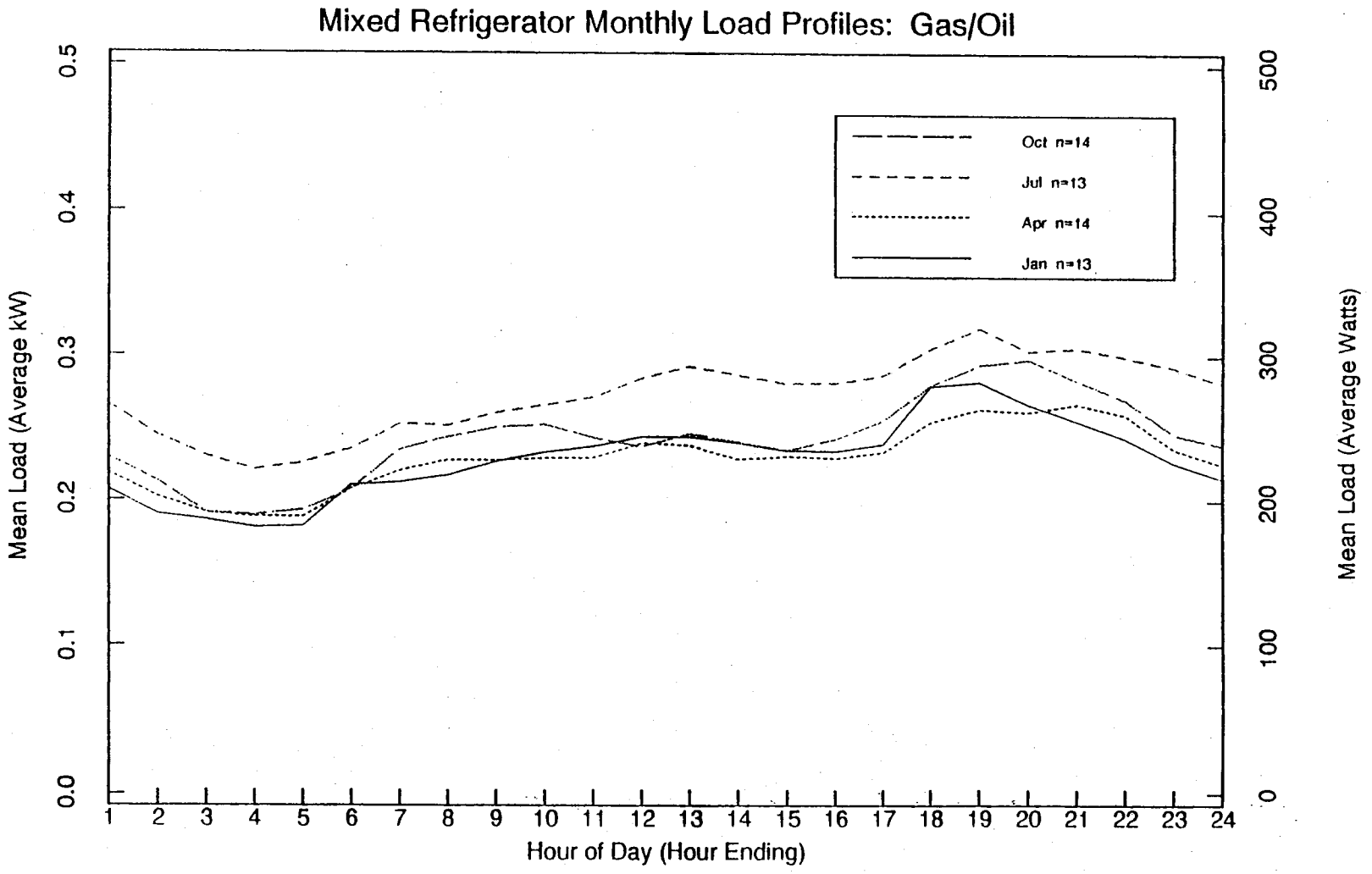
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.9(c)



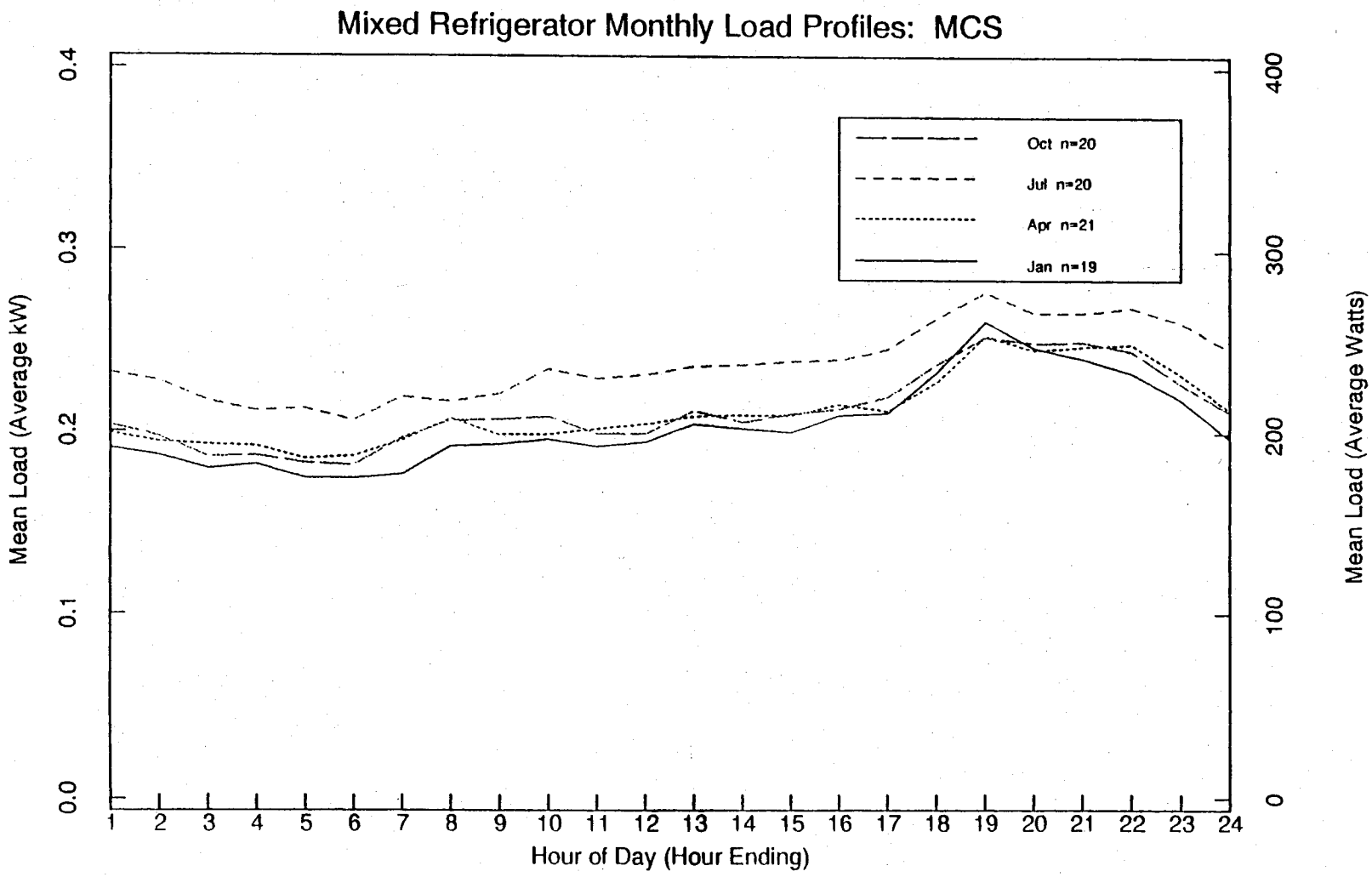
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.9(d)



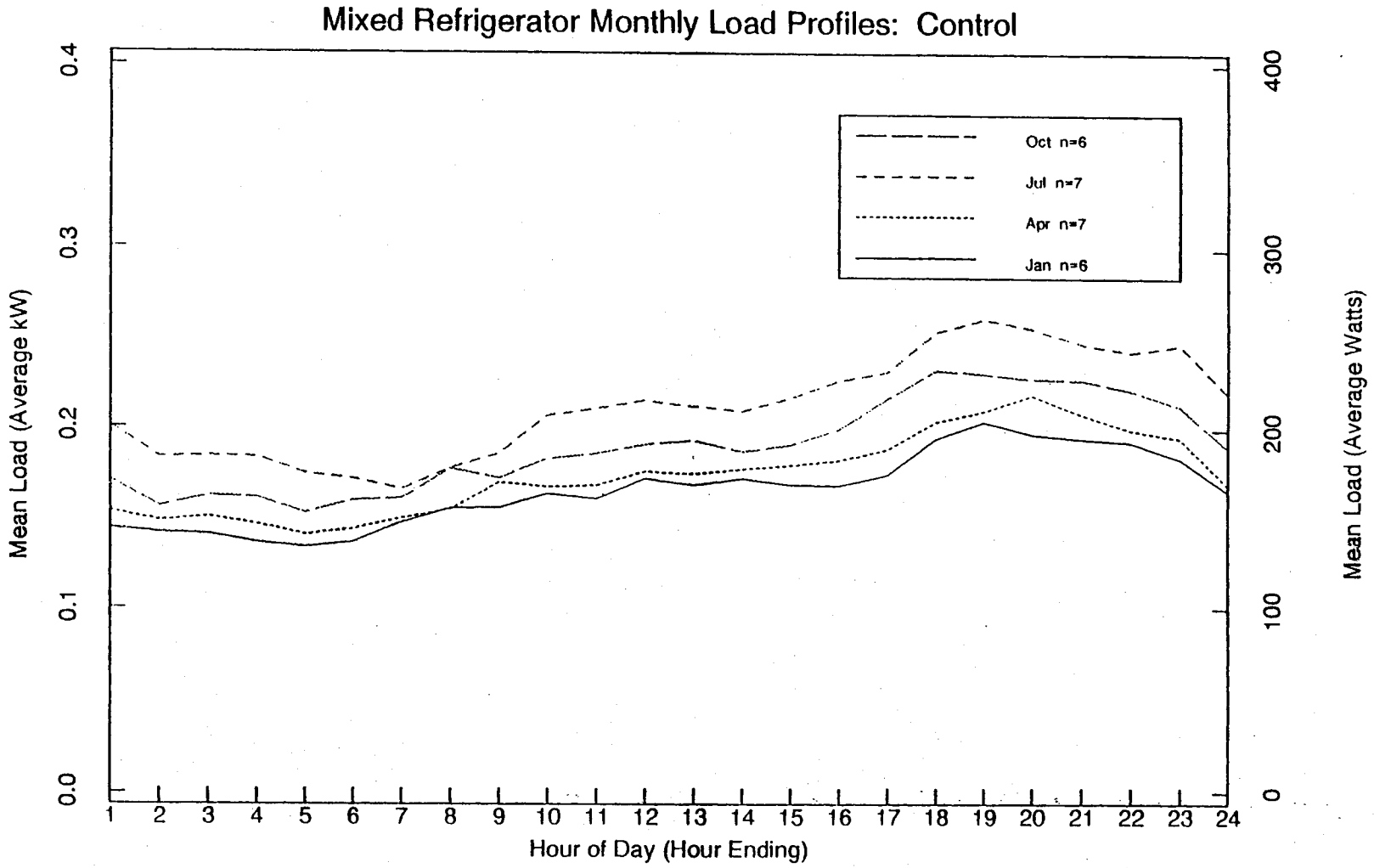
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

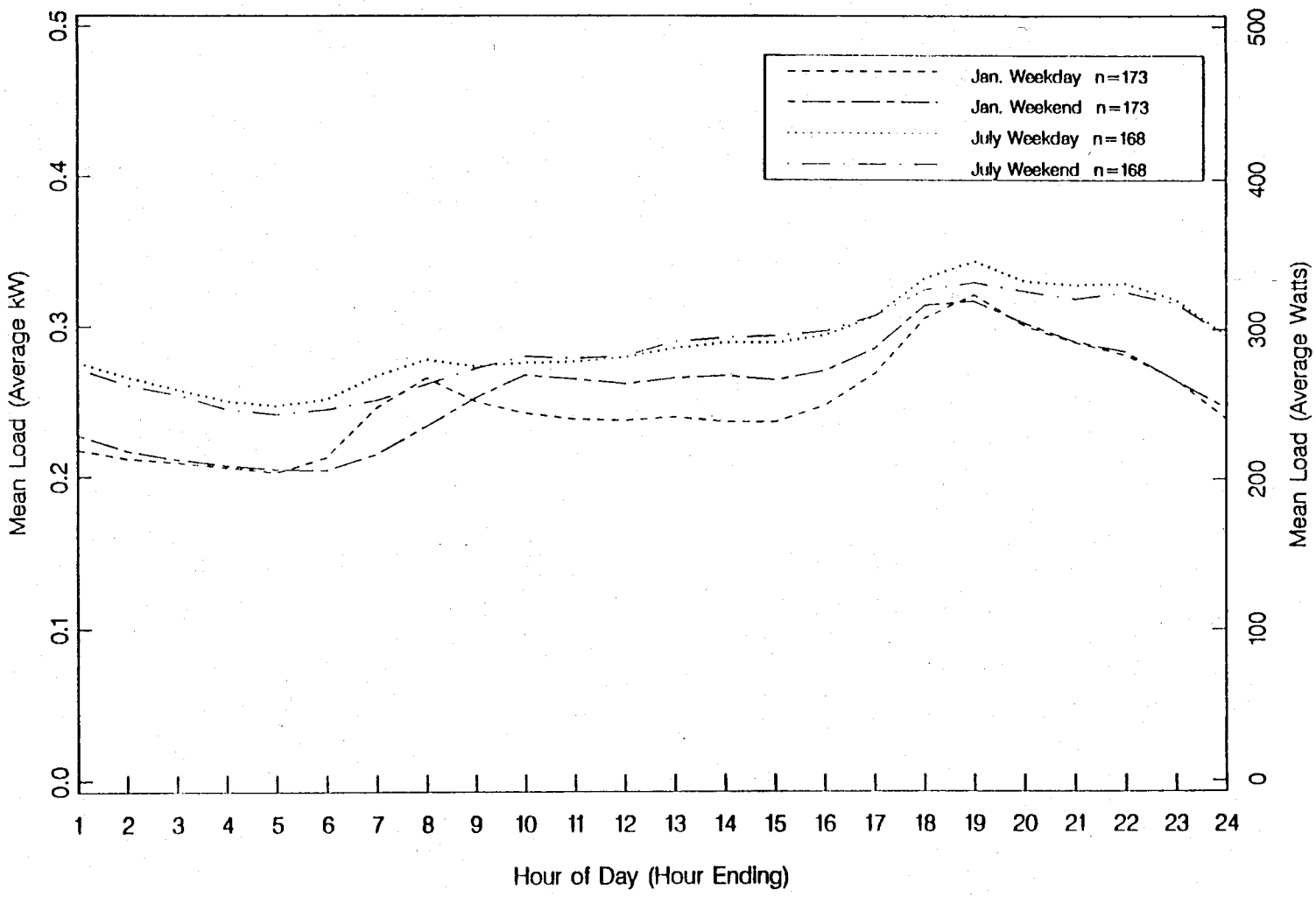
FIGURE 7I.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7I.10(a)

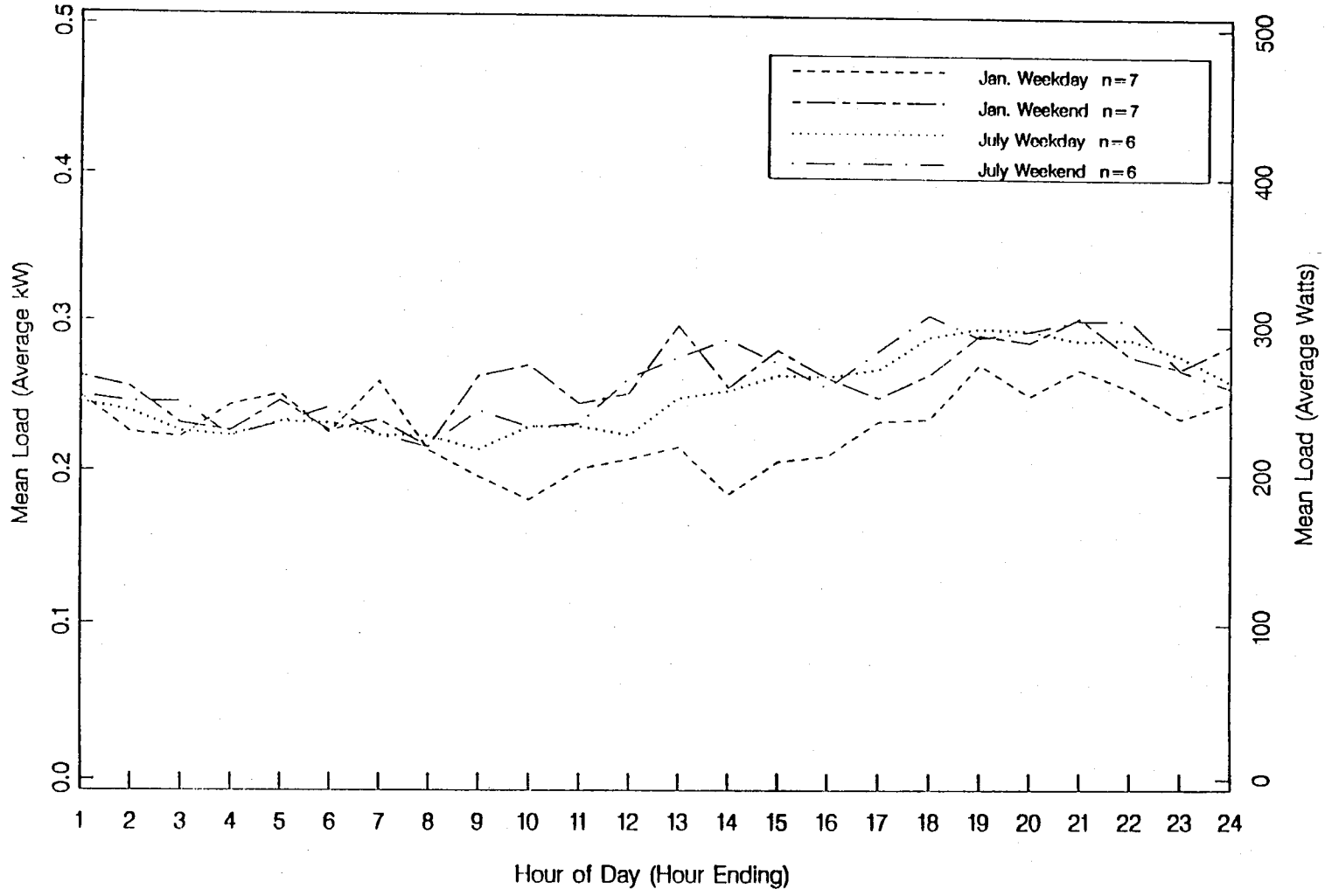
Mixed Refrigerator January and July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.10(b)

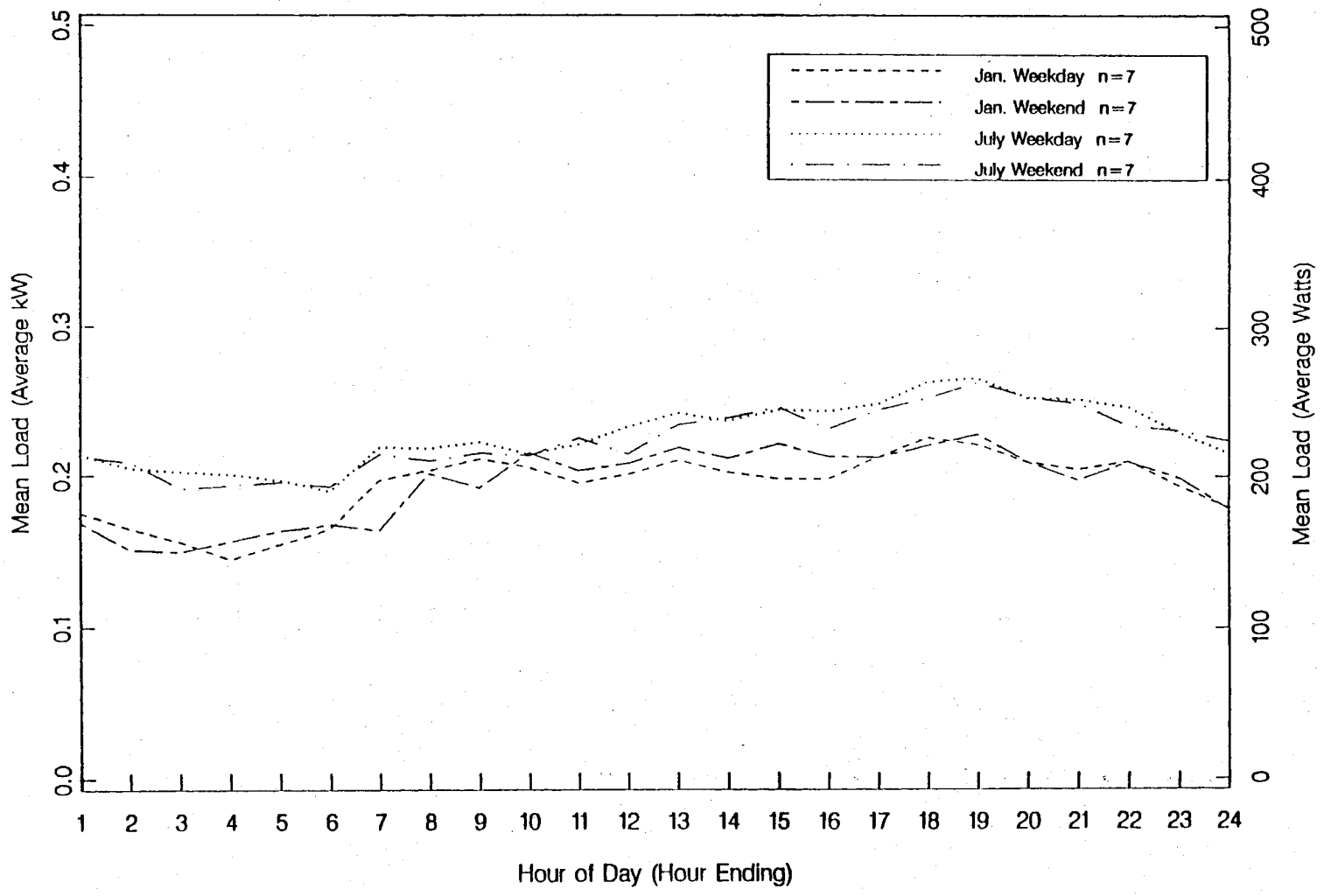
Mixed Refrigeration January/July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.10(c)

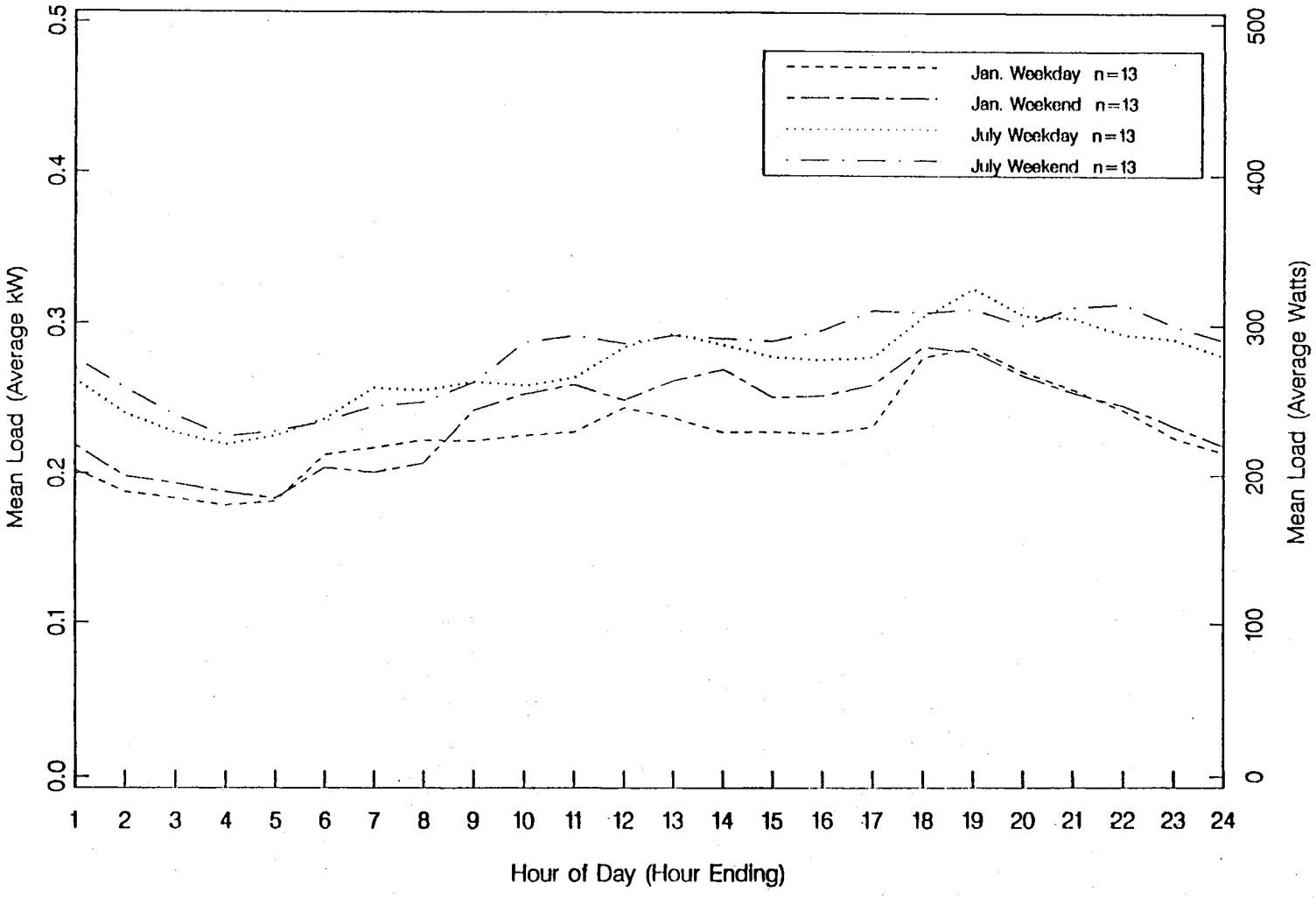
Mixed Refrigerator January/July Weekday/Weekend Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.10(d)

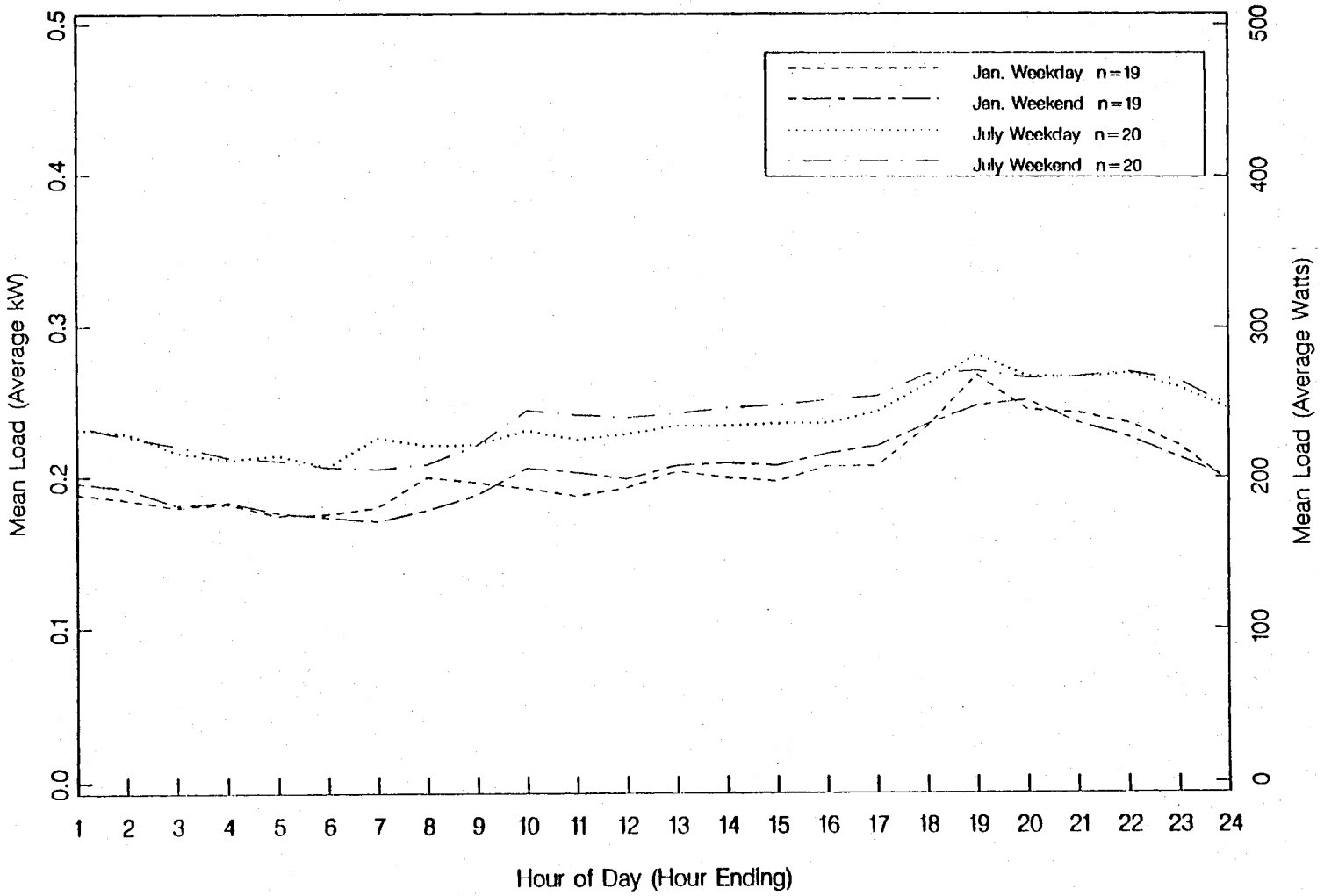
Mixed Refrigerator January and July Weekday/Weekend Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.10(e)

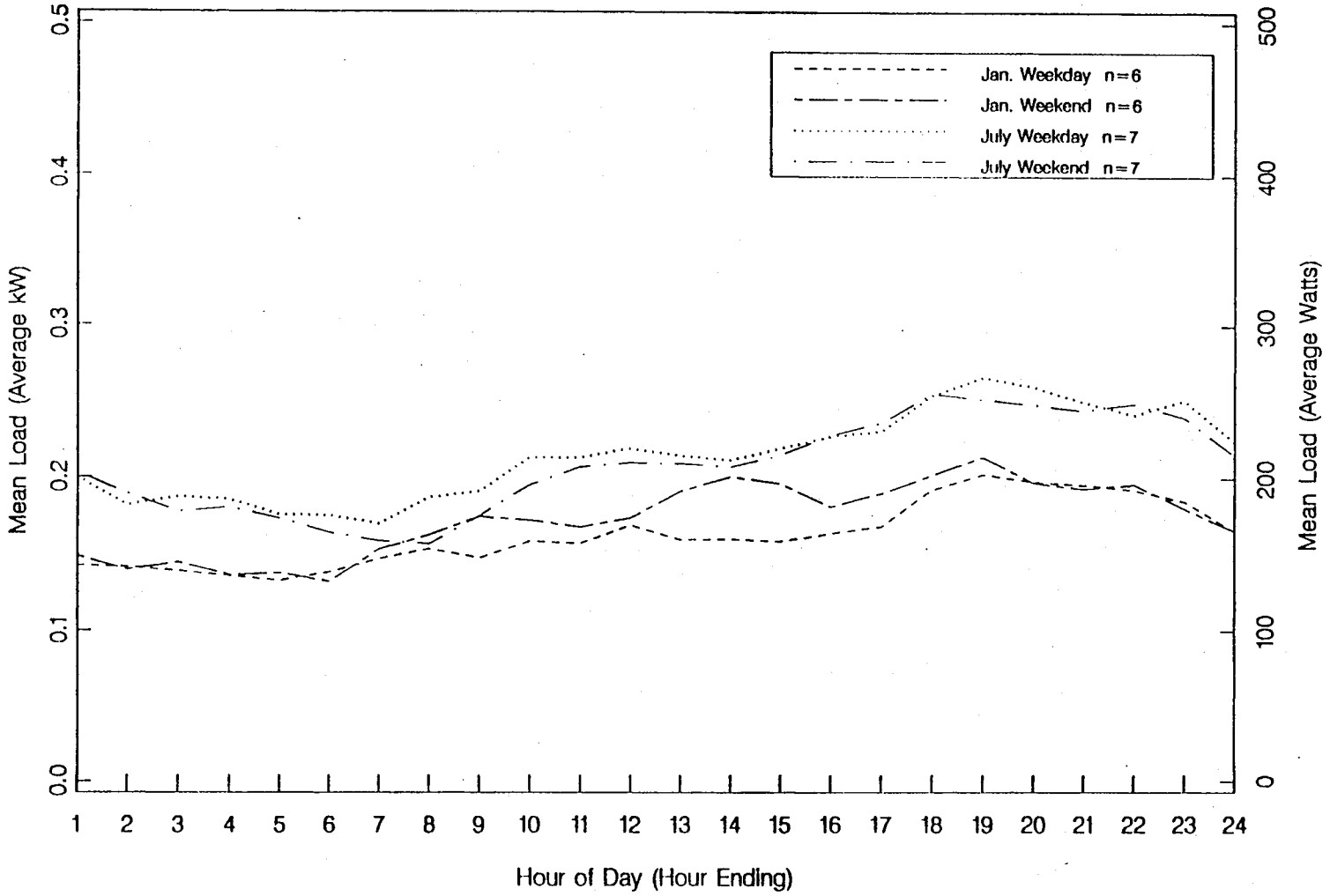
Mixed Refrigerator January and July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.10(f)

Mixed Refrigerator January/July Weekday/Weekend Load Profiles: Control



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7I.11

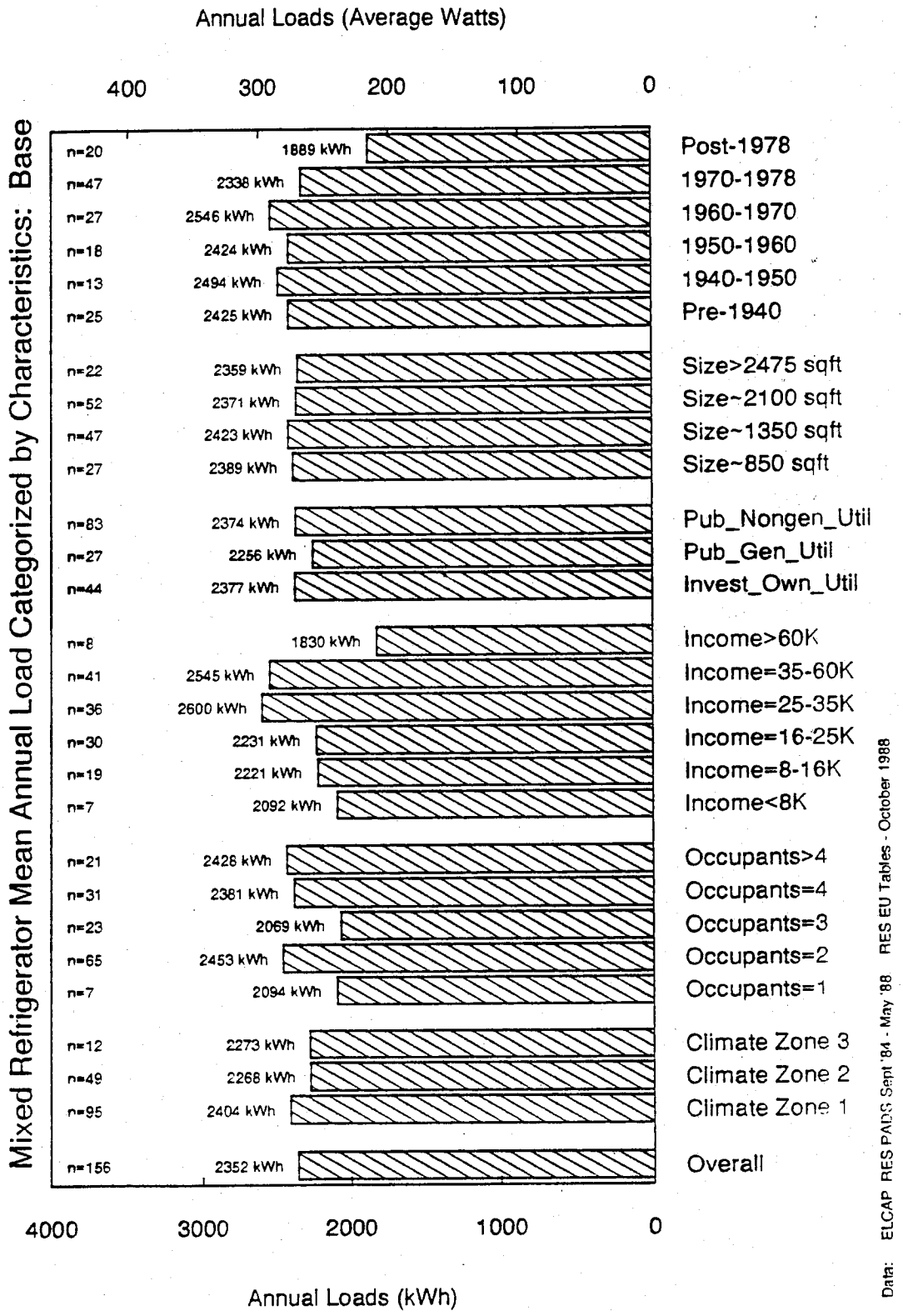

Mixed Refrigerator Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
400
300
200
100
0
n=20 1889 kWh Post-1978
n=47 2338 kWh 1970-1978
n=27 2546 kWh 1960-1970
n=18 2424 kWh 1950-1960
n=13 2494 kWh 1940-1950
n=25 2425 kWh Pre-1940
n=22 2359 kWh Size>2475 sqft
n=52 2371 kWh Size~2100 sqft
n=47 2423 kWh Size~1350 sqft
n=27 2389 kWh Size~850 sqft
n=83 2374 kWh Pub_Nongen_Util
n=27 2256 kWh Pub_Gen_Util
n=44 2377 kWh Invest_Own_Util
n=8 1830 kWh Income>60K
n=41 2545 kWh Income=35-60K
n=36 2600 kWh Income=25-35K
n=30 2231 kWh Income=16-25K
n=19 2221 kWh Income=8-16K
n=7 2092 kWh Income<8K
n=21 2426 kWh Occupants>4
n=31 2361 kWh Occupants=4
n=23 2069 kWh Occupants=3
n=65 2453 kWh Occupants=2
n=7 2094 kWh Occupants=1
n=12 2273 kWh Climate Zone 3
n=49 2268 kWh Climate Zone 2
n=95 2404 kWh Climate Zone 1
n=156 2352 kWh Overall
4000
3000
2000
1000
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7I.12

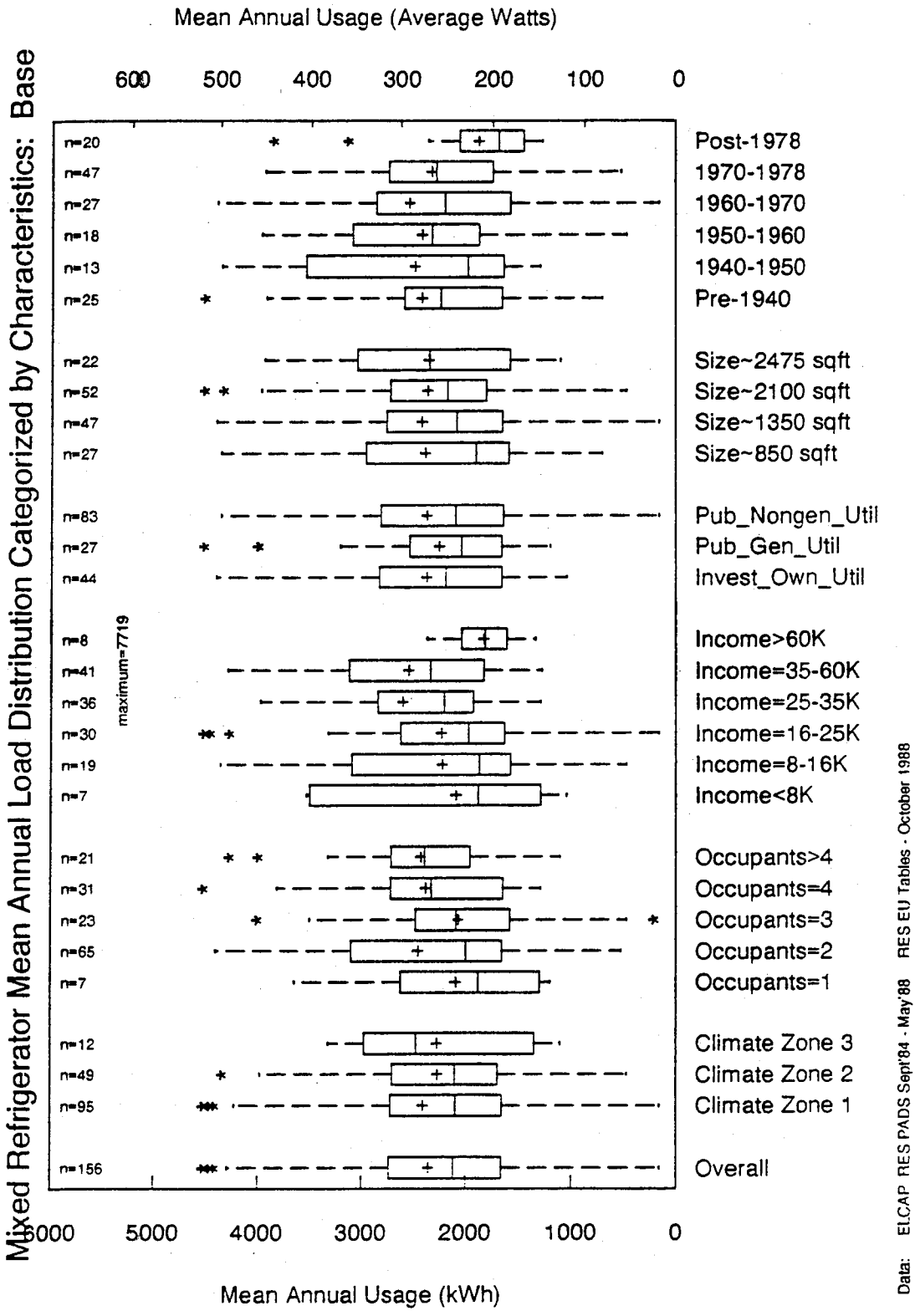

Mixed Refrigerator Mean Annual Load Distribution Categorized by Characteristics: Base
Mean Annual Usage (Average Watts)
600
500
400
300
200
100
0
maximum=7719
n=20
n=47
n=27
n=18
n=13
n=25
n=22
n=52
n=47
n=27
n=83
n=27
n=44
n=8
n=41
n=36
n=30
n=19
n=7
n=21
n=31
n=23
n=65
n=7
n=12
n=49
n=95
n=156
Post-1978
1970-1978
1960-1970
1950-1960
1940-1950
Pre-1940
Size~2475 sqft
Size~2100 sqft
Size~1350 sqft
Size~850 sqft
Pub_Nongen_Util
Pub_Gen_Util
Invest_Own_Util
Income>60K
Income=35-60K
Income=25-35K
Income=16-25K
Income=8-16K
Income<8K
Occupants>4
Occupants=4
Occupants=3
Occupants=2
Occupants=1
Climate Zone 3
Climate Zone 2
Climate Zone 1
Overall
6000
5000
4000
3000
2000
1000
0
Mean Annual Usage (kWh)
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7I.1

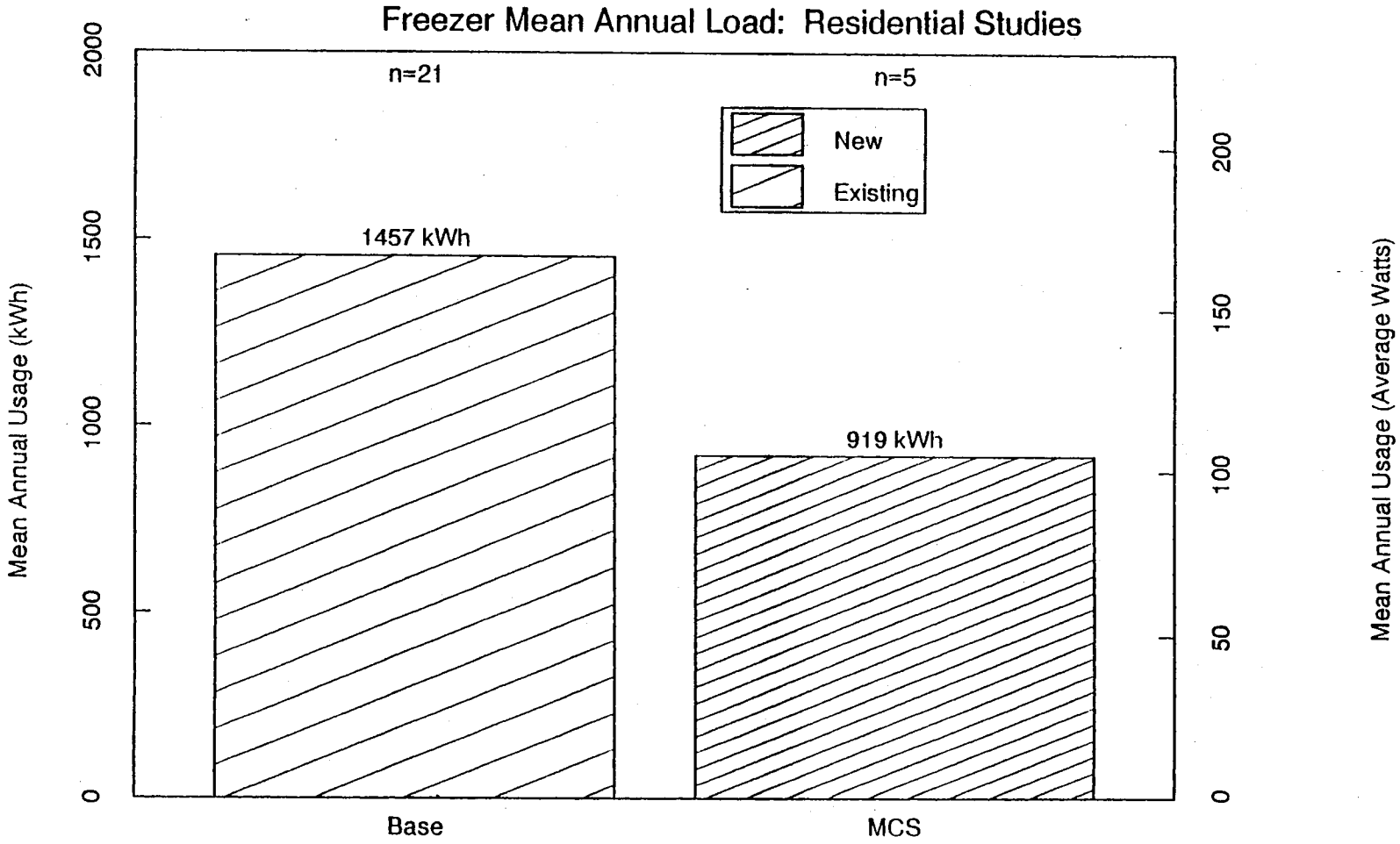
Mixed Refrigerator Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	156	2352	1025	7	1626	515	20	1908	740	183	2275	998
Climate Zone 1	95	2404	1132	4	1404	443	11	1969	819	110	2325	1105
Climate Zone 2	49	2268	847	3	1922	519	8	1772	690	60	2185	825
Climate Zone 3	12	2273	806	0	-	-	1	2331	0	13	2278	772
Occupants=1	7	2094	854	0	-	-	1	1497	0	8	2019	818
Occupants=2	65	2453	1238	0	-	-	5	1974	894	70	2419	1218
Occupants=3	23	2069	870	1	2435	0	3	1376	385	27	2005	842
Occupants=4	31	2381	927	2	1514	167	3	1510	691	36	2260	926
Occupants>4	21	2428	776	1	1936	0	2	2279	1100	24	2395	766
Income<8K	7	2092	1021	0	-	-	1	713	0	8	1920	1064
Income=8-16K	19	2221	1072	0	-	-	1	1182	0	20	2169	1069
Income=16-25K	30	2231	963	0	-	-	1	1501	0	31	2208	956
Income=25-35K	36	2600	1214	3	1821	544	4	1724	219	43	2464	1159
Income=35-60K	41	2545	1028	1	1936	0	7	2041	906	49	2460	1009
Income>60K	8	1830	324	0	-	-	0	-	-	8	1830	324
Invest_Own_Util	44	2377	927	2	1784	215	11	2040	668	57	2291	876
Pub_Gen_Util	27	2256	826	3	1328	509	4	1371	618	34	2070	852
Pub_Nongen_Util	83	2374	1144	2	1915	734	3	2248	1089	88	2359	1128
Size~850 sqft	27	2389	1133	1	1396	0	1	1182	0	29	2313	1129
Size~1350 sqft	47	2423	1234	4	1404	443	8	1678	531	59	2252	1170
Size~2100 sqft	52	2371	879	2	2185	352	7	2165	854	61	2341	859
Size>2475 sqft	22	2359	799	0	-	-	3	2418	813	25	2368	784
Pre-1940	25	2425	1074	0	-	-	0	-	-	25	2425	1074
1940-1950	13	2494	1156	0	-	-	0	-	-	13	2494	1156
1950-1960	18	2424	881	0	-	-	0	-	-	18	2424	881
1960-1970	27	2546	1484	0	-	-	0	-	-	27	2546	1484
1970-1978	47	2338	825	0	-	-	0	-	-	47	2338	825
Post-1978	20	1889	636	7	1626	515	20	1908	740	47	1858	661

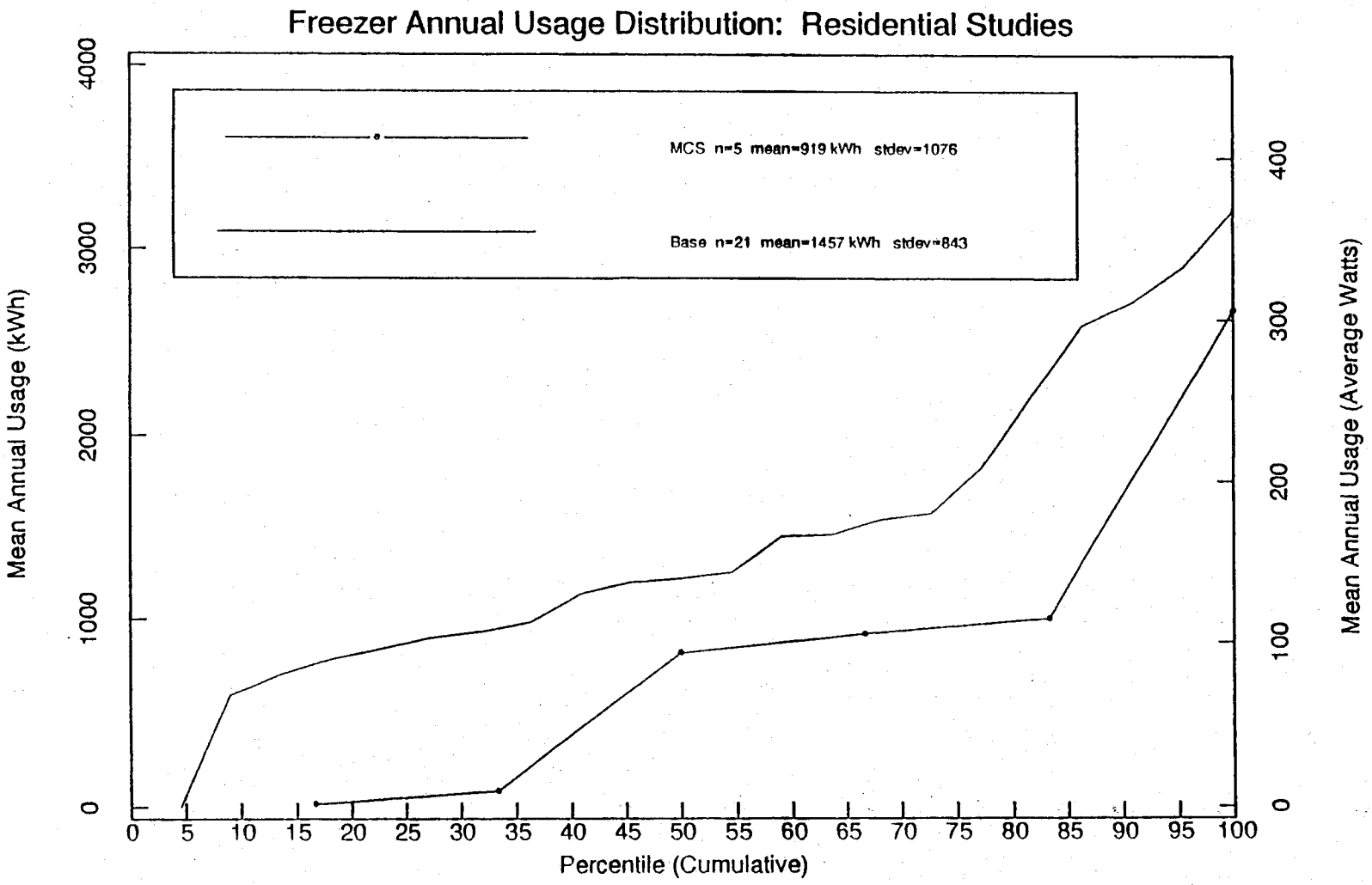
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7J.1



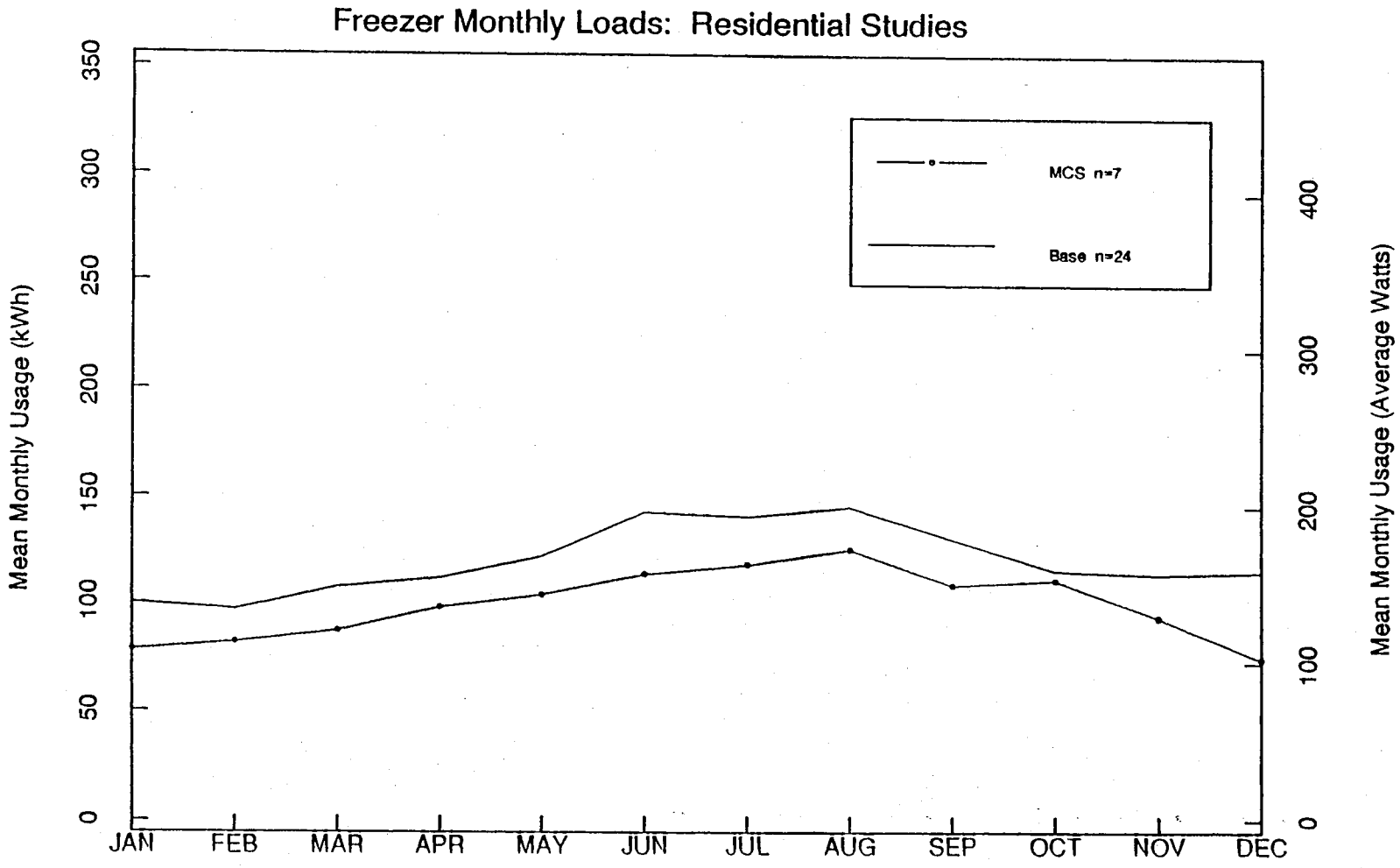
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.2



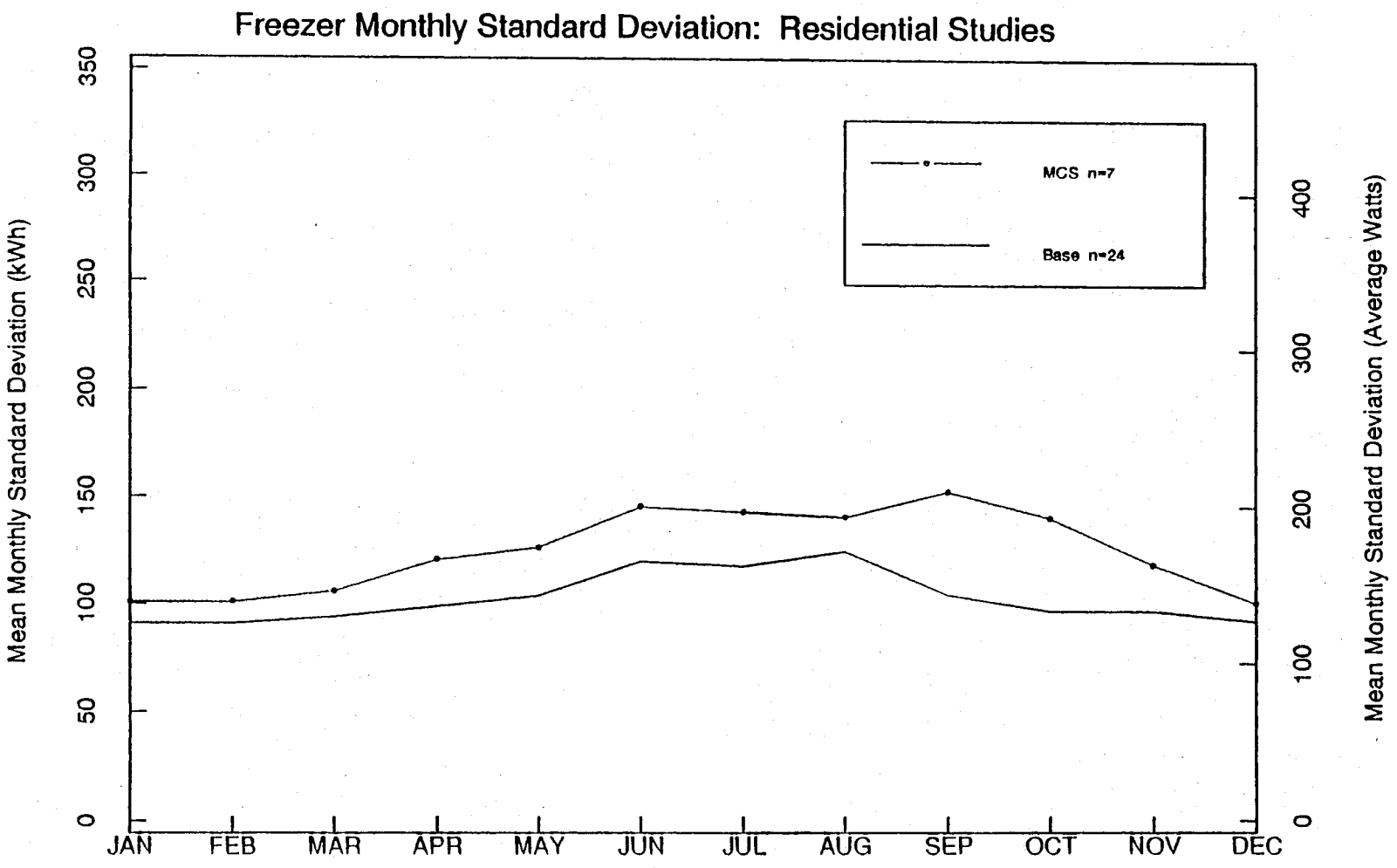
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.3



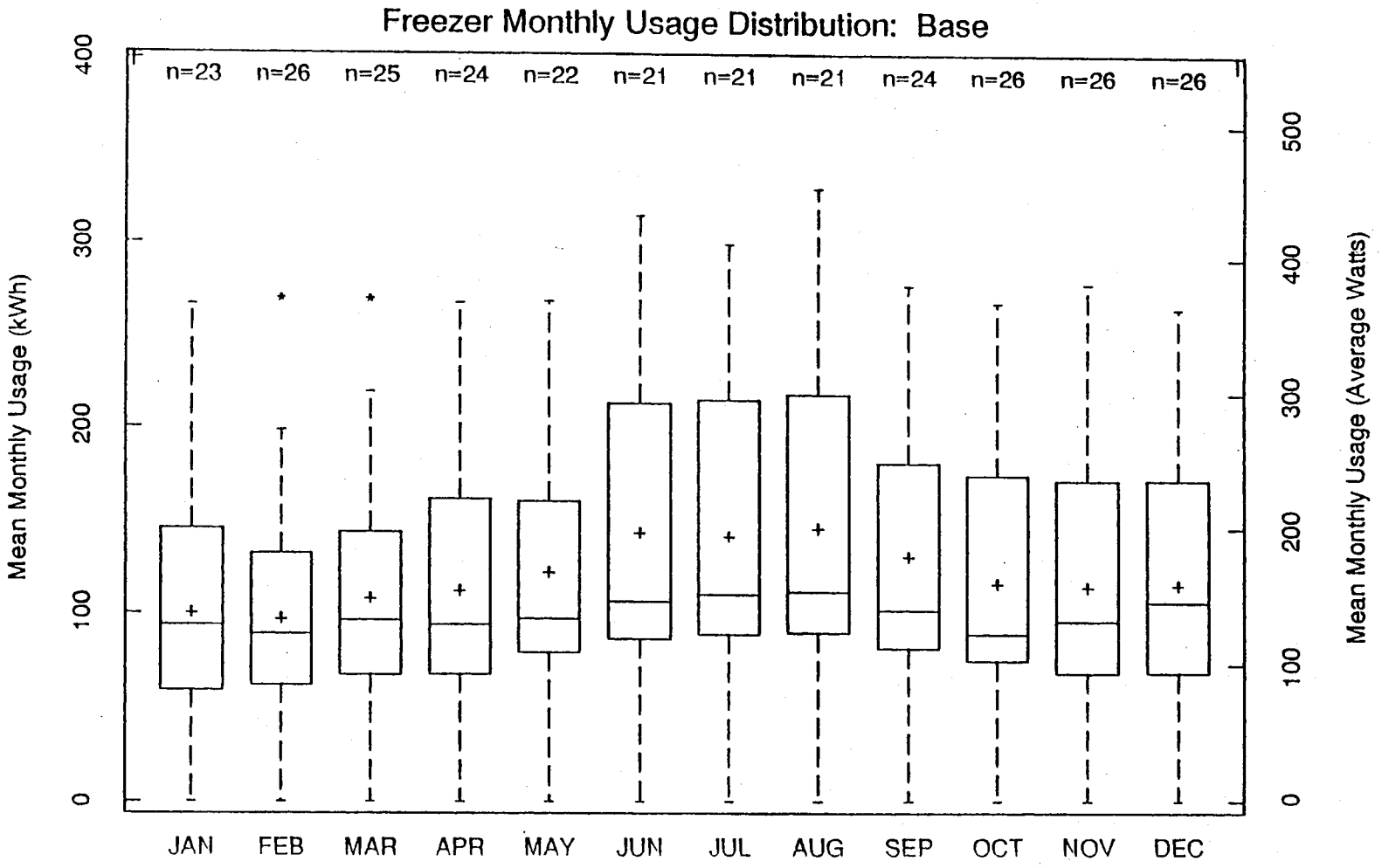
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.4



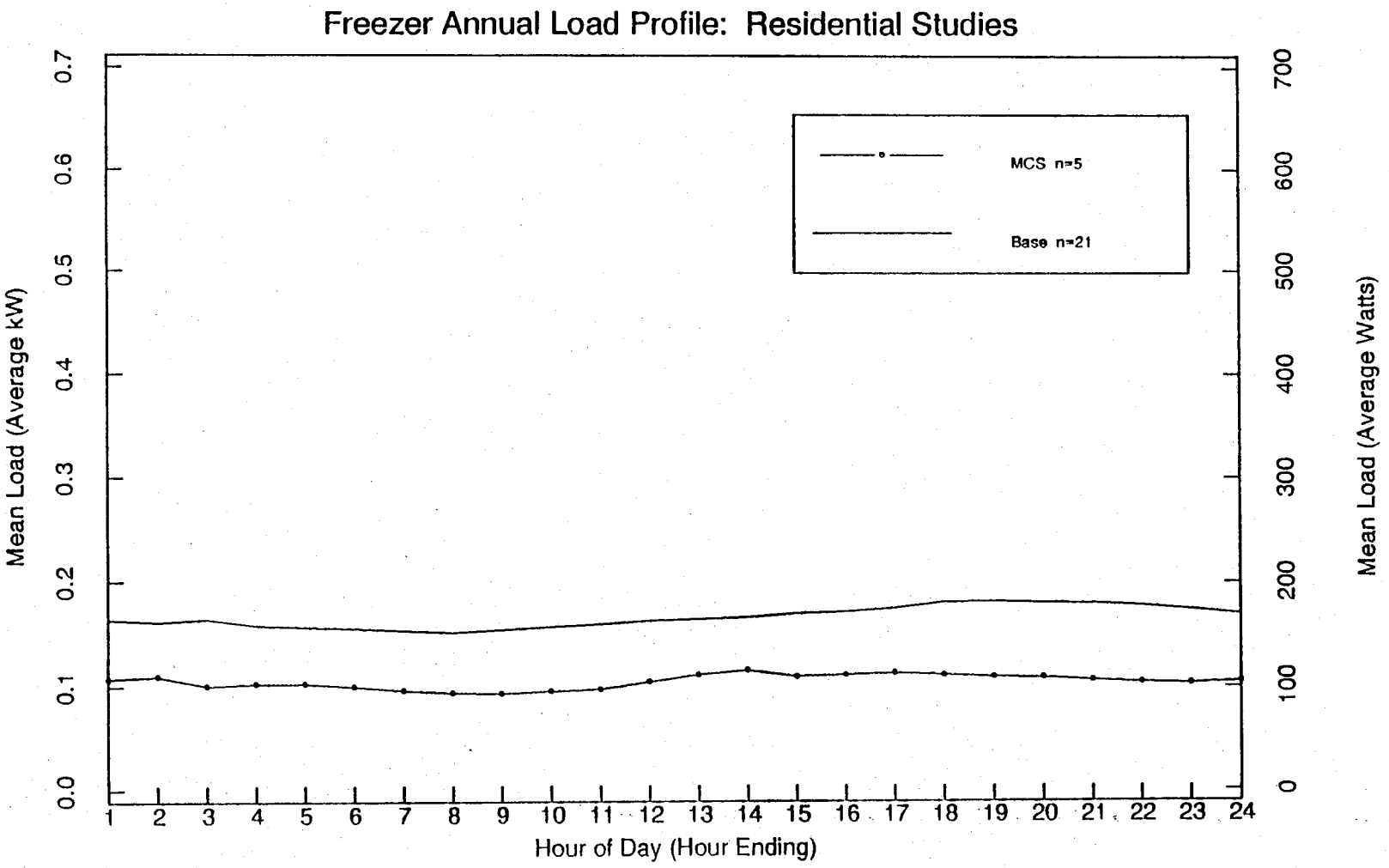
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

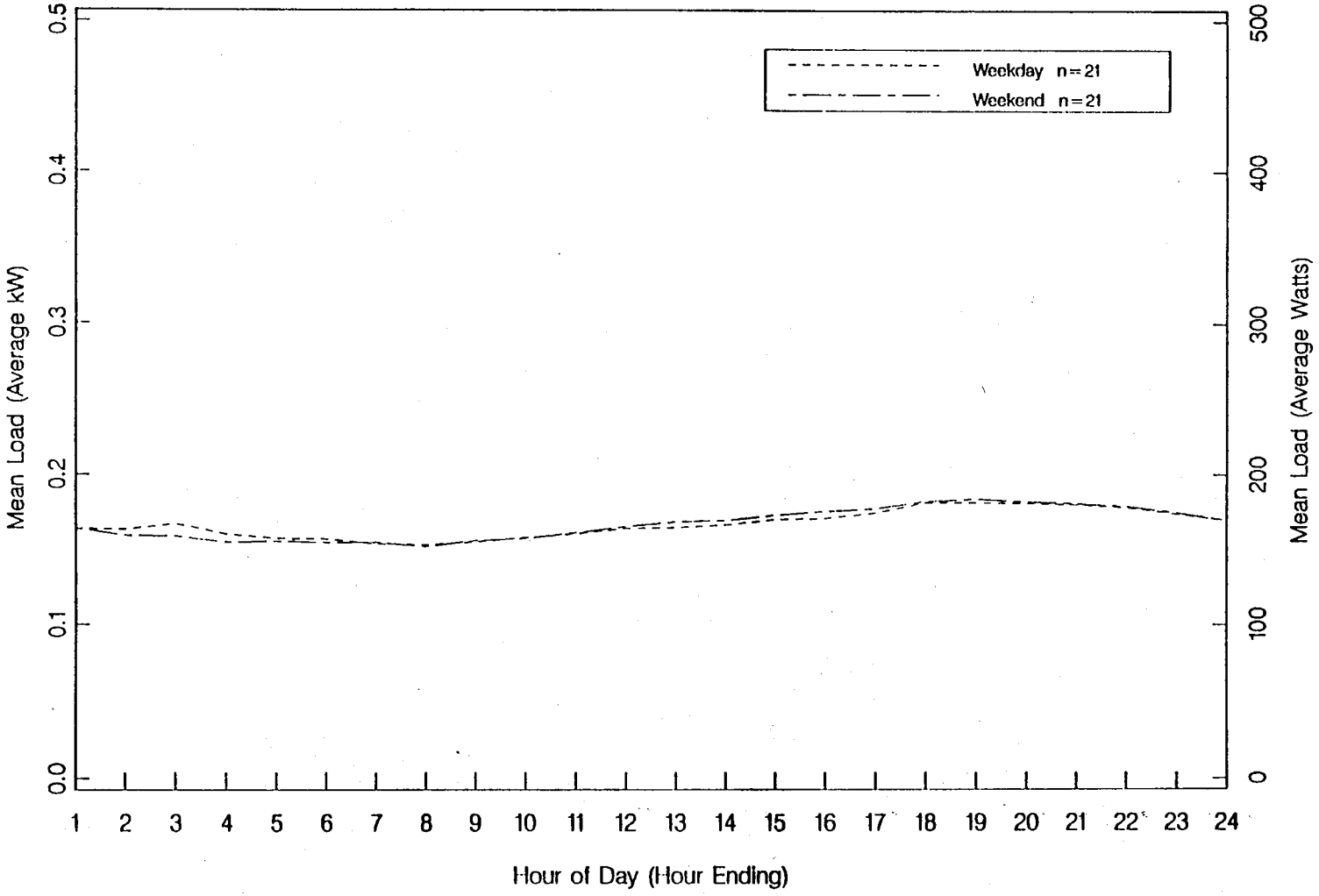
FIGURE 7J.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

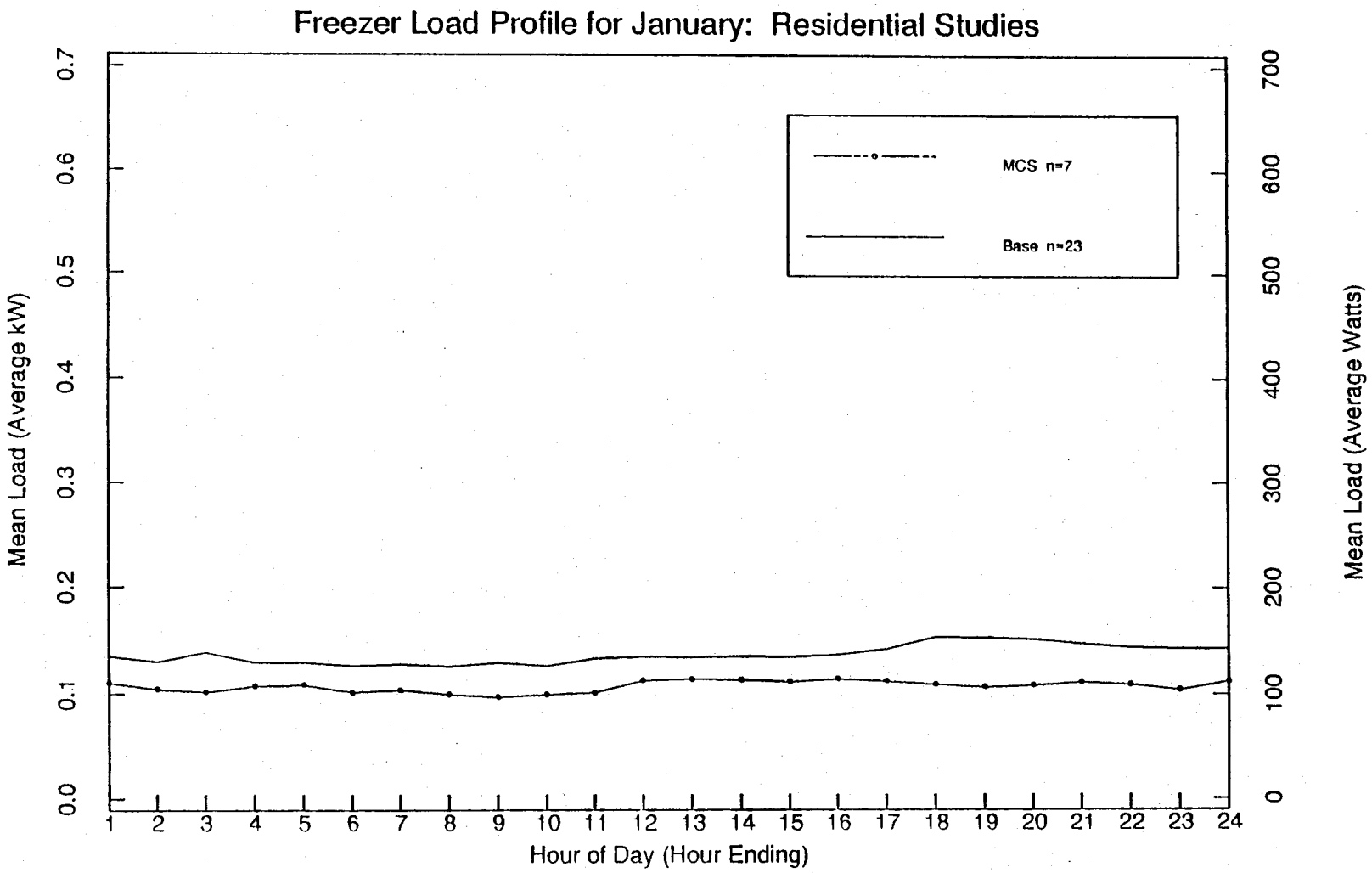
FIGURE 7J.7

Freezer Annual Weekday/Weekend Load Profiles: Base



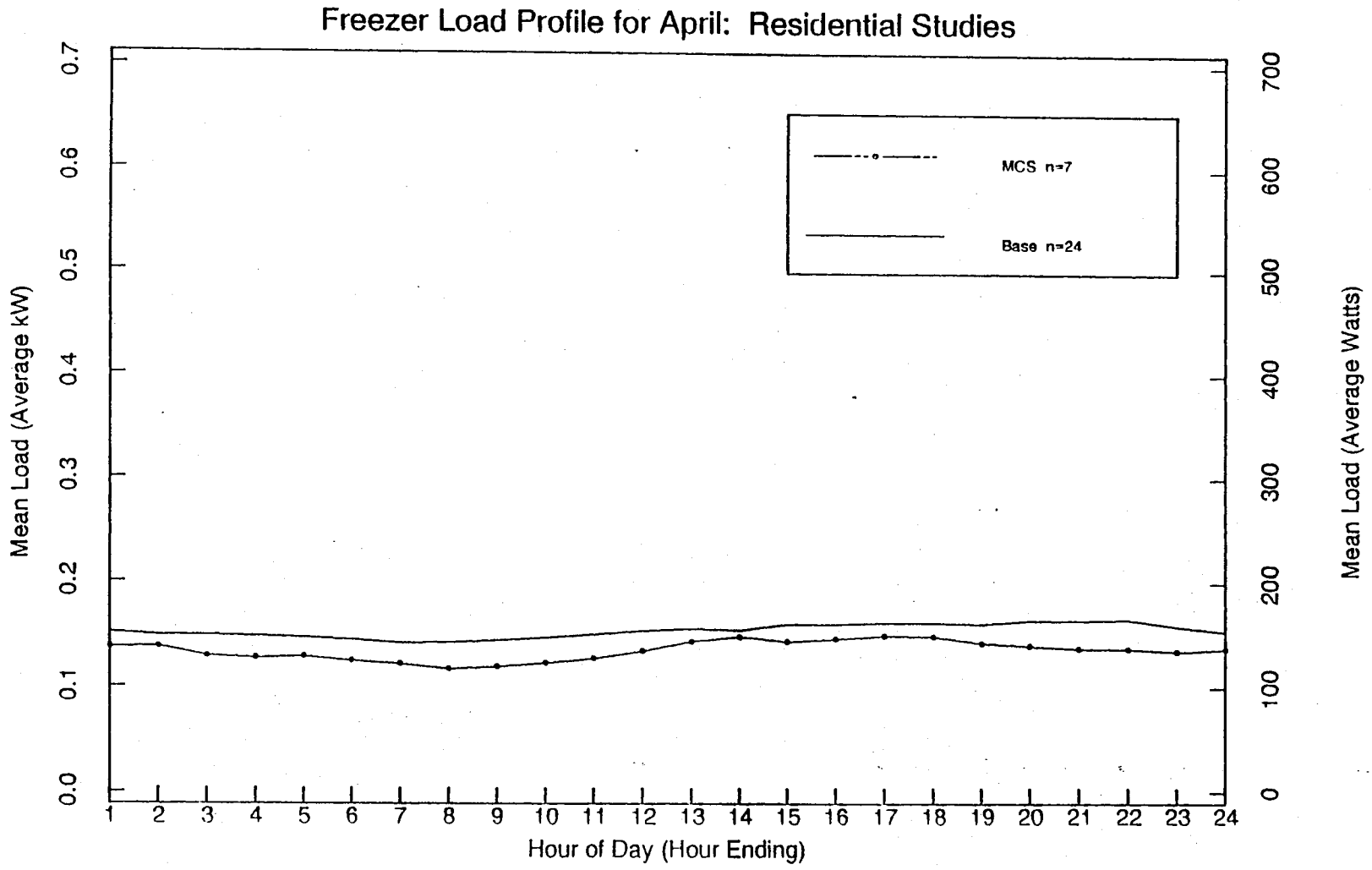
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7J.8(a)



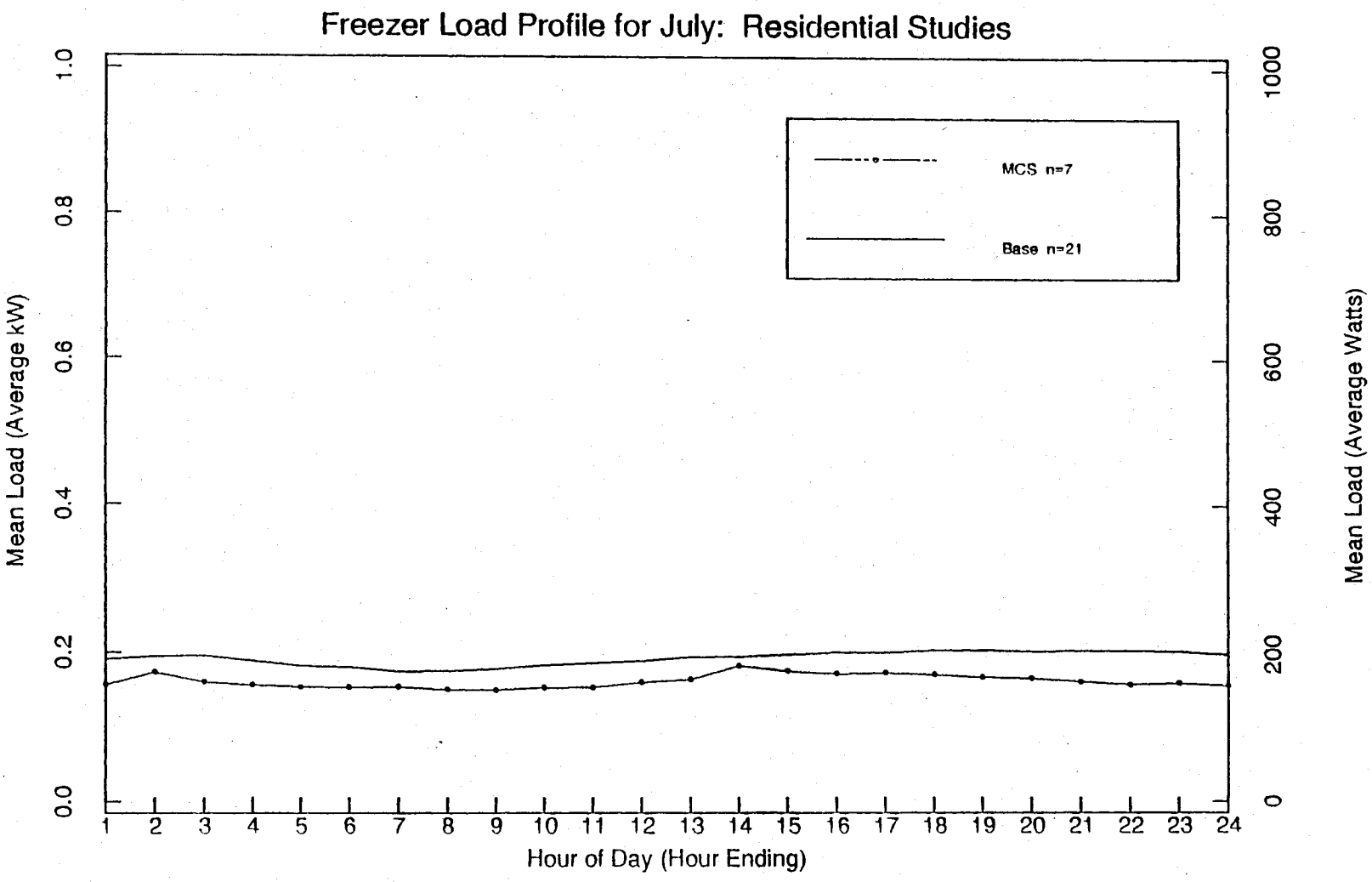
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.8(b)



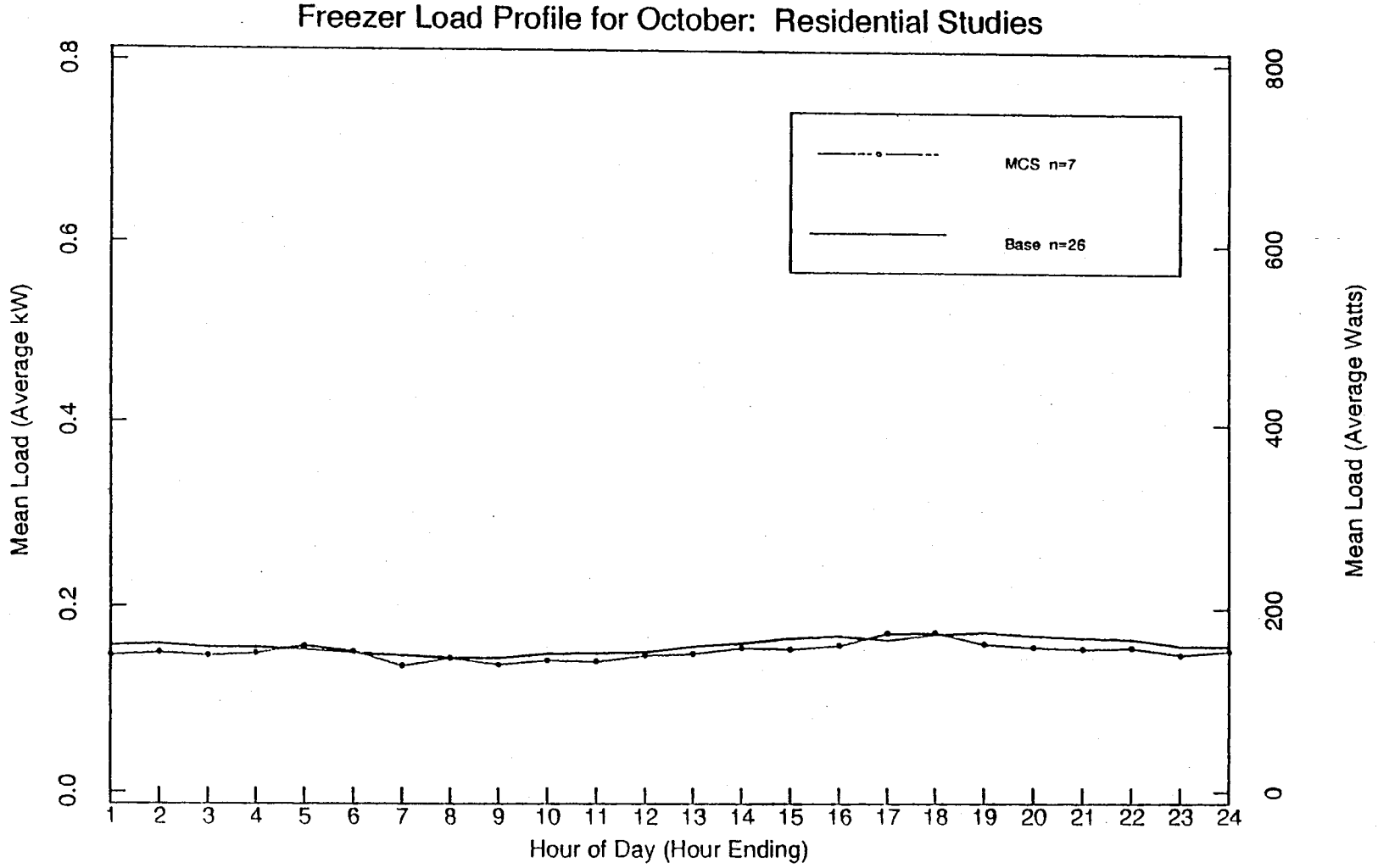
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.8(c)



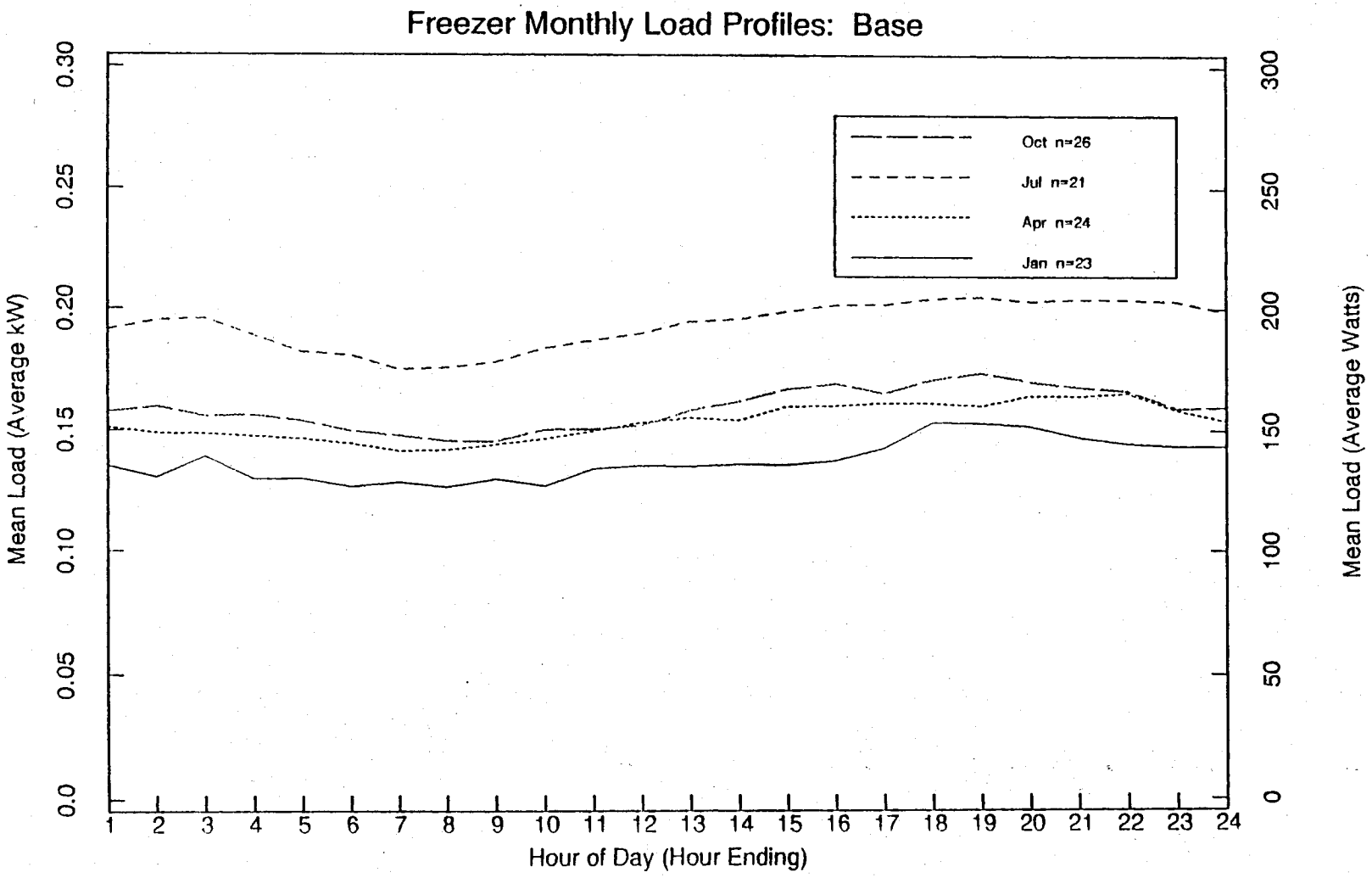
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.8(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.9(a)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7J.9(b)

Freezer Monthly Load Profiles: Renter

NO DATA TO PLOT

FIGURE 7J.9(c)

Freezer Monthly Load Profiles: Manufactured

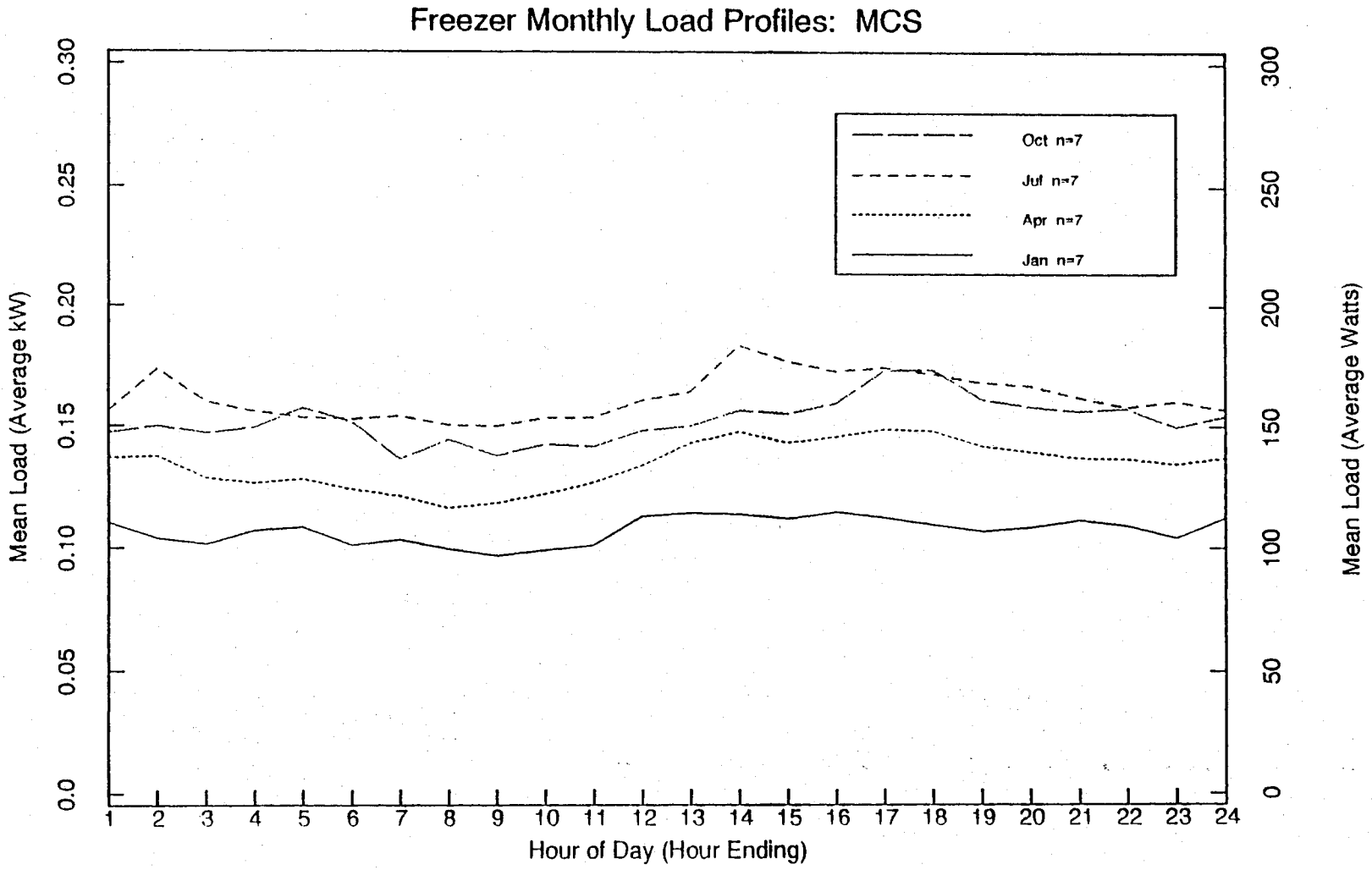
NO DATA TO PLOT

FIGURE 7J.9(d)

Freezer Monthly Load Profiles: Gas/Oil

NO DATA TO PLOT

FIGURE 7J.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

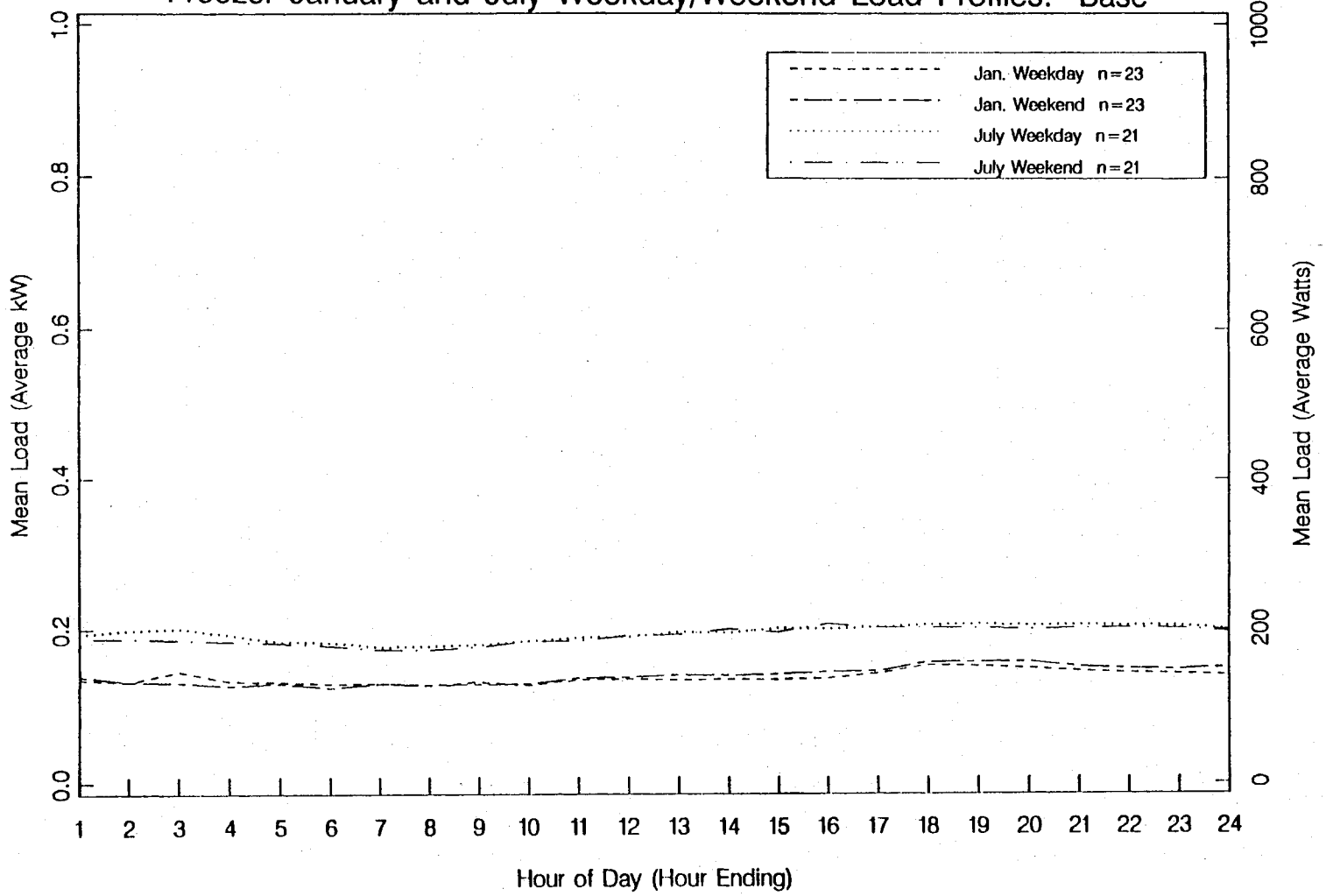
FIGURE 7J.9(f)

Freezer Monthly Load Profiles: Control

NO DATA TO PLOT

FIGURE 7J.10(a)

Freezer January and July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7J.10(b)

Freezer January and July Weekday/Weekend Load Profiles: Renter

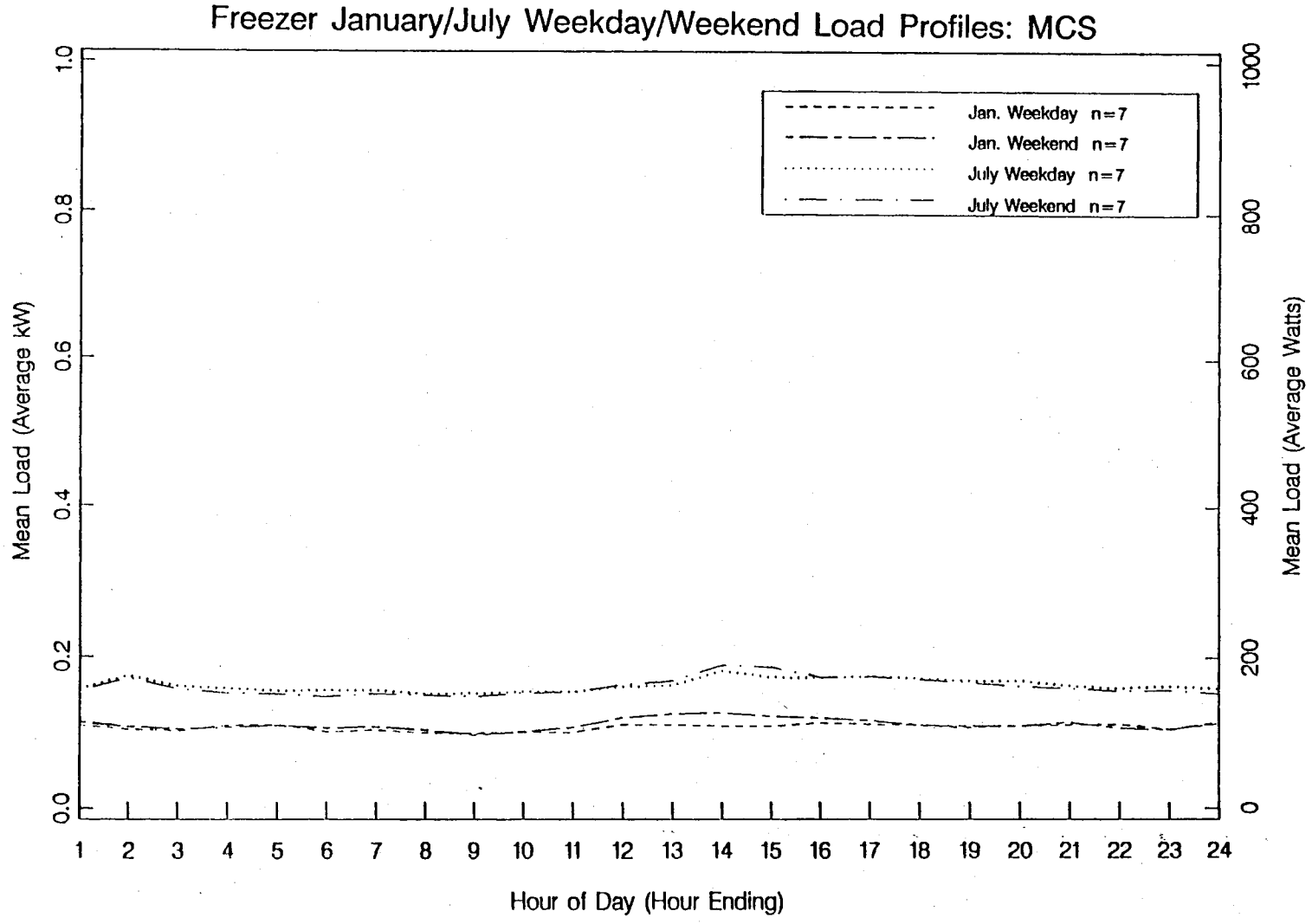
NO DATA TO PLOT

FIGURE 7J.10(c)

Freezer January and July Weekday/Weekend Load Profiles: Manufactured

NO DATA TO PLOT

FIGURE 7J.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7J.10(e)

Freezer January and July Weekday/Weekend Load Profiles: MCS

NO DATA TO PLOT

FIGURE 7J.10(f)

Freezer January and July Weekday/Weekend Load Profiles: Control

NO DATA TO PLOT

FIGURE 7J.11

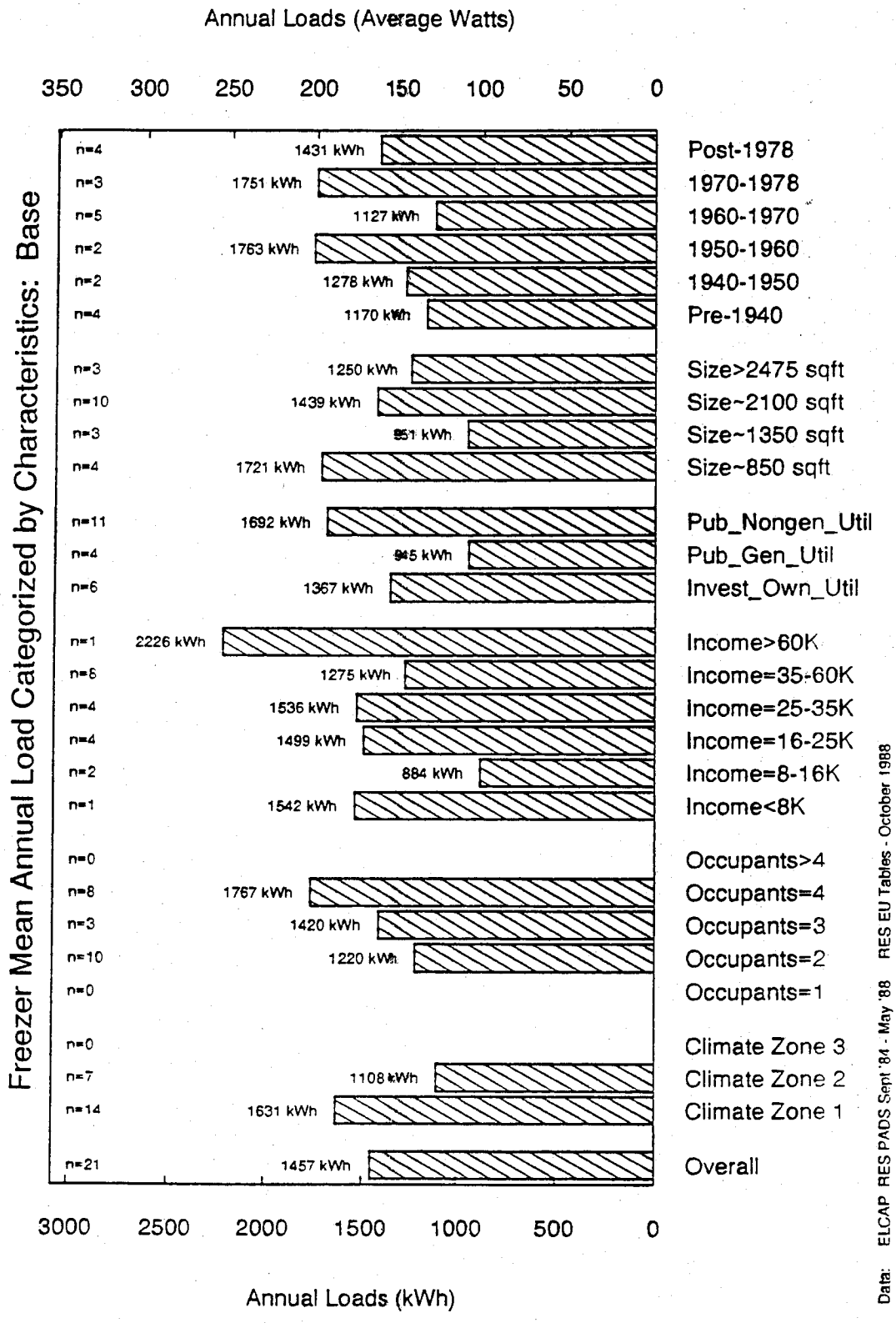
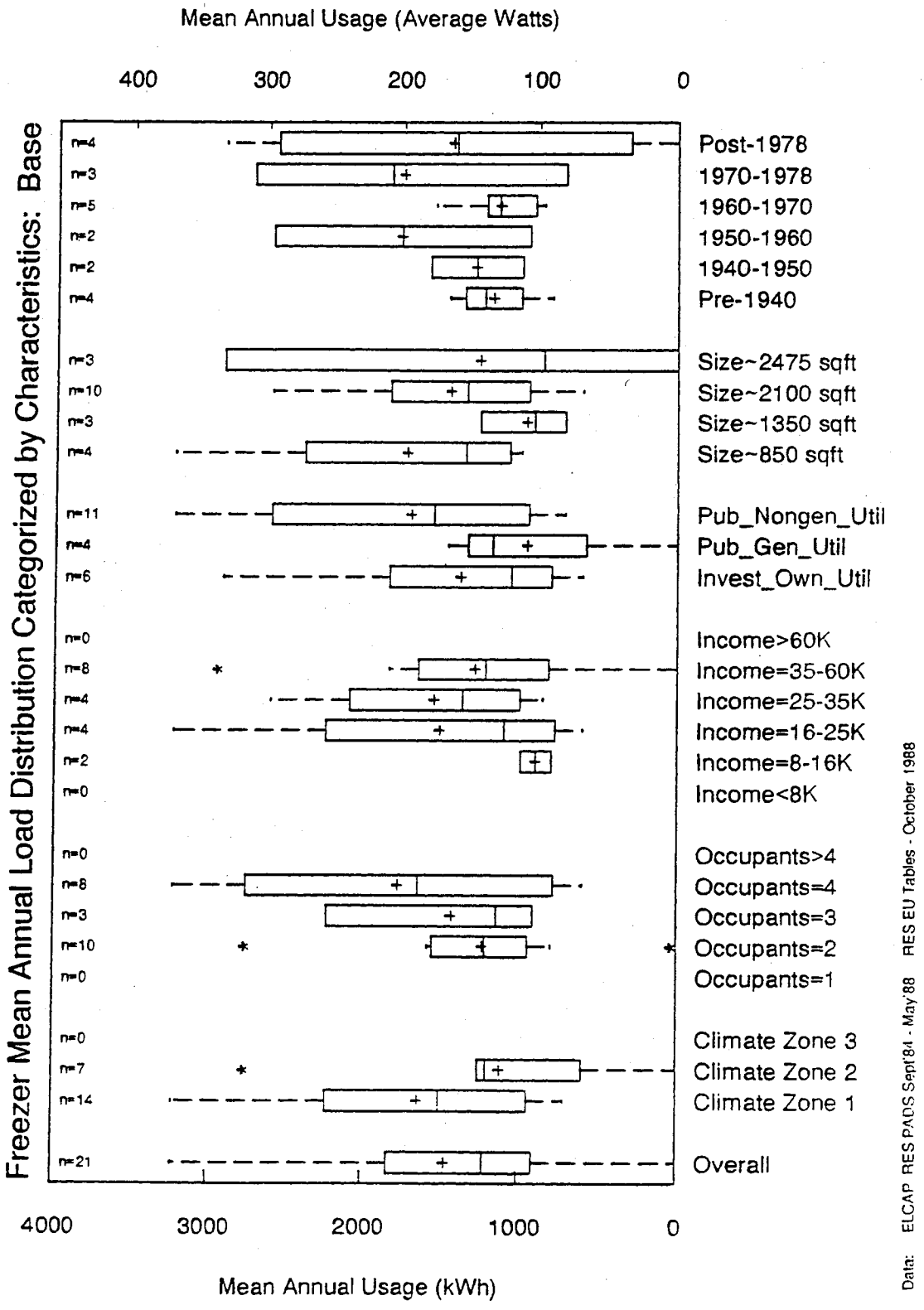

Freezer Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
350 300 250 200 150 100 50 0
n=4 1431 kWh Post-1978
n=3 1751 kWh 1970-1978
n=5 1127 kWh 1960-1970
n=2 1763 kWh 1950-1960
n=2 1278 kWh 1940-1950
n=4 1170 kWh Pre-1940
n=3 1250 kWh Size>2475 sqft
n=10 1439 kWh Size~2100 sqft
n=3 951 kWh Size~1350 sqft
n=4 1721 kWh Size~850 sqft
n=11 1692 kWh Pub_Nongen_Util
n=4 945 kWh Pub_Gen_Util
n=6 1367 kWh Invest_Own_Util
n=1 2226 kWh Income>60K
n=6 1275 kWh Income=35-60K
n=4 1536 kWh Income=25-35K
n=4 1499 kWh Income=16-25K
n=2 884 kWh Income=8-16K
n=1 1542 kWh Income<8K
n=0 Occupants>4
n=8 1767 kWh Occupants=4
n=3 1420 kWh Occupants=3
n=10 1220 kWh Occupants=2
n=0 Occupants=1
n=0 Climate Zone 3
n=7 1108 kWh Climate Zone 2
n=14 1631 kWh Climate Zone 1
n=21 1457 kWh Overall
3000 2500 2000 1500 1000 500 0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7J.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7J.1

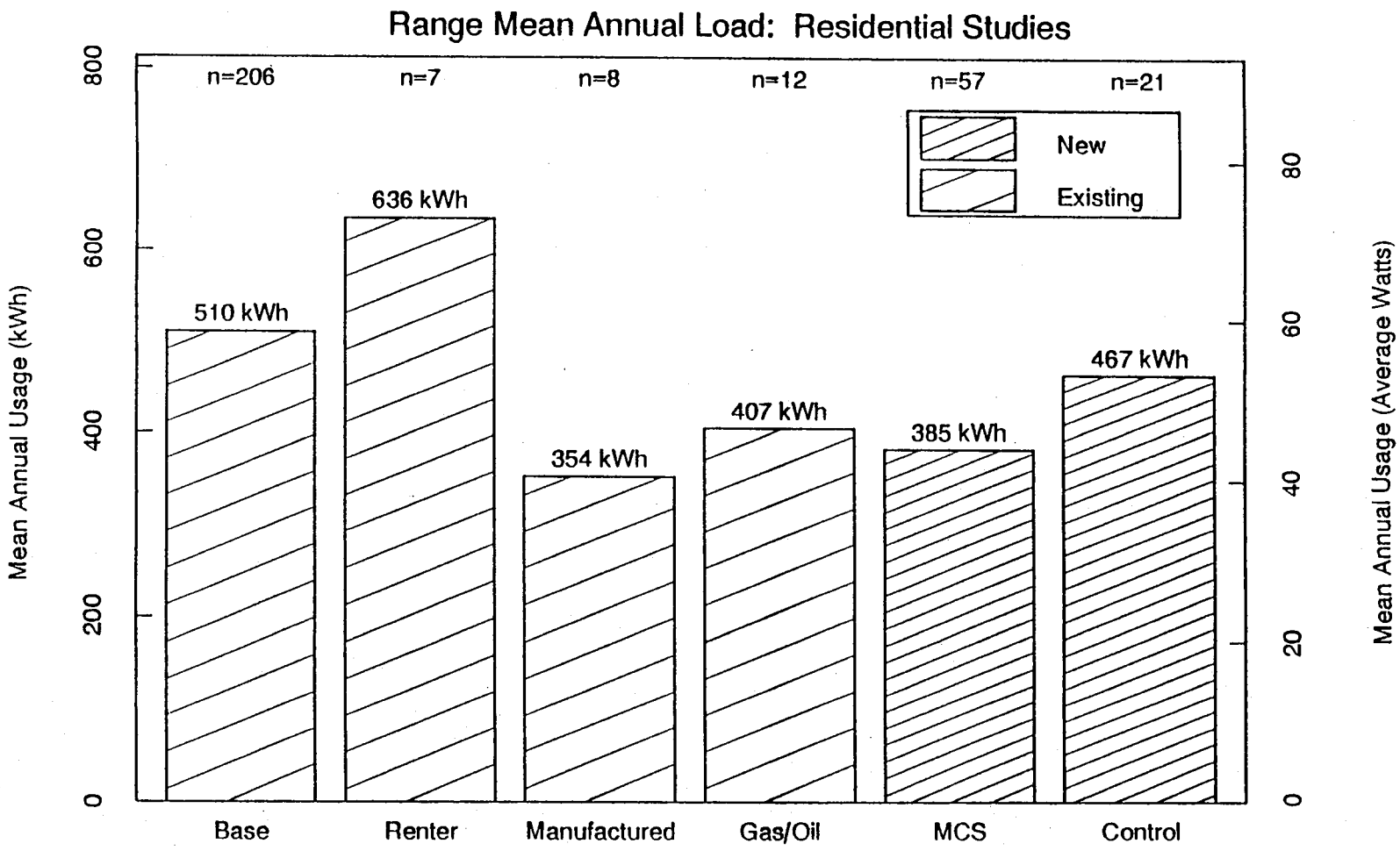
Freezer Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base and MCS

	Base			MCS			Base + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	21	1457	843	5	919	1076	26	1354	895
Climate Zone 1	14	1631	819	3	366	552	17	1408	911
Climate Zone 2	7	1108	841	2	1749	1315	9	1251	909
Climate Zone 3	0	-	-	0	-	-	0	-	-
Occupants=1	0	-	-	1	2679	0	1	2679	0
Occupants=2	10	1220	691	0	-	-	10	1220	691
Occupants=3	3	1420	707	0	-	-	3	1420	707
Occupants=4	8	1767	1041	2	450	521	10	1504	1087
Occupants>4	0	-	-	0	-	-	0	-	-
Income<8K	1	1542	0	0	-	-	1	1542	0
Income=8-16K	2	884	139	0	-	-	2	884	139
Income=16-25K	4	1499	1180	0	-	-	4	1499	1180
Income=25-35K	4	1536	767	1	2679	0	5	1764	838
Income=35-60K	8	1275	855	2	450	521	10	1110	848
Income>60K	1	2226	0	0	-	-	1	2226	0
Invest_Own_Util	6	1367	875	4	898	1241	10	1180	999
Pub_Gen_Util	4	945	644	1	1002	0	5	958	559
Pub_Nongen_Util	11	1692	863	0	-	-	11	1692	863
Size<850 sqft	4	1721	1029	0	-	-	4	1721	1029
Size=1350 sqft	3	951	277	3	1232	1347	6	1091	883
Size=2100 sqft	10	1439	636	2	450	521	12	1274	709
Size>2475 sqft	3	1250	1497	0	-	-	3	1250	1497
Pre-1940	4	1170	278	0	-	-	4	1170	278
1940-1950	2	1278	418	0	-	-	2	1278	418
1950-1960	2	1763	1175	0	-	-	2	1763	1175
1960-1970	5	1127	280	0	-	-	5	1127	280
1970-1978	3	1751	1012	0	-	-	3	1751	1012
Post-1978	4	1431	1363	5	919	1076	9	1147	1161

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

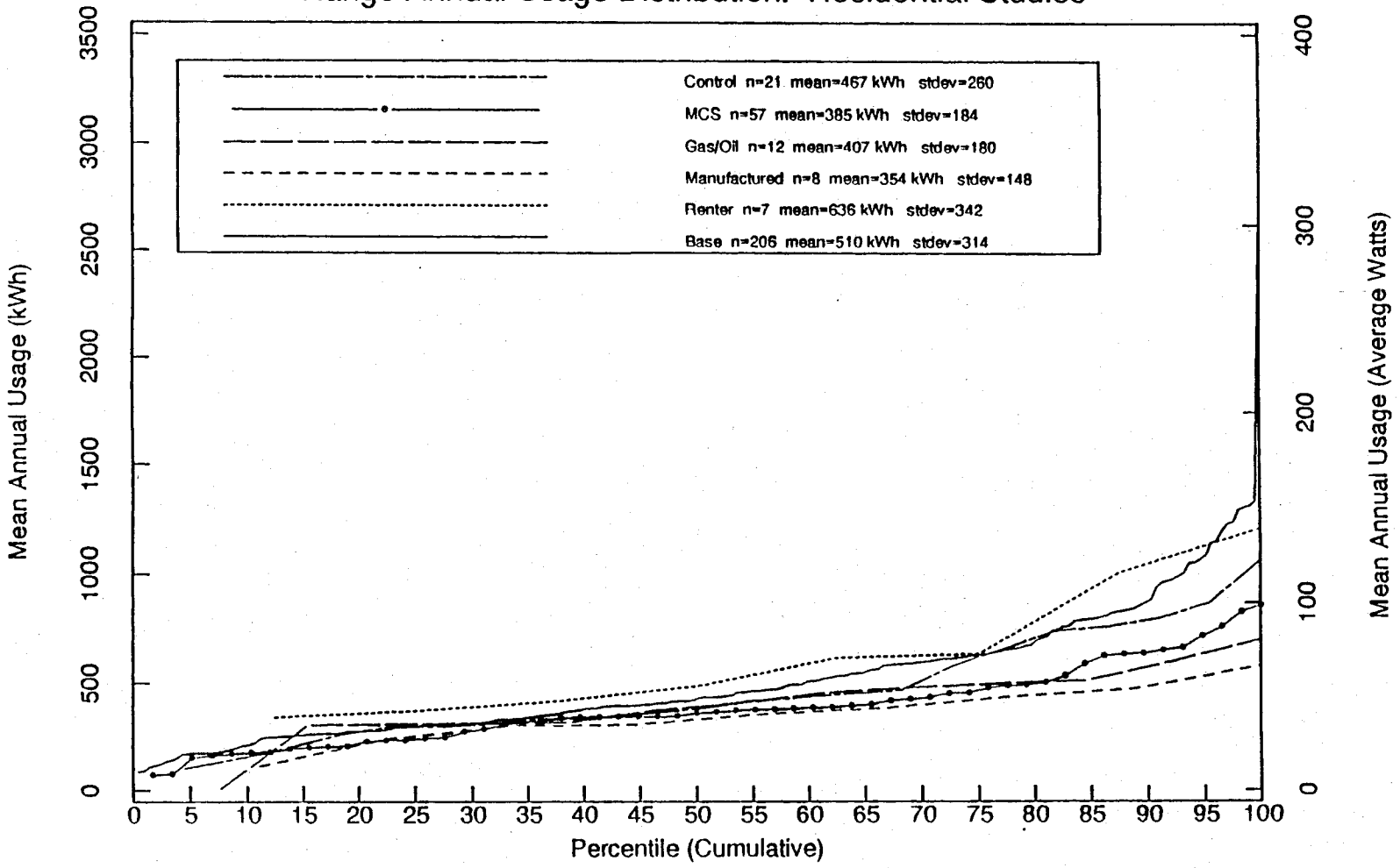
FIGURE 7K.1



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.2

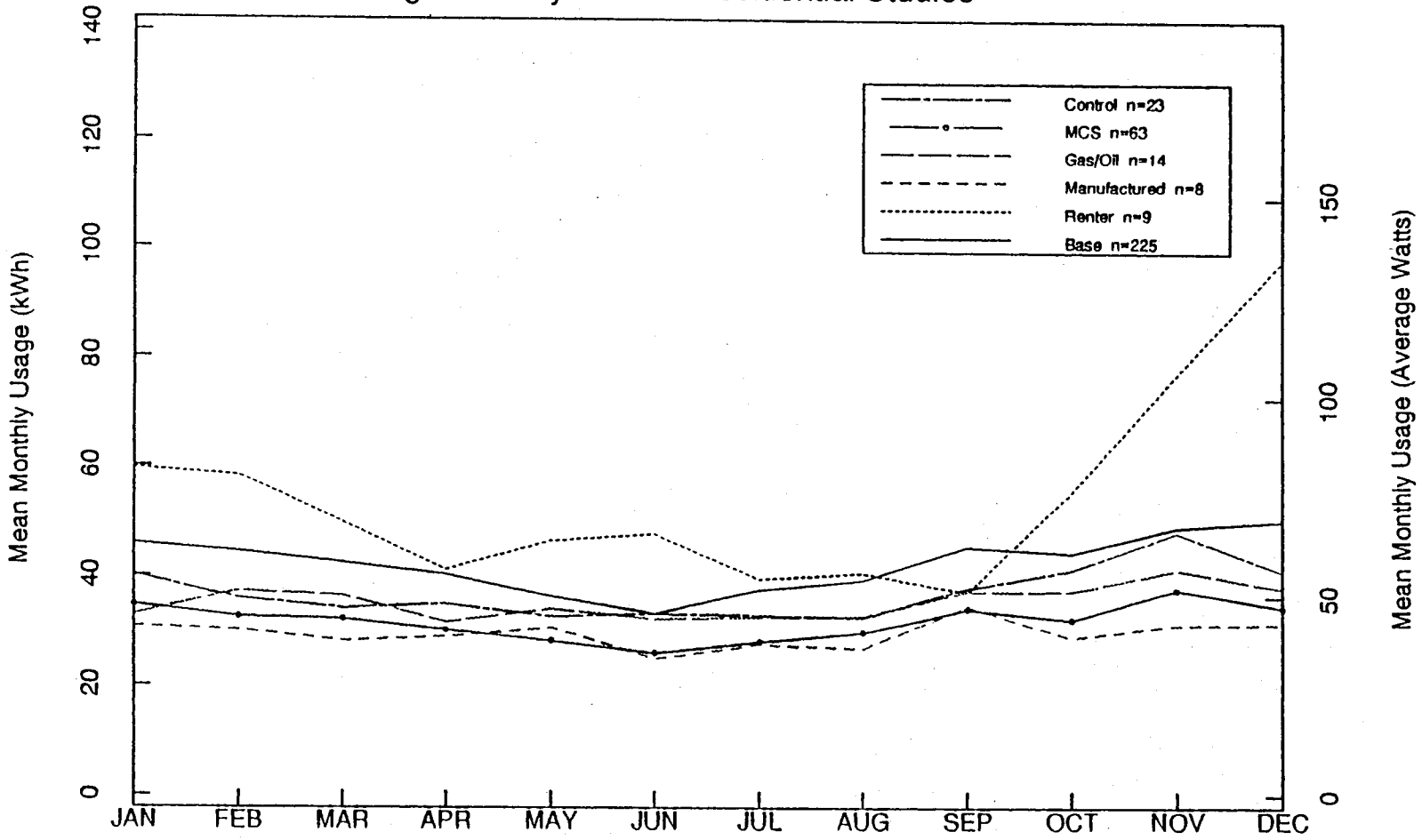
Range Annual Usage Distribution: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.3

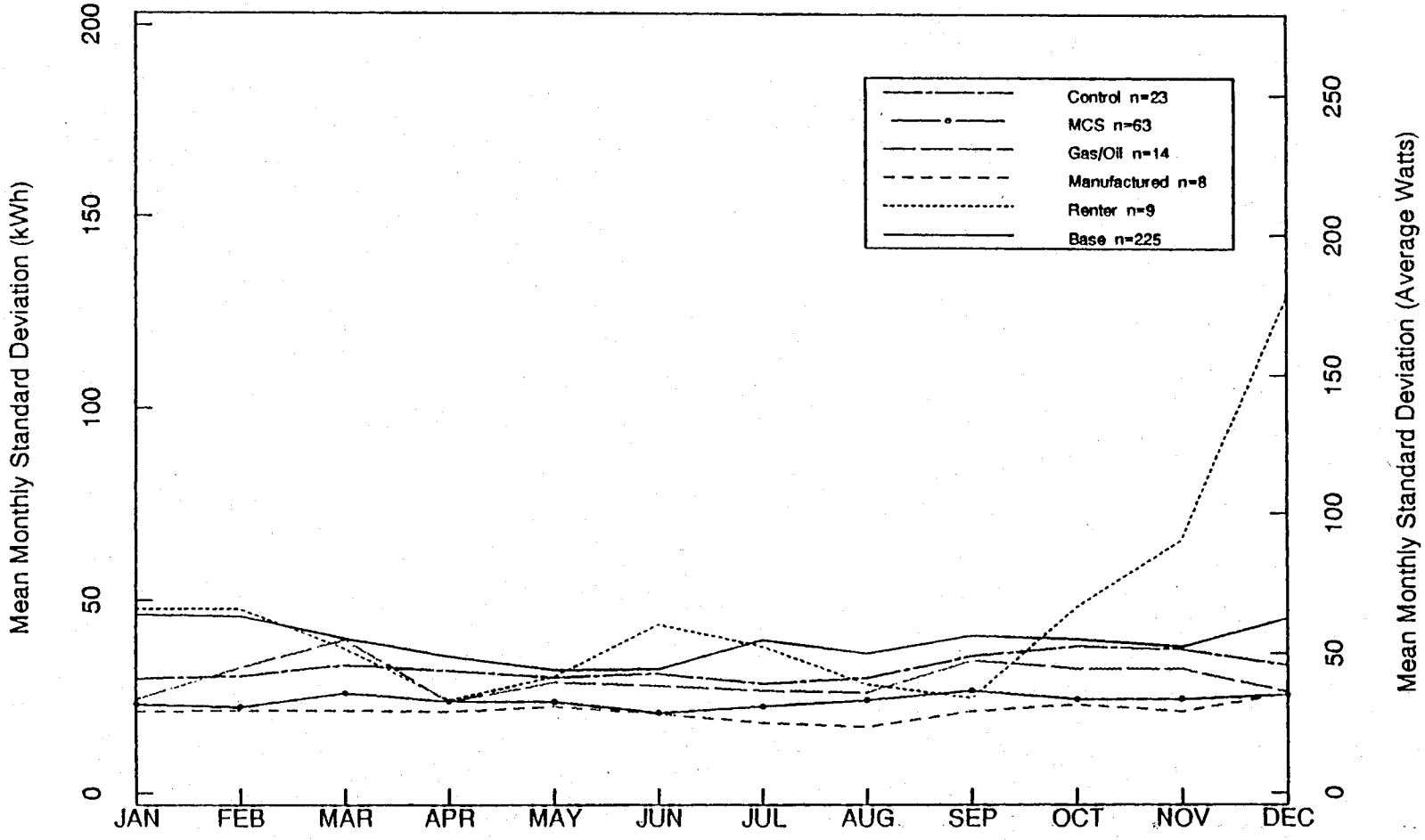
Range Monthly Loads: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

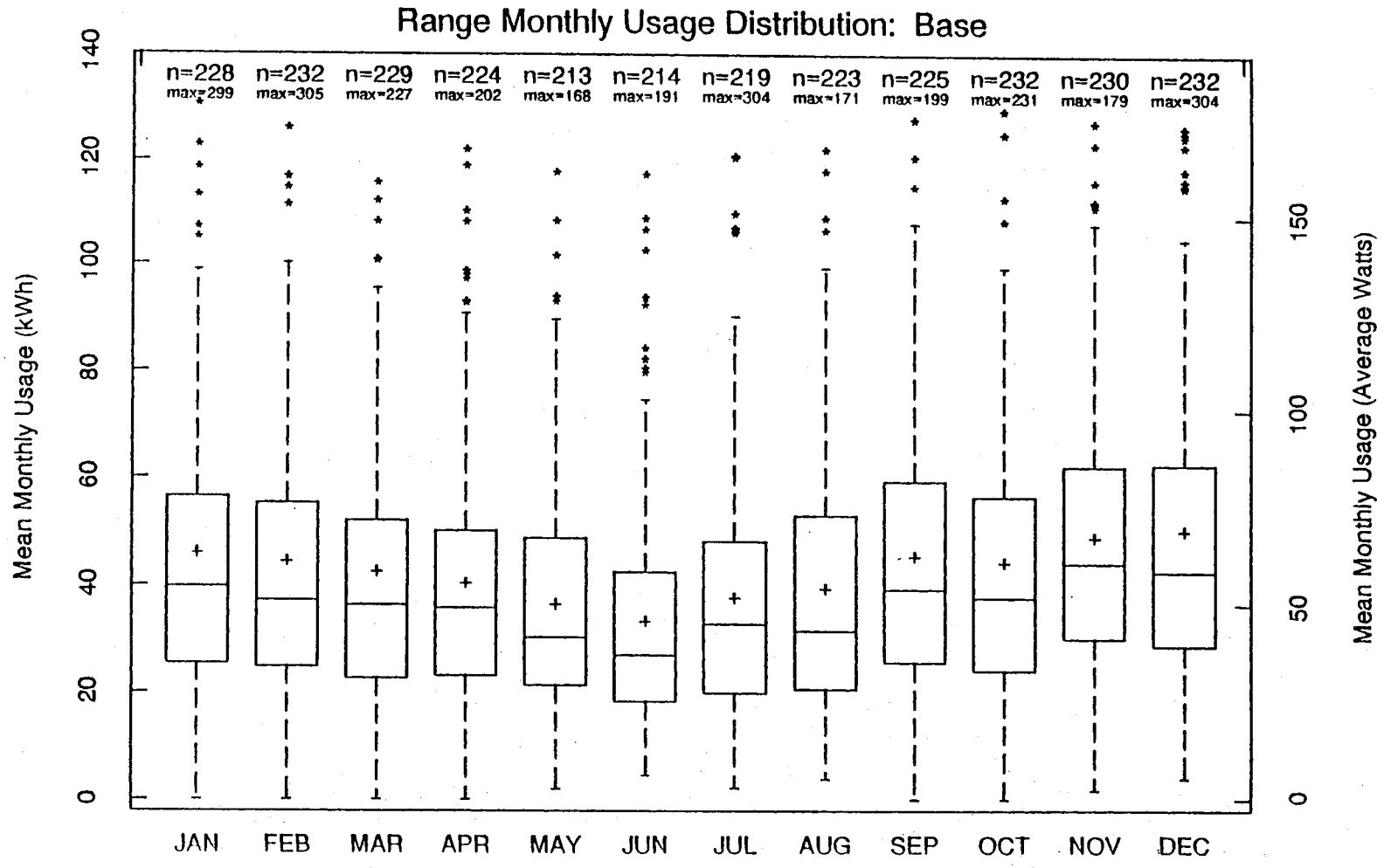
FIGURE 7K.4

Range Monthly Standard Deviation: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

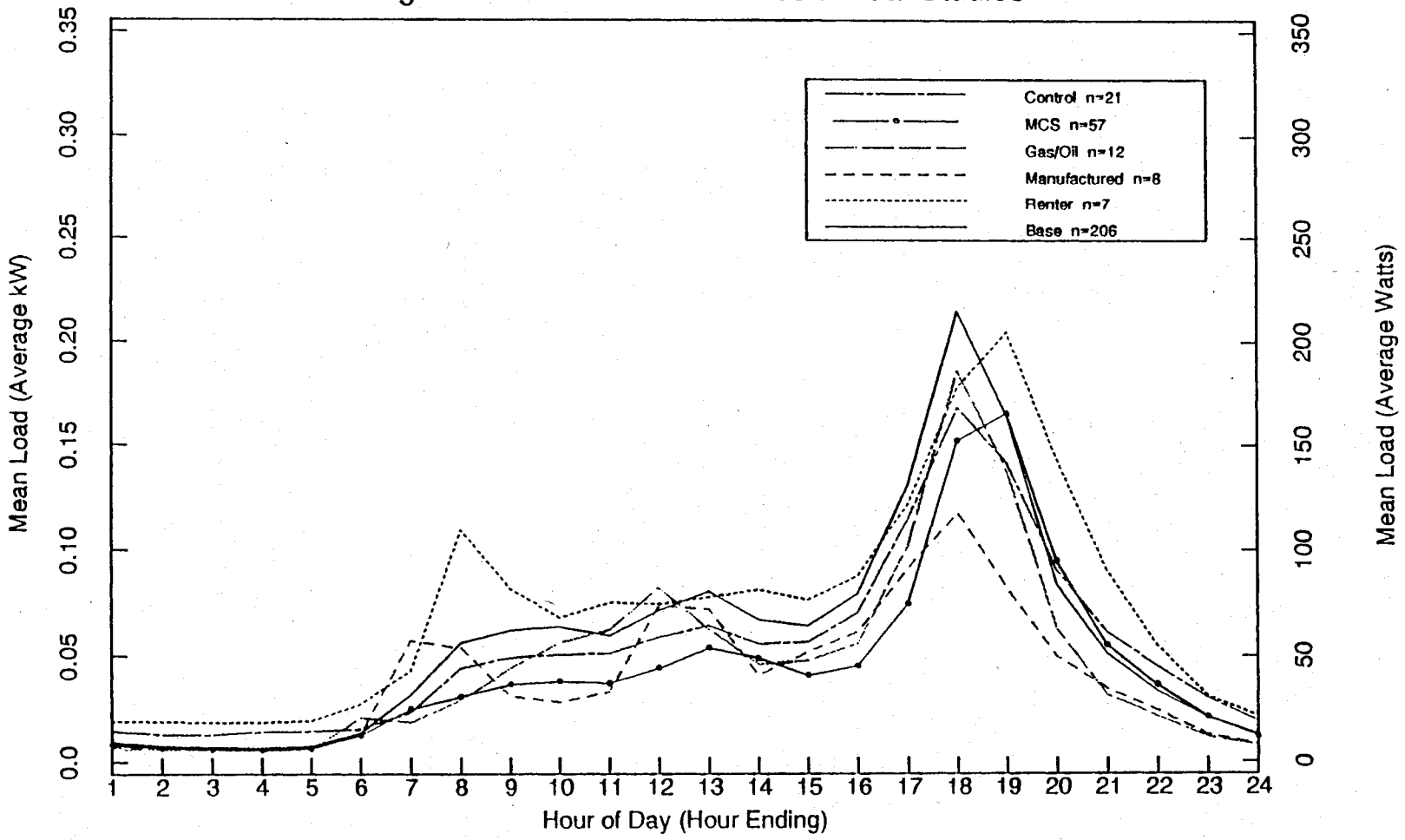
FIGURE 7K.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.6

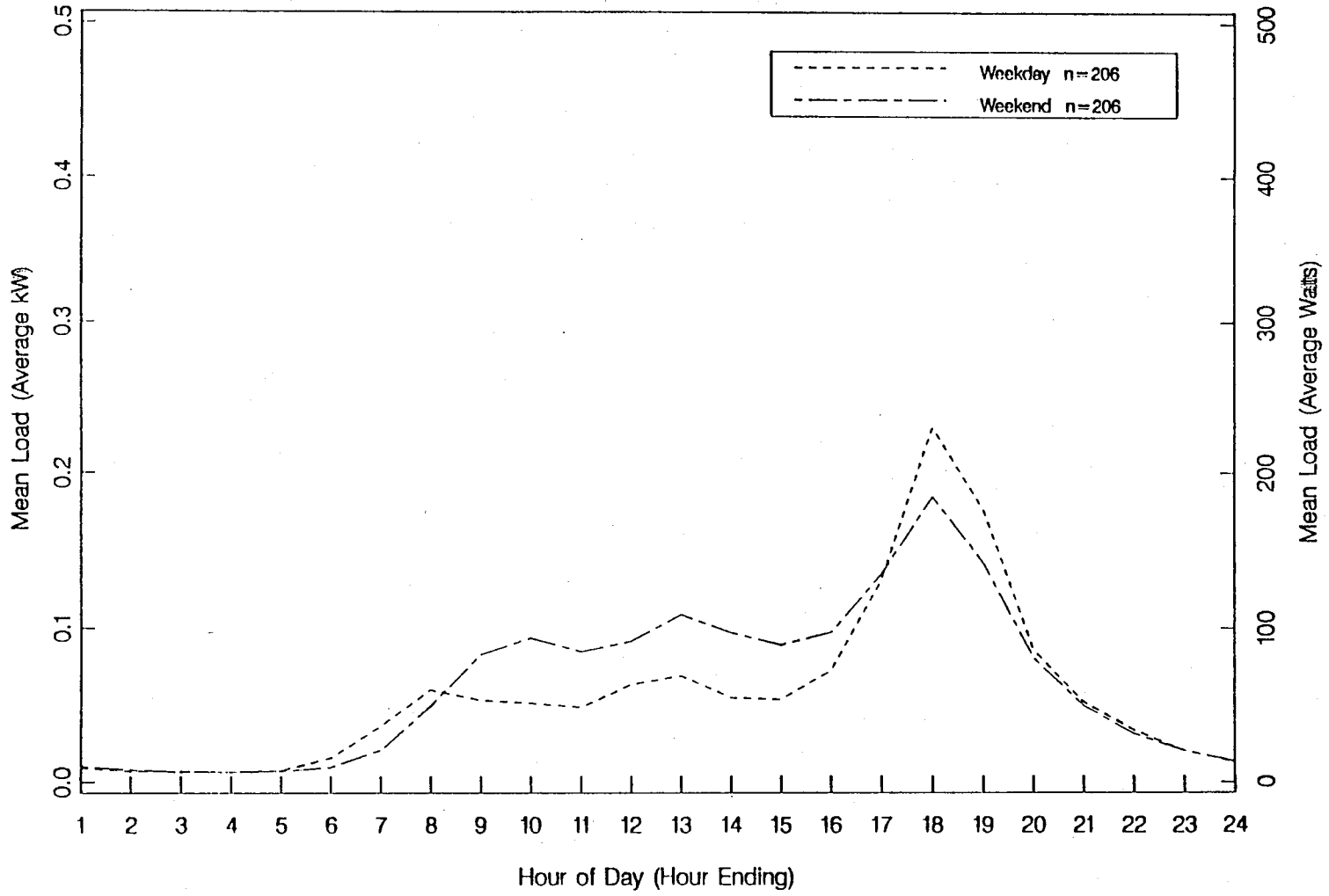
Range Annual Load Profile: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

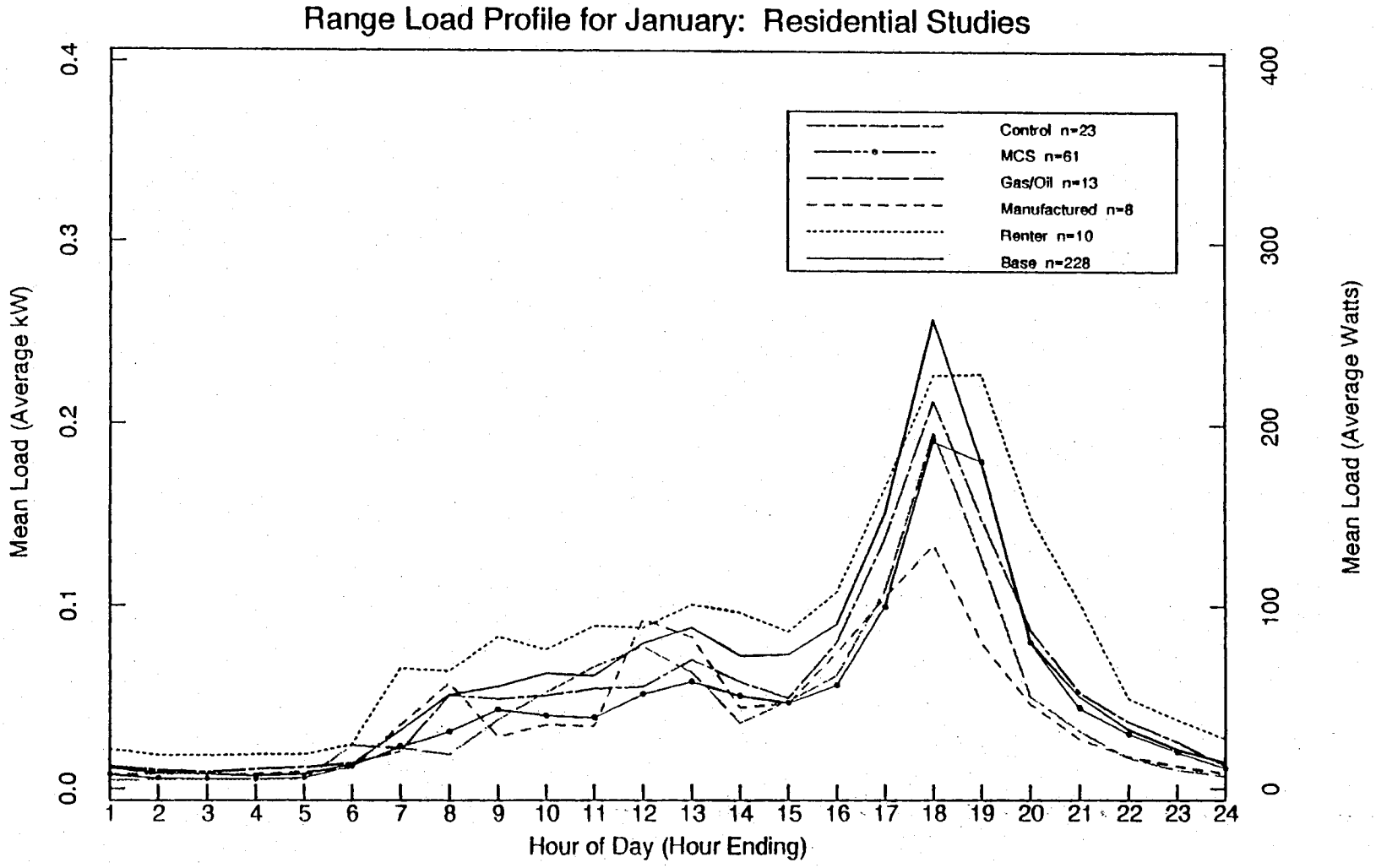
FIGURE 7K.7

Range Annual Weekday/Weekend Load Profiles: Base



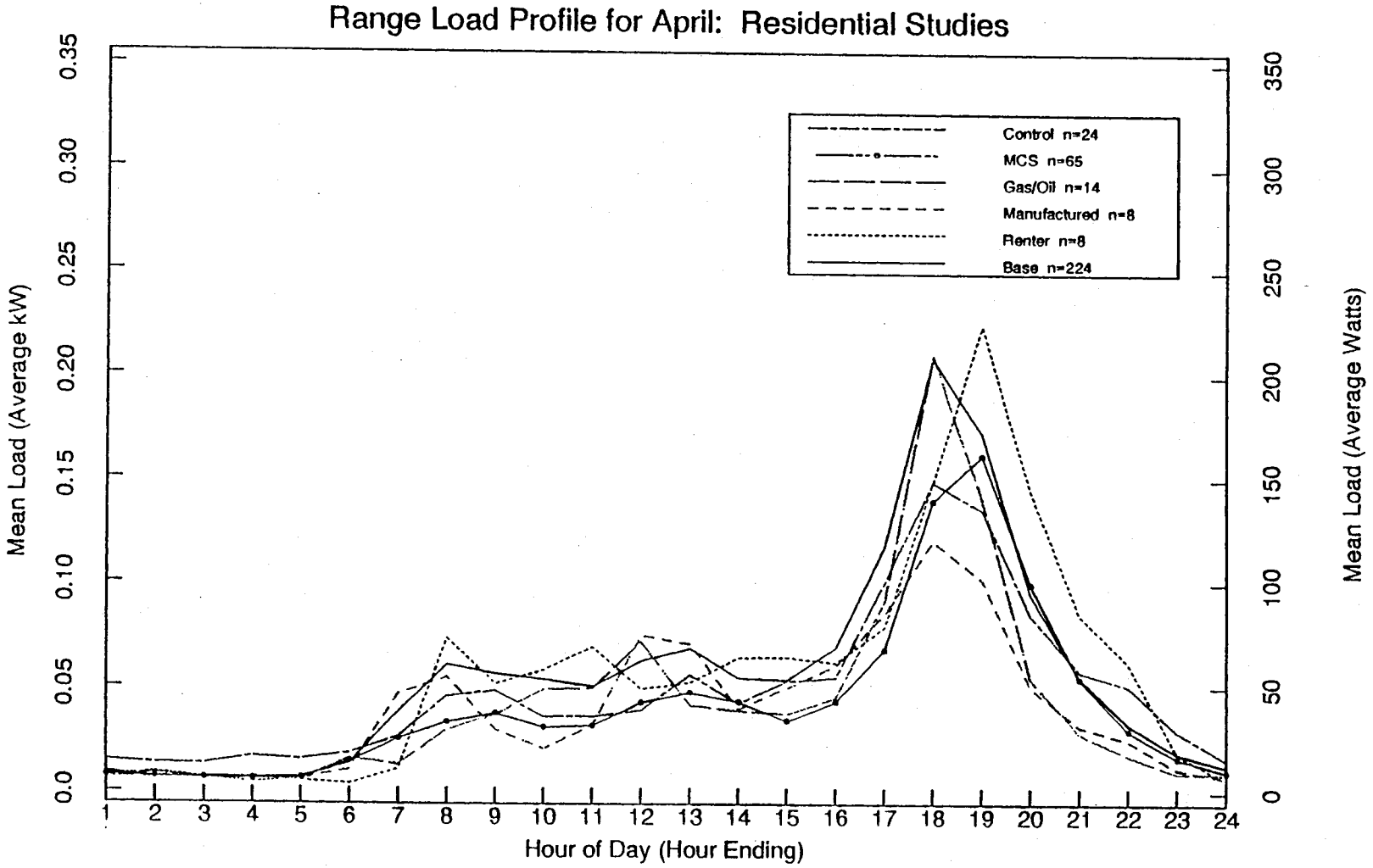
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.8(a)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

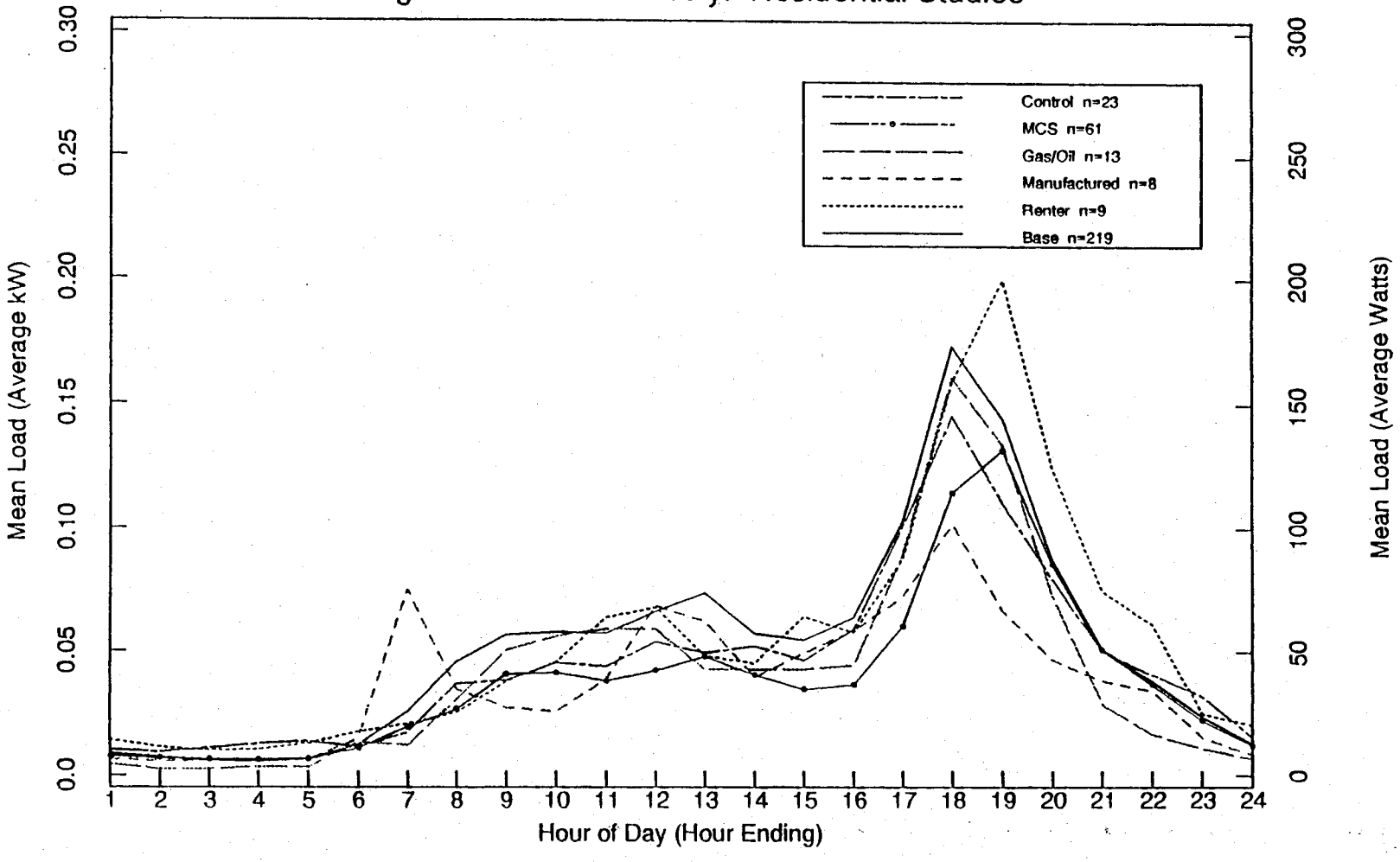
FIGURE 7K.8(b)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

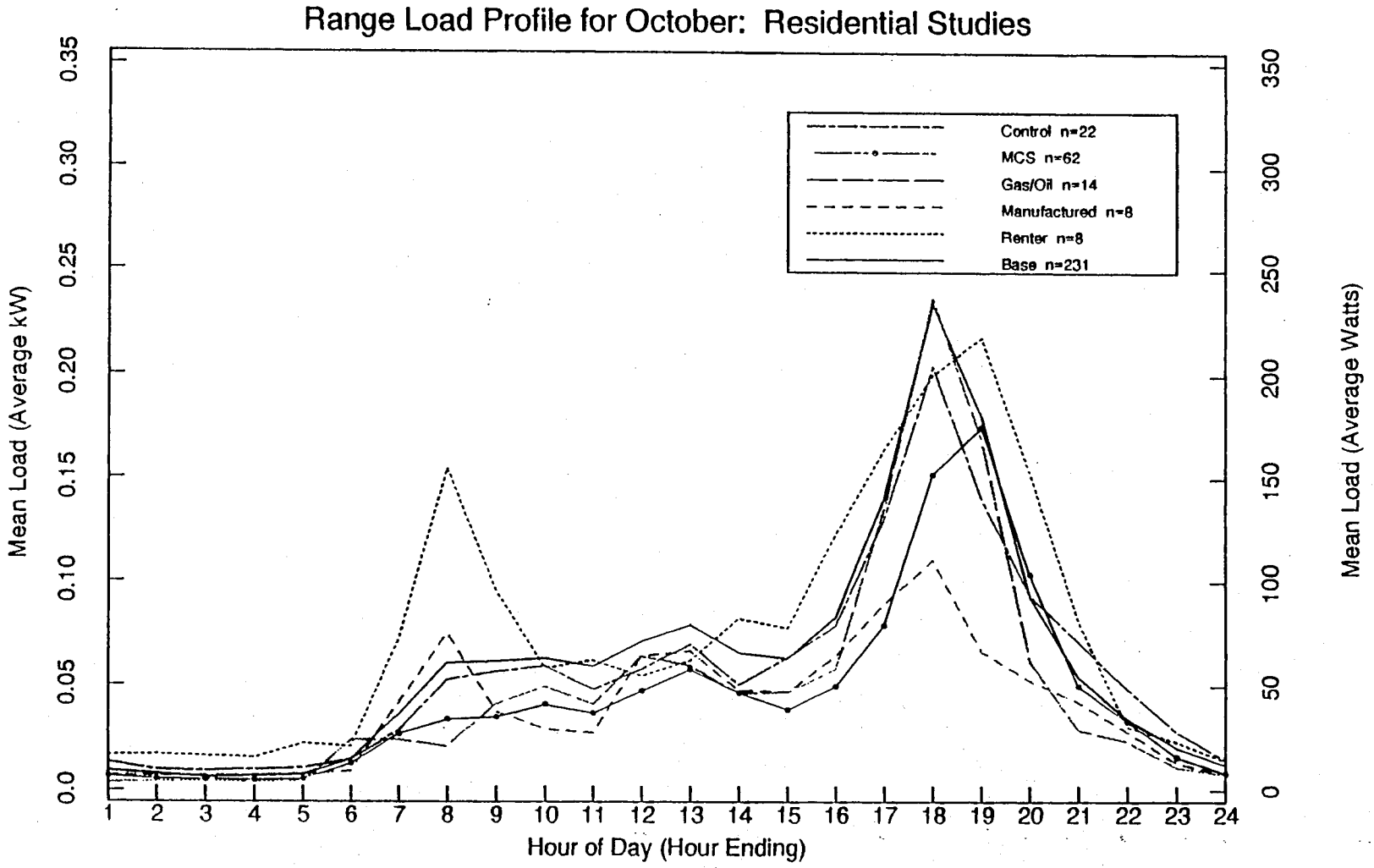
FIGURE 7K.8(c)

Range Load Profile for July: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

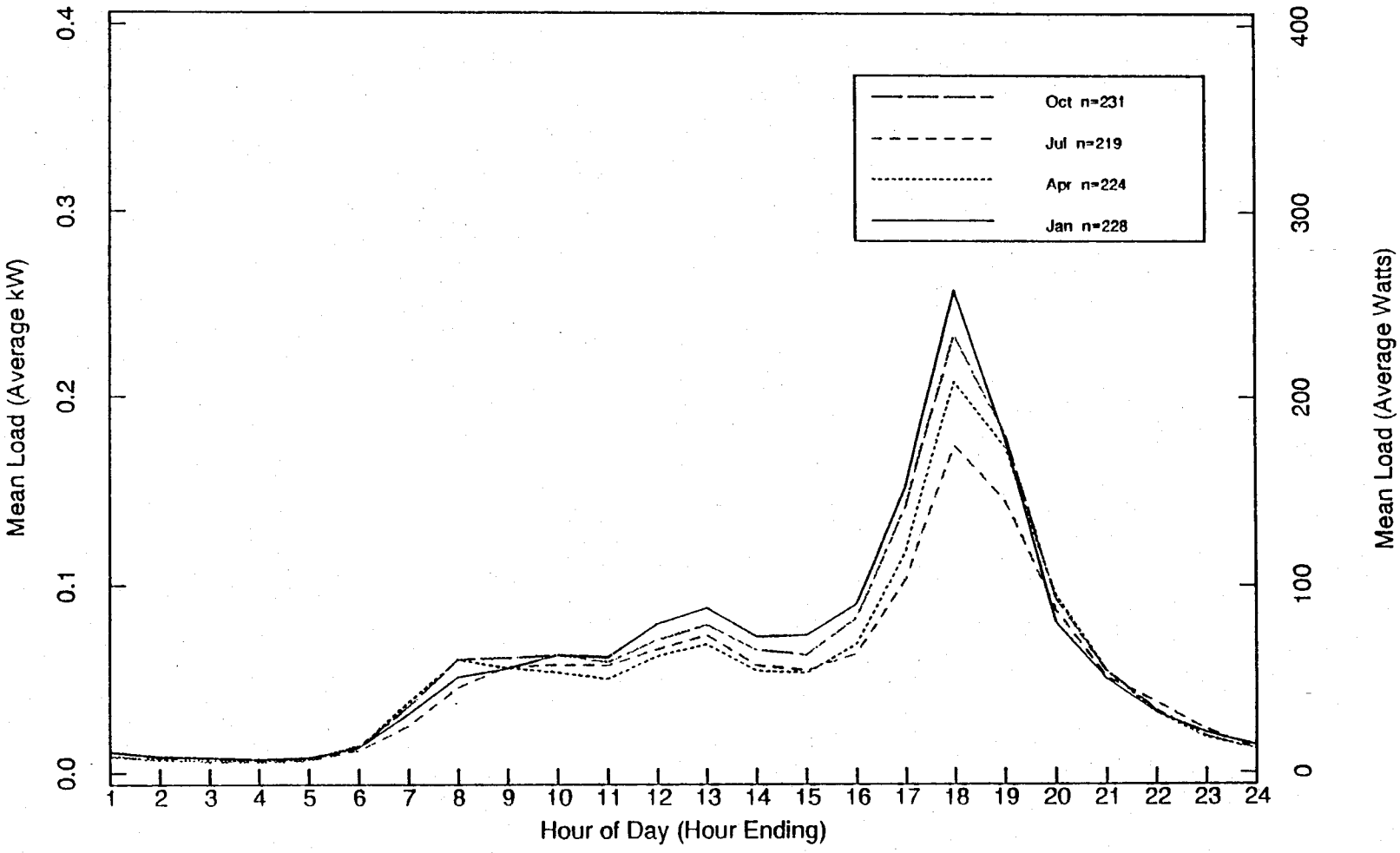
FIGURE 7K.8(d)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(a)

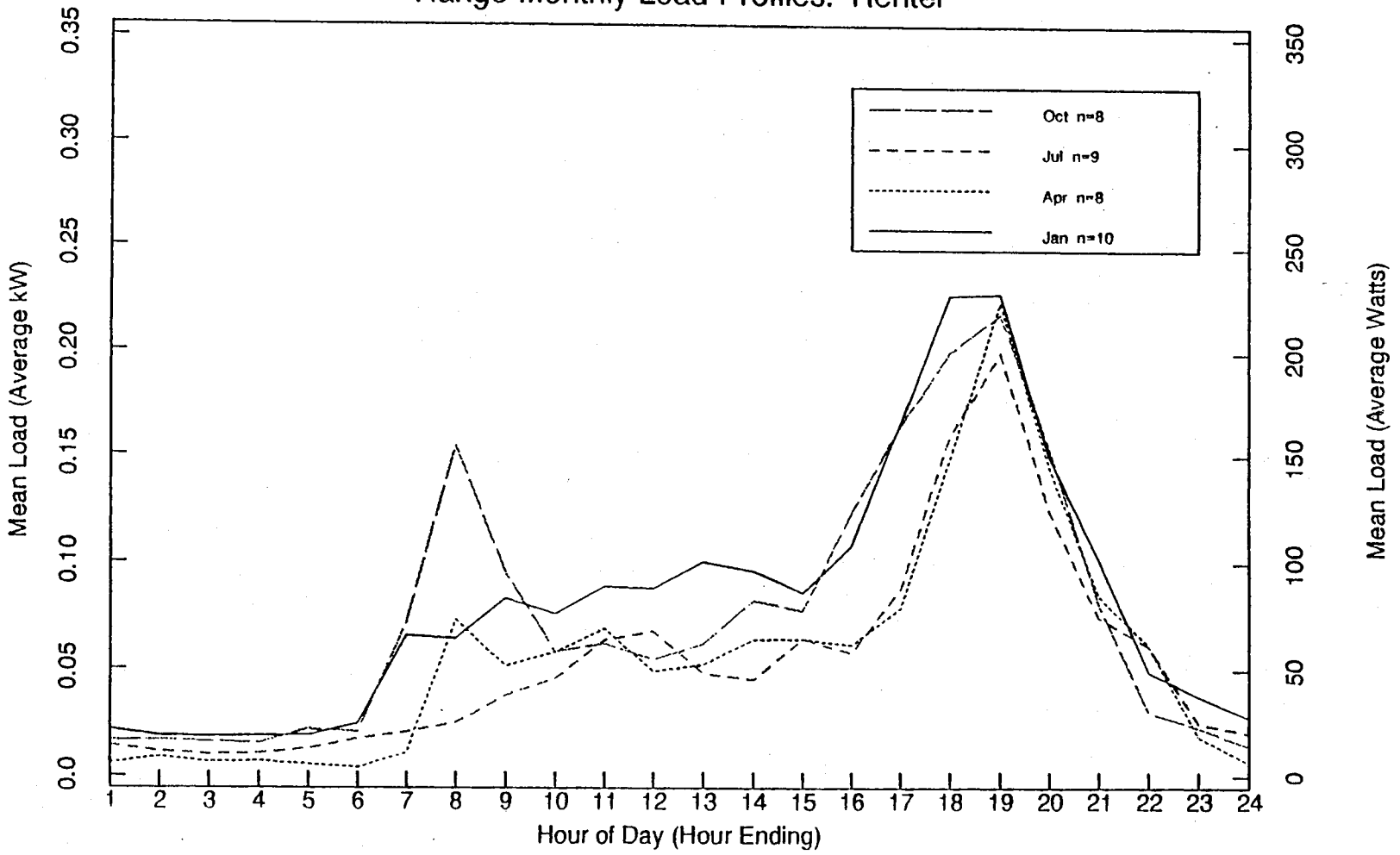
Range Monthly Load Profiles: Base



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(b)

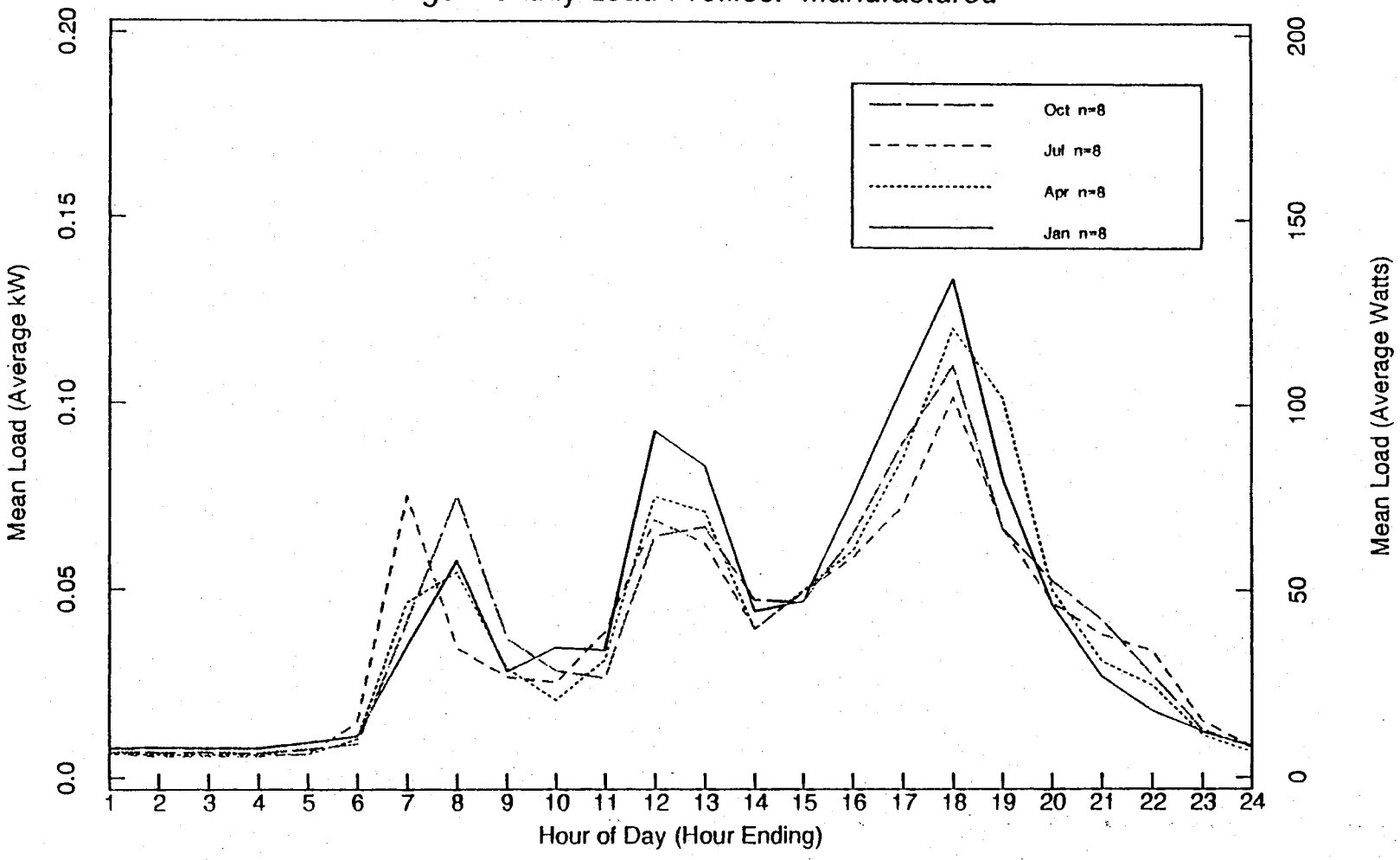
Range Monthly Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(c)

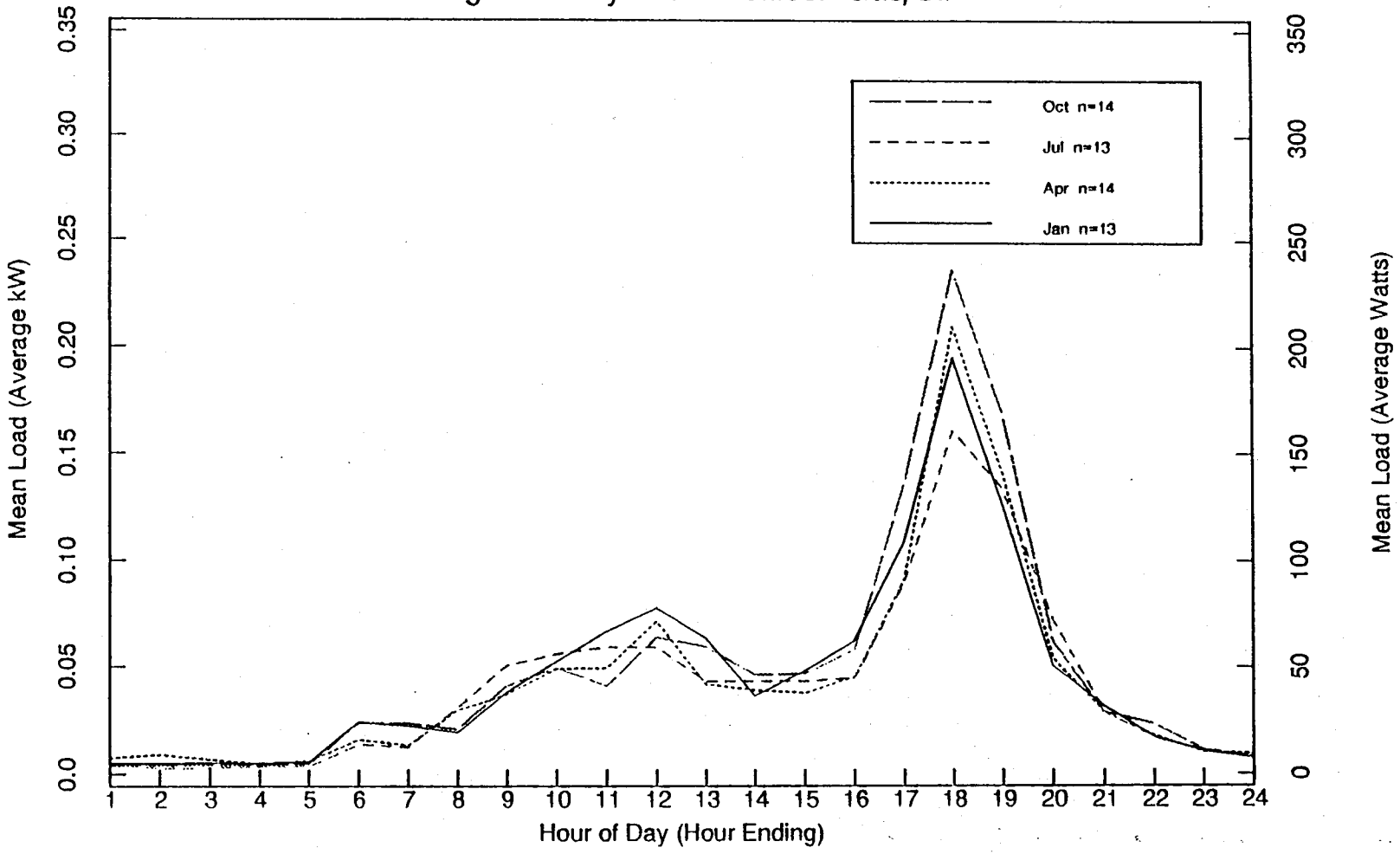
Range Monthly Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(d)

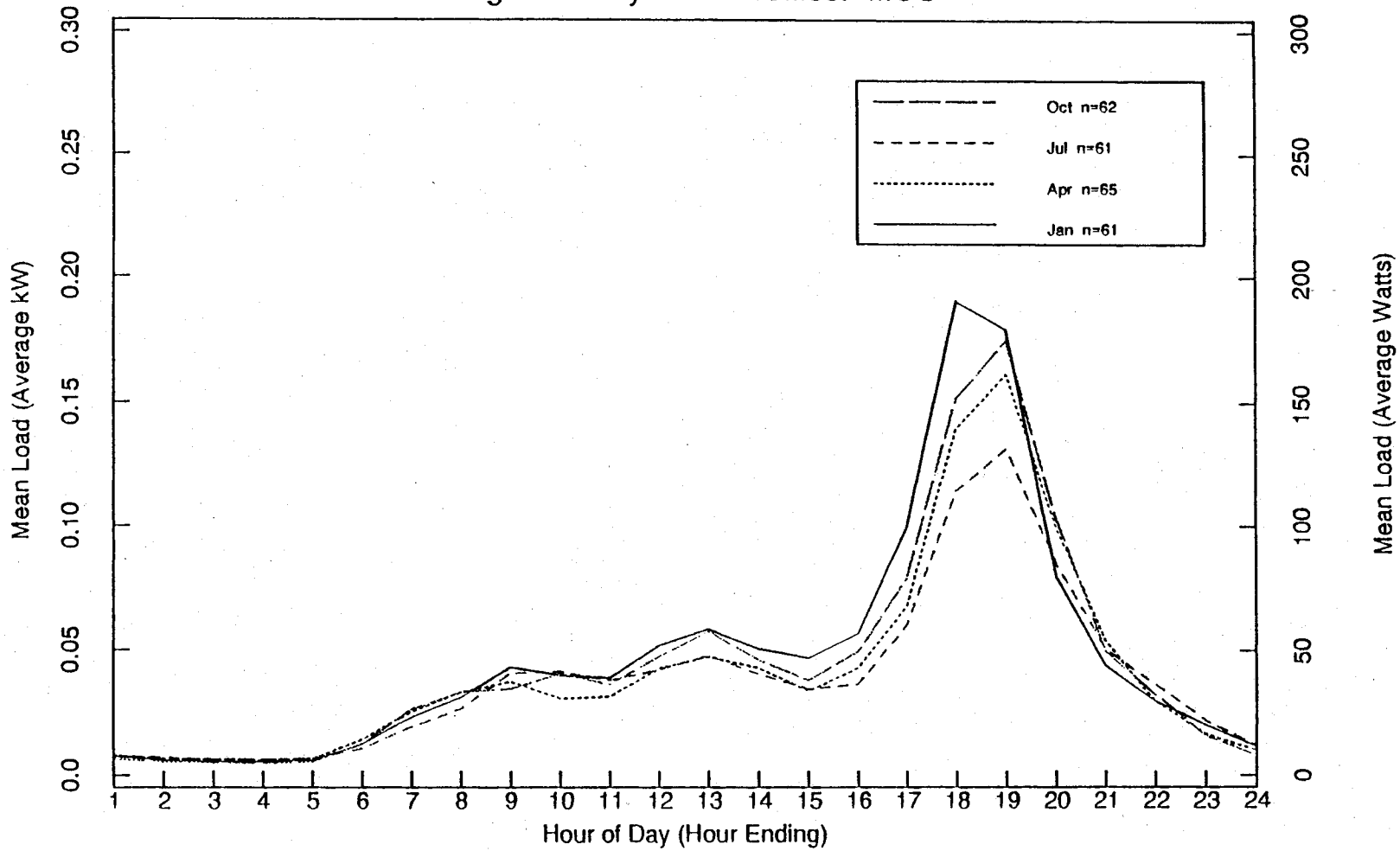
Range Monthly Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(e)

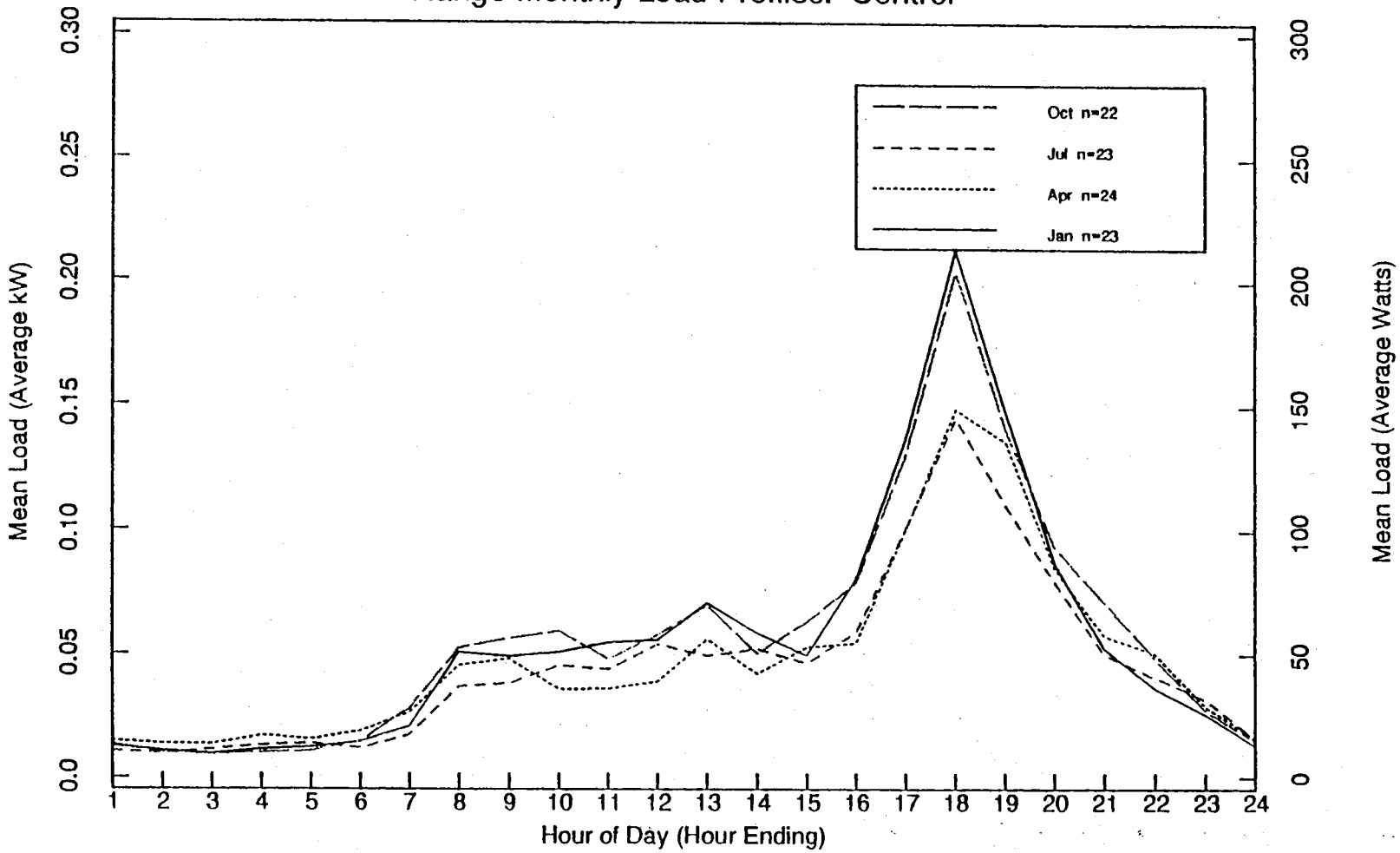
Range Monthly Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.9(f)

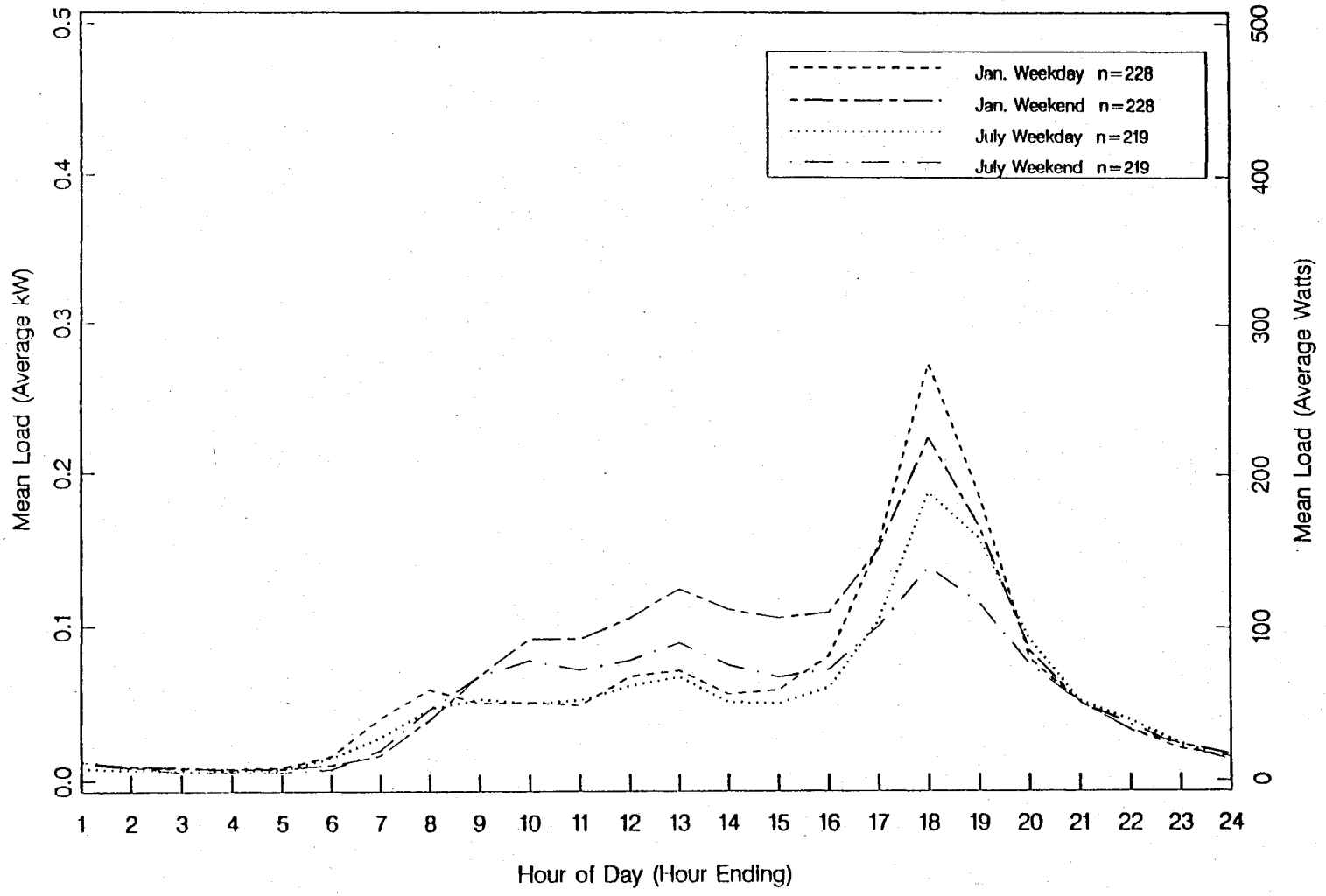
Range Monthly Load Profiles: Control



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7K.10(a)

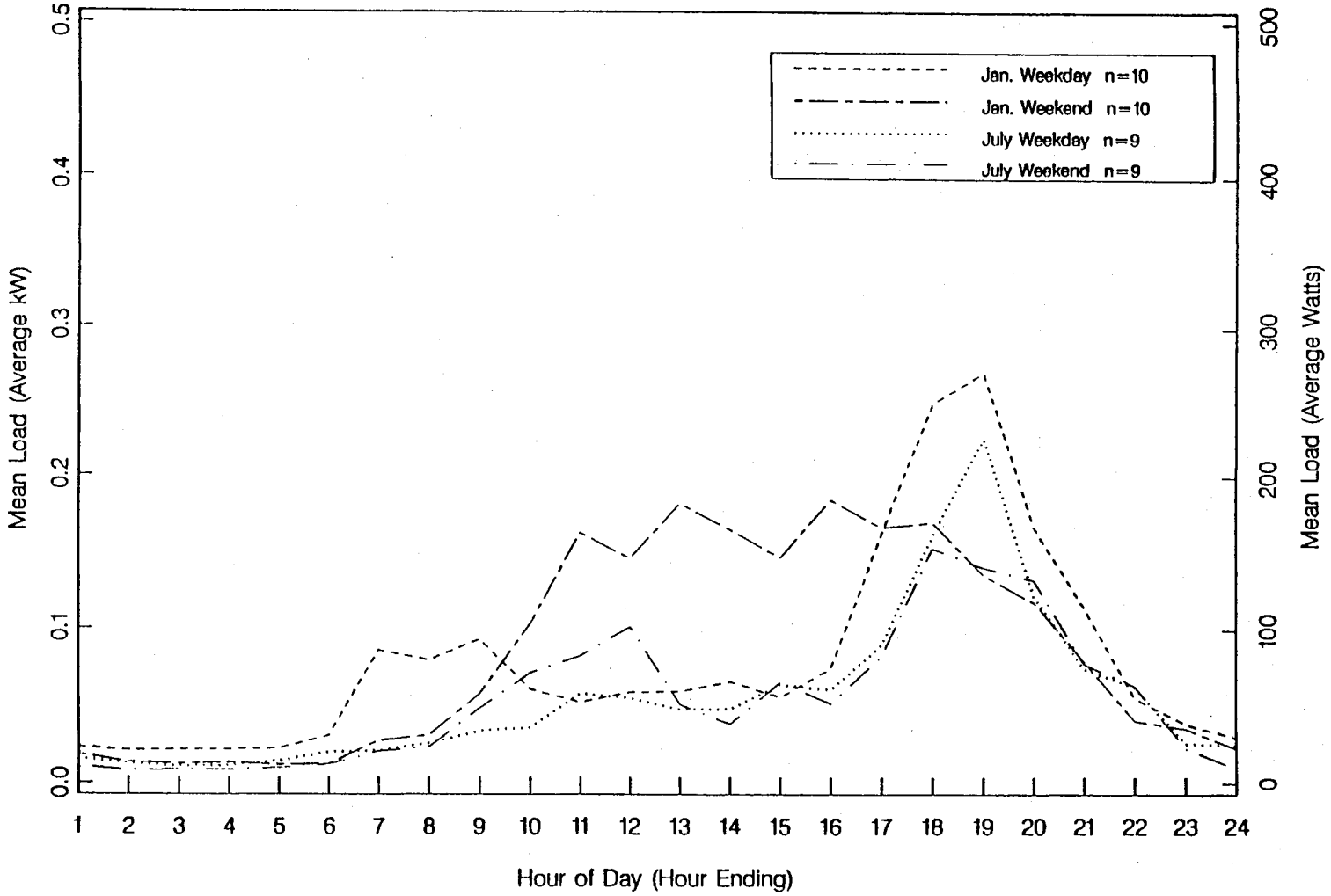
Range January/July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84–Mar '88 SAS/PADS November 1988

FIGURE 7K.10(b)

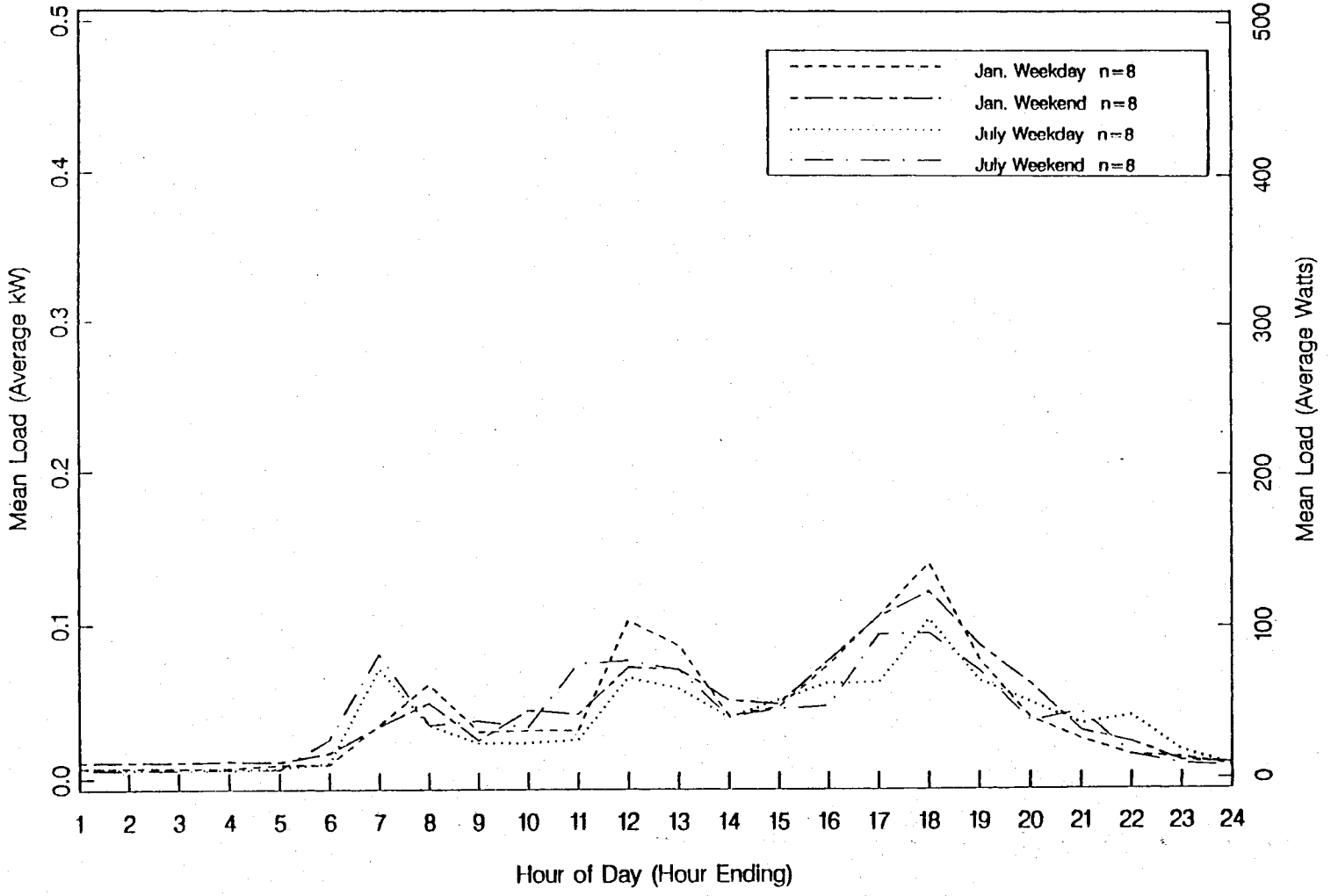
Range January/July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.10(c)

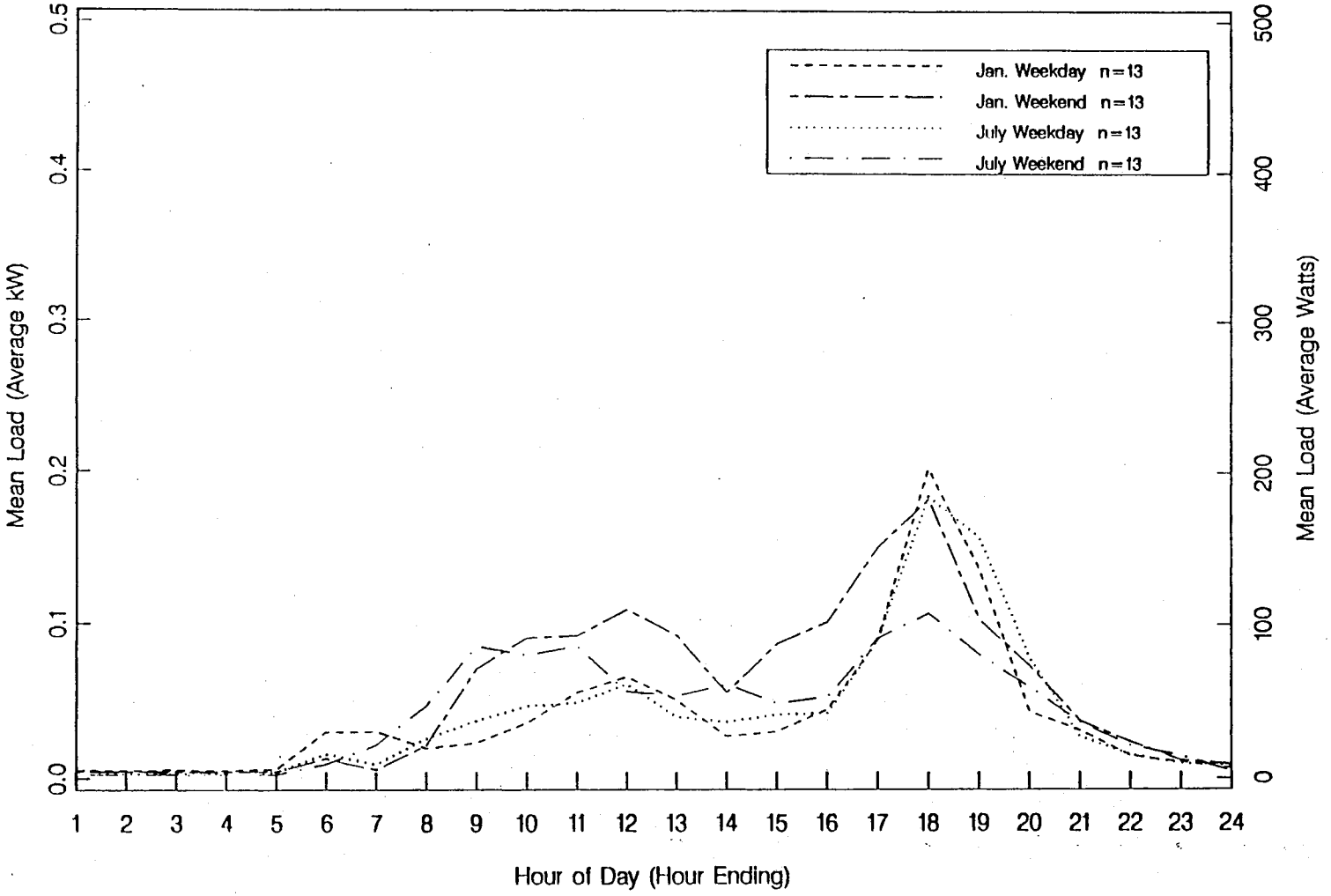
Range January/July Weekday/Weekend Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.10(d)

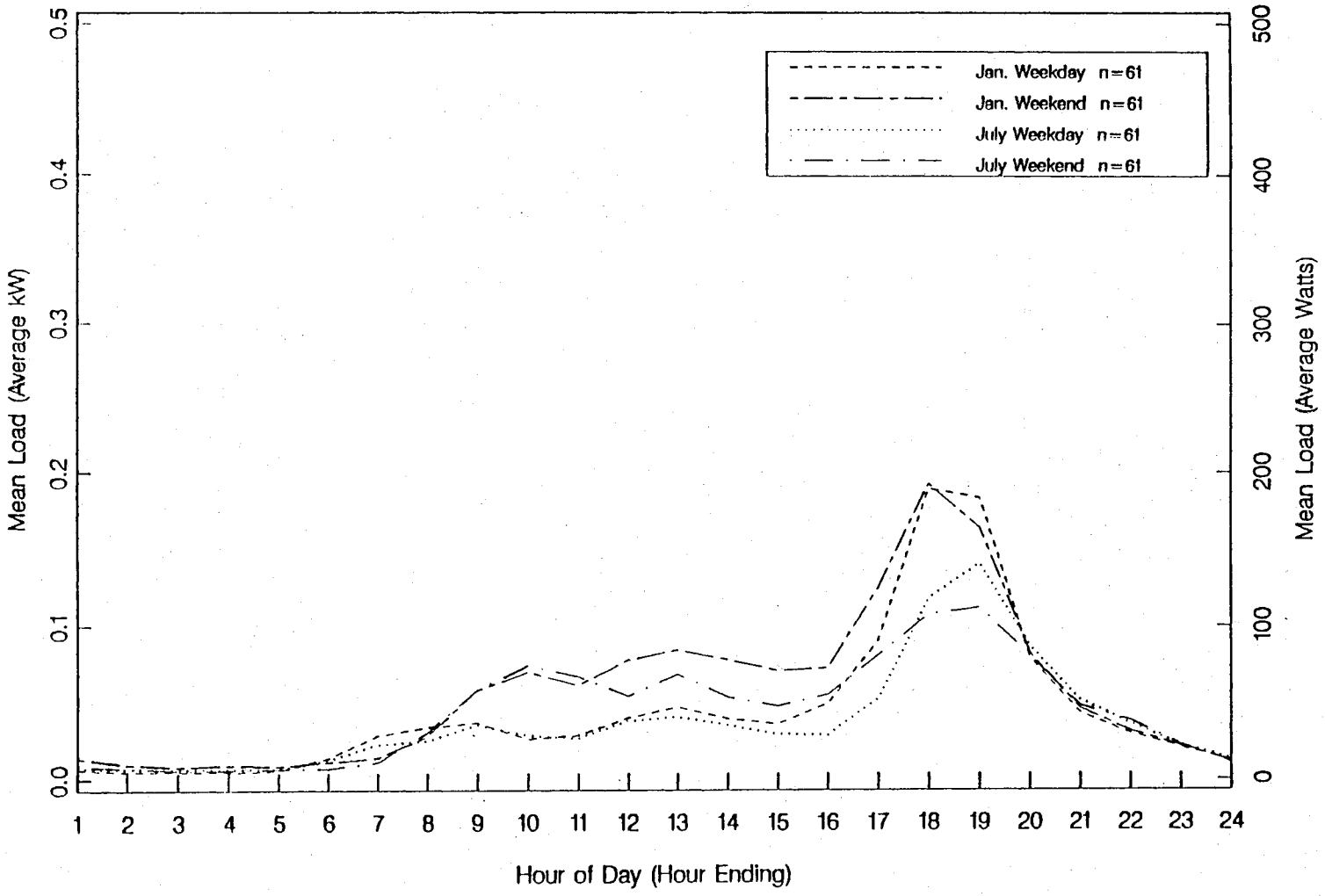
Range January/July Weekday/Weekend Load Profiles: Gas/Oil



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.10(e)

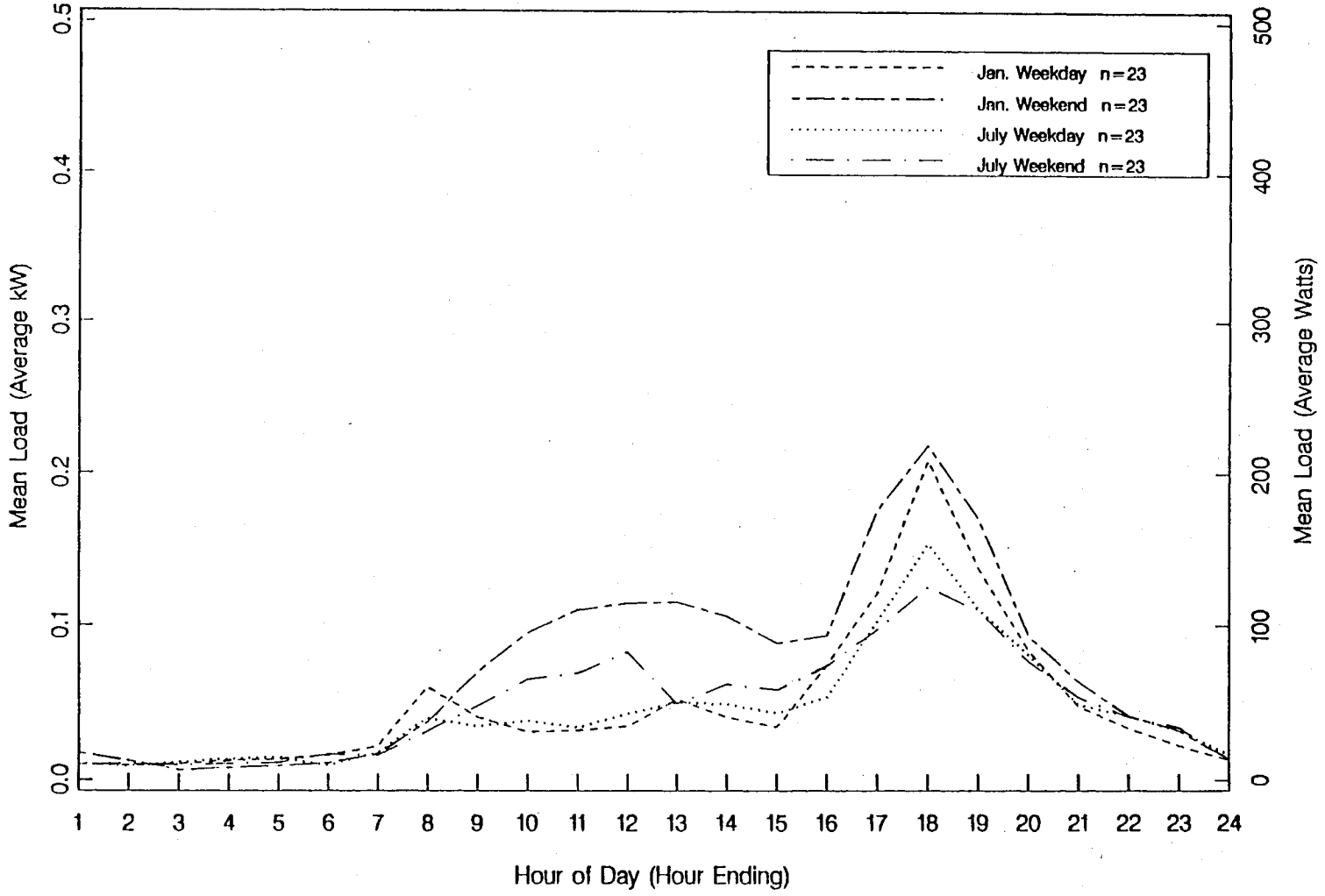
Range January/July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.10(f)

Range January/July Weekday/Weekend Load Profiles: Control



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7K.11

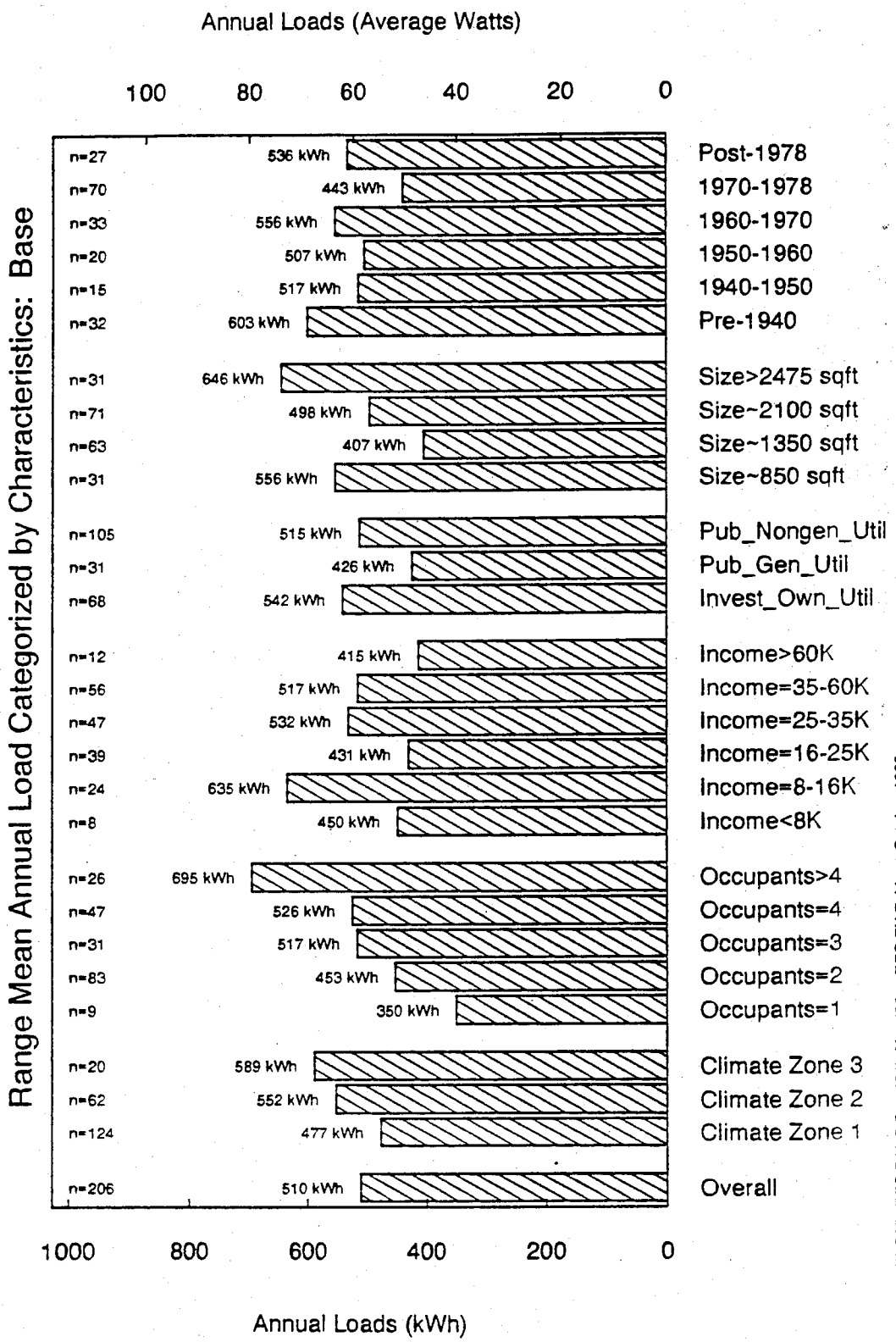
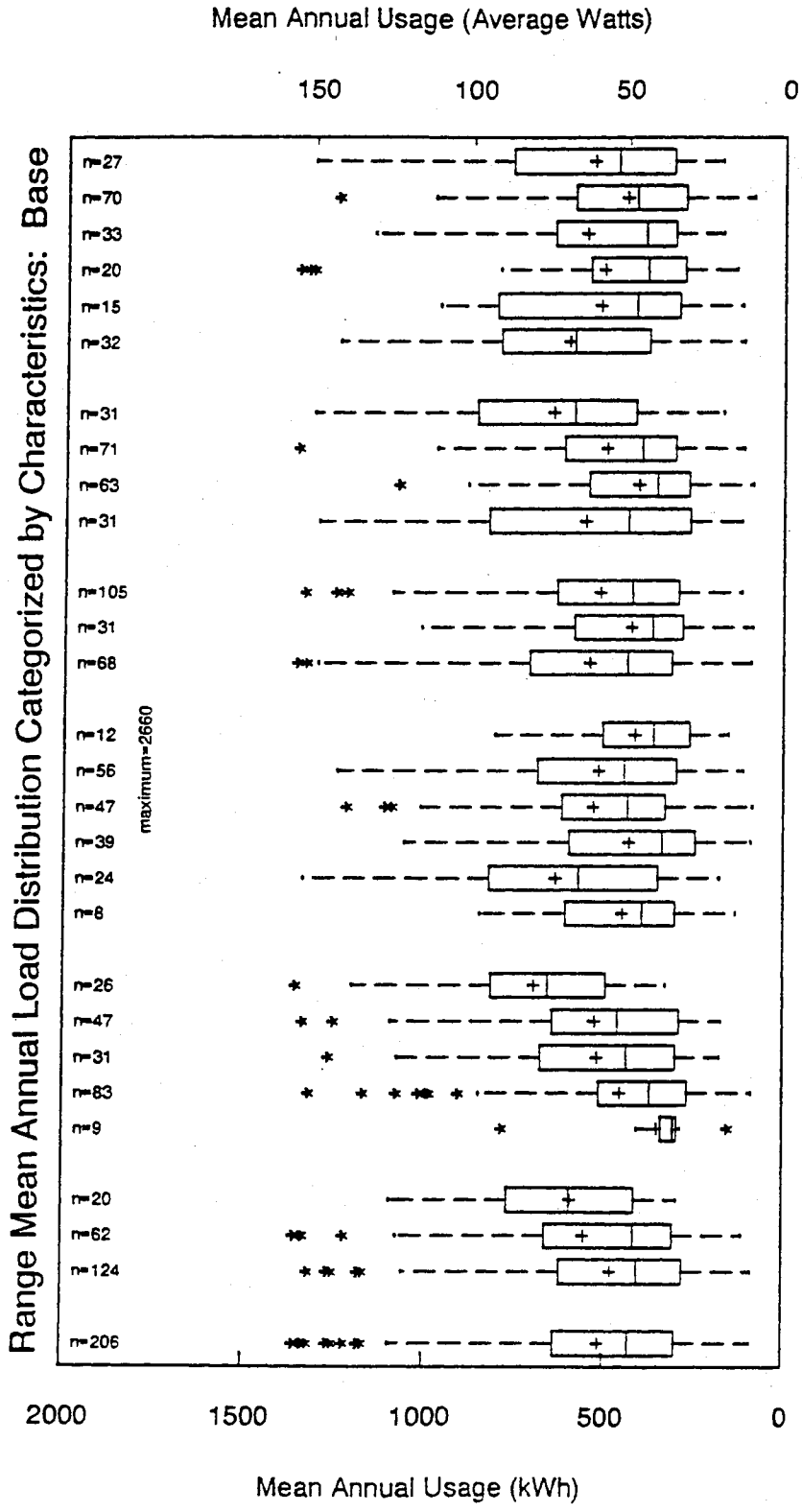

Range Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
100
80
60
40
20
0
n=27 536 kWh Post-1978
n=70 443 kWh 1970-1978
n=33 556 kWh 1960-1970
n=20 507 kWh 1950-1960
n=15 517 kWh 1940-1950
n=32 603 kWh Pre-1940
n=31 646 kWh Size>2475 sqft
n=71 498 kWh Size~2100 sqft
n=63 407 kWh Size~1350 sqft
n=31 556 kWh Size~850 sqft
n=105 515 kWh Pub_Nongen_Util
n=31 426 kWh Pub_Gen_Util
n=68 542 kWh Invest_Own_Util
n=12 415 kWh Income>60K
n=56 517 kWh Income=35-60K
n=47 532 kWh Income=25-35K
n=39 431 kWh Income=16-25K
n=24 635 kWh Income=8-16K
n=8 450 kWh Income<8K
n=26 695 kWh Occupants>4
n=47 526 kWh Occupants=4
n=31 517 kWh Occupants=3
n=83 453 kWh Occupants=2
n=9 350 kWh Occupants=1
n=20 589 kWh Climate Zone 3
n=62 552 kWh Climate Zone 2
n=124 477 kWh Climate Zone 1
n=206 510 kWh Overall
1000
800
600
400
200
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7K.12

Range Mean Annual Load Distribution Categorized by Characteristics: Base



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7K.1

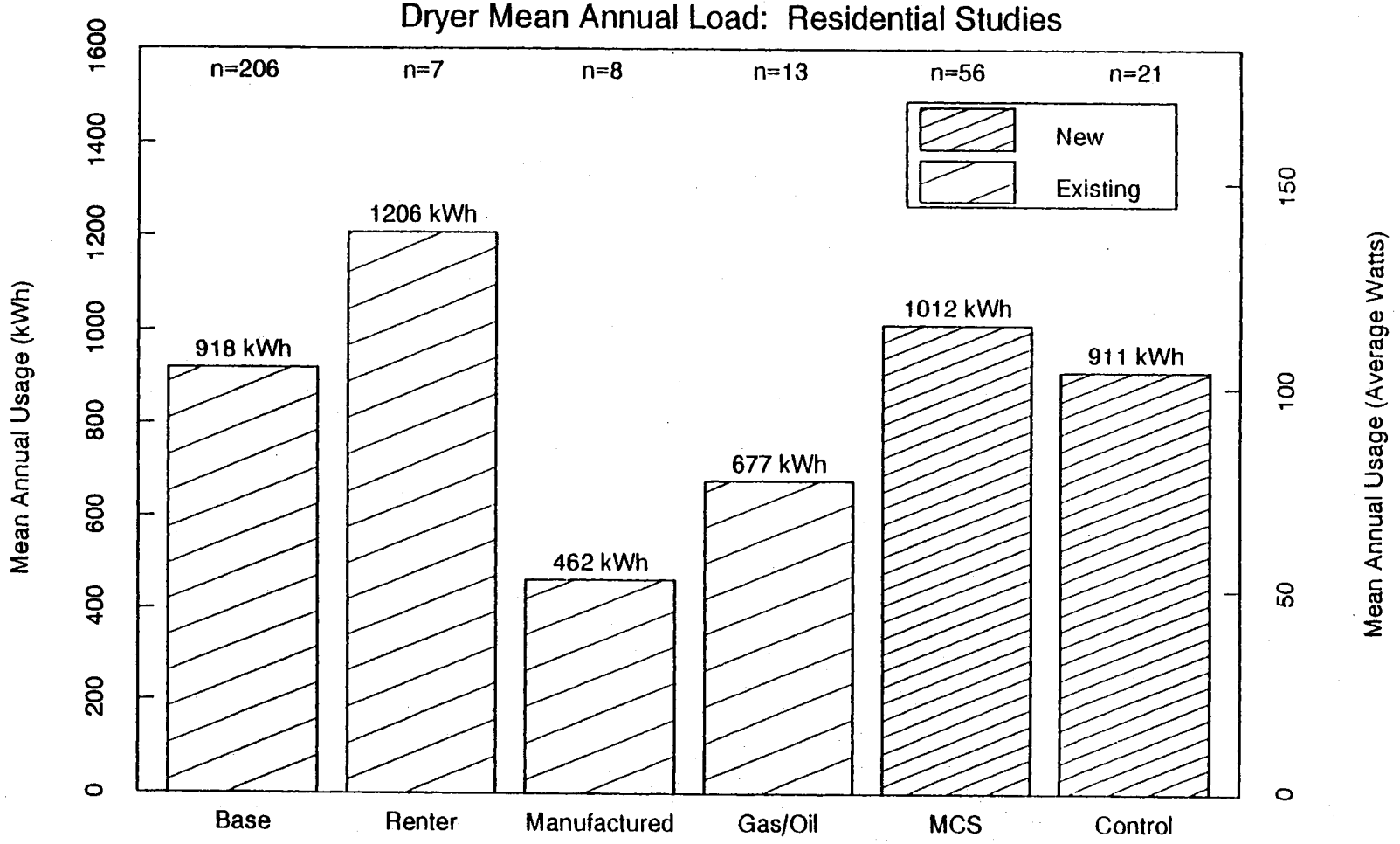
Range Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	208	510	314	21	467	260	57	385	184	284	482	292
Climate Zone 1	124	477	273	13	475	241	36	369	156	173	454	253
Climate Zone 2	62	552	399	4	644	336	17	413	237	83	528	370
Climate Zone 3	20	589	227	4	264	89	4	406	203	28	517	239
Occupants=1	9	350	172	1	294	0	2	385	99	12	351	151
Occupants=2	83	453	350	7	398	268	14	380	218	104	439	330
Occupants=3	31	517	287	3	495	509	8	405	124	42	494	278
Occupants=4	47	526	278	3	568	183	7	316	105	57	502	267
Occupants>4	26	695	257	1	450	0	5	563	144	32	667	245
Income<8K	8	450	227	0	-	-	1	197	0	9	422	229
Income=8-16K	24	635	341	1	1070	0	1	168	0	26	634	351
Income=16-25K	39	431	256	1	258	0	8	467	226	48	433	248
Income=25-35K	47	532	401	8	525	220	12	308	100	67	491	356
Income=35-60K	58	517	282	3	264	163	13	475	158	72	499	263
Income>60K	12	415	212	1	298	0	1	387	0	14	405	197
Invest_Own_Util	68	542	310	10	472	302	32	361	161	110	483	284
Pub_Gen_Util	31	426	227	7	524	198	10	447	160	48	444	209
Pub_Nongen_Util	105	515	339	4	354	275	11	381	268	120	497	332
Size~850 sqft	31	556	340	1	745	0	1	168	0	33	550	338
Size~1350 sqft	63	407	205	13	428	253	26	386	163	102	404	200
Size~2100 sqft	71	498	341	6	514	307	17	436	199	94	488	316
Size>2475 sqft	31	646	331	0	-	-	9	366	216	40	583	329
Pre-1940	32	603	295	0	-	-	0	-	-	32	603	295
1940-1950	15	517	266	0	-	-	0	-	-	15	517	266
1950-1960	20	507	380	0	-	-	0	-	-	20	507	380
1960-1970	33	556	464	0	-	-	0	-	-	33	556	464
1970-1978	70	443	219	0	-	-	0	-	-	70	443	219
Post-1978	27	536	302	21	467	260	57	385	184	105	440	241

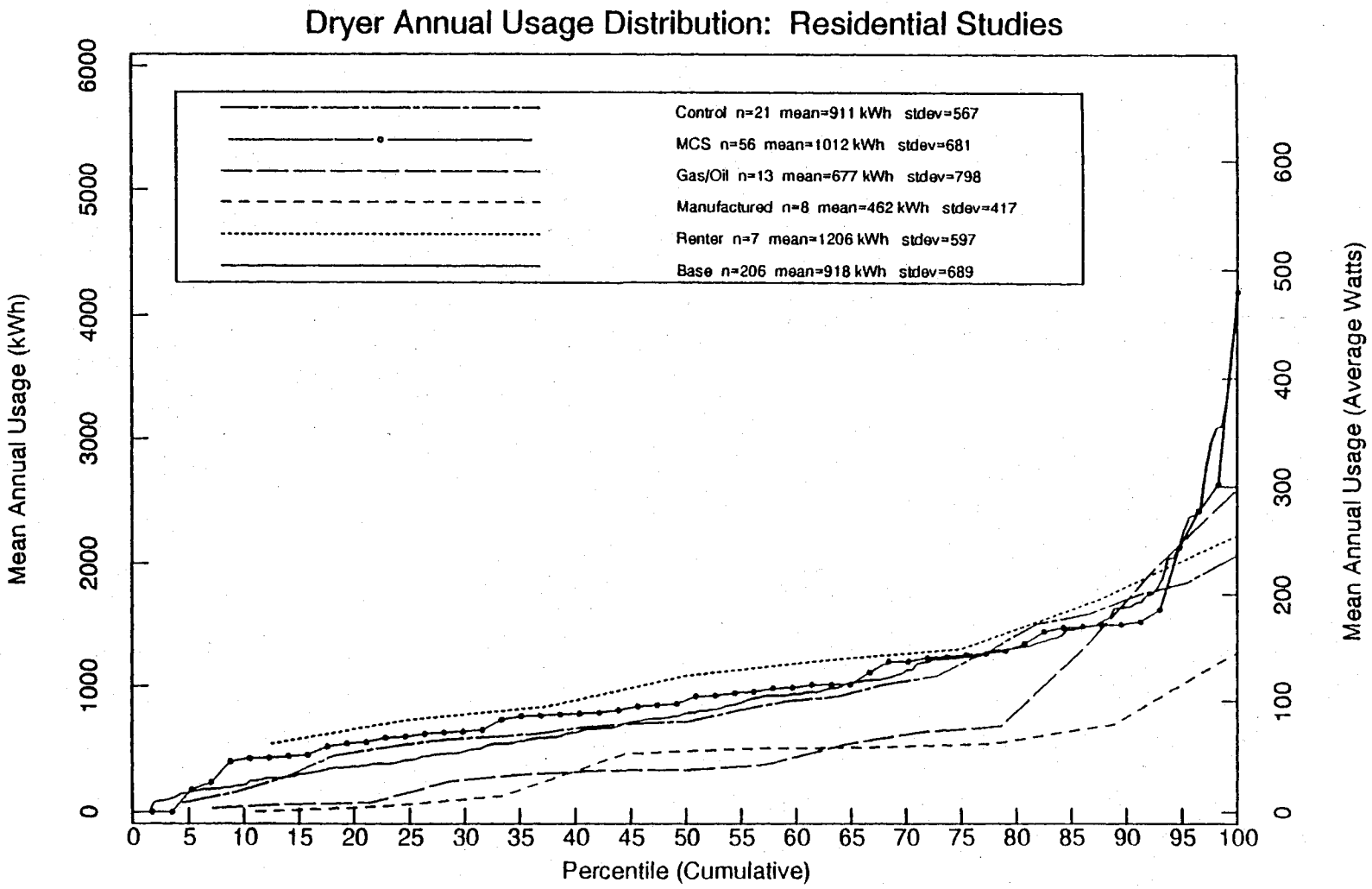
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7L.1
Dryer Mean Annual Load: Residential Studies



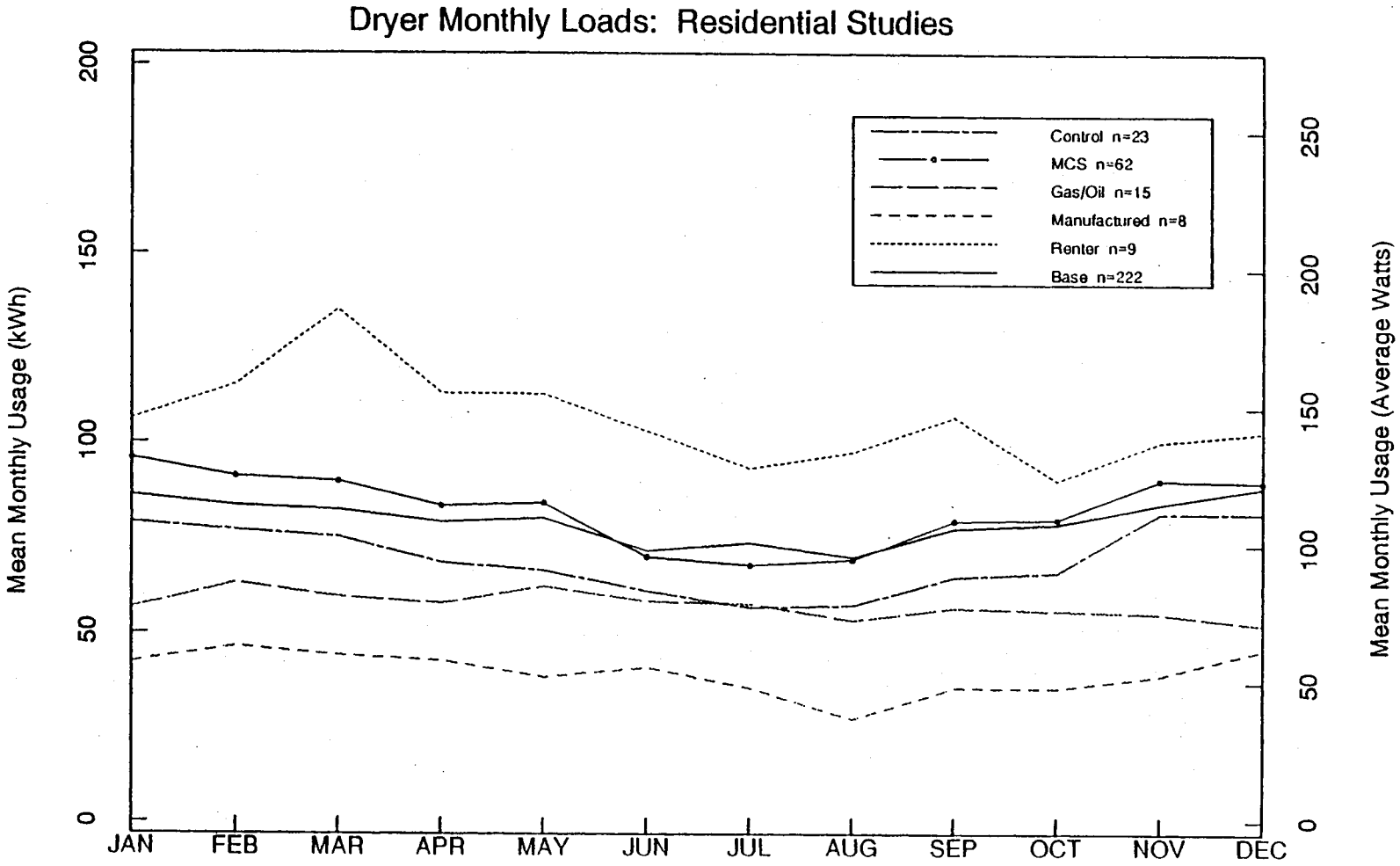
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.2



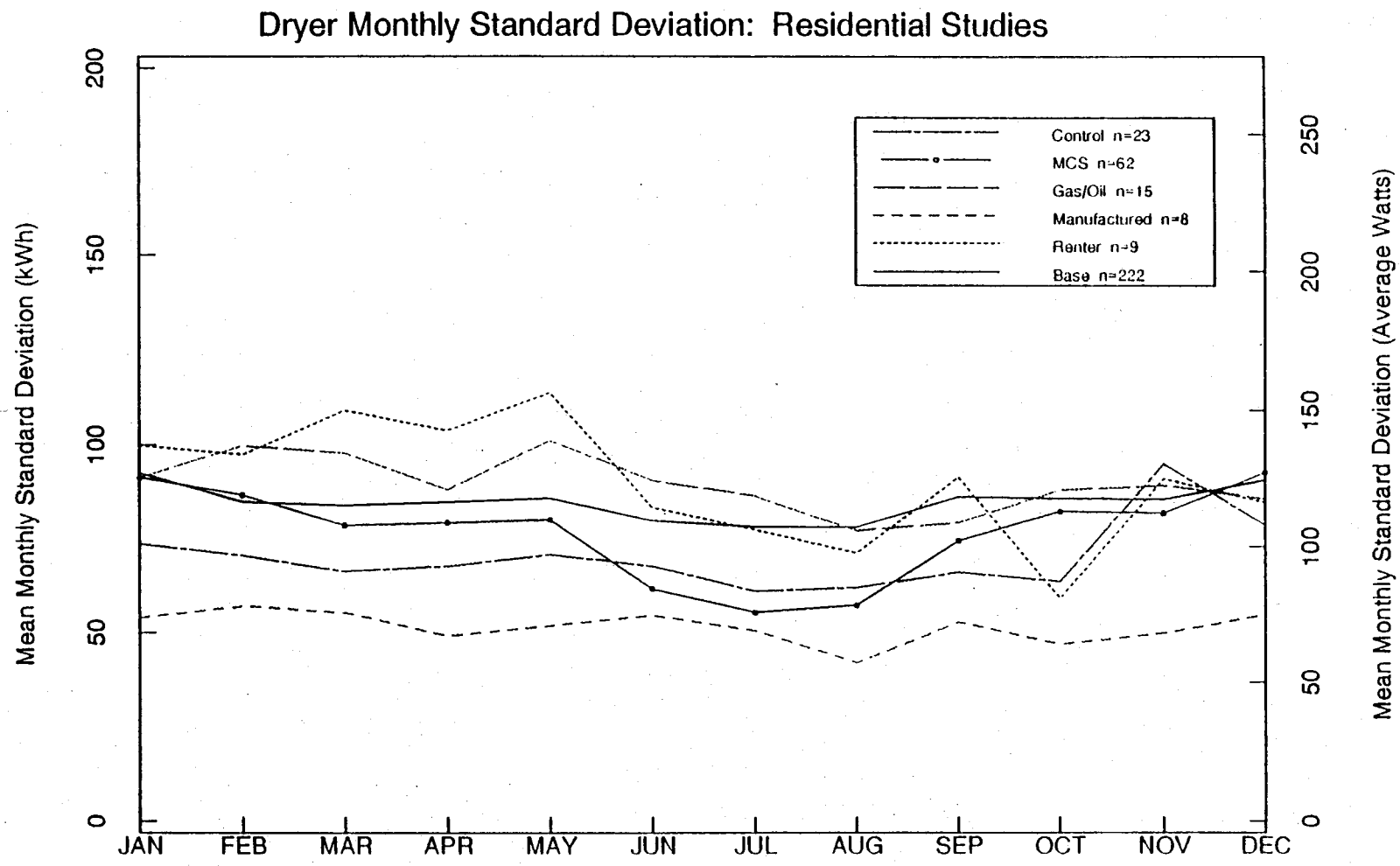
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.3



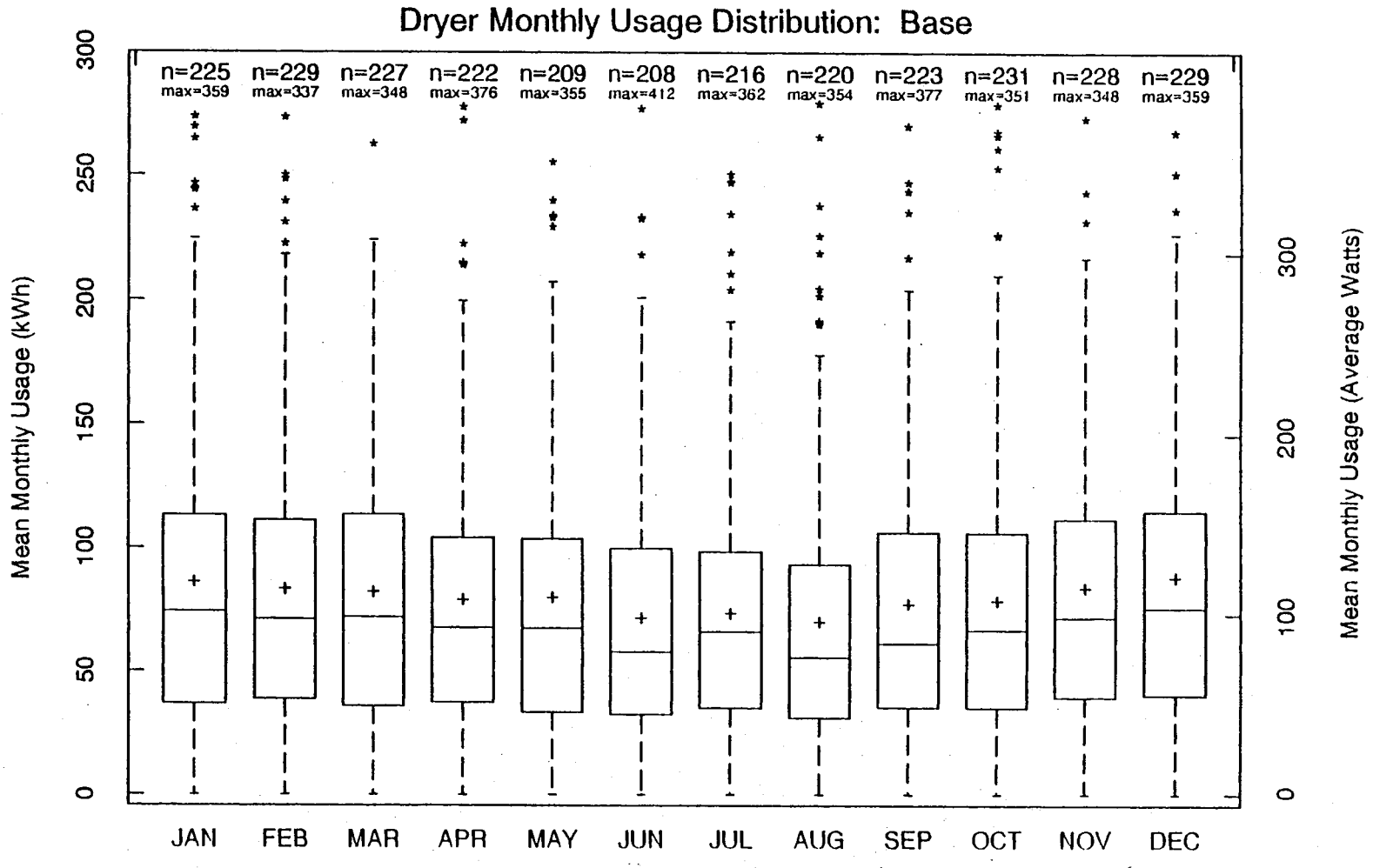
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.4



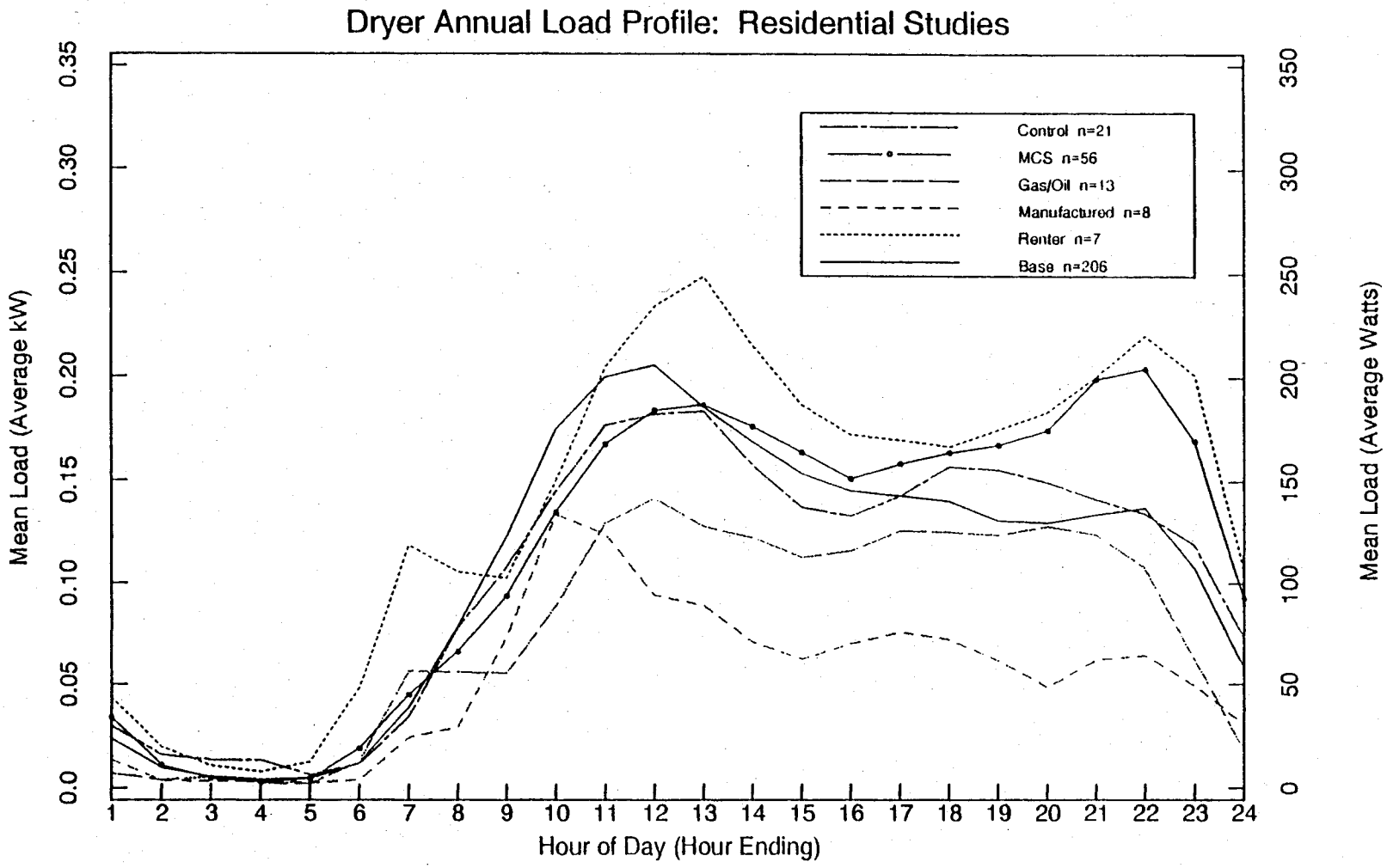
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.5



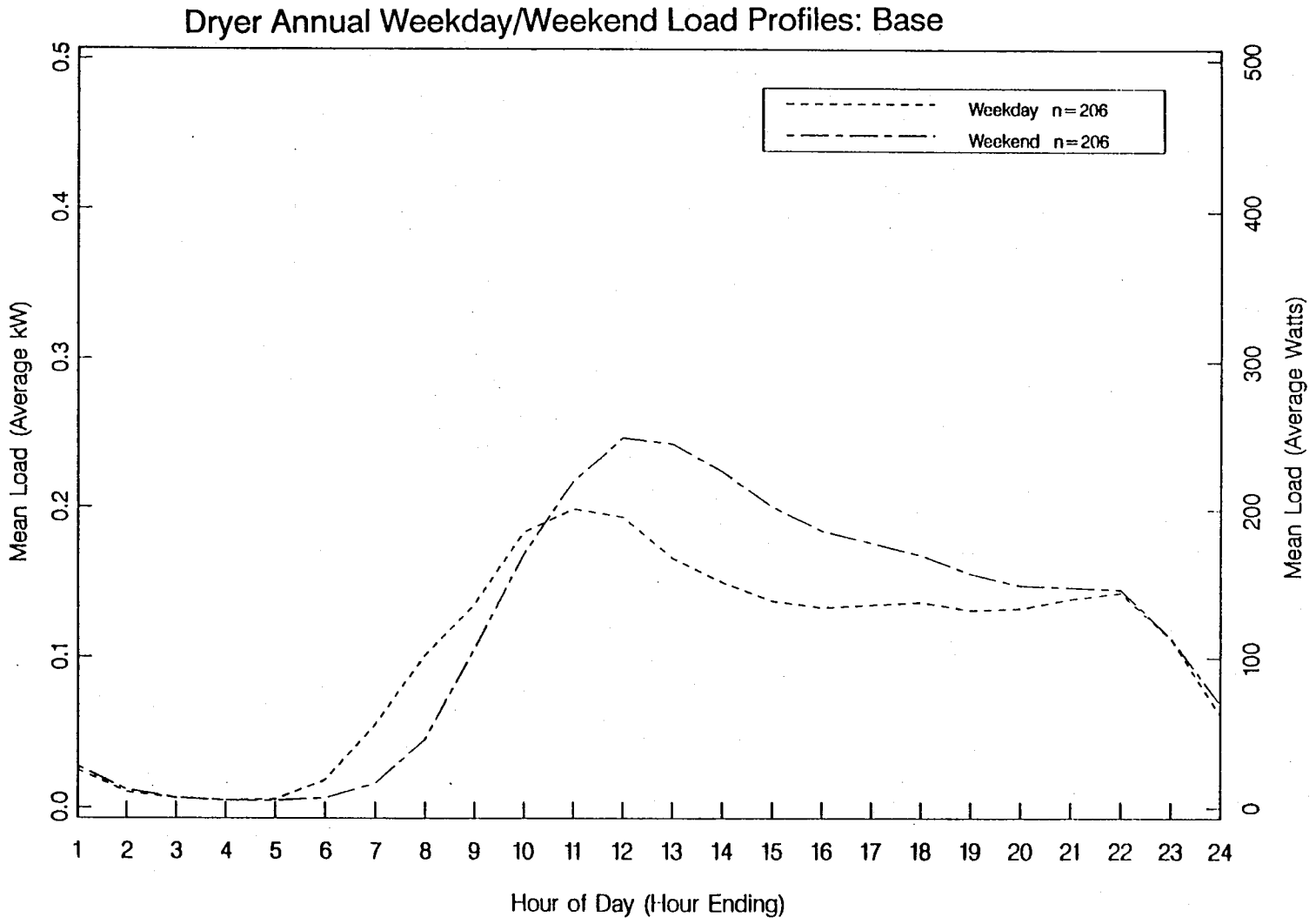
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.6



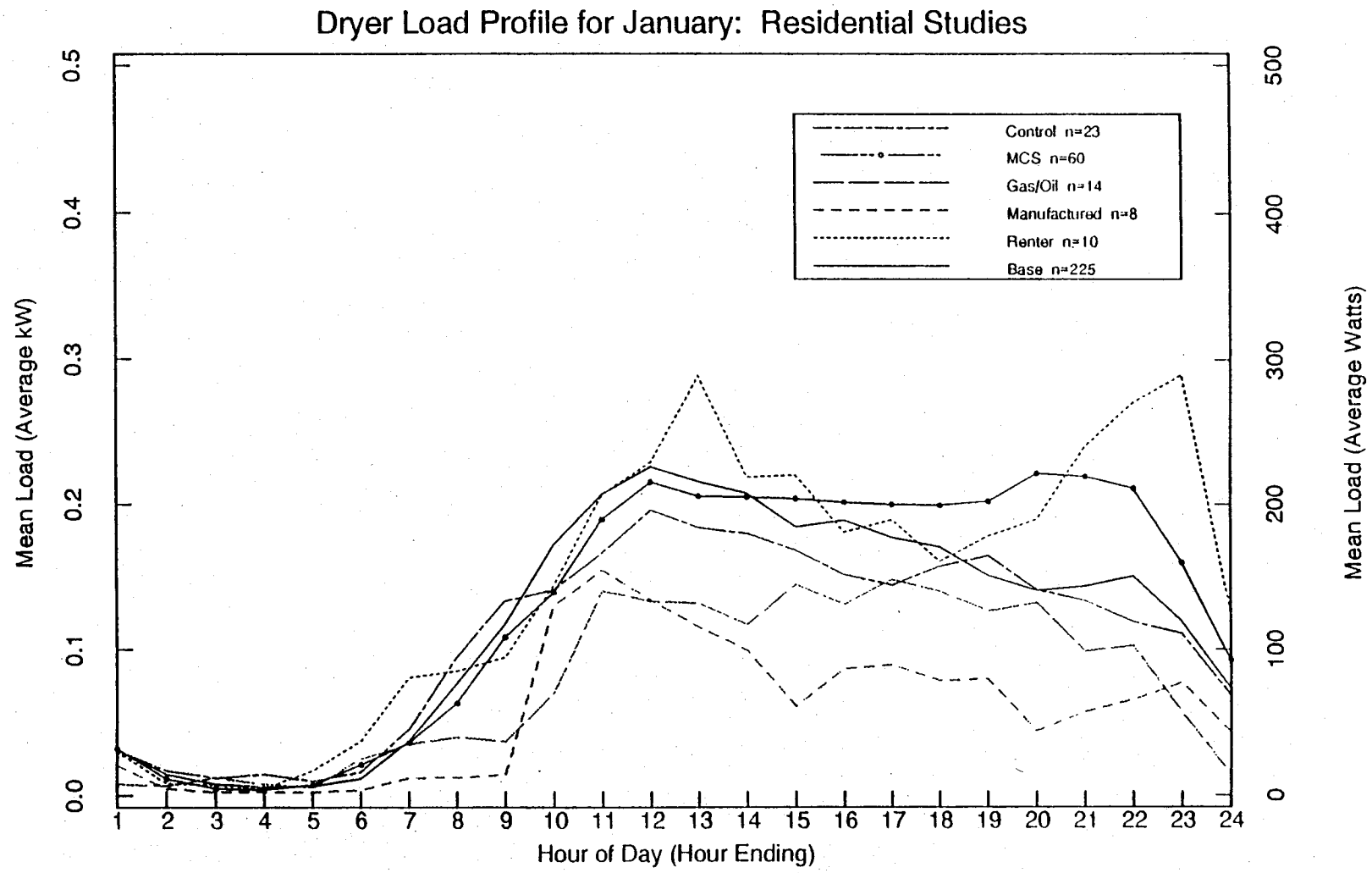
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.7



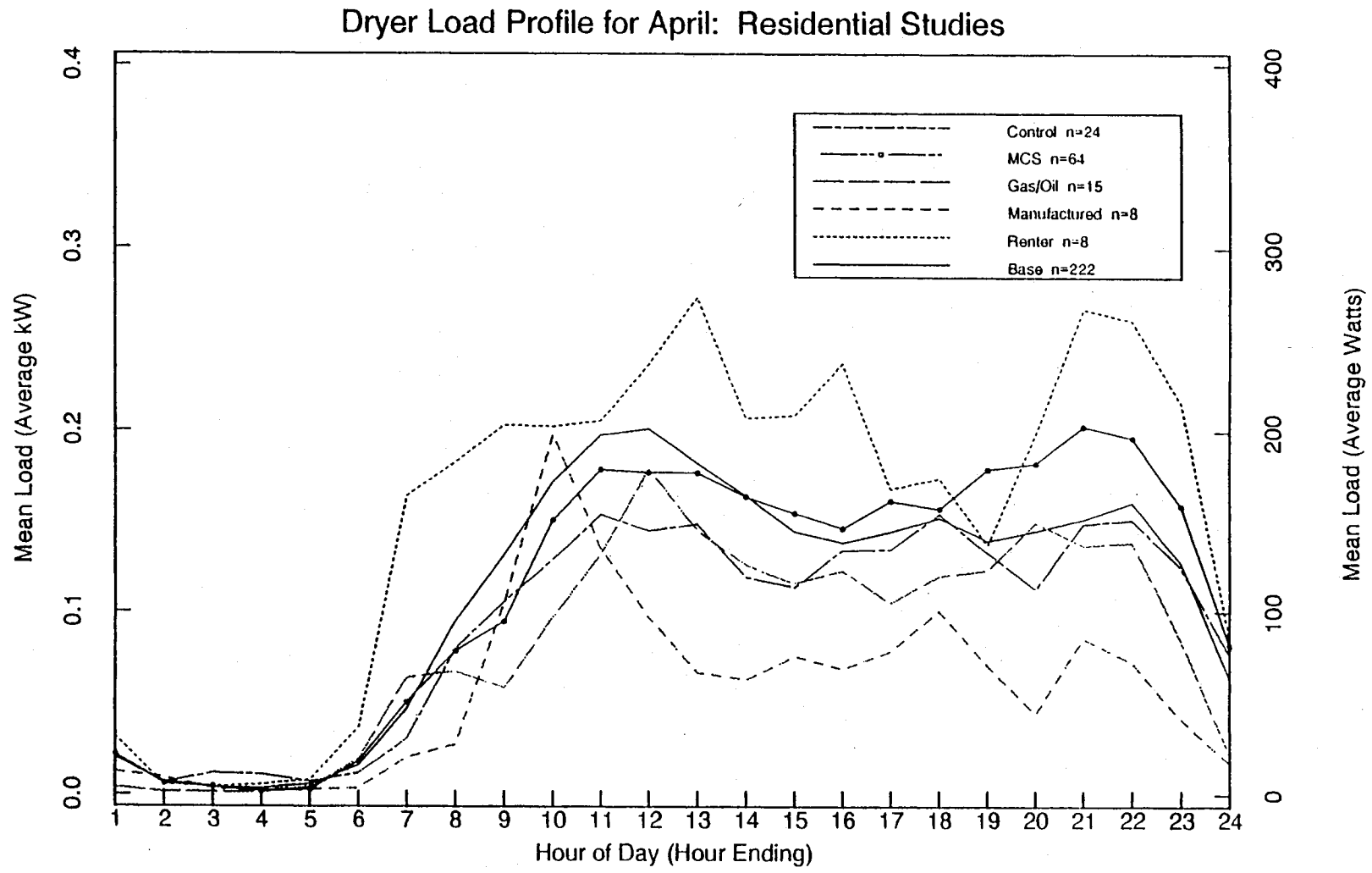
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.8(a)



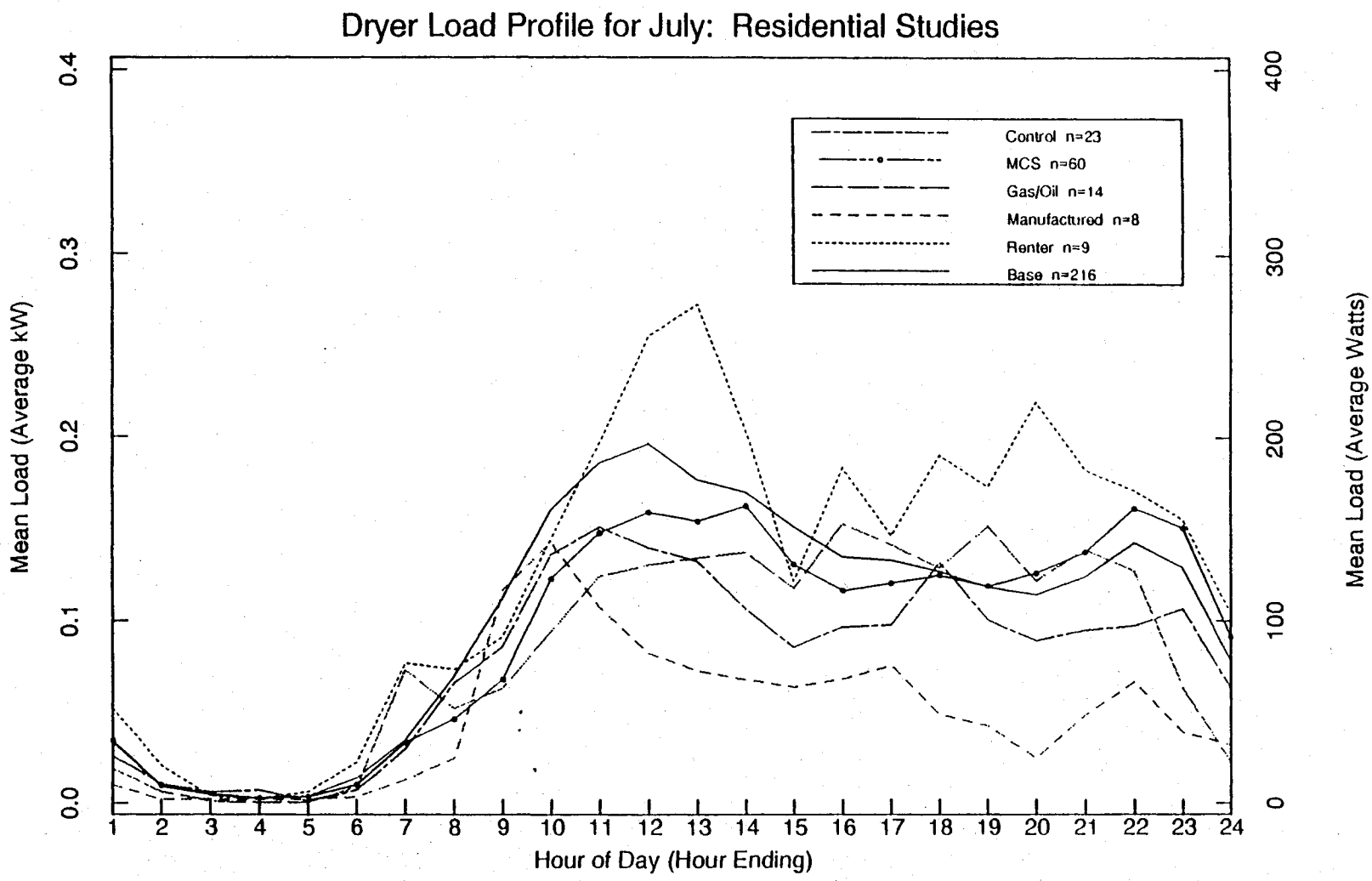
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.8(b)



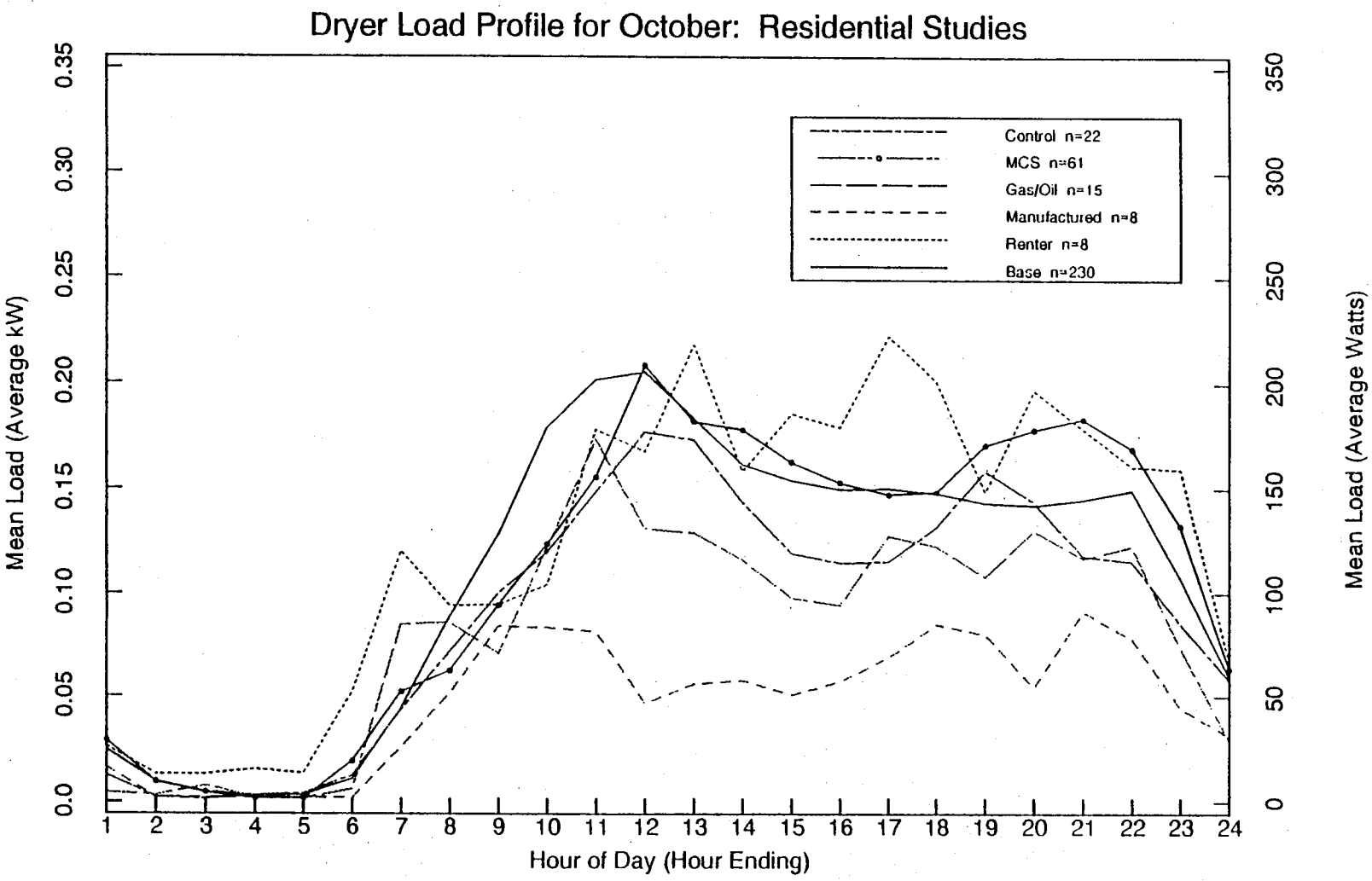
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.8(c)



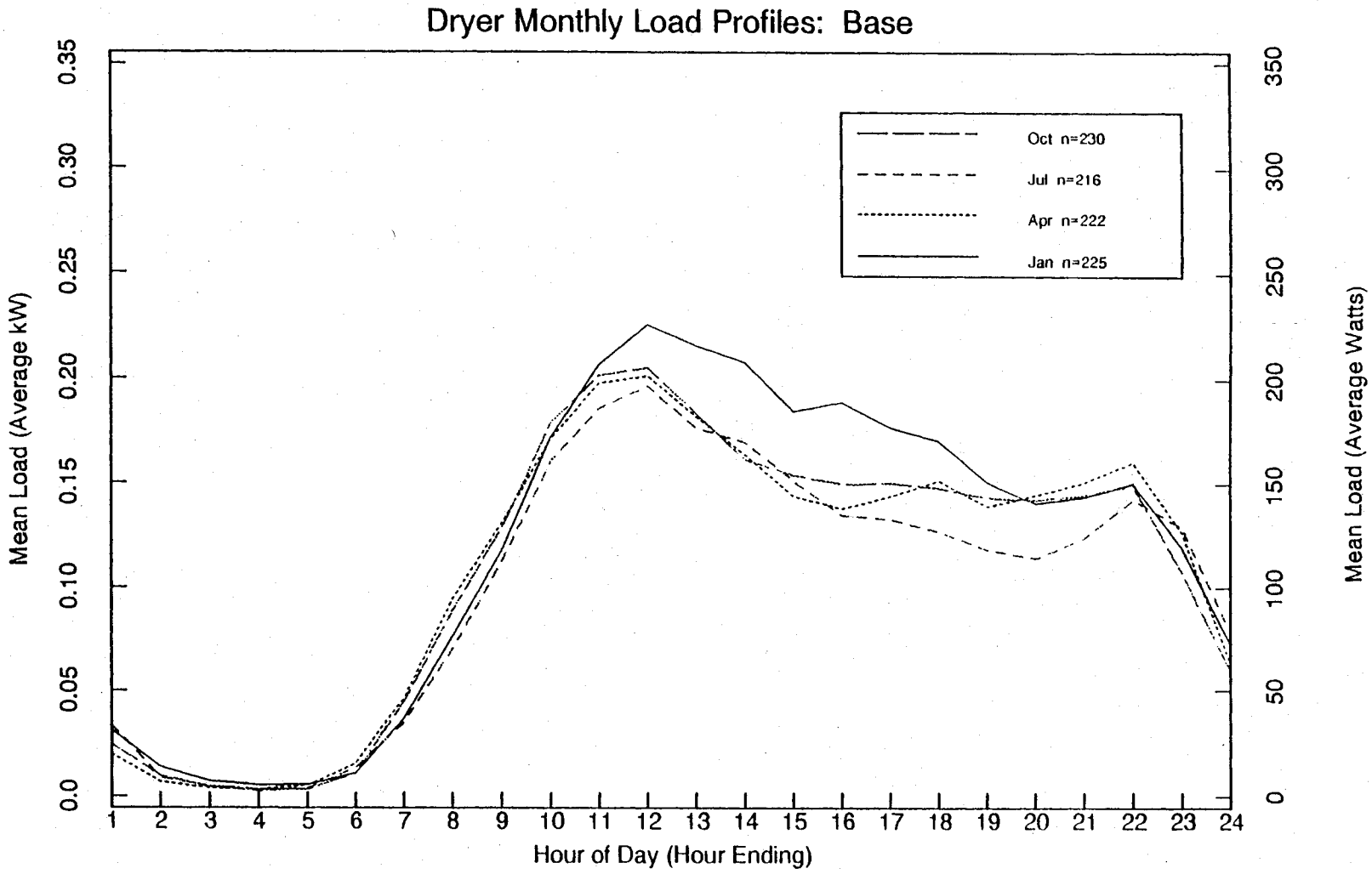
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.8(d)



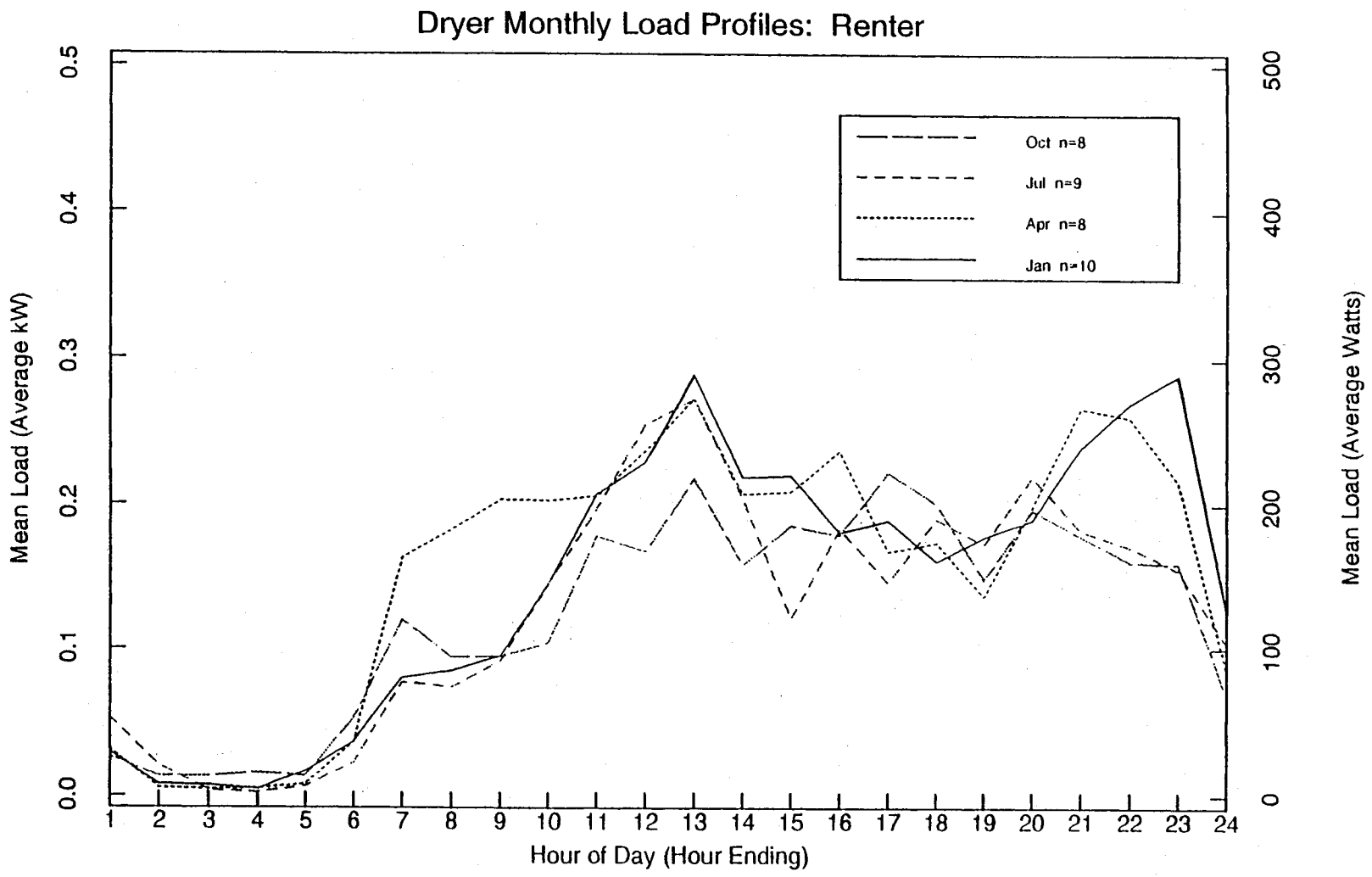
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.9(a)



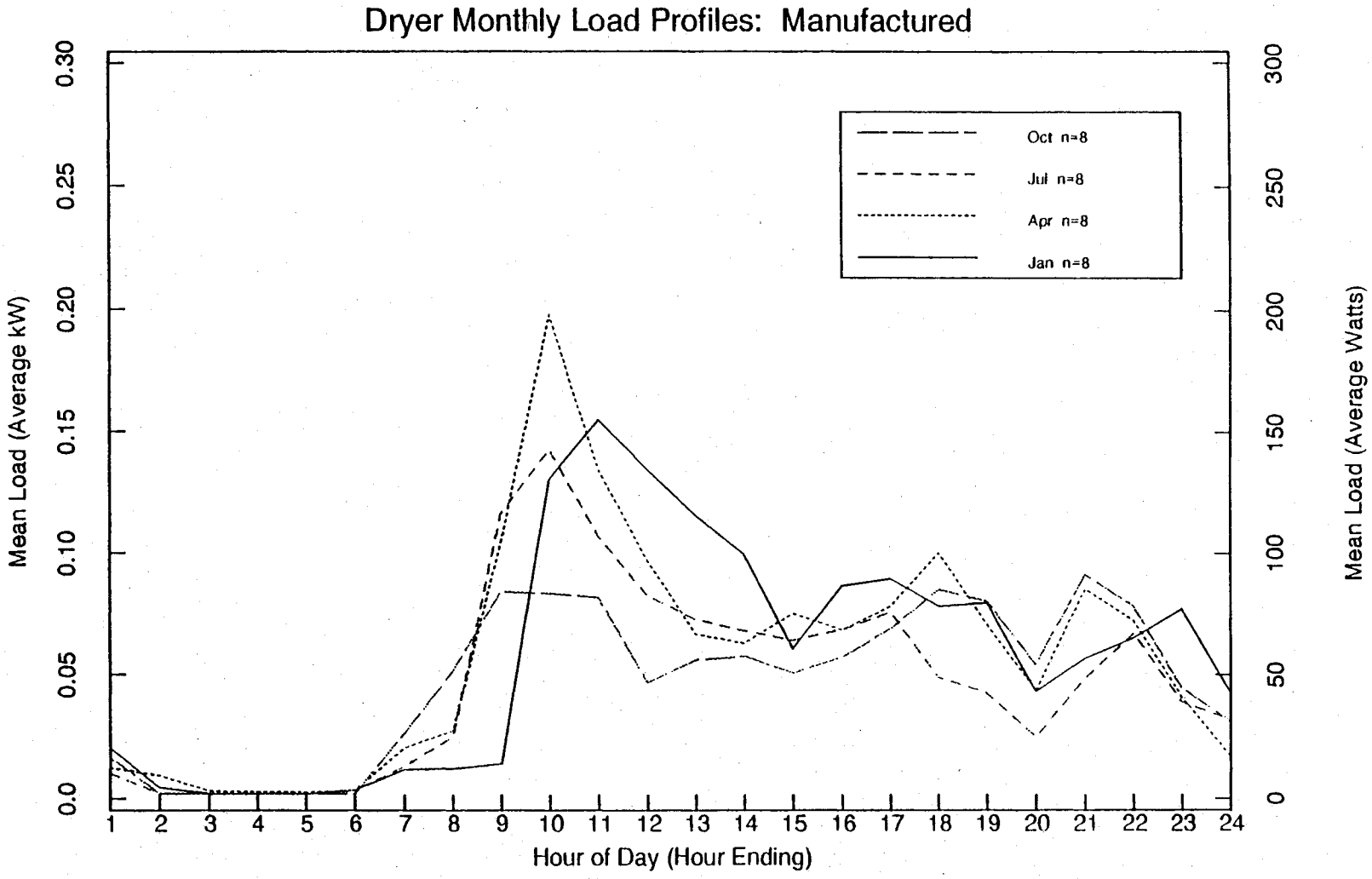
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.9(b)



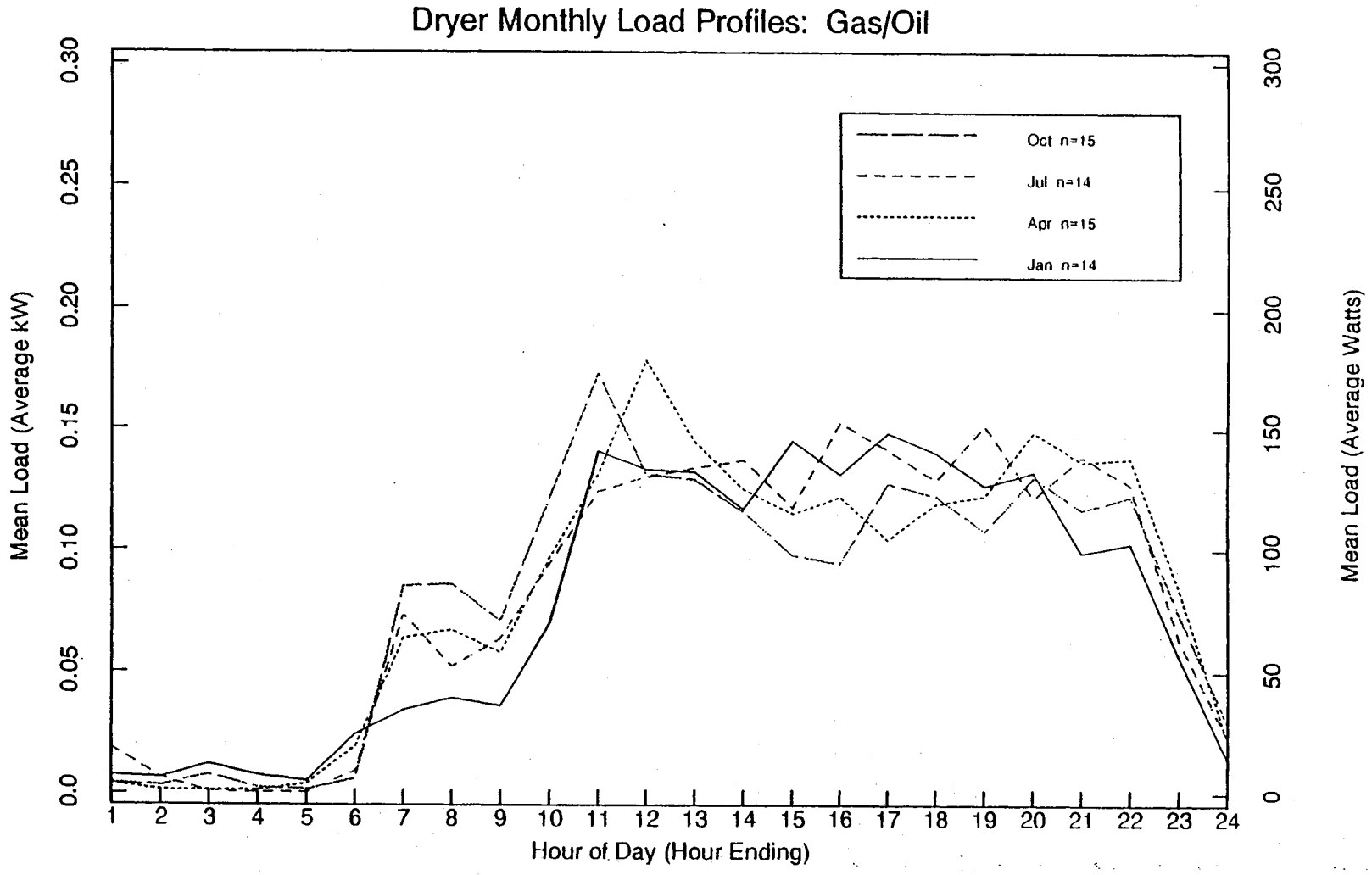
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.9(c)



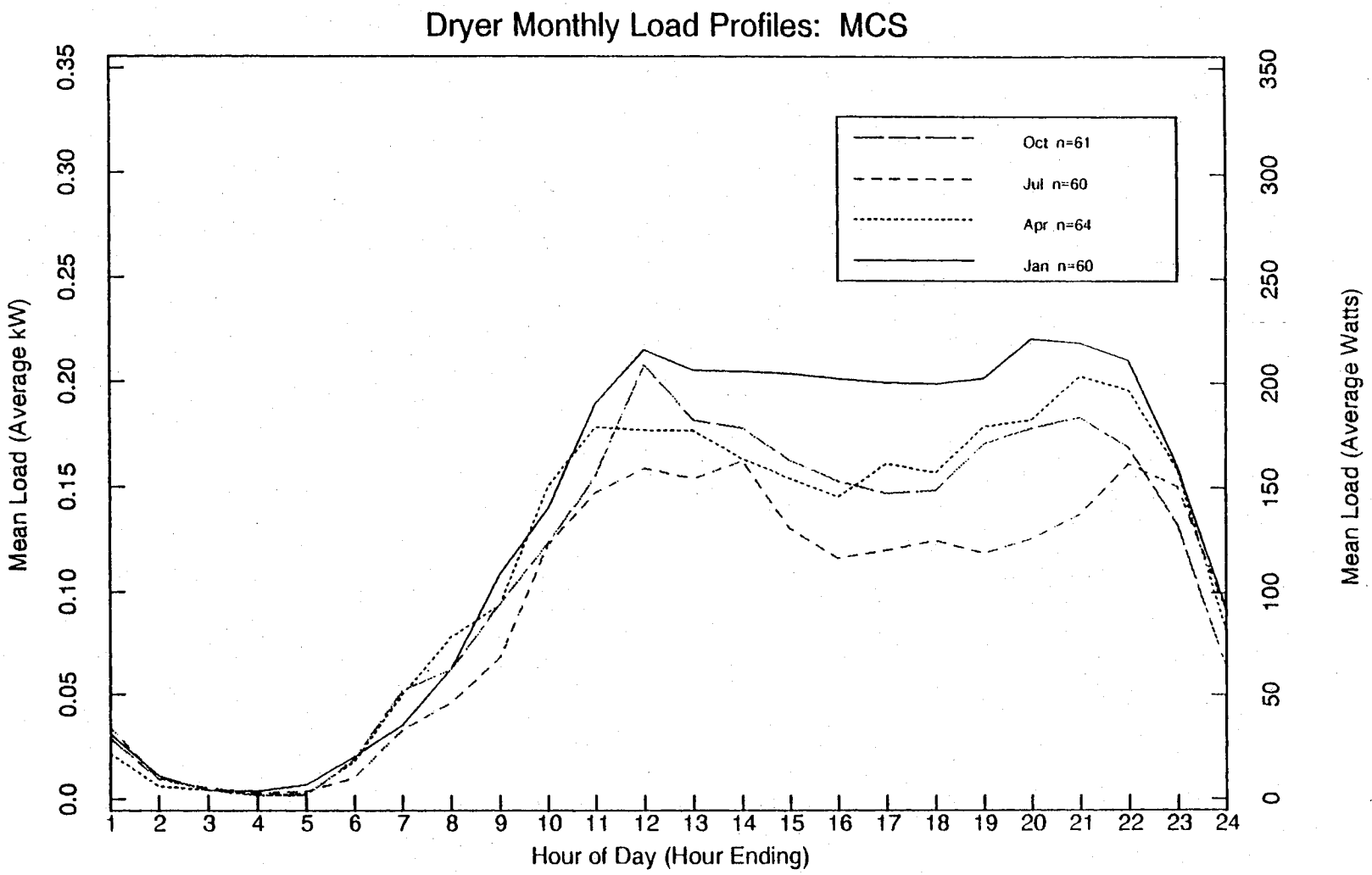
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FIGURE 7L.9(d)



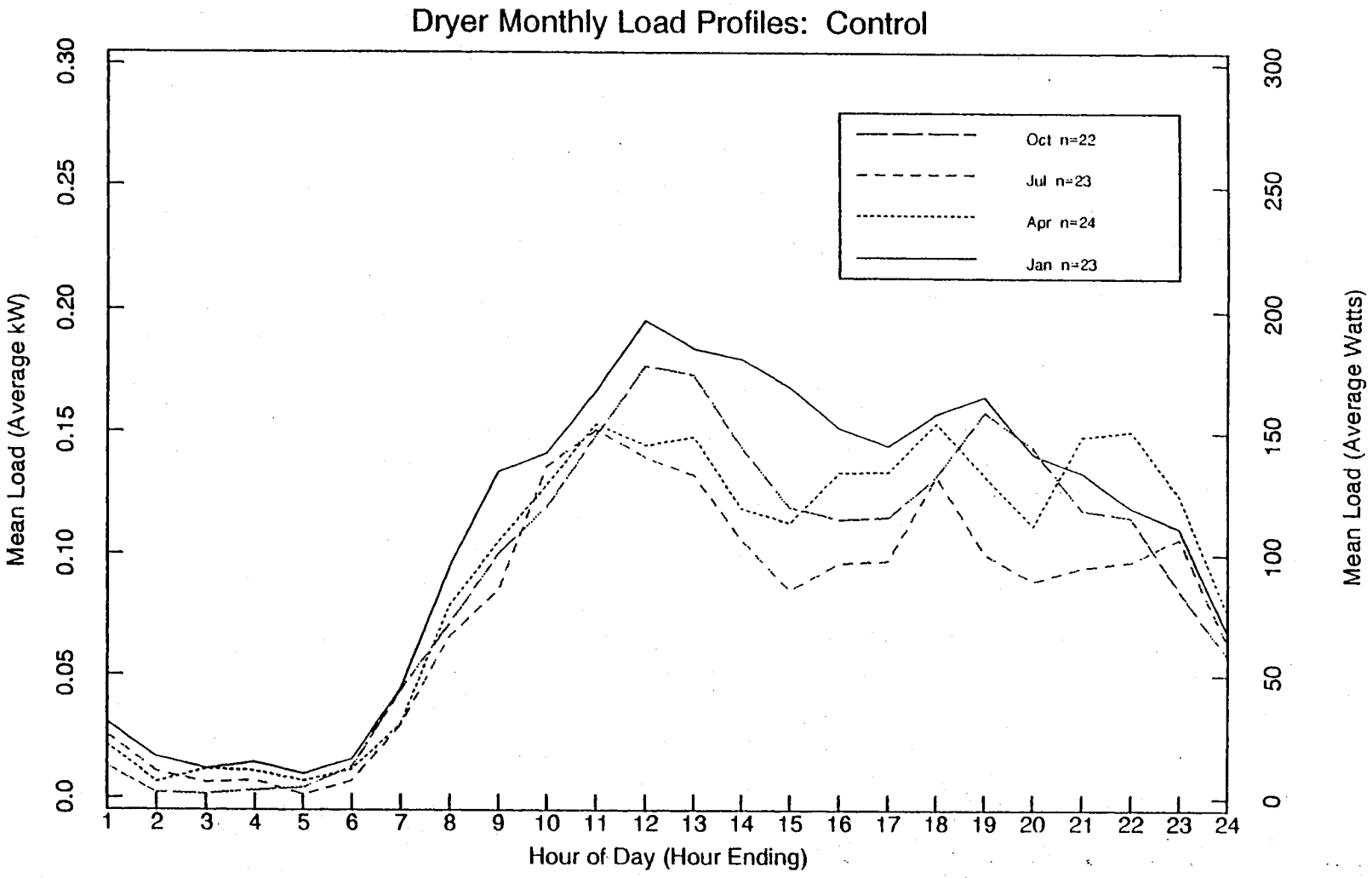
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

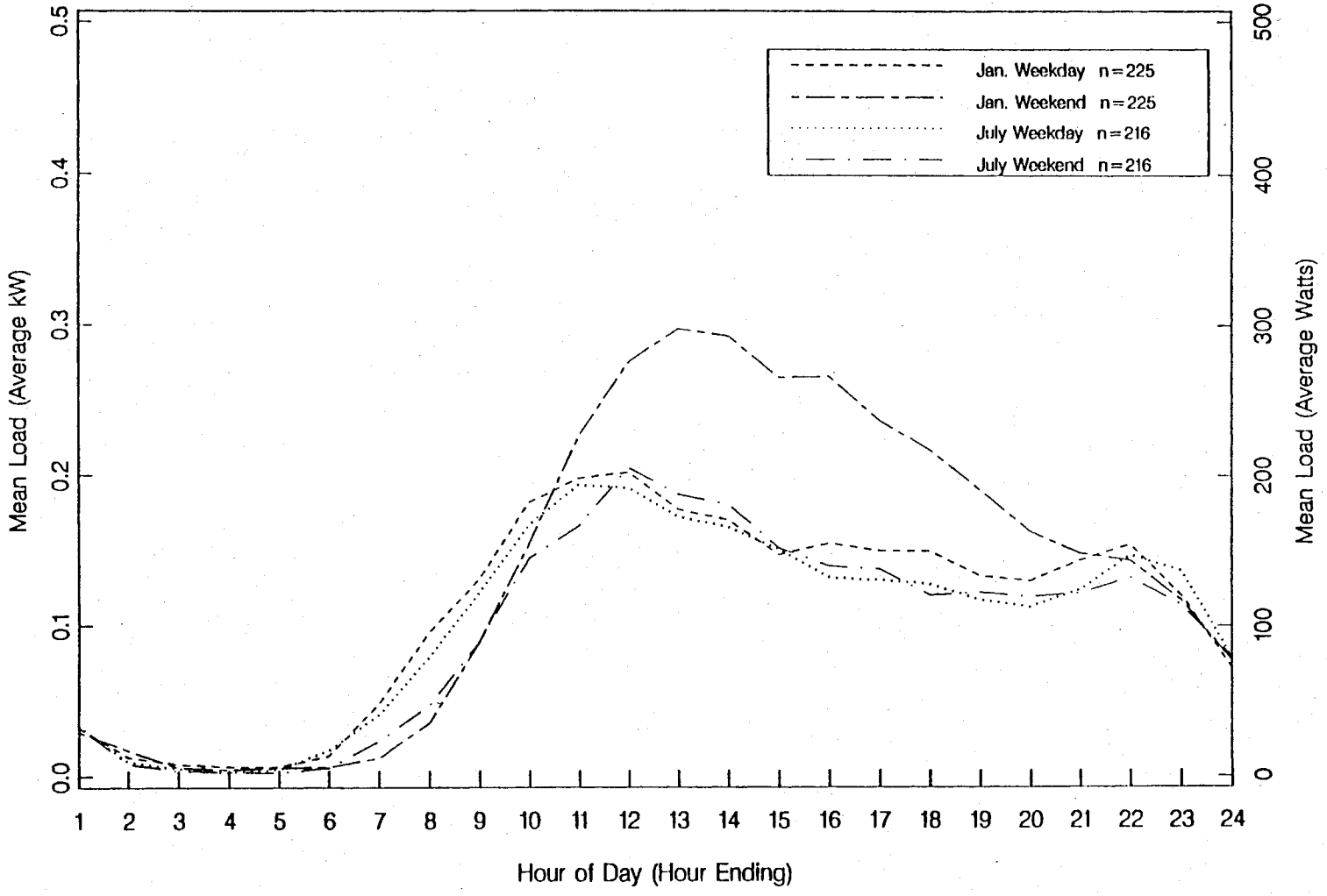
FIGURE 7L.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7L.10(a)

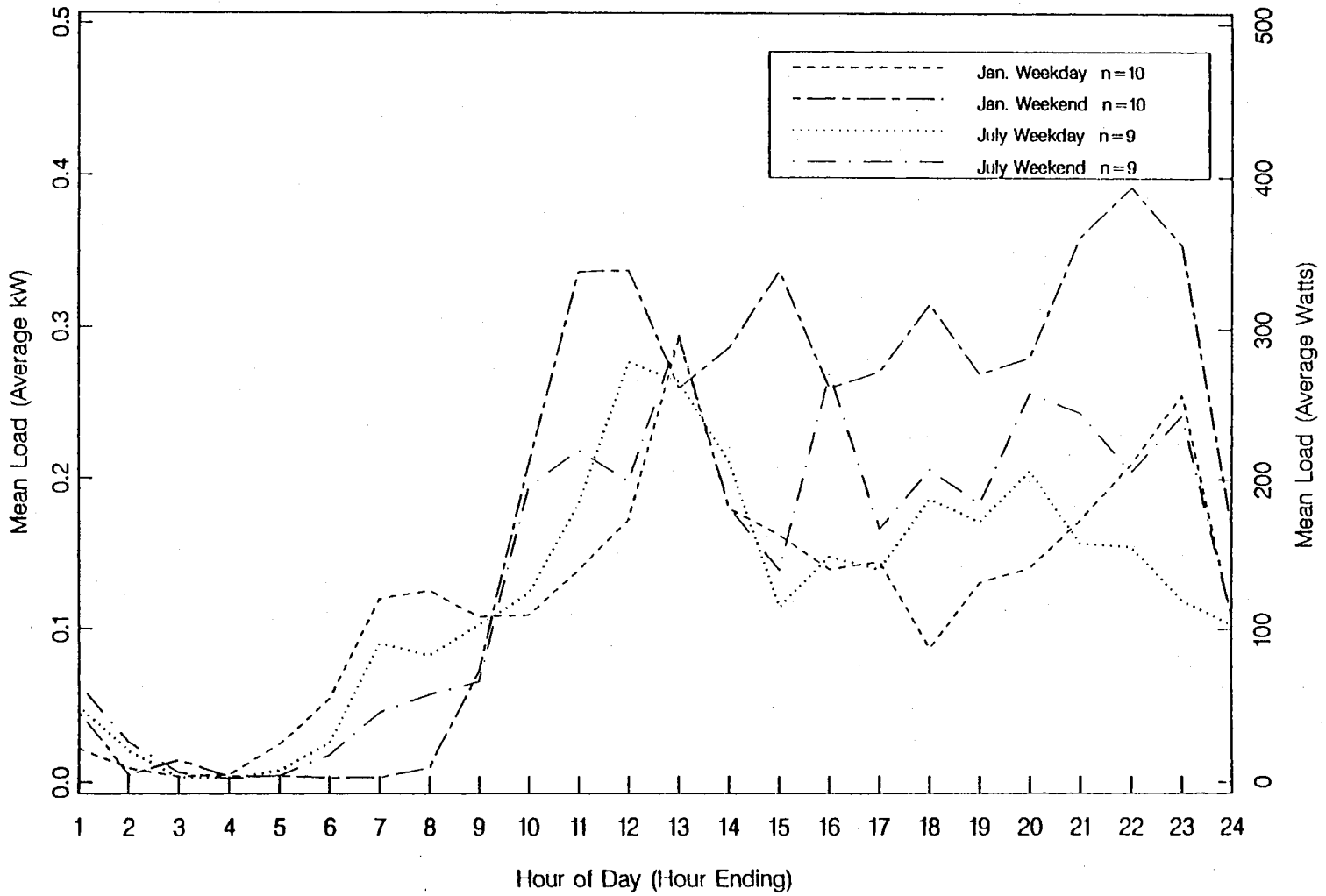
Dryer January/July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.10(b)

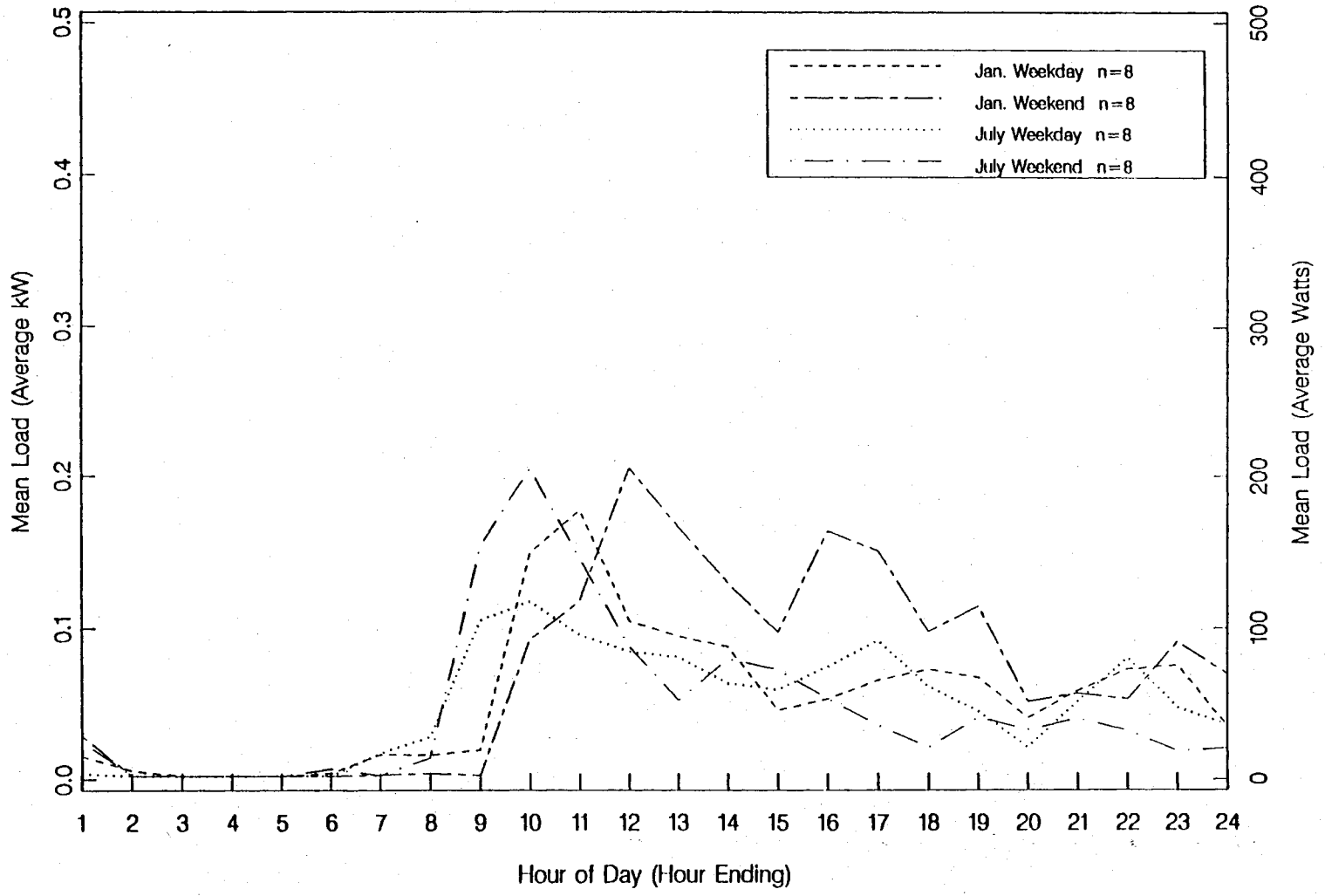
Dryer January/July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

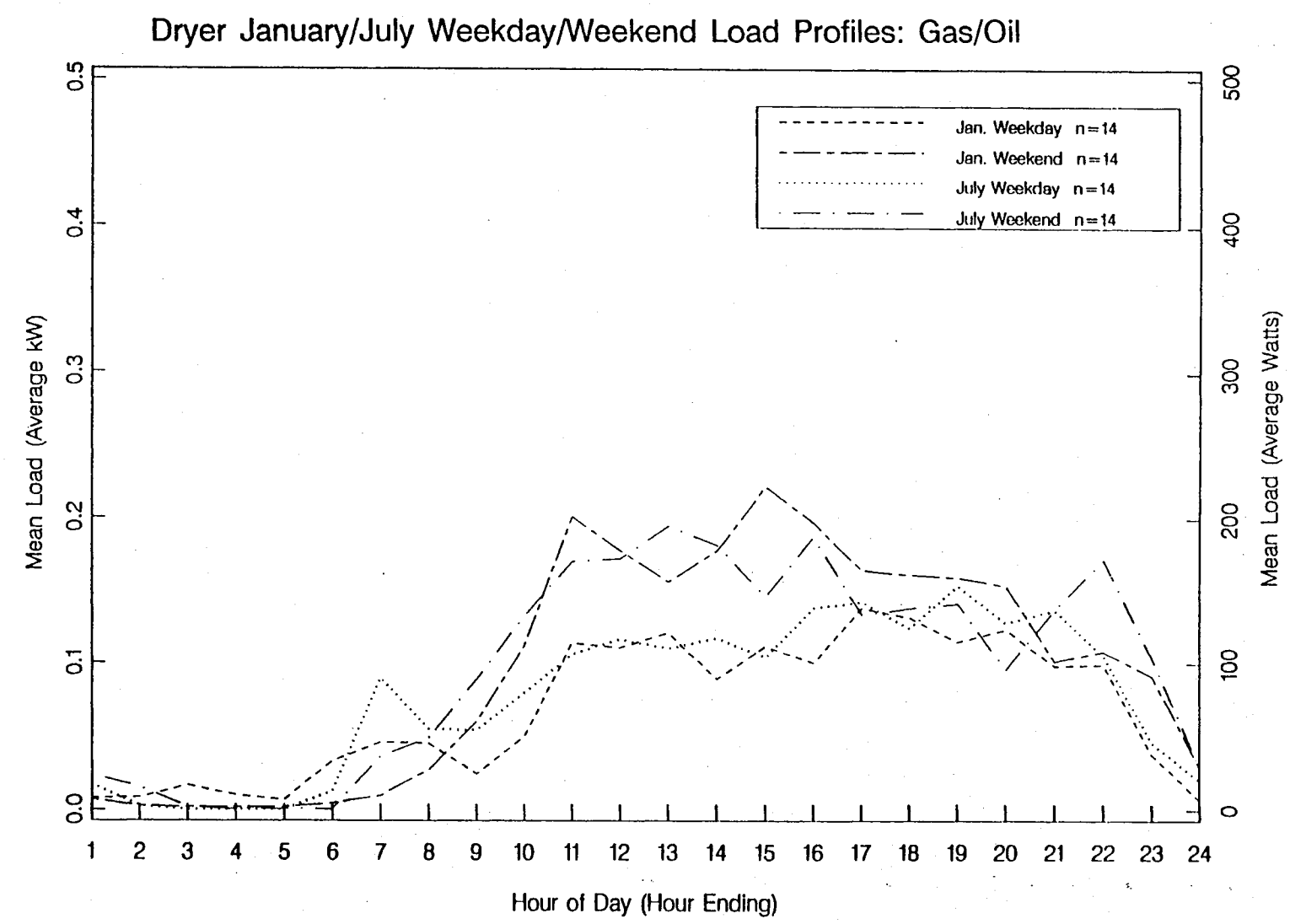
FIGURE 7L.10(c)

Dryer January/July Weekday/Weekend Load Profiles: Manufactured



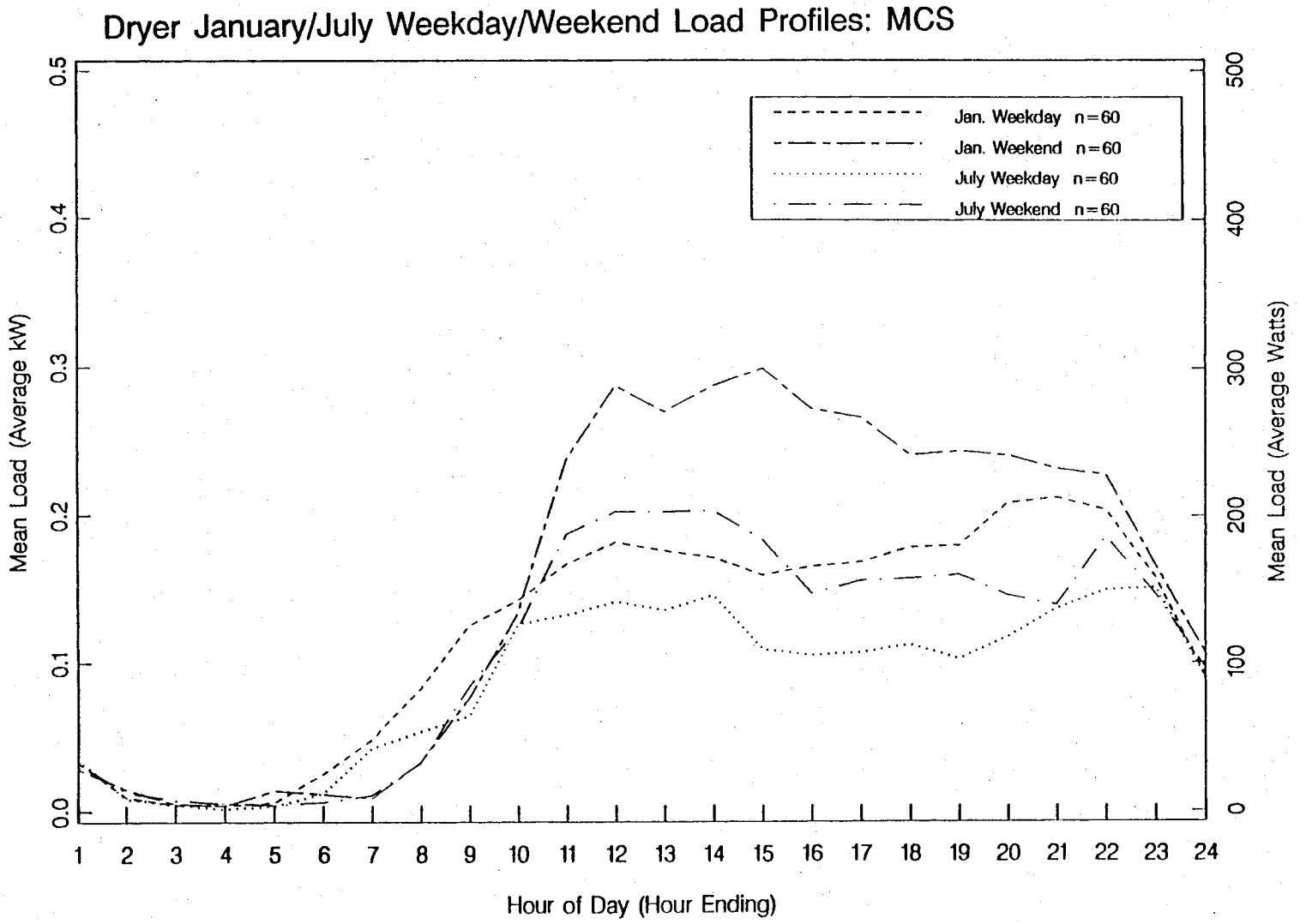
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.10(d)



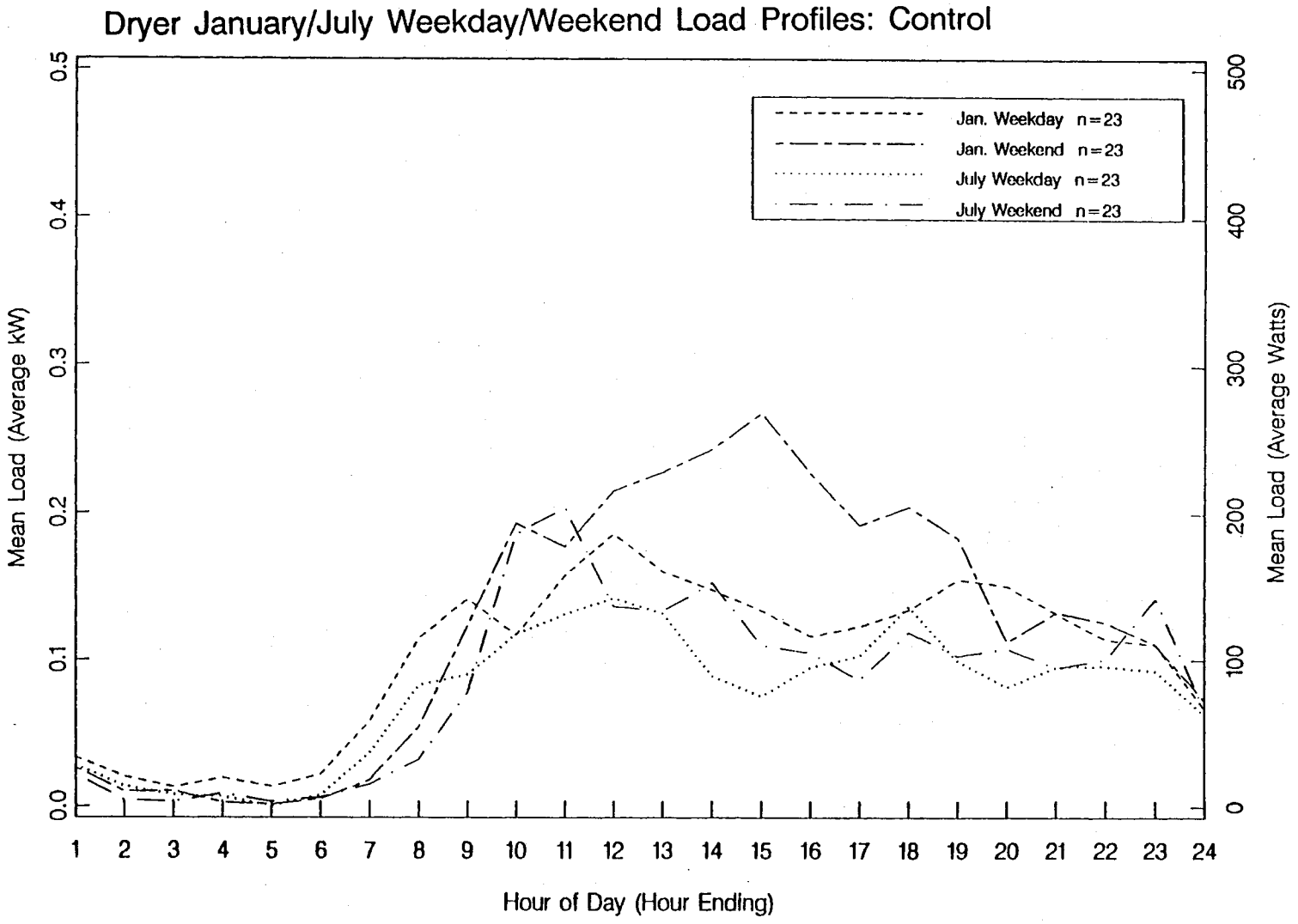
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.10(e)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7L.11

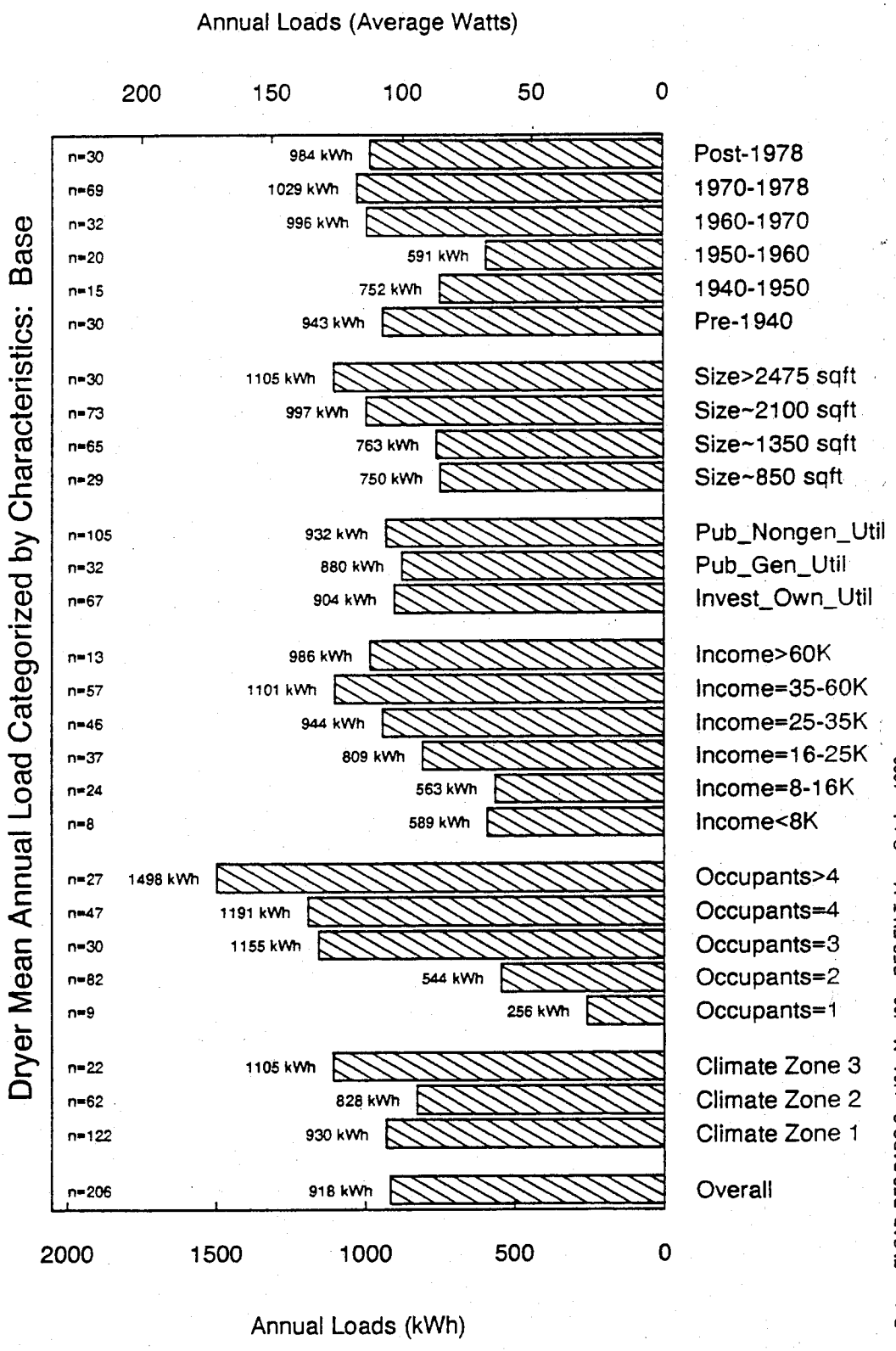
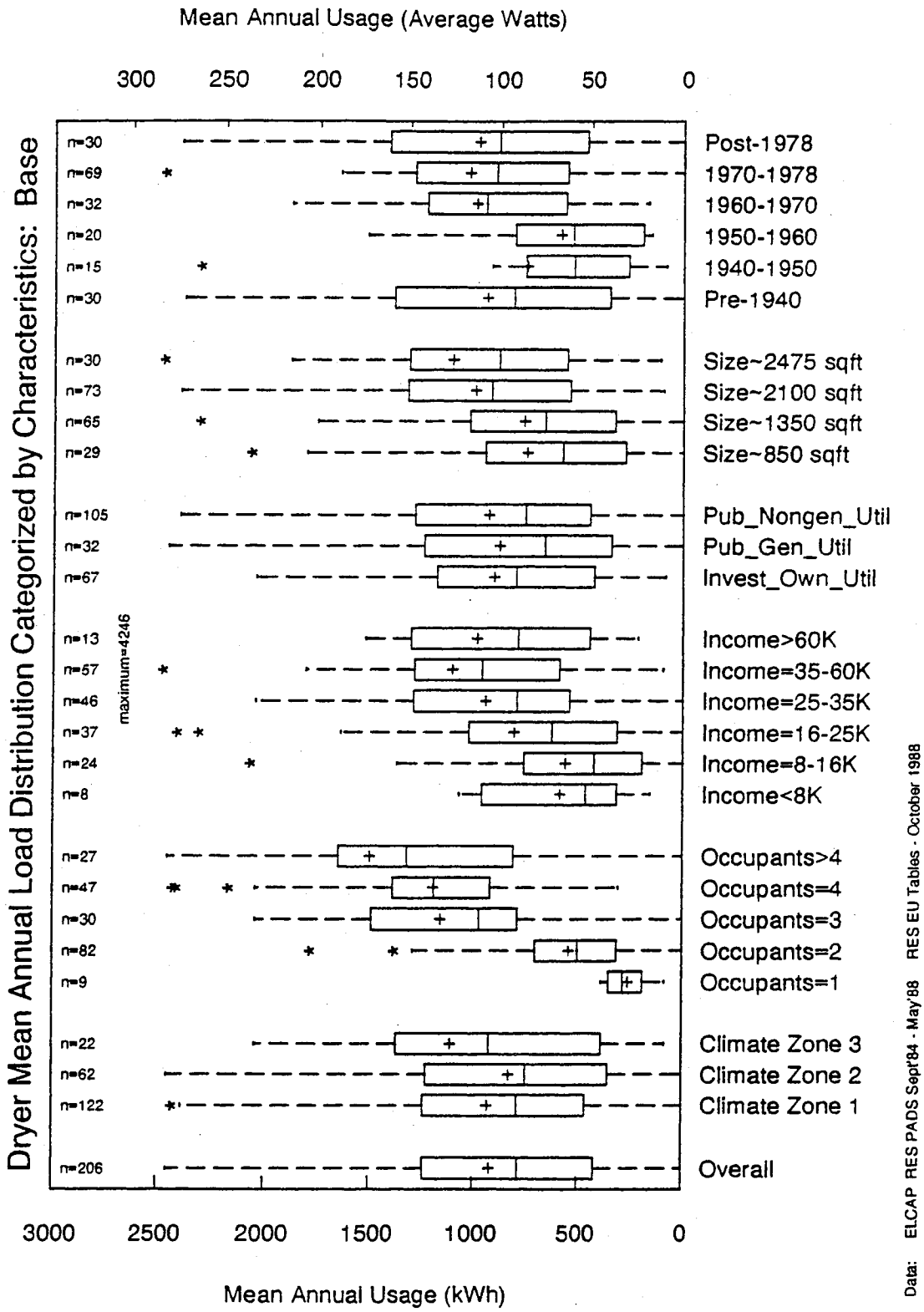

Dryer Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
200
150
100
50
0
n=30 984 kWh Post-1978
n=69 1029 kWh 1970-1978
n=32 996 kWh 1960-1970
n=20 591 kWh 1950-1960
n=15 752 kWh 1940-1950
n=30 943 kWh Pre-1940
n=30 1105 kWh Size>2475 sqft
n=73 997 kWh Size~2100 sqft
n=65 763 kWh Size~1350 sqft
n=29 750 kWh Size~850 sqft
n=105 932 kWh Pub_Nongen_Util
n=32 880 kWh Pub_Gen_Util
n=67 904 kWh Invest_Own_Util
n=13 986 kWh Income>60K
n=57 1101 kWh Income=35-60K
n=46 944 kWh Income=25-35K
n=37 809 kWh Income=16-25K
n=24 563 kWh Income=8-16K
n=8 589 kWh Income<8K
n=27 1498 kWh Occupants>4
n=47 1191 kWh Occupants=4
n=30 1155 kWh Occupants=3
n=82 544 kWh Occupants=2
n=9 256 kWh Occupants=1
n=22 1105 kWh Climate Zone 3
n=62 828 kWh Climate Zone 2
n=122 930 kWh Climate Zone 1
n=206 918 kWh Overall
2000
1500
1000
500
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7L.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7L.1

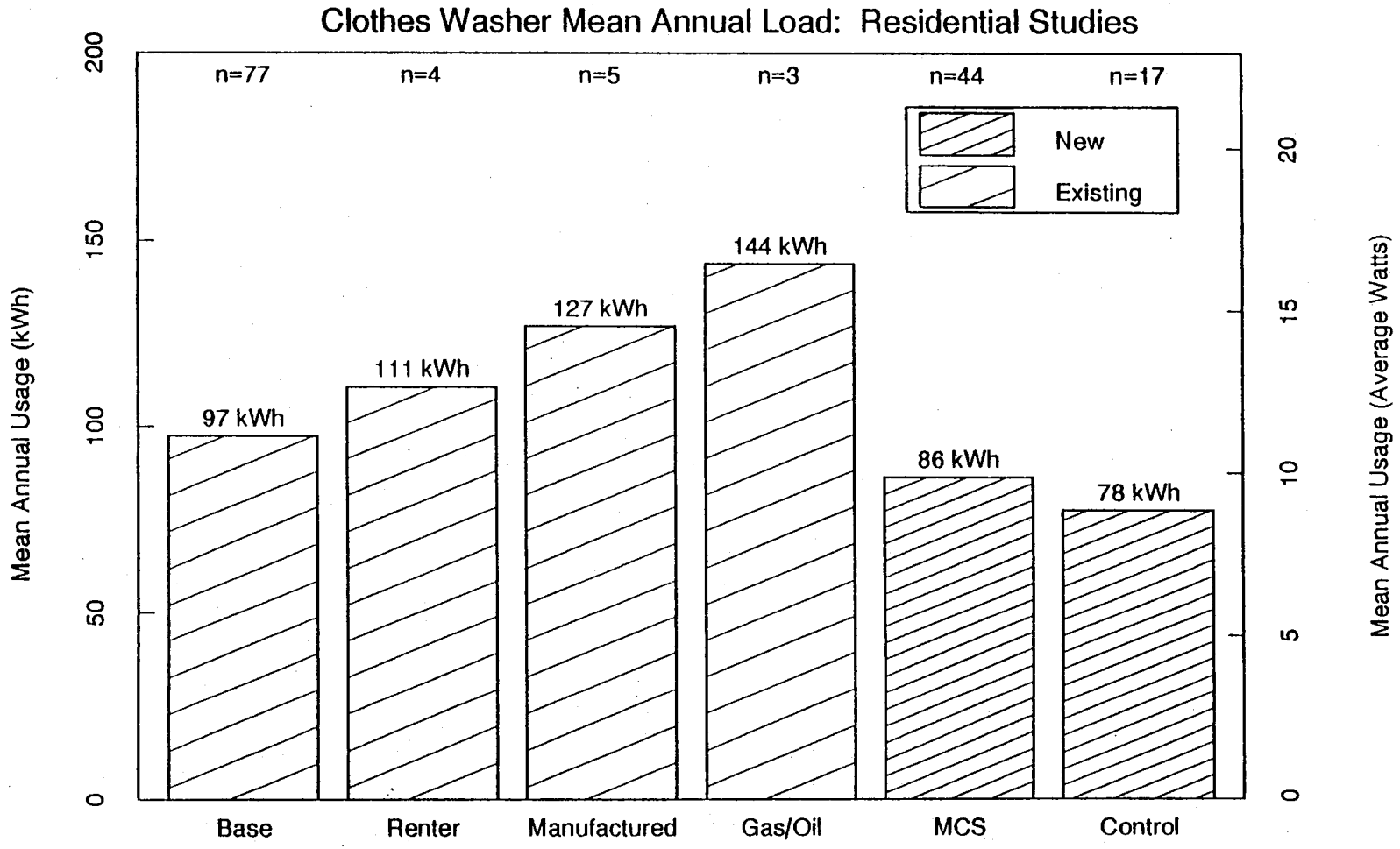
Dryer Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	206	918	689	21	911	567	56	1012	681	283	936	678
Climate Zone 1	122	930	662	13	903	574	35	1013	547	170	945	631
Climate Zone 2	62	828	598	4	1079	847	17	1092	957	83	894	695
Climate Zone 3	22	1105	1007	4	771	208	4	674	211	30	1003	879
Occupants=1	9	256	105	1	449	0	2	766	312	12	357	238
Occupants=2	82	544	319	7	616	343	13	597	314	102	555	317
Occupants=3	30	1155	717	3	411	222	8	1142	775	41	1098	720
Occupants=4	47	1191	470	3	1571	286	7	1364	527	57	1232	473
Occupants>4	27	1498	1048	1	1746	0	5	2065	1254	33	1591	1064
Income<8K	8	589	359	0	-	-	1	779	0	9	610	342
Income=8-16K	24	563	493	1	156	0	1	0	0	26	526	492
Income=16-25K	37	809	736	1	715	0	8	1086	942	46	855	764
Income=25-35K	46	944	555	8	837	649	12	990	350	66	939	530
Income=35-60K	57	1101	759	3	1099	569	12	1290	1066	72	1133	803
Income>60K	13	986	762	1	1077	0	1	1478	0	15	1024	717
Invest_Own_Util	67	904	636	10	753	574	31	1153	794	108	962	686
Pub_Gen_Util	32	880	722	7	1138	525	10	956	432	49	932	644
Pub_Nongen_Util	105	932	722	4	910	632	11	741	551	120	913	703
Size~850 sqft	29	750	664	1	1849	0	1	0	0	31	761	686
Size~1350 sqft	65	763	603	13	886	512	26	935	520	104	821	573
Size~2100 sqft	73	997	609	6	711	599	16	1240	941	95	1020	677
Size>2475 sqft	30	1105	886	0	-	-	9	1113	514	39	1107	809
Pre-1940	30	943	725	0	-	-	0	-	-	30	943	725
1940-1950	15	752	838	0	-	-	0	-	-	15	752	838
1950-1960	20	591	427	0	-	-	0	-	-	20	591	427
1960-1970	32	998	566	0	-	-	0	-	-	32	998	566
1970-1978	69	1029	775	0	-	-	0	-	-	69	1029	775
Post-1978	30	984	646	21	911	567	56	1012	681	107	985	646

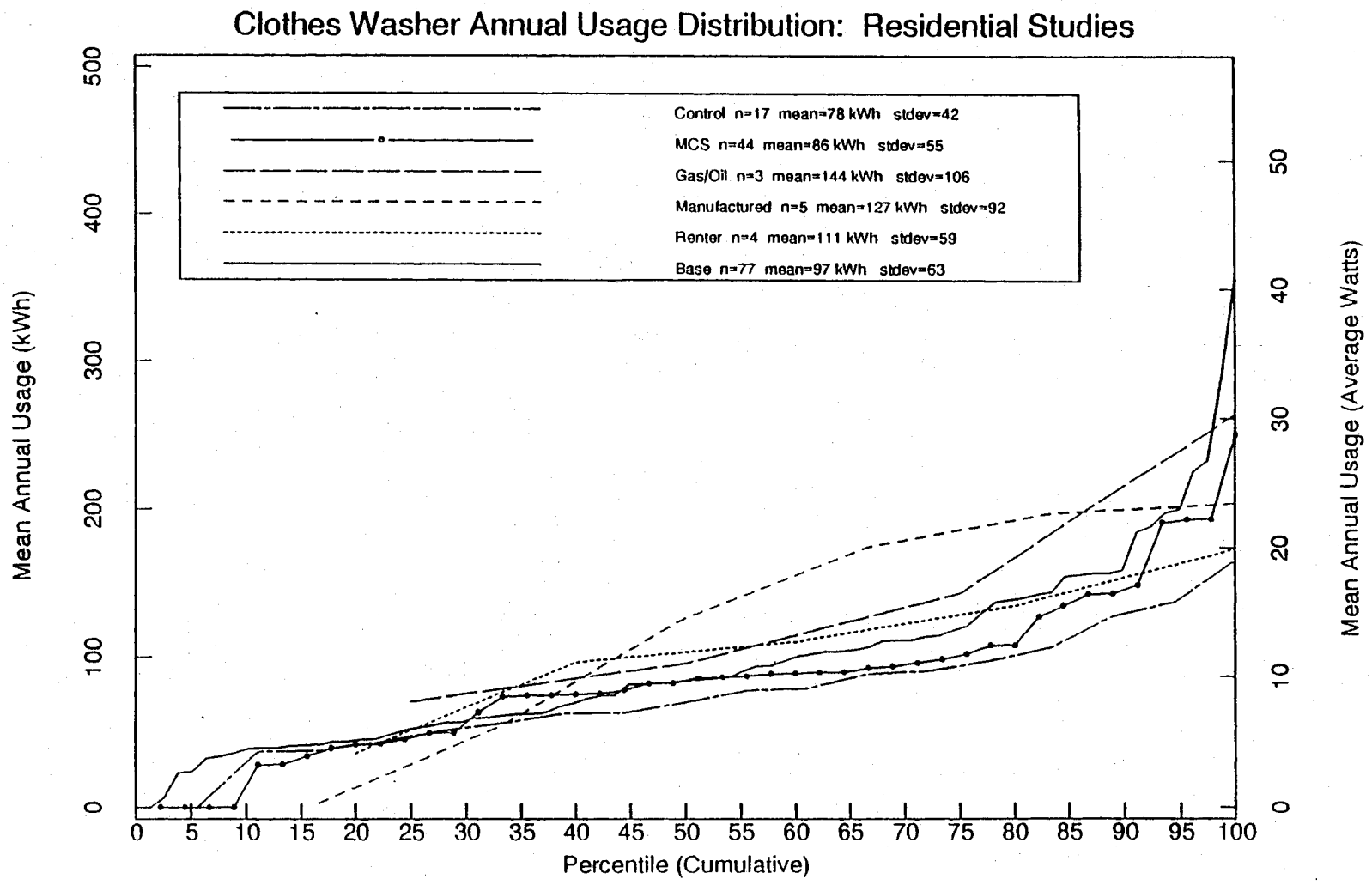
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7M.1



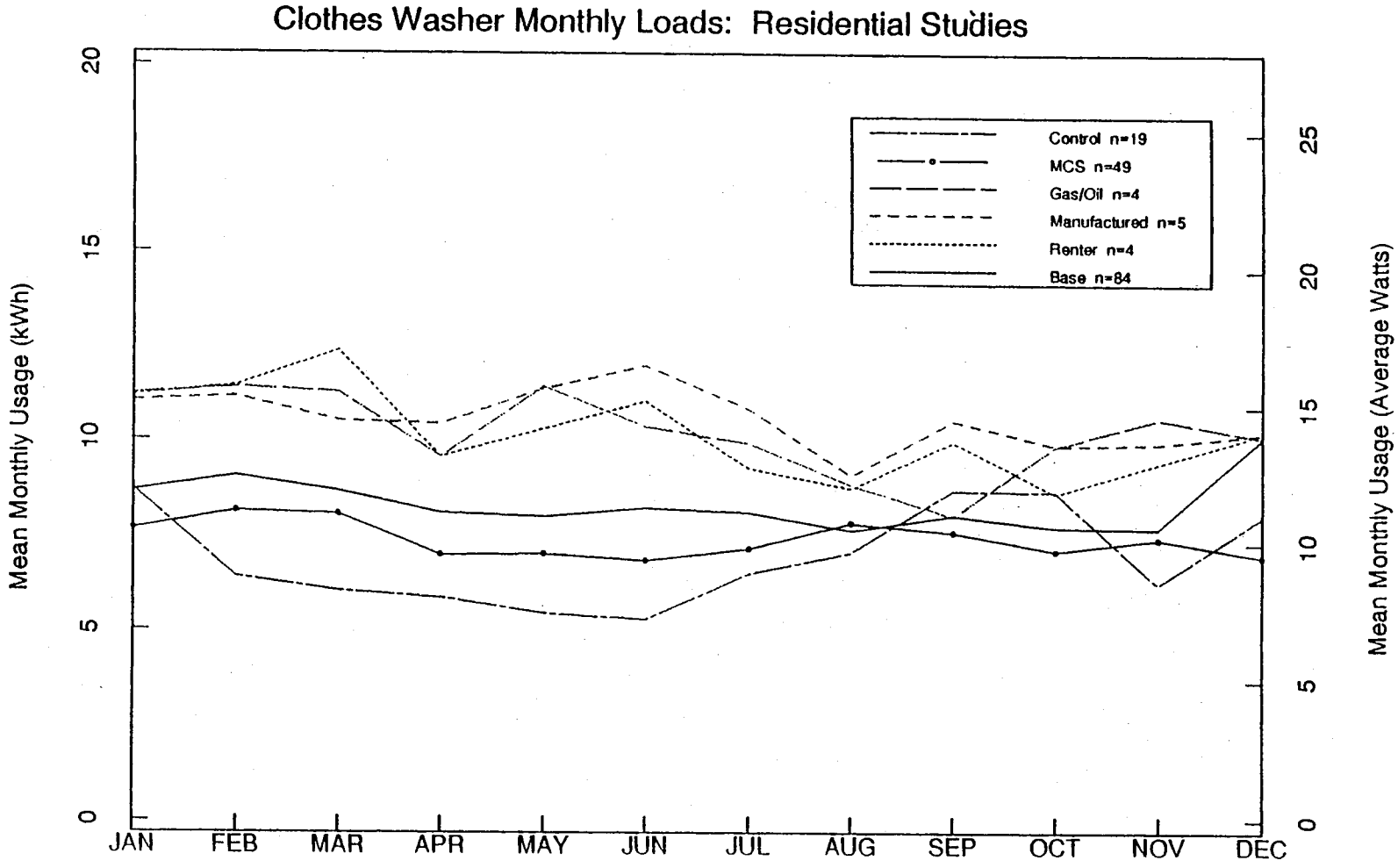
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.2



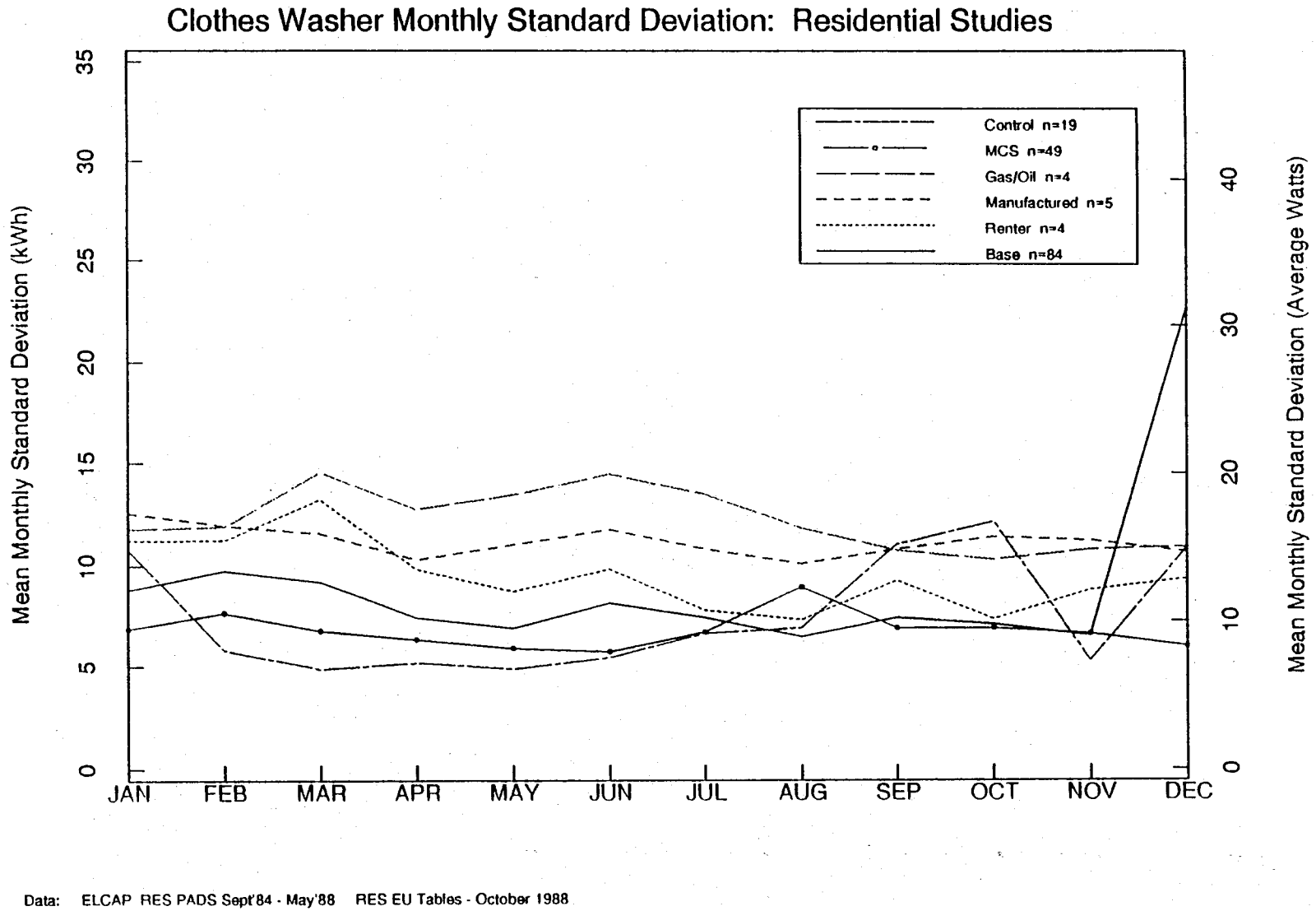
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.3



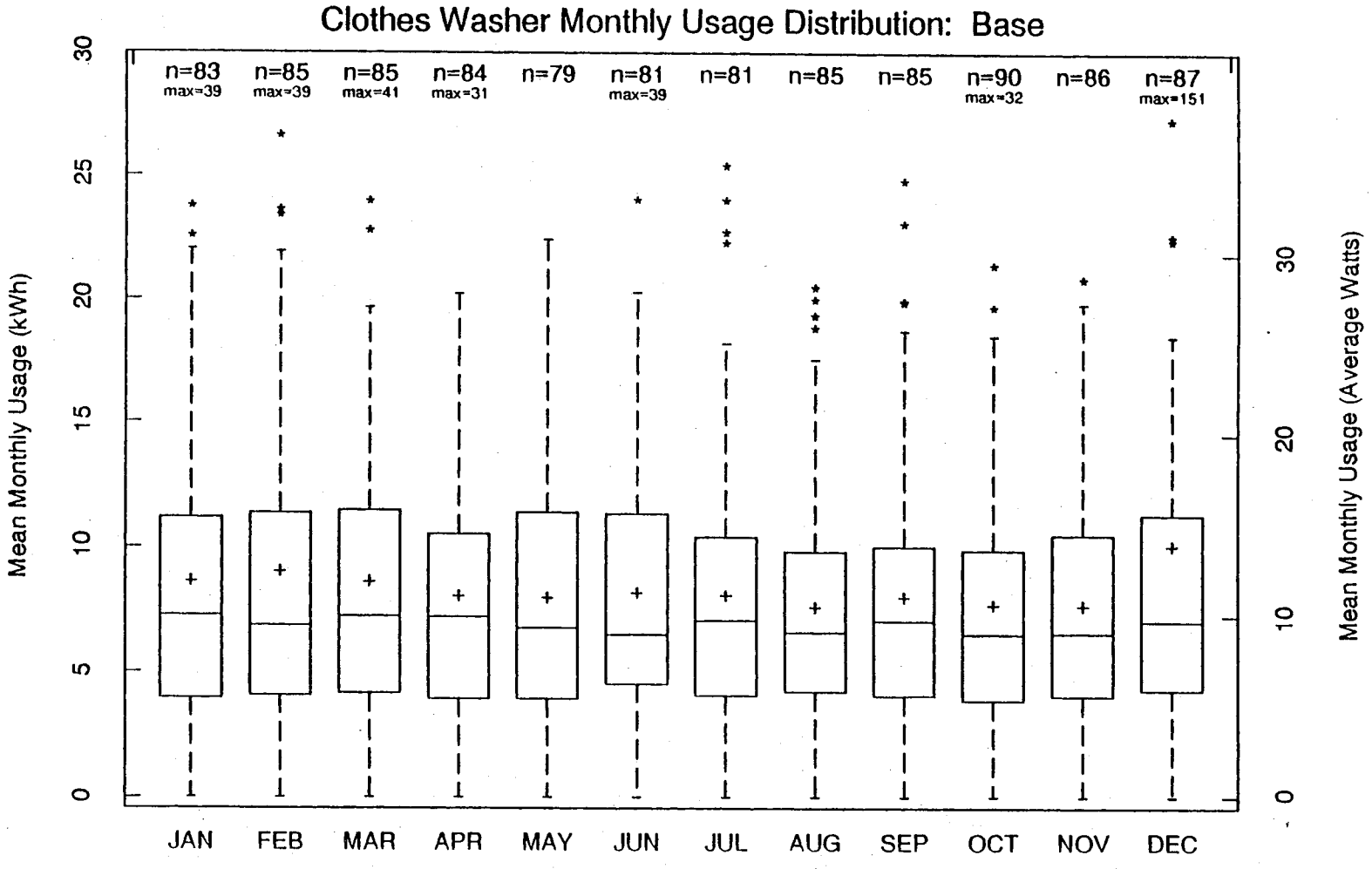
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FIGURE 7M.4



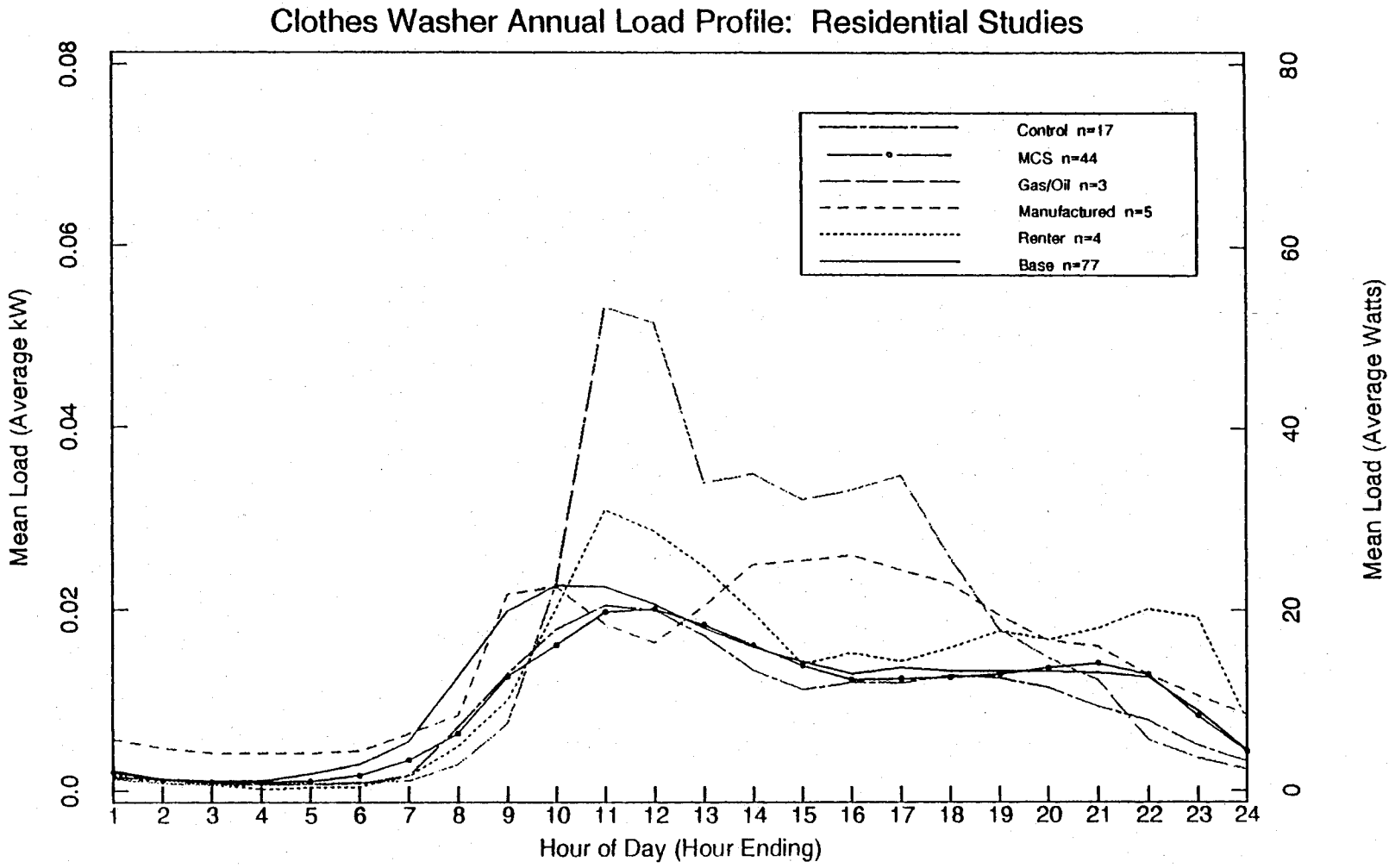
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

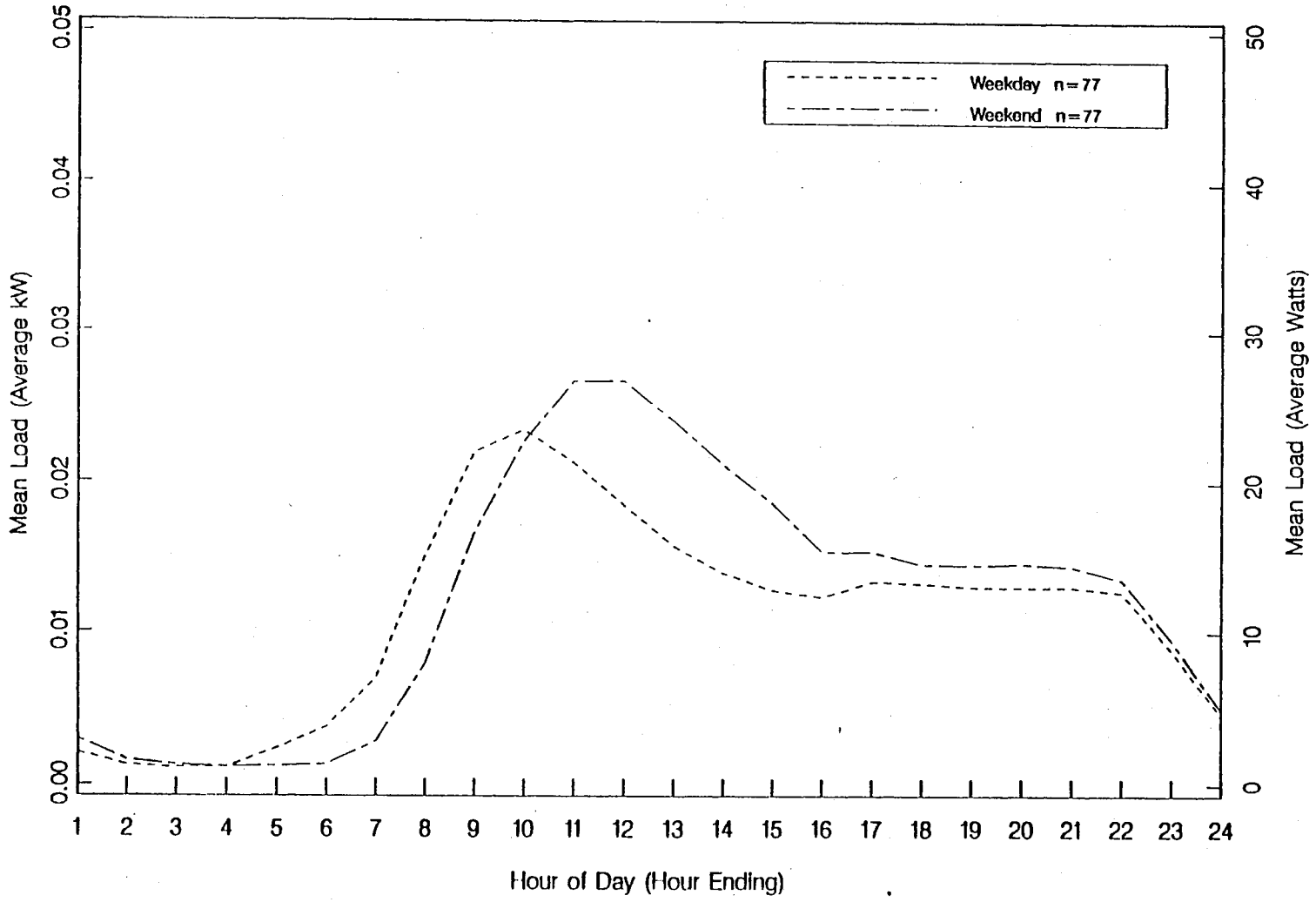
FIGURE 7M.6



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

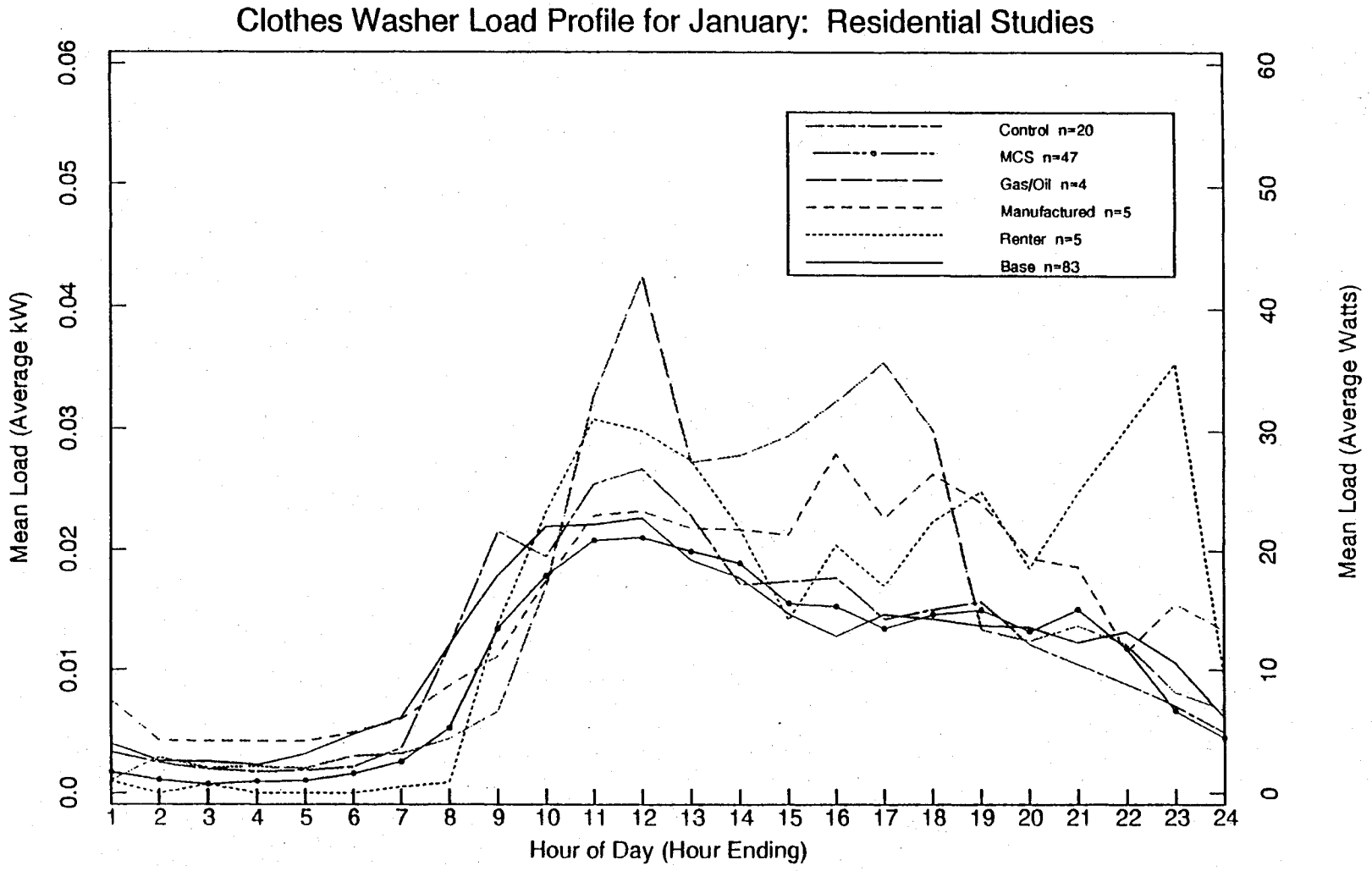
FIGURE 7M.7

Clothes Washer Annual Weekday/Weekend Load Profiles: Base



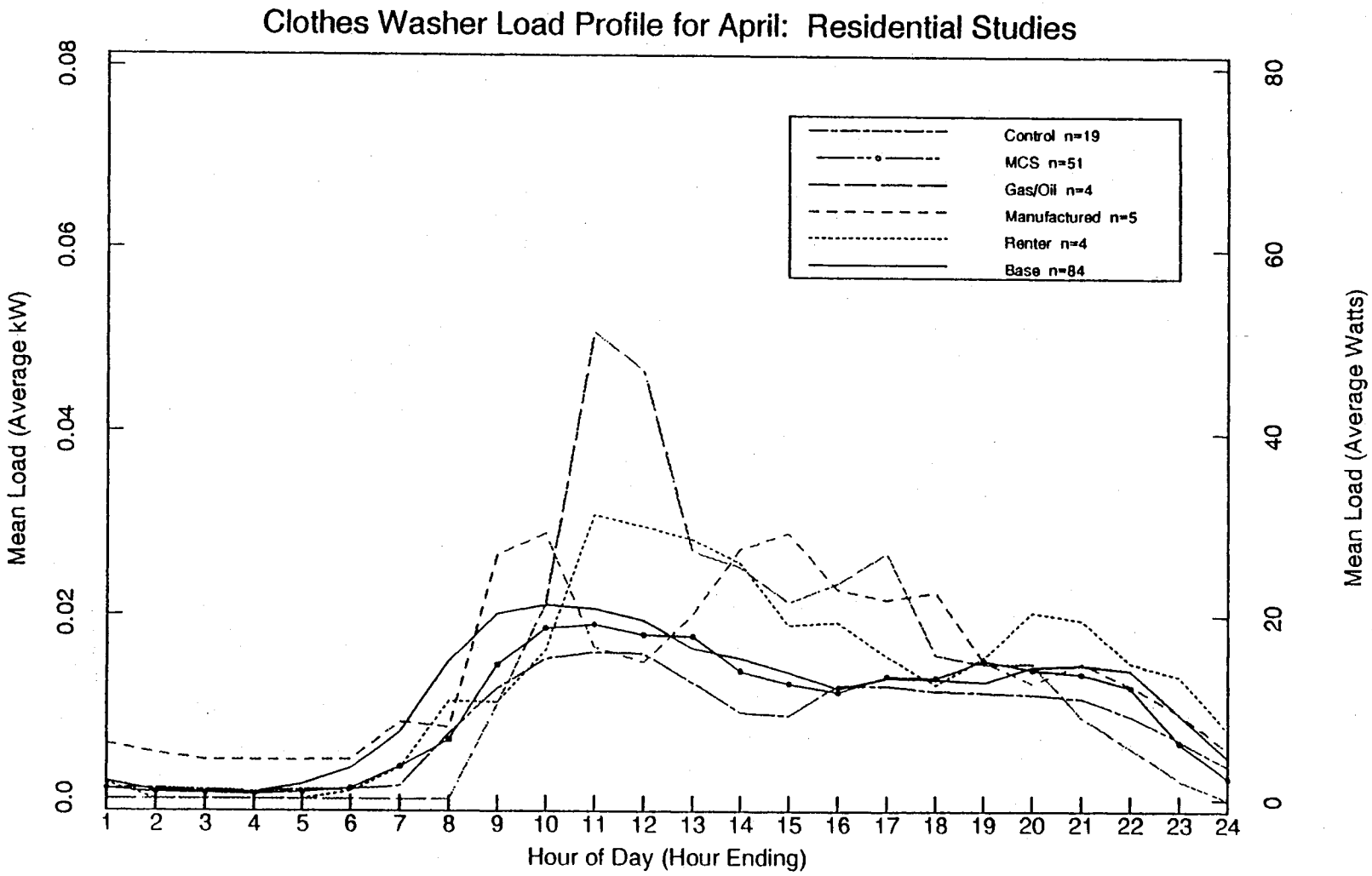
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.8(a)



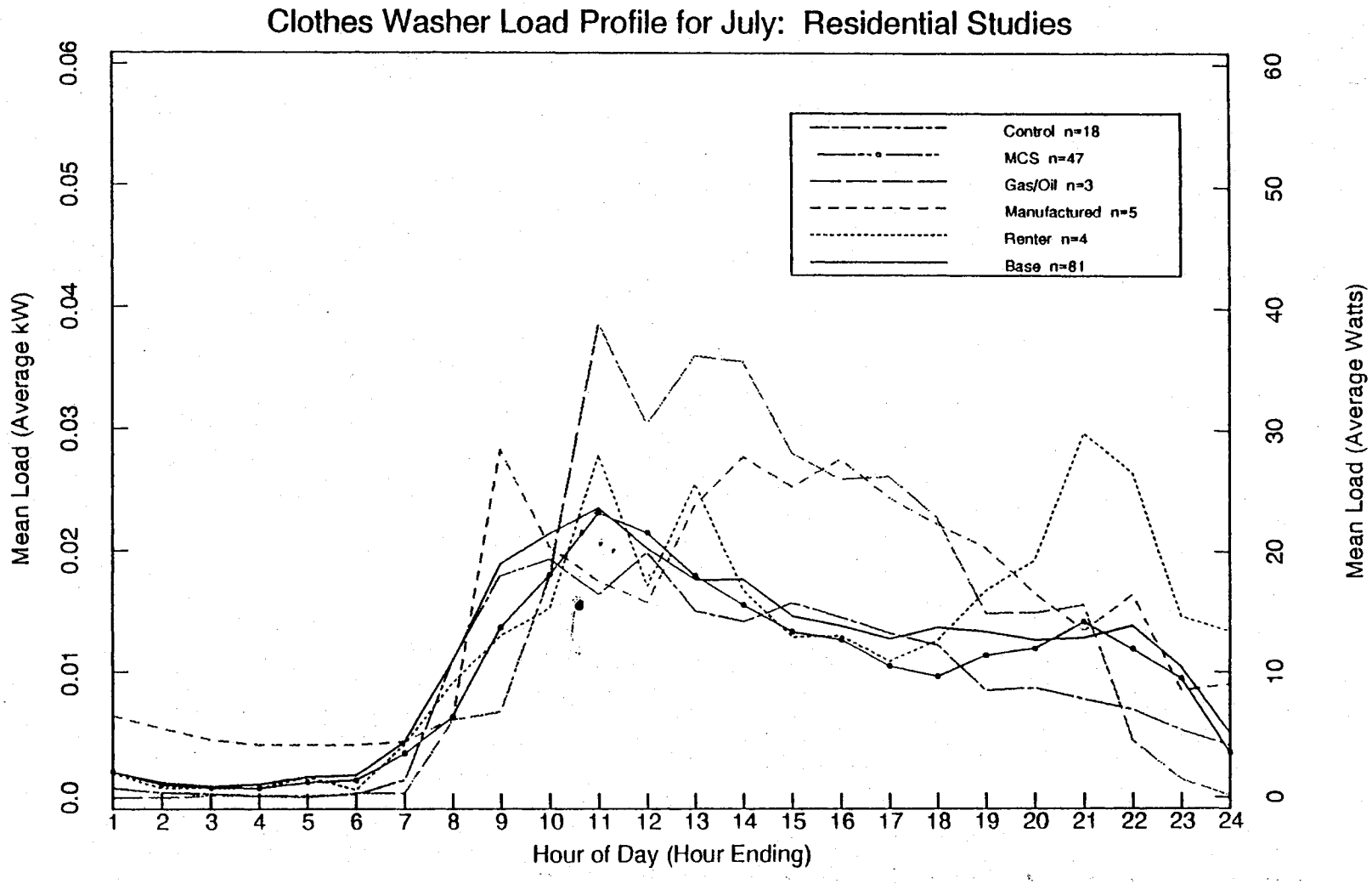
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.8(b)



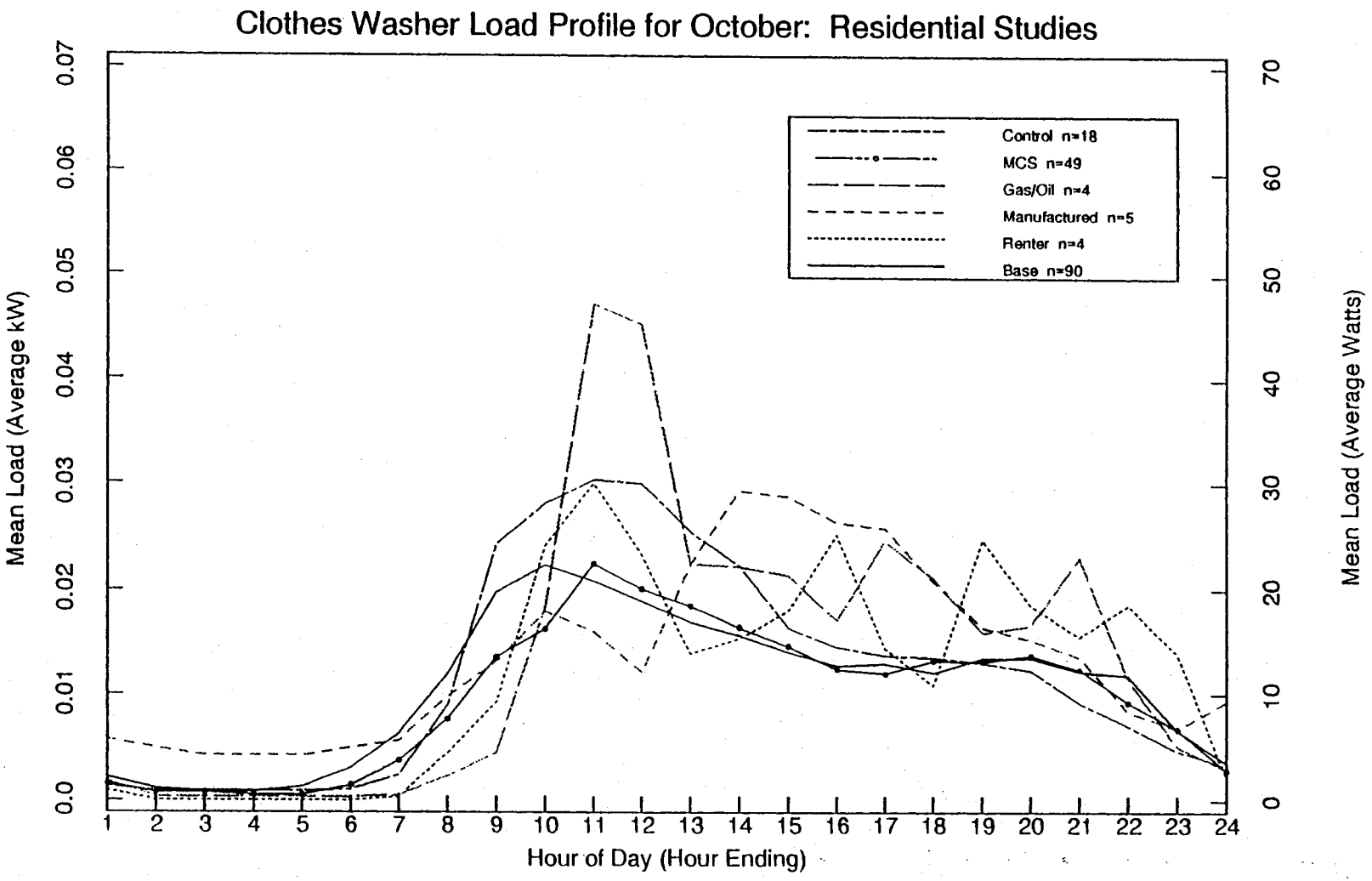
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.8(c)



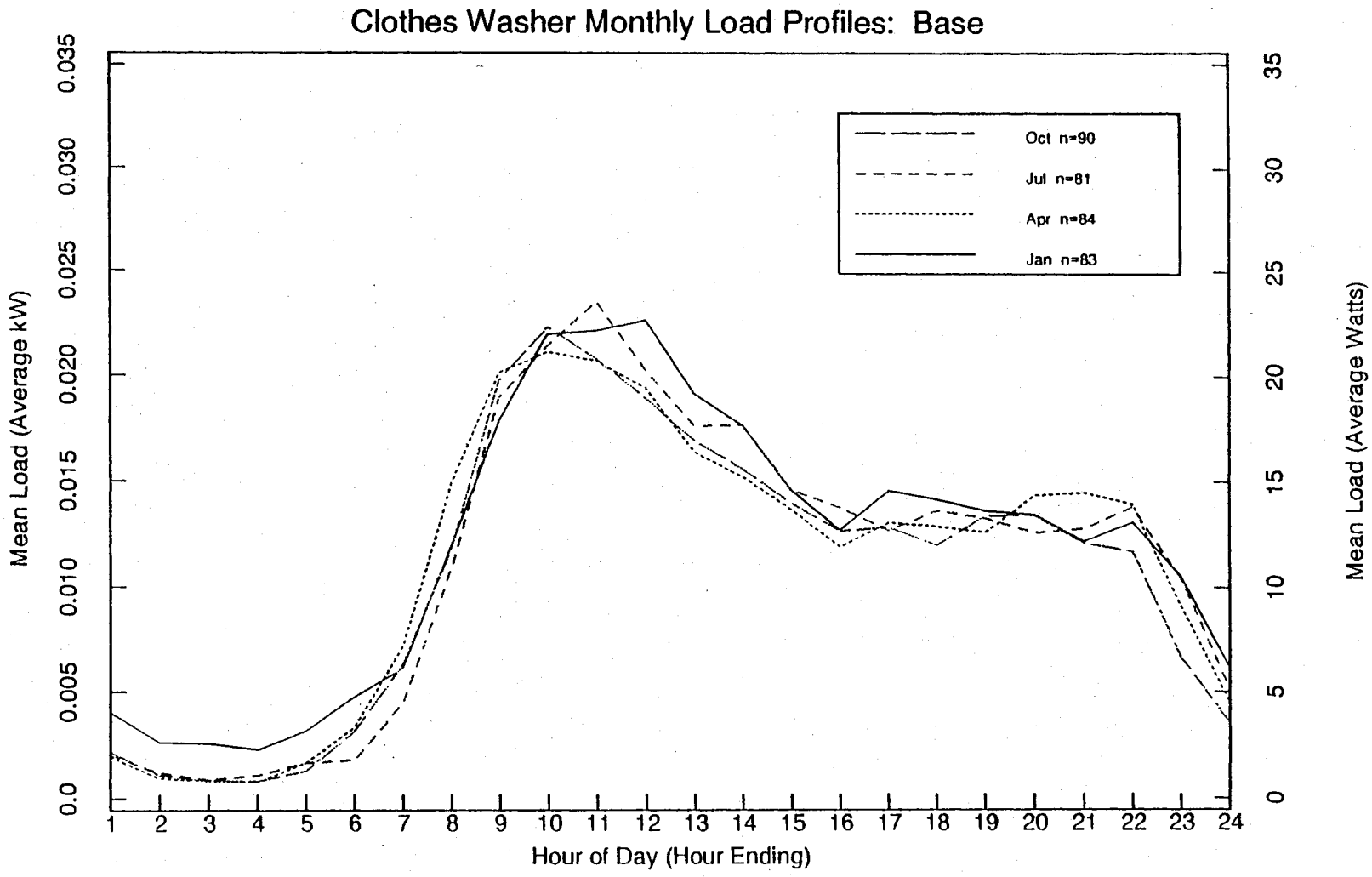
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.8(d)



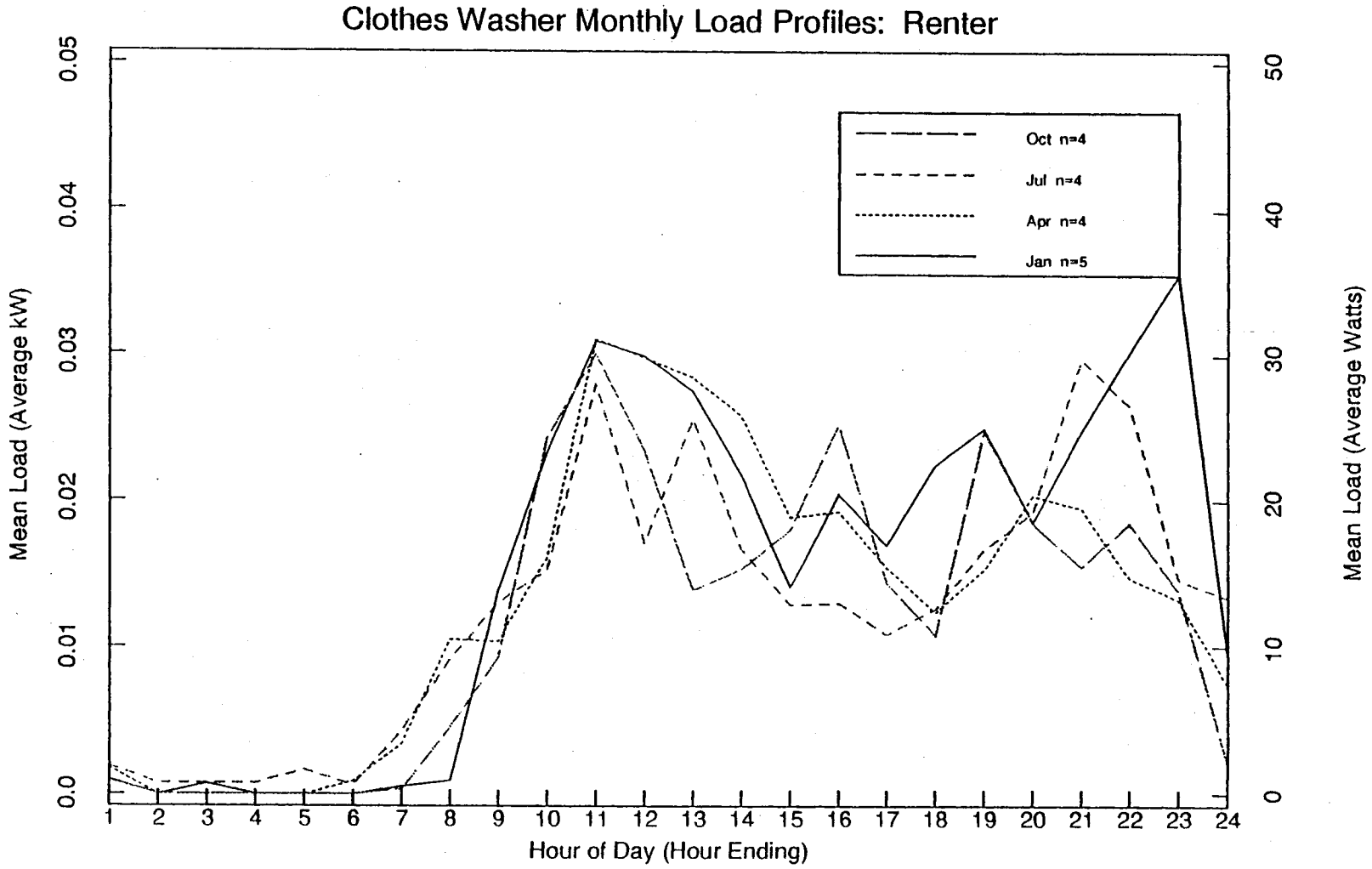
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(a)



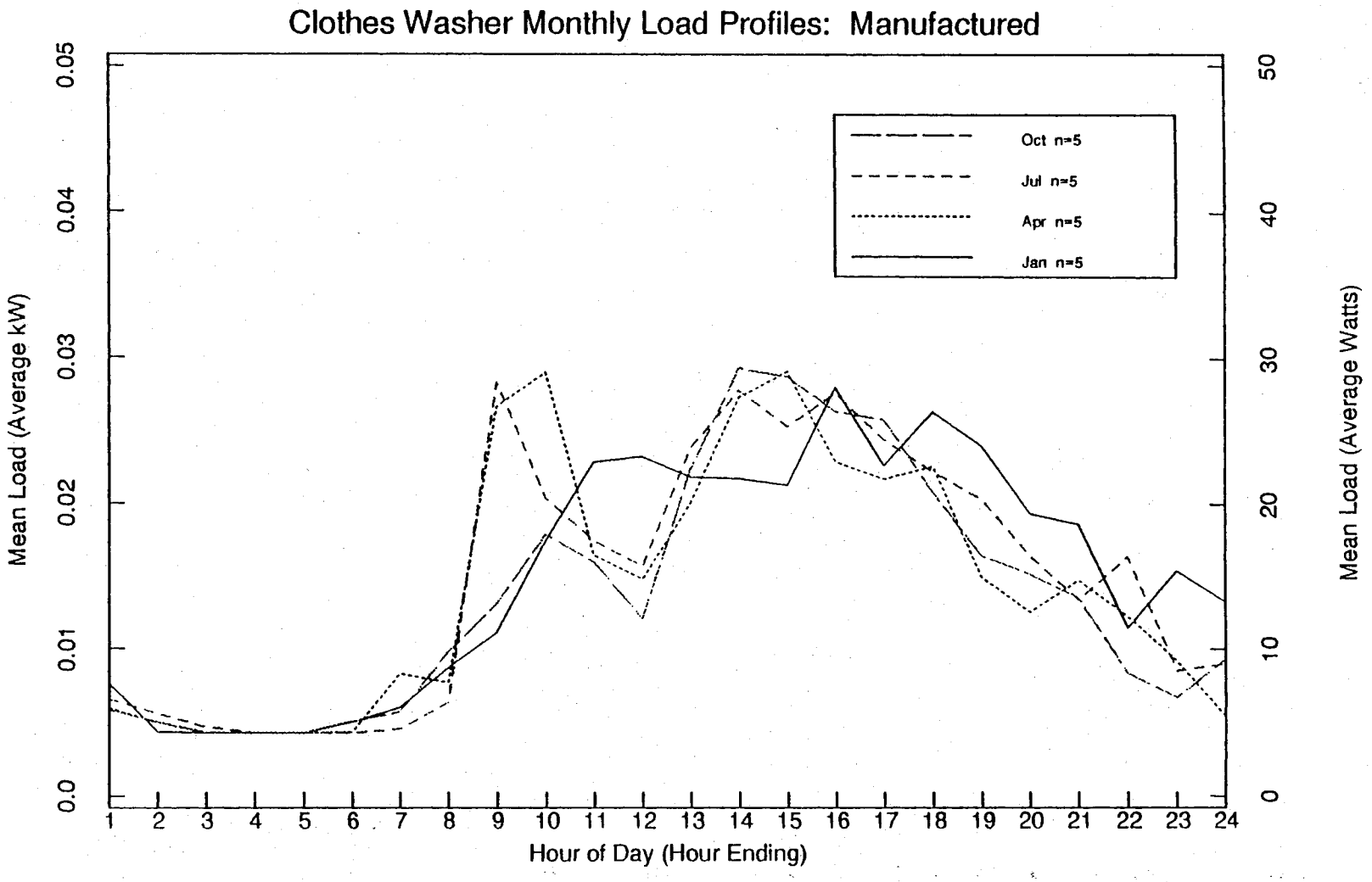
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(b)



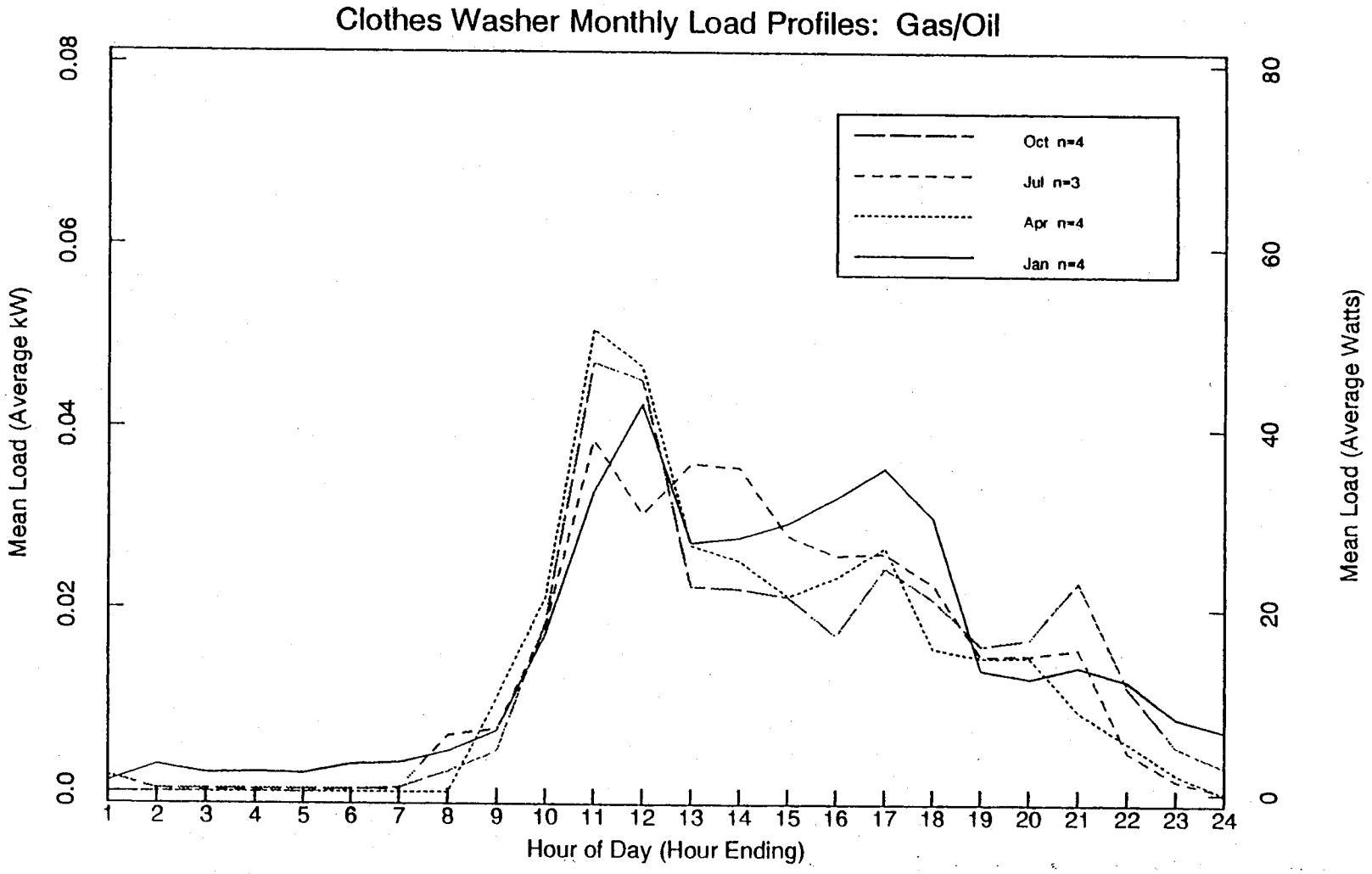
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(c)



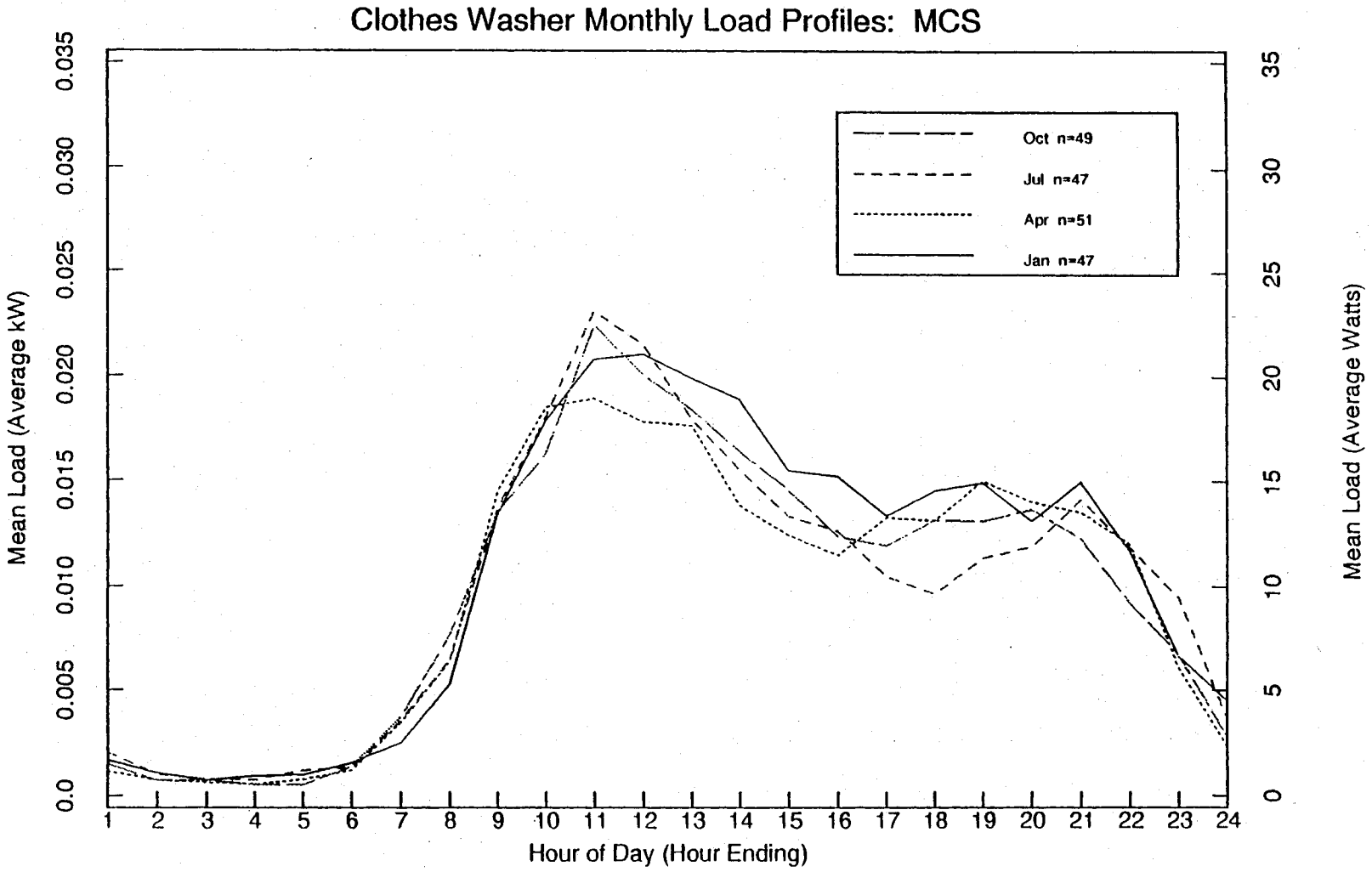
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(d)



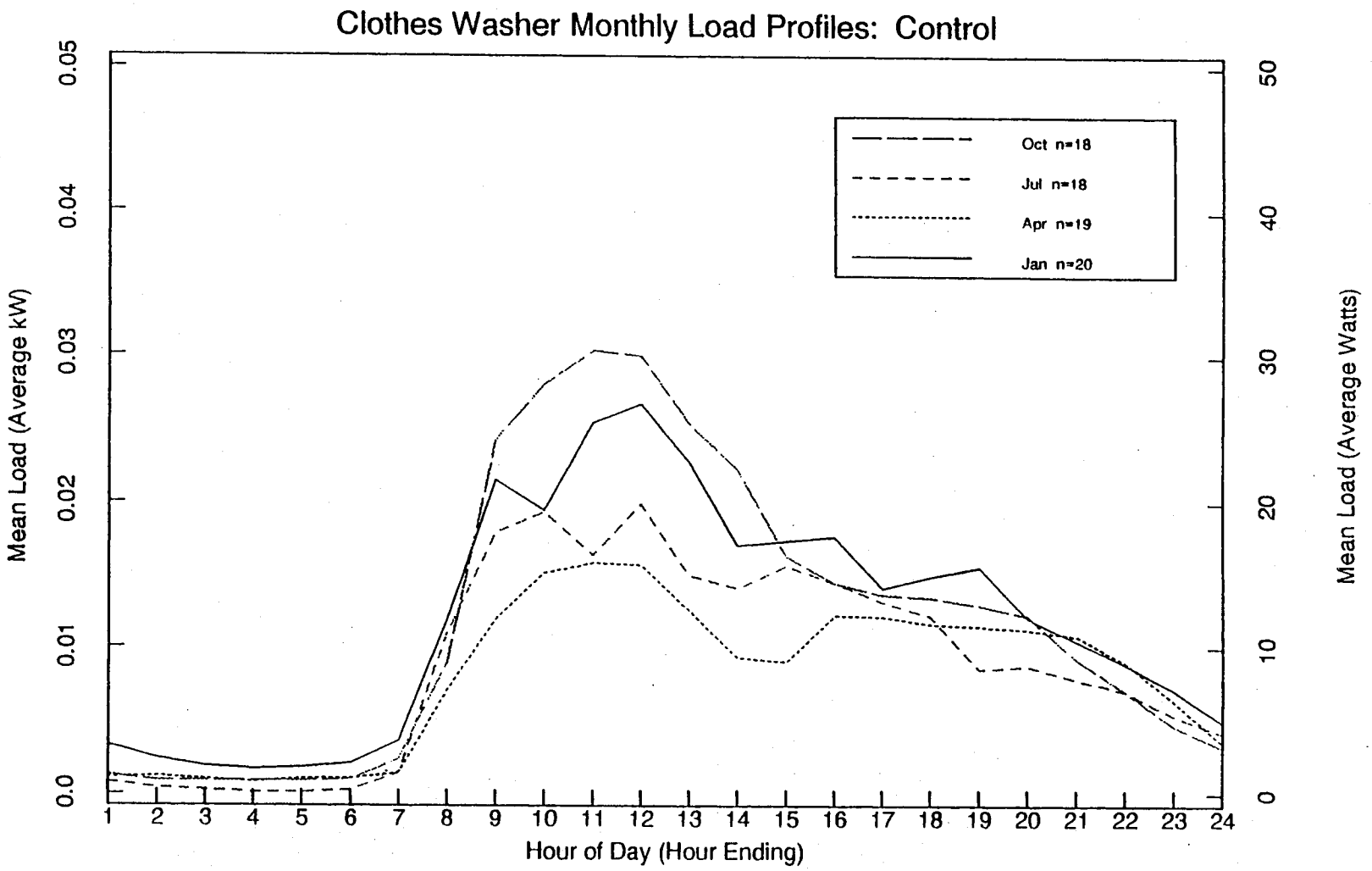
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(e)



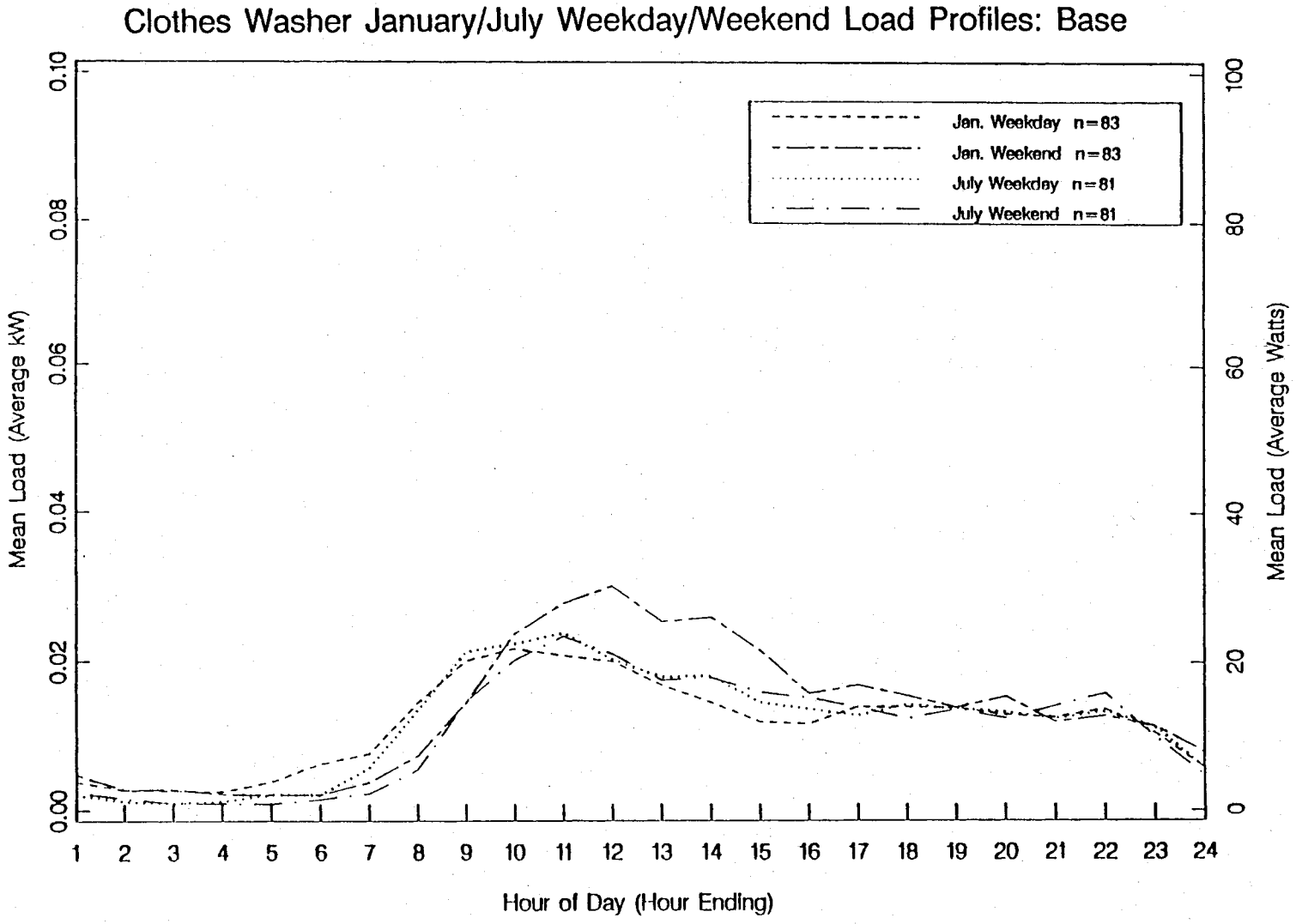
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7M.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

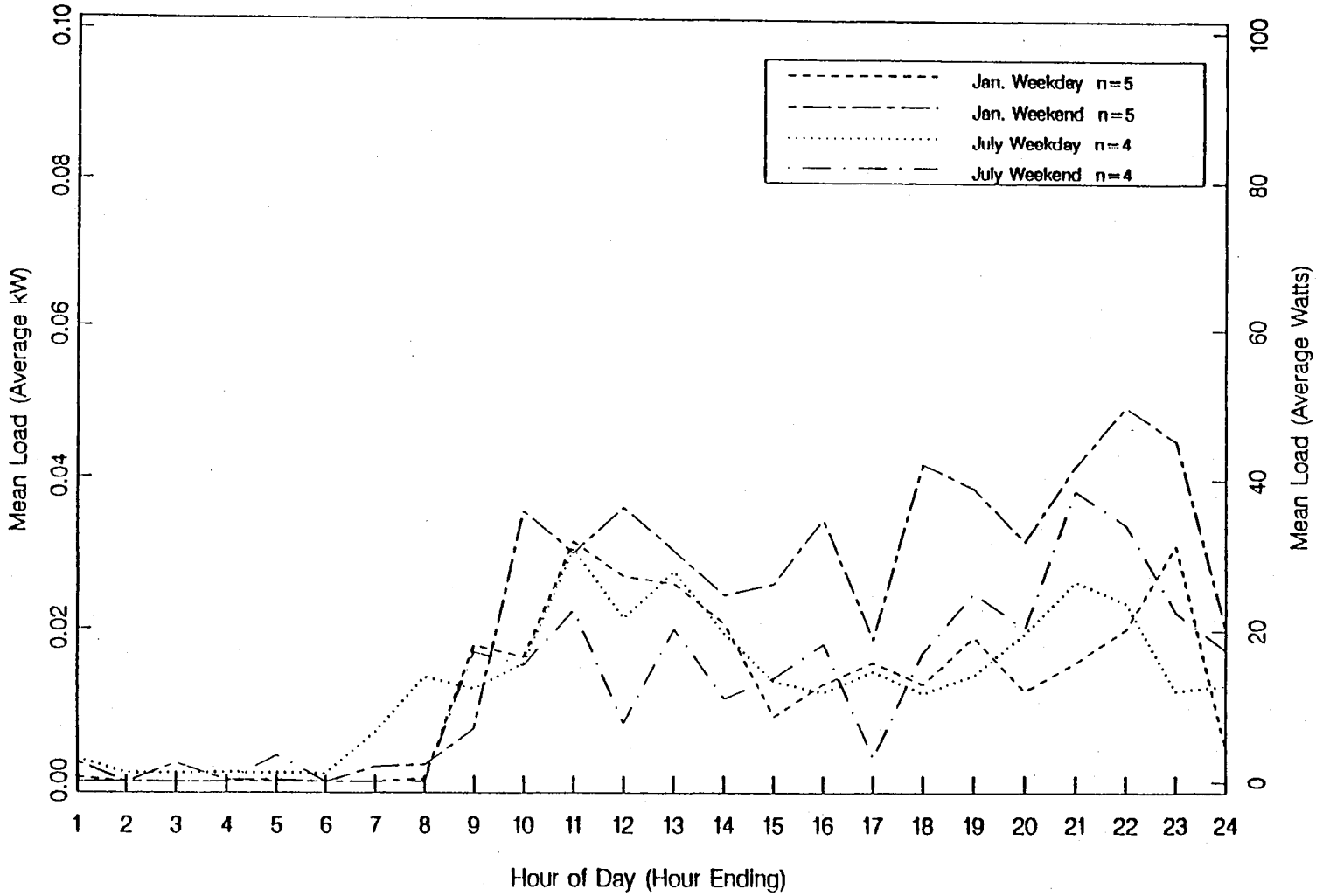
FIGURE 7M.10(a)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.10(b)

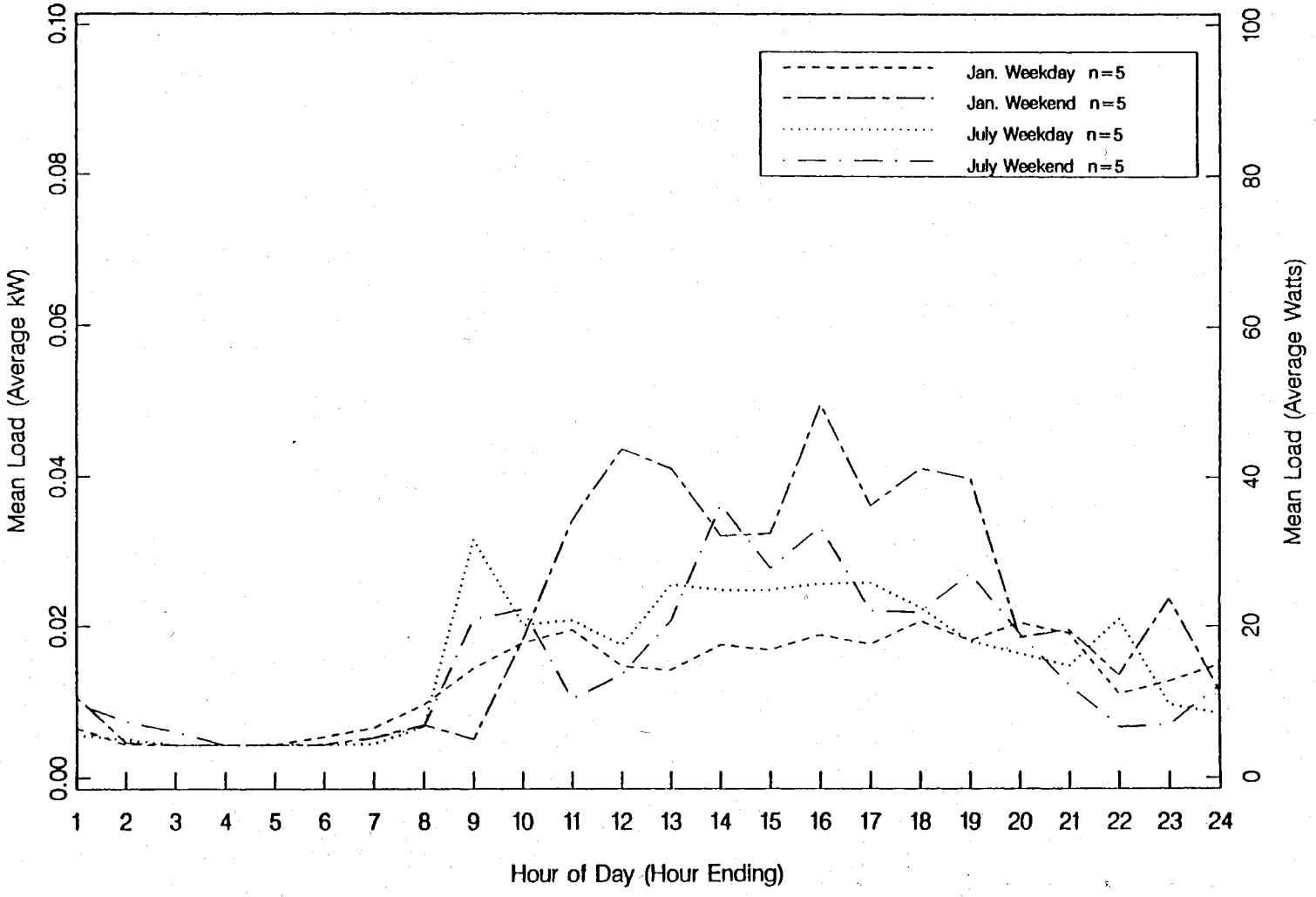
Clothes Washer January/July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

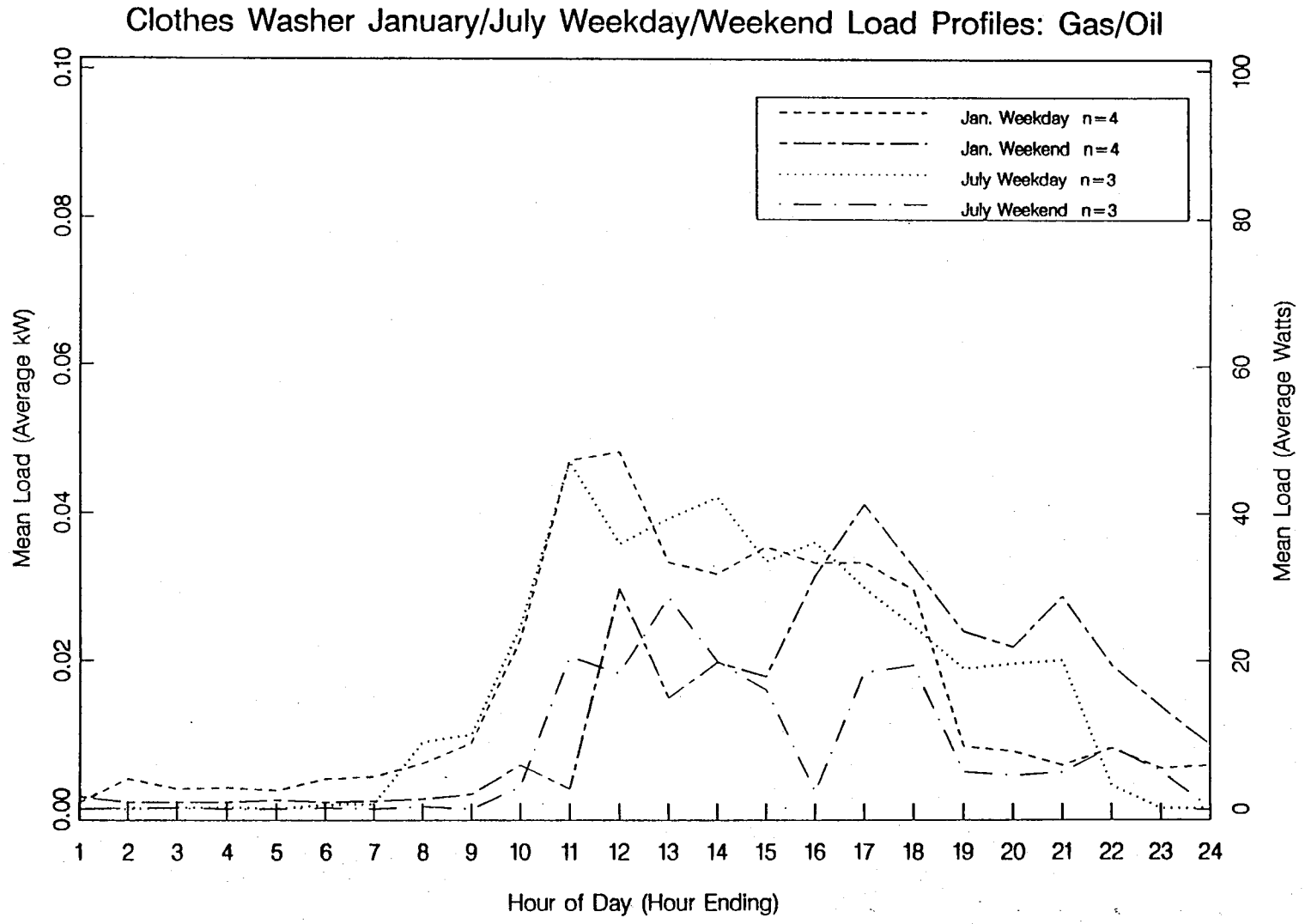
FIGURE 7M.10(c)

Clothes Washer January/July Weekday/Weekend Load Profiles: Manufactured



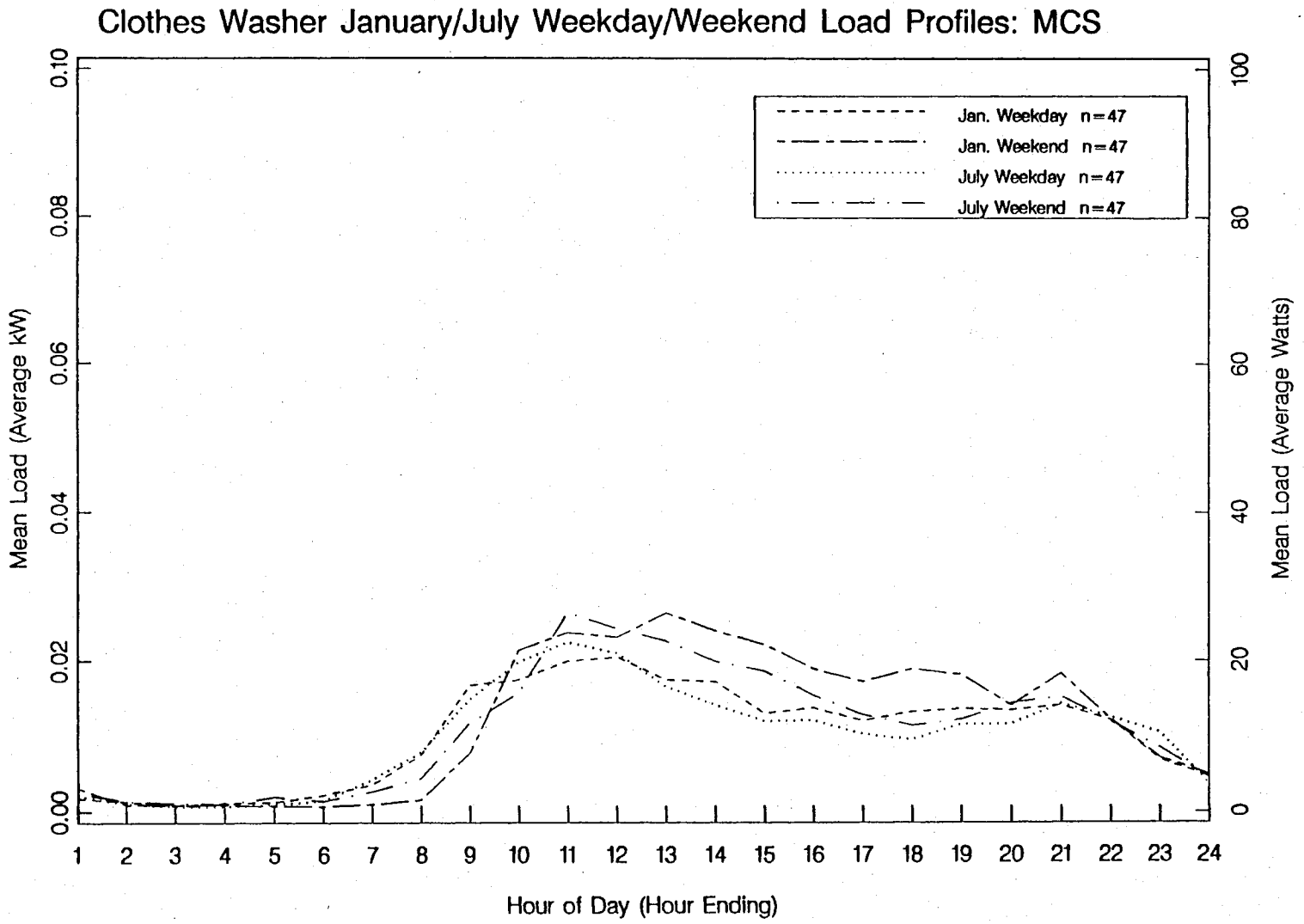
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.10(d)



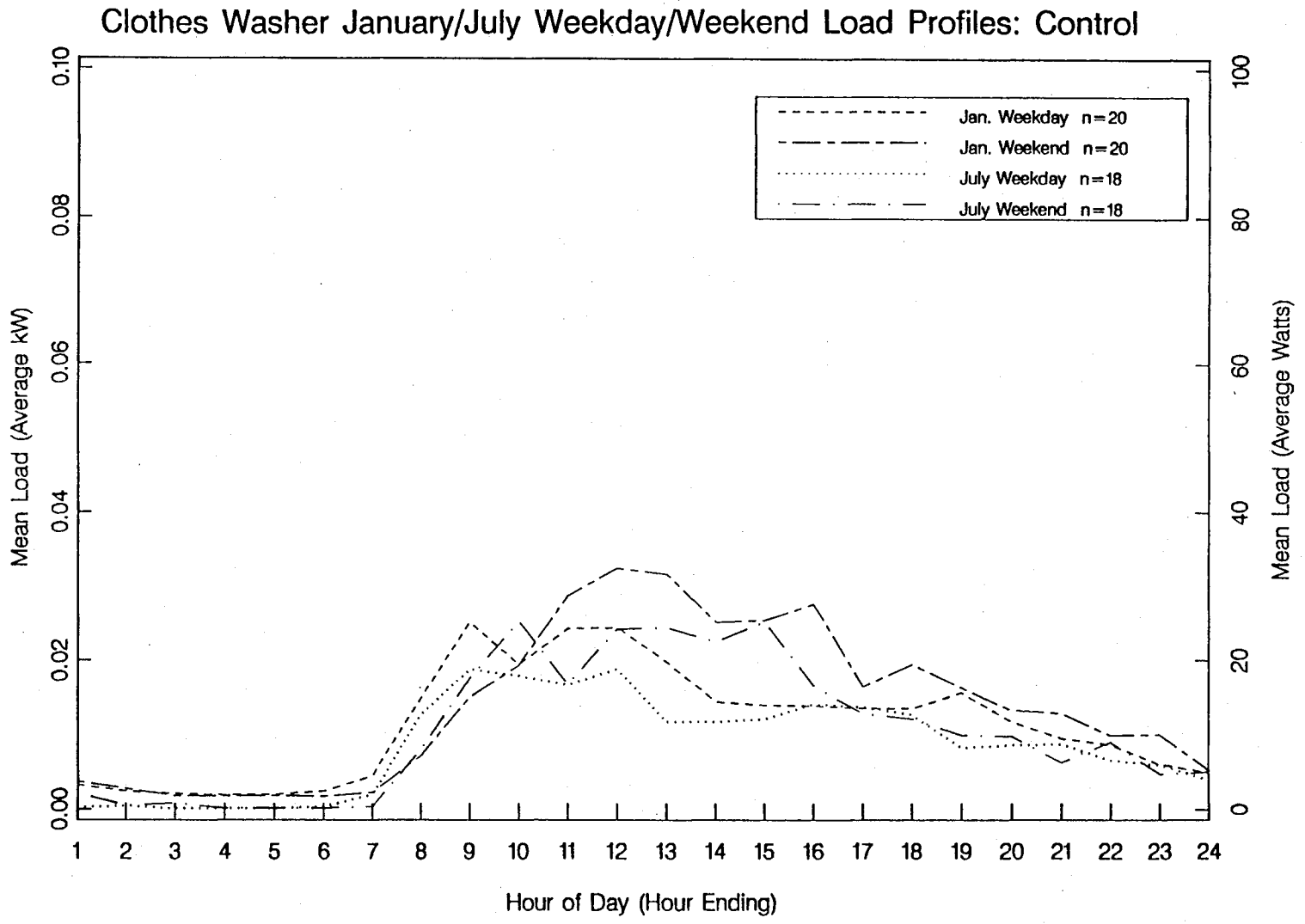
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.10(e)



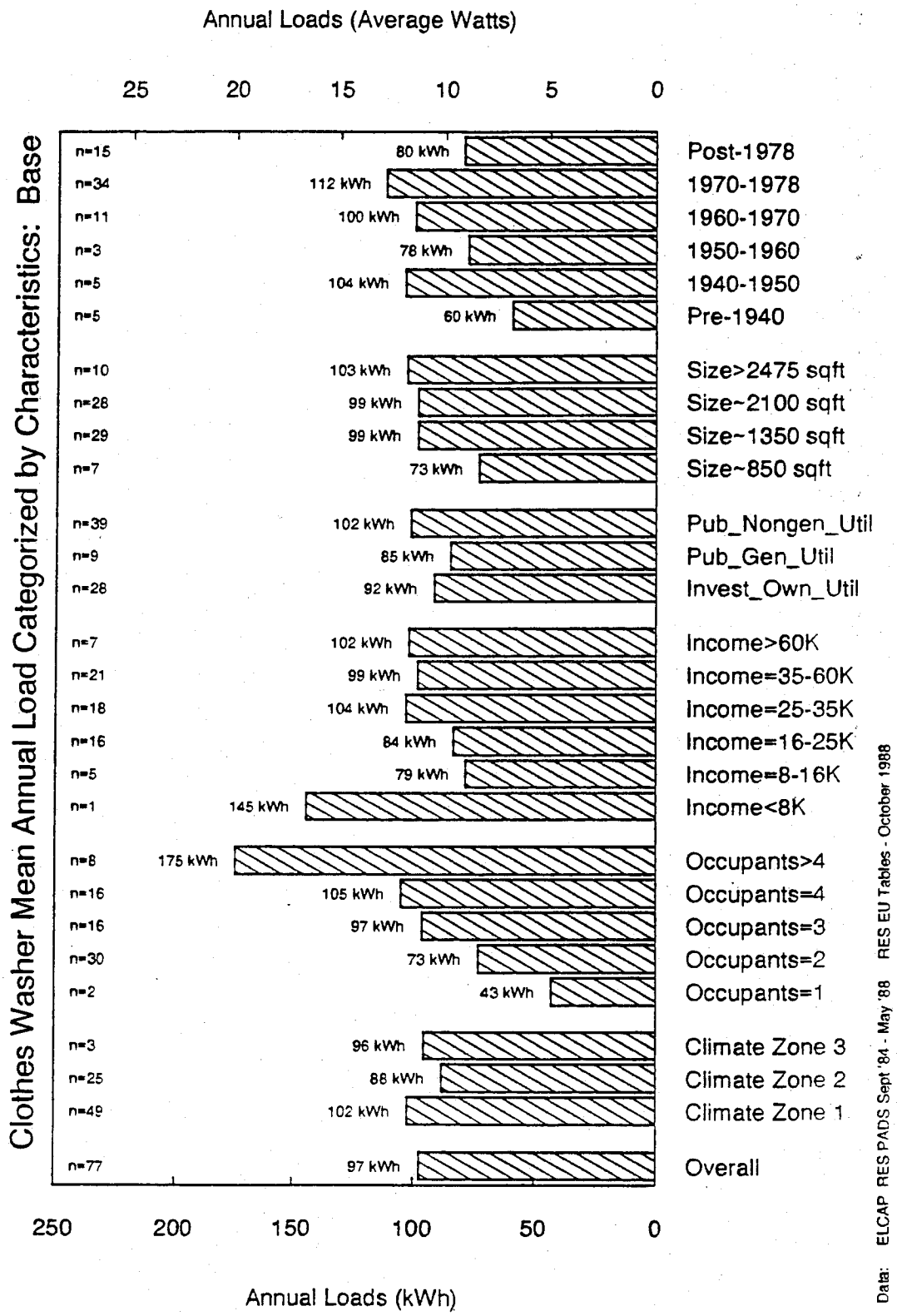
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7M.11



Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7M.12

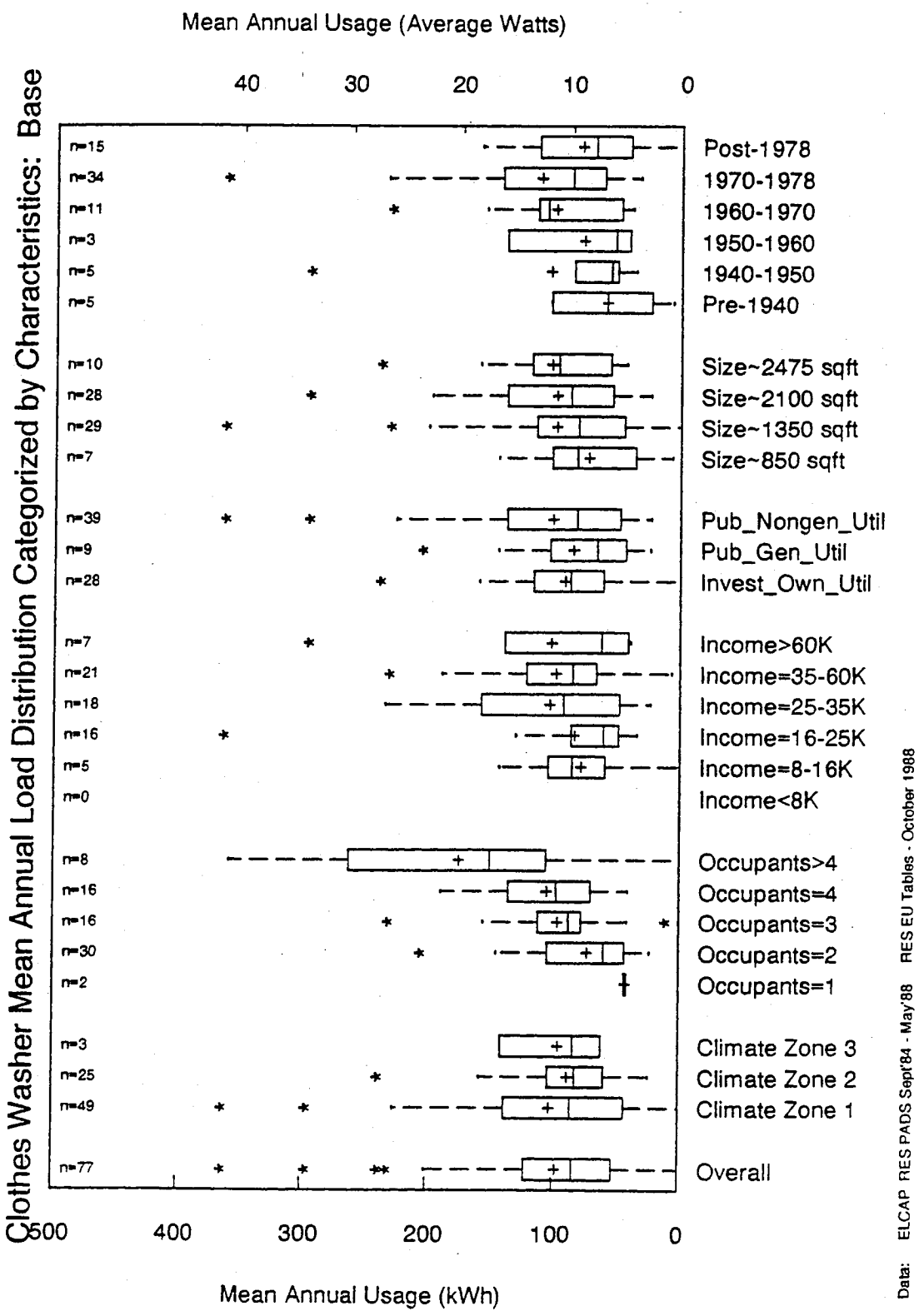

Clothes Washer Mean Annual Load Distribution Categorized by Characteristics: Base
Mean Annual Usage (Average Watts)
40
30
20
10
0
n=15
n=34
n=11
n=3
n=5
n=5
Post-1978
1970-1978
1960-1970
1950-1960
1940-1950
Pre-1940
n=10
n=28
n=29
n=7
Size~2475 sqft
Size~2100 sqft
Size~1350 sqft
Size~850 sqft
n=39
n=9
n=28
Pub_Nongen_Util
Pub_Gen_Util
Invest_Own_Util
n=7
n=21
n=18
n=16
n=5
n=0
Income>60K
Income=35-60K
Income=25-35K
Income=16-25K
Income=8-16K
Income<8K
n=8
n=16
n=16
n=30
n=2
Occupants>4
Occupants=4
Occupants=3
Occupants=2
Occupants=1
n=3
n=25
n=49
Climate Zone 3
Climate Zone 2
Climate Zone 1
n=77
Overall
500
400
300
200
100
0
Mean Annual Usage (kWh)
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7M.1

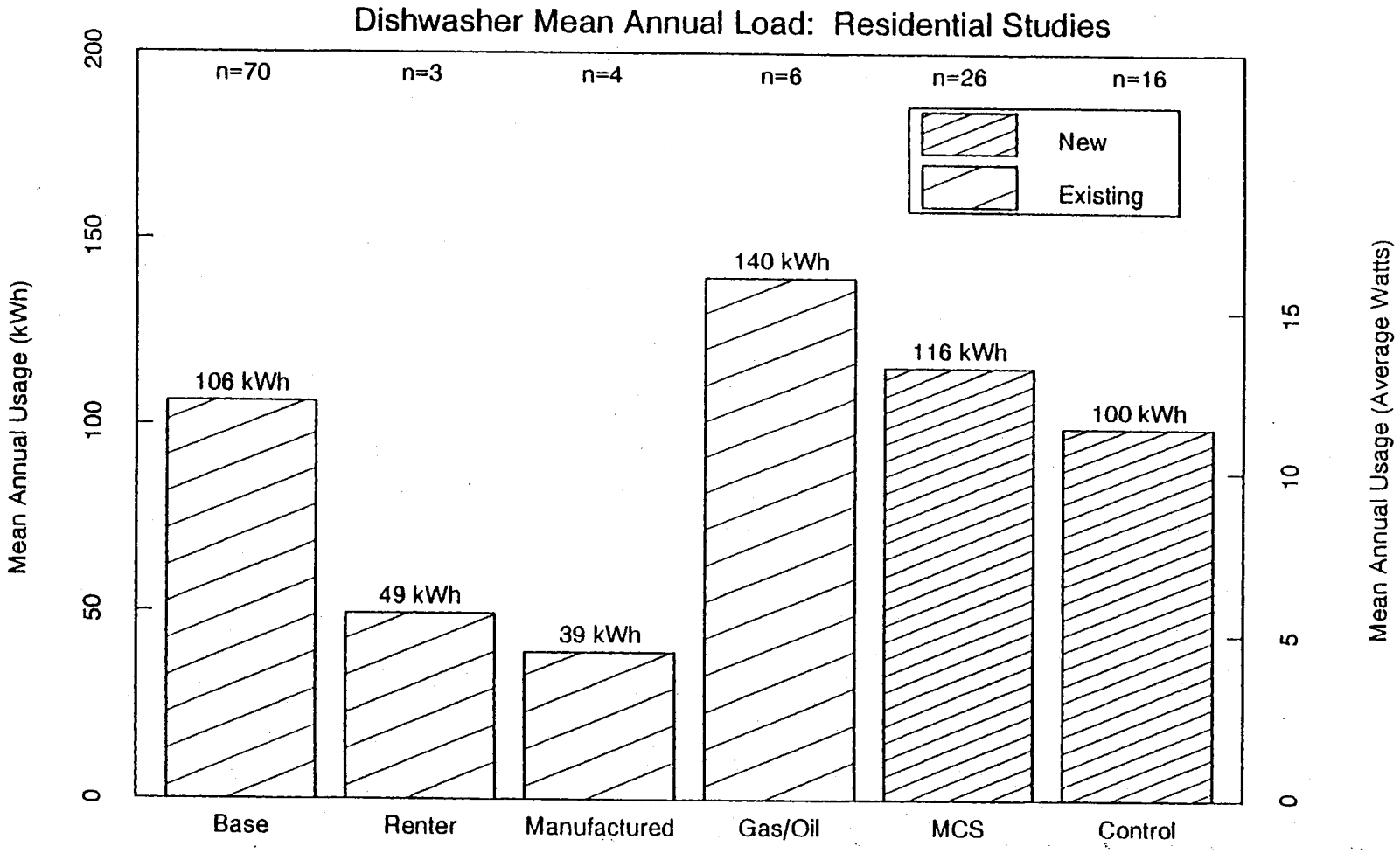
Clothes Washer Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	77	97	63	17	78	42	44	88	55	138	92	59
Climate Zone 1	49	102	72	11	78	36	27	85	49	87	94	63
Climate Zone 2	25	88	44	2	31	44	14	96	69	41	88	54
Climate Zone 3	3	98	41	4	99	48	3	59	26	10	86	40
Occupants=1	2	43	1	1	38	0	2	60	22	5	49	15
Occupants=2	30	73	42	6	88	42	10	61	48	46	73	43
Occupants=3	16	97	50	3	33	32	6	84	45	25	86	50
Occupants=4	18	105	46	1	107	0	5	120	45	22	109	44
Occupants>4	8	175	116	0	-	-	3	175	89	11	175	105
Income<8K	1	145	0	0	-	-	0	-	-	1	145	0
Income=8-16K	5	79	53	1	0	0	1	0	0	7	56	58
Income=16-25K	16	84	77	1	62	0	6	74	67	23	80	72
Income=25-35K	18	104	62	5	71	25	9	91	42	32	95	53
Income=35-60K	21	99	55	2	75	33	10	109	68	33	100	57
Income>60K	7	102	90	1	167	0	0	-	-	8	110	87
Invest_Own_Util	28	92	49	7	72	52	22	94	54	57	90	51
Pub_Gen_Util	9	85	57	7	93	35	9	100	55	25	93	49
Pub_Nongen_Util	39	102	73	3	54	15	10	67	60	52	92	70
Size<850 sqft	7	73	45	0	-	-	1	0	0	8	64	49
Size<1350 sqft	29	99	76	12	76	28	22	84	44	63	89	59
Size<2100 sqft	28	99	59	4	67	71	14	94	68	46	95	62
Size>2475 sqft	10	103	59	0	-	-	5	112	47	15	106	54
Pre-1940	5	60	45	0	-	-	0	-	-	5	60	45
1940-1950	5	104	106	0	-	-	0	-	-	5	104	106
1950-1960	3	78	53	0	-	-	0	-	-	3	78	53
1960-1970	11	100	56	0	-	-	0	-	-	11	100	56
1970-1978	34	112	69	0	-	-	0	-	-	34	112	69
Post-1978	15	80	46	17	78	42	44	88	55	76	83	50

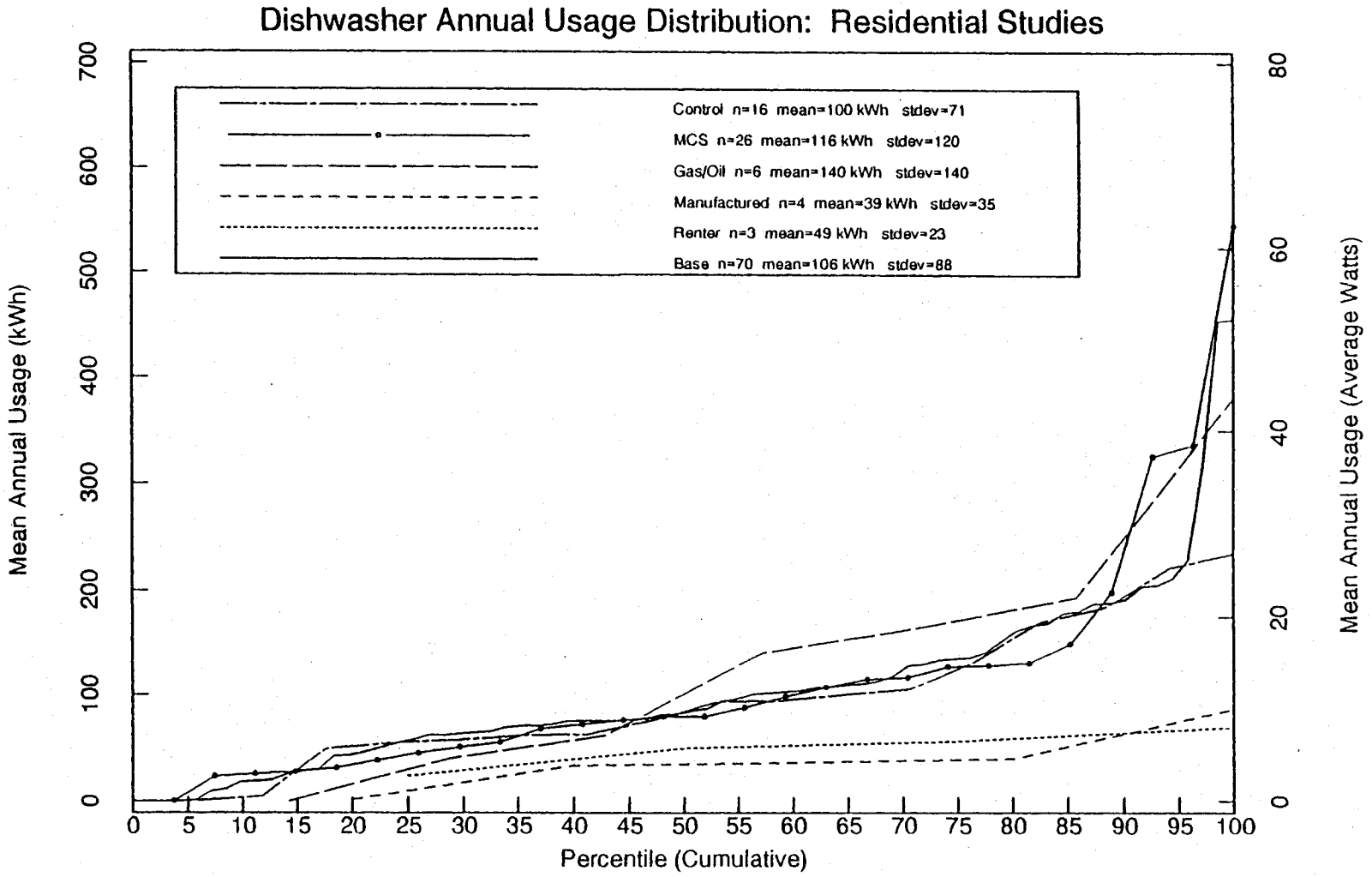
Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7N.1



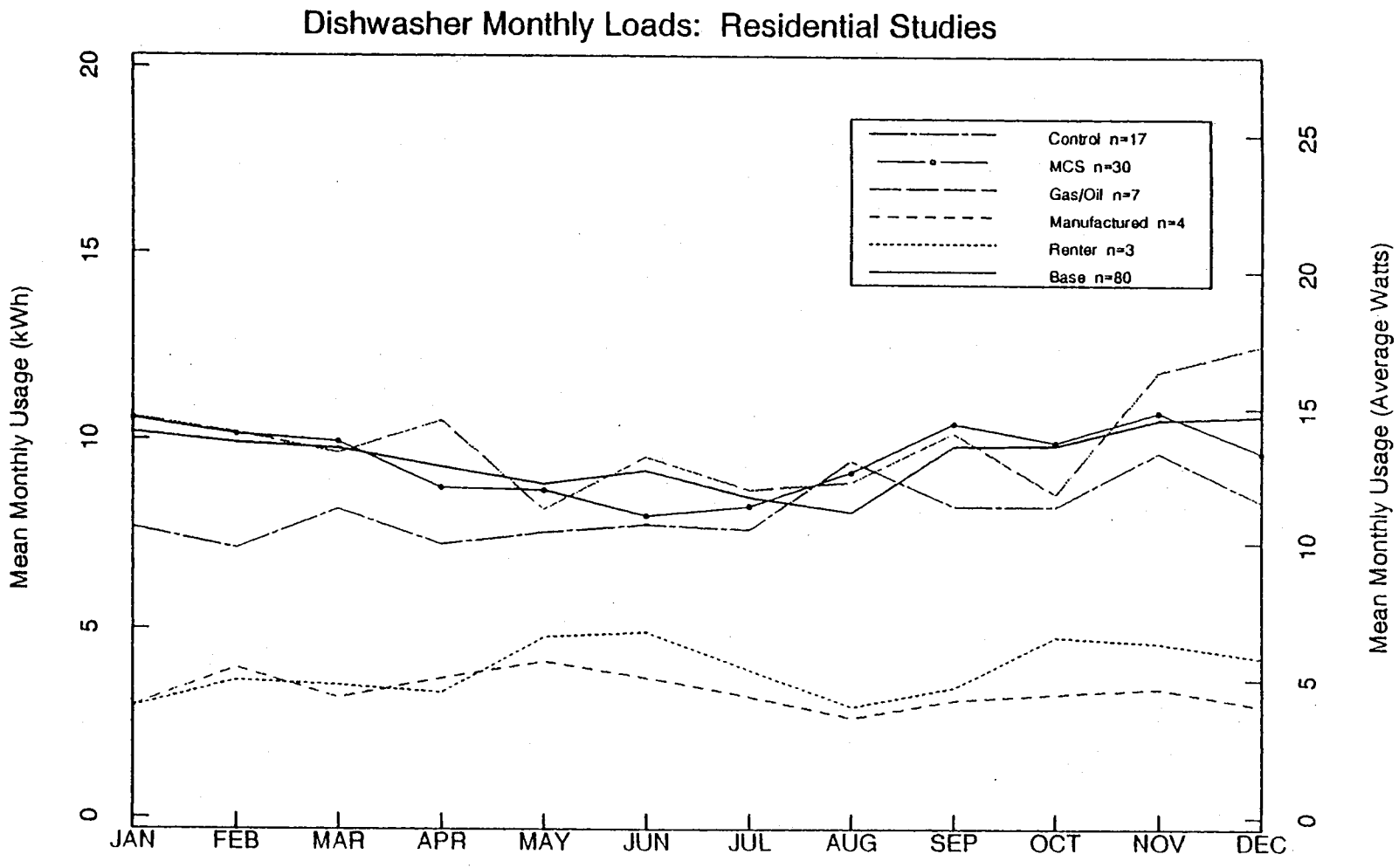
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.2



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

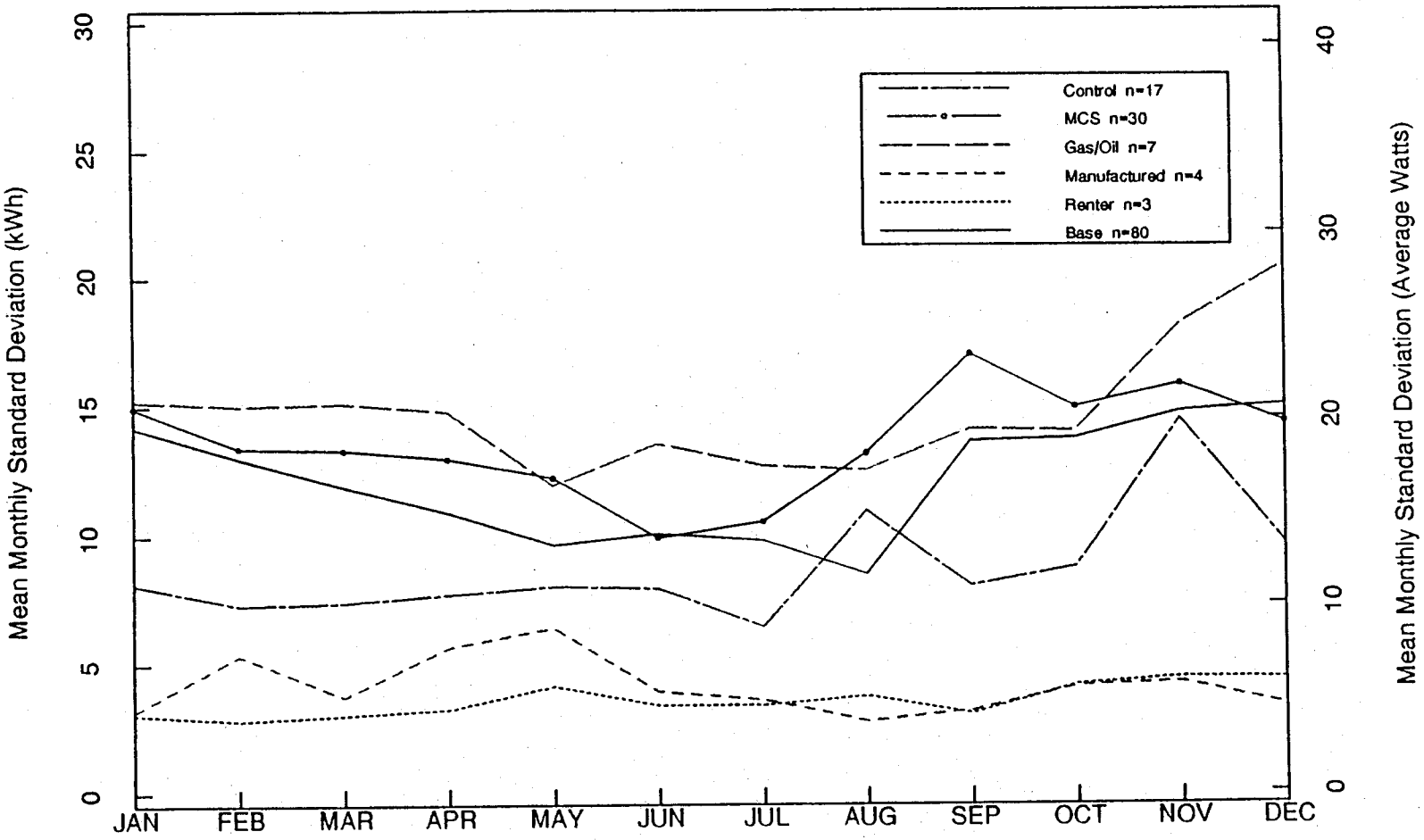
FIGURE 7N.3



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

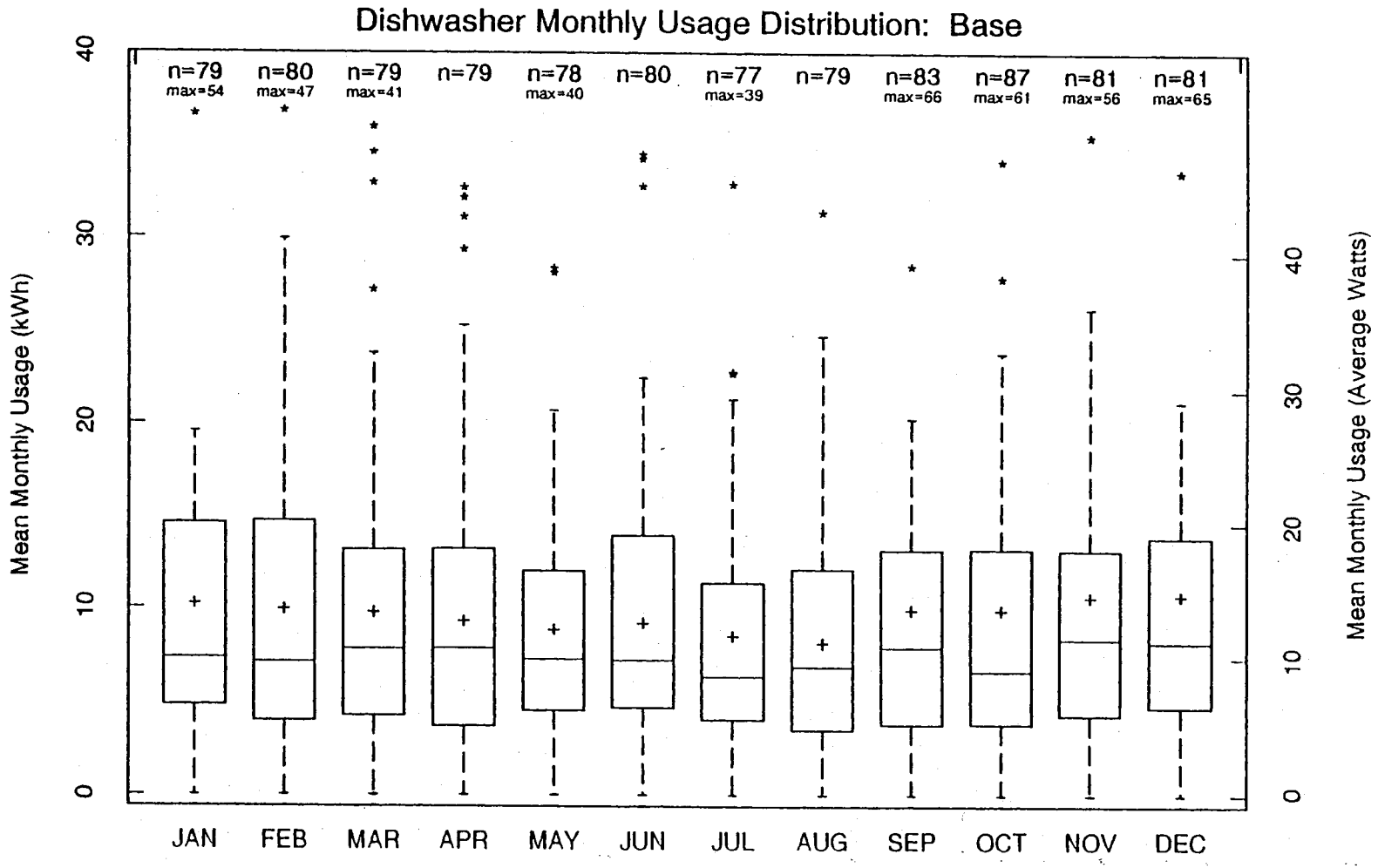
FIGURE 7N.4

Dishwasher Monthly Standard Deviation: Residential Studies



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

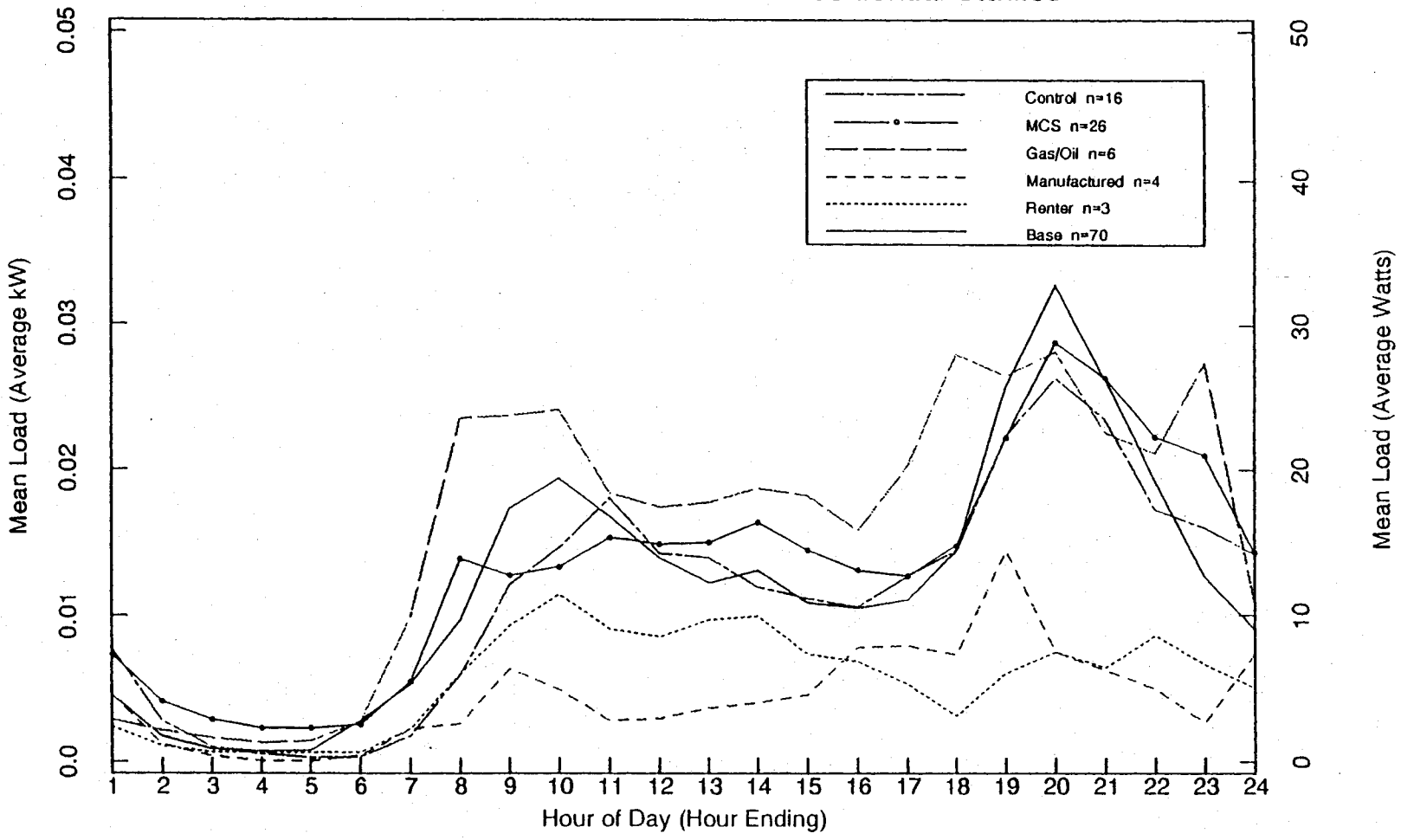
FIGURE 7N.5



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

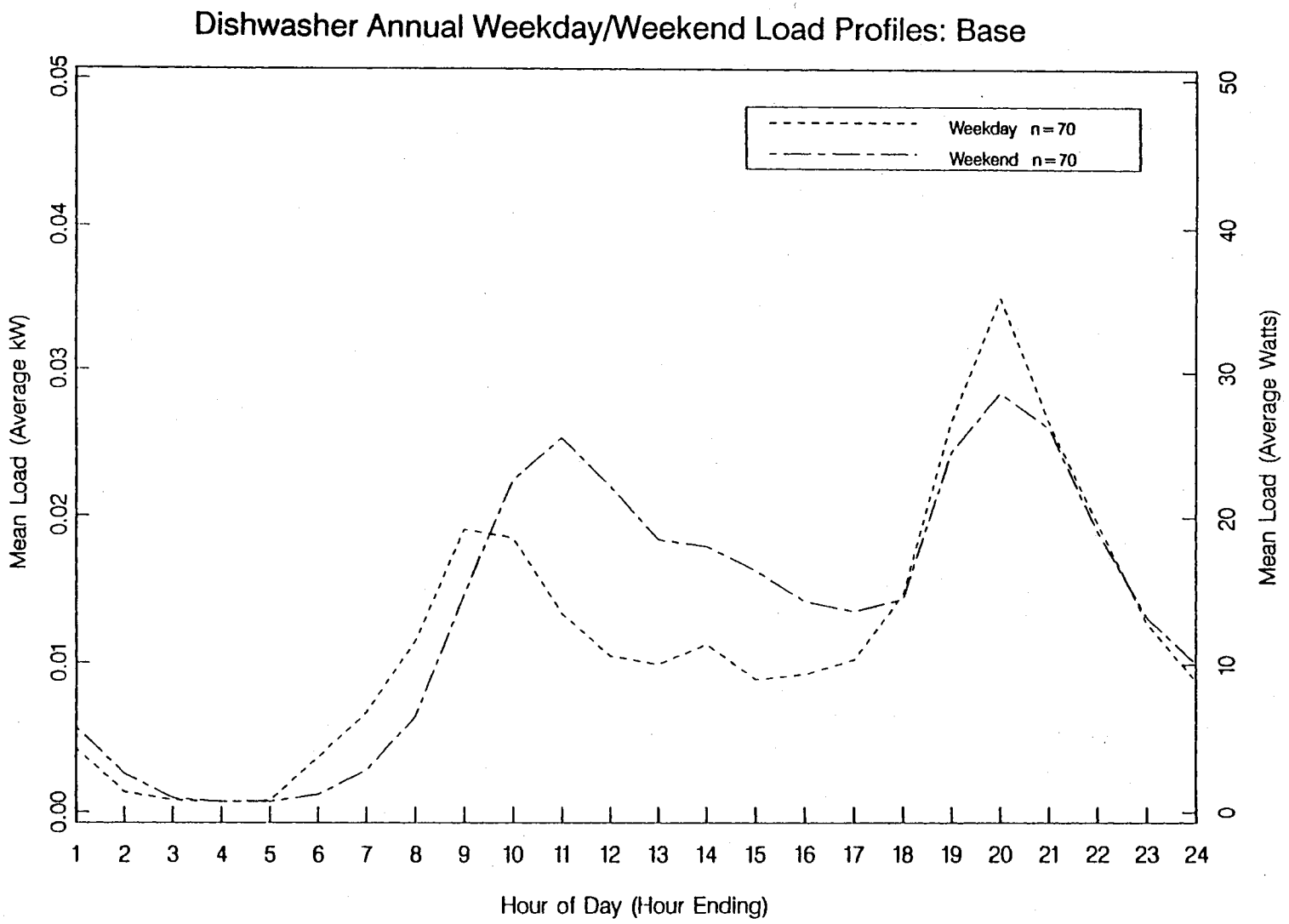
FIGURE 7N.6

Dishwasher Annual Load Profile: Residential Studies



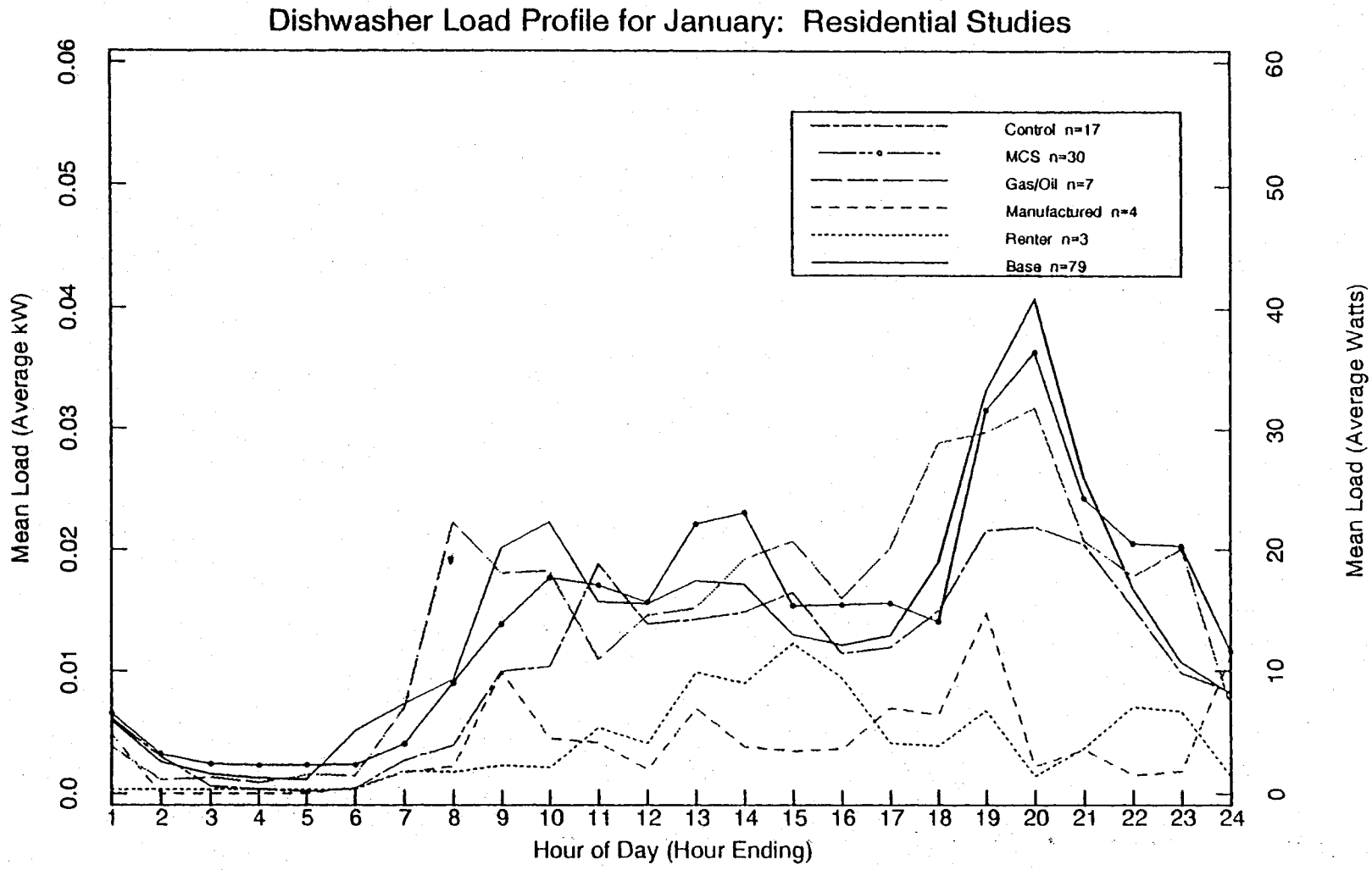
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.7



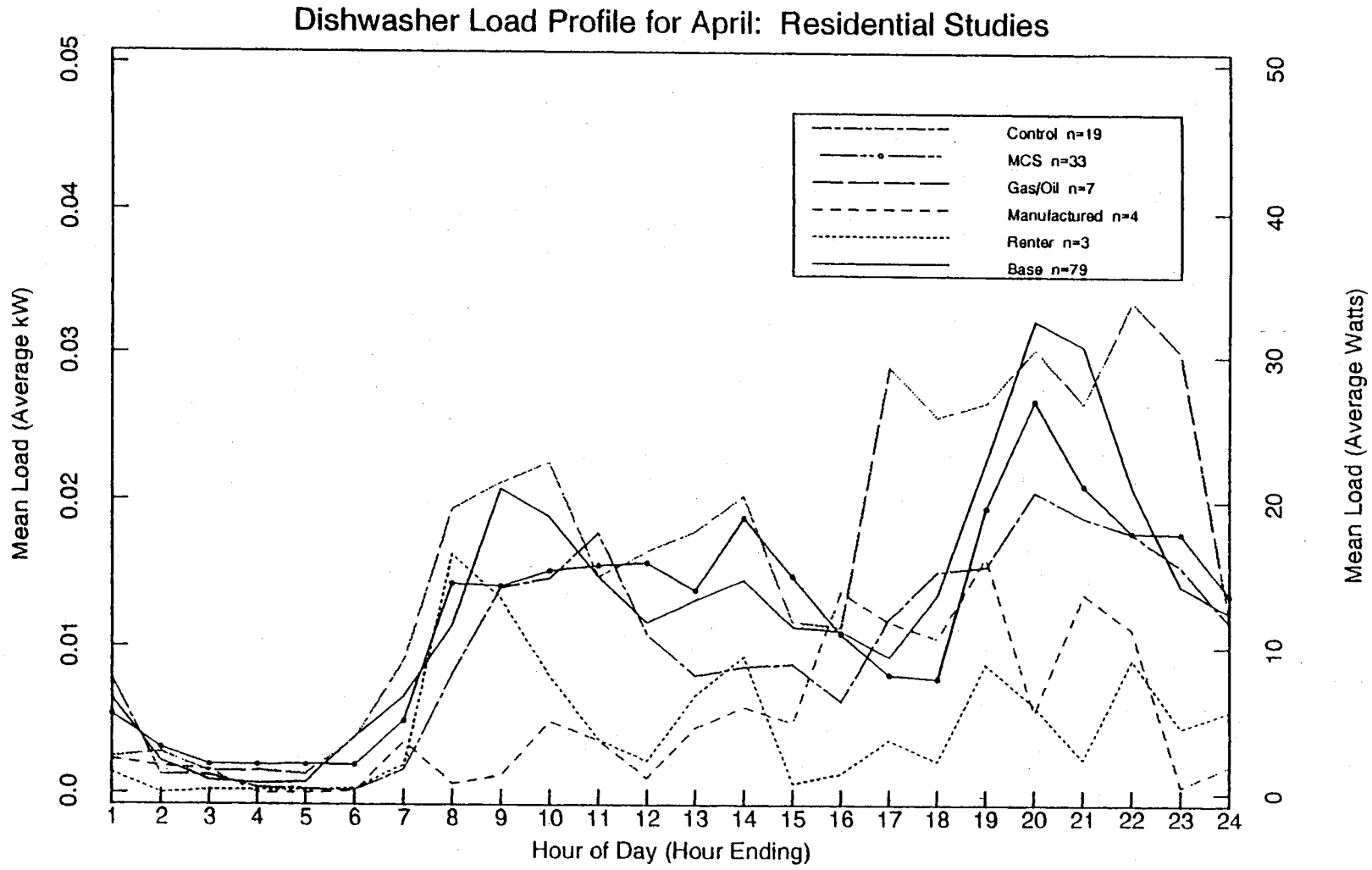
Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7N.8(a)



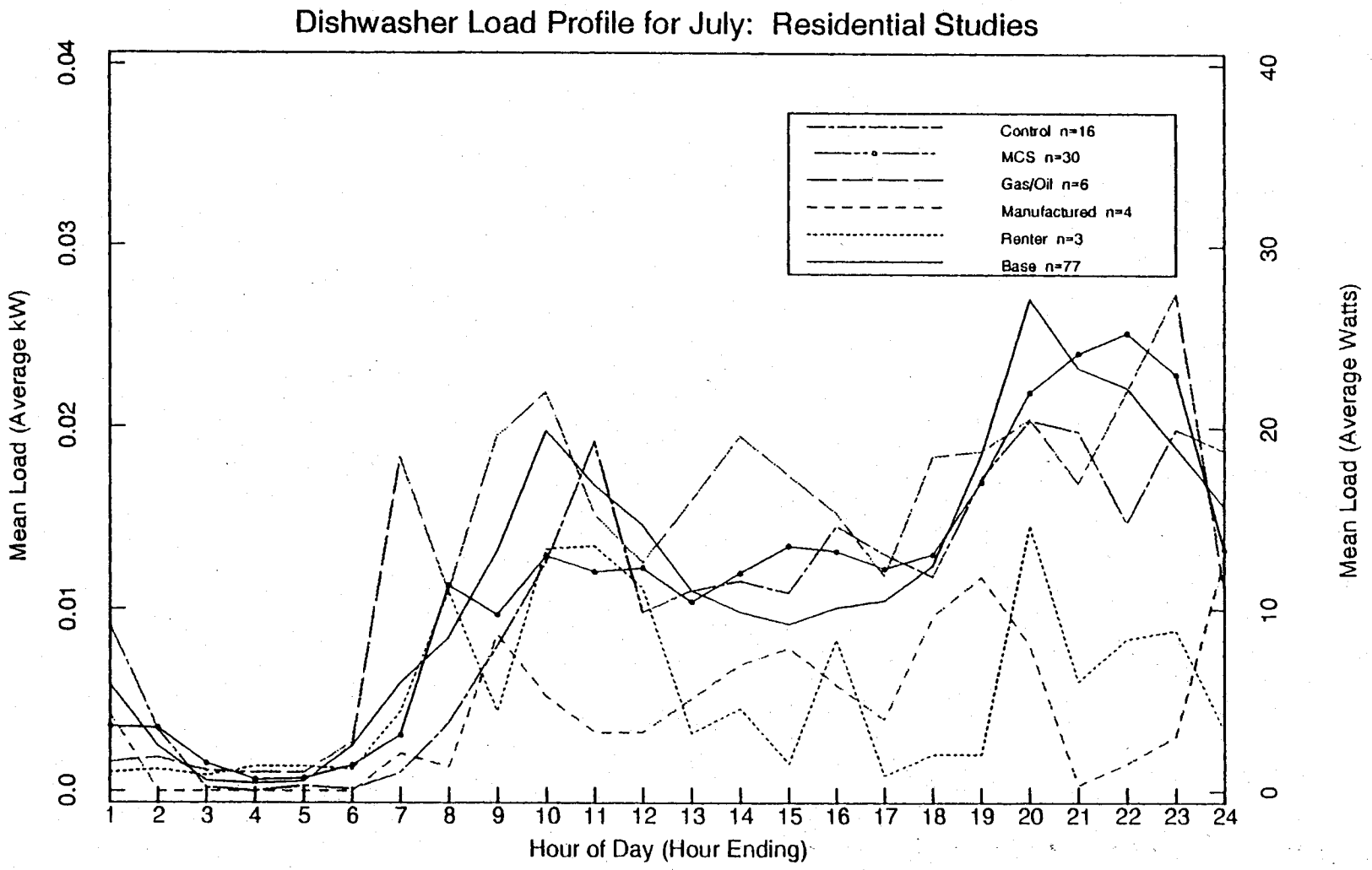
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.8(b)



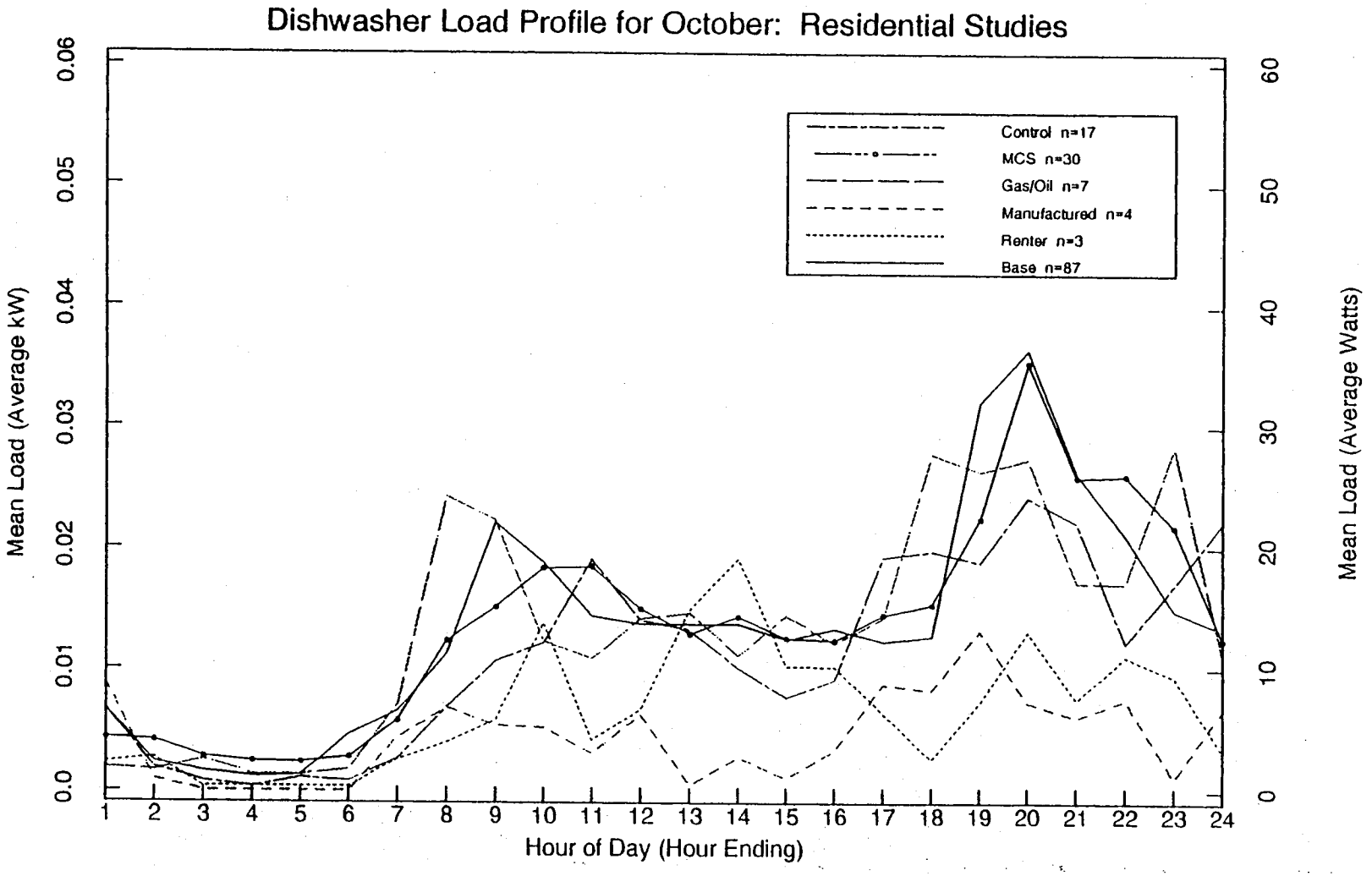
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.8(c)



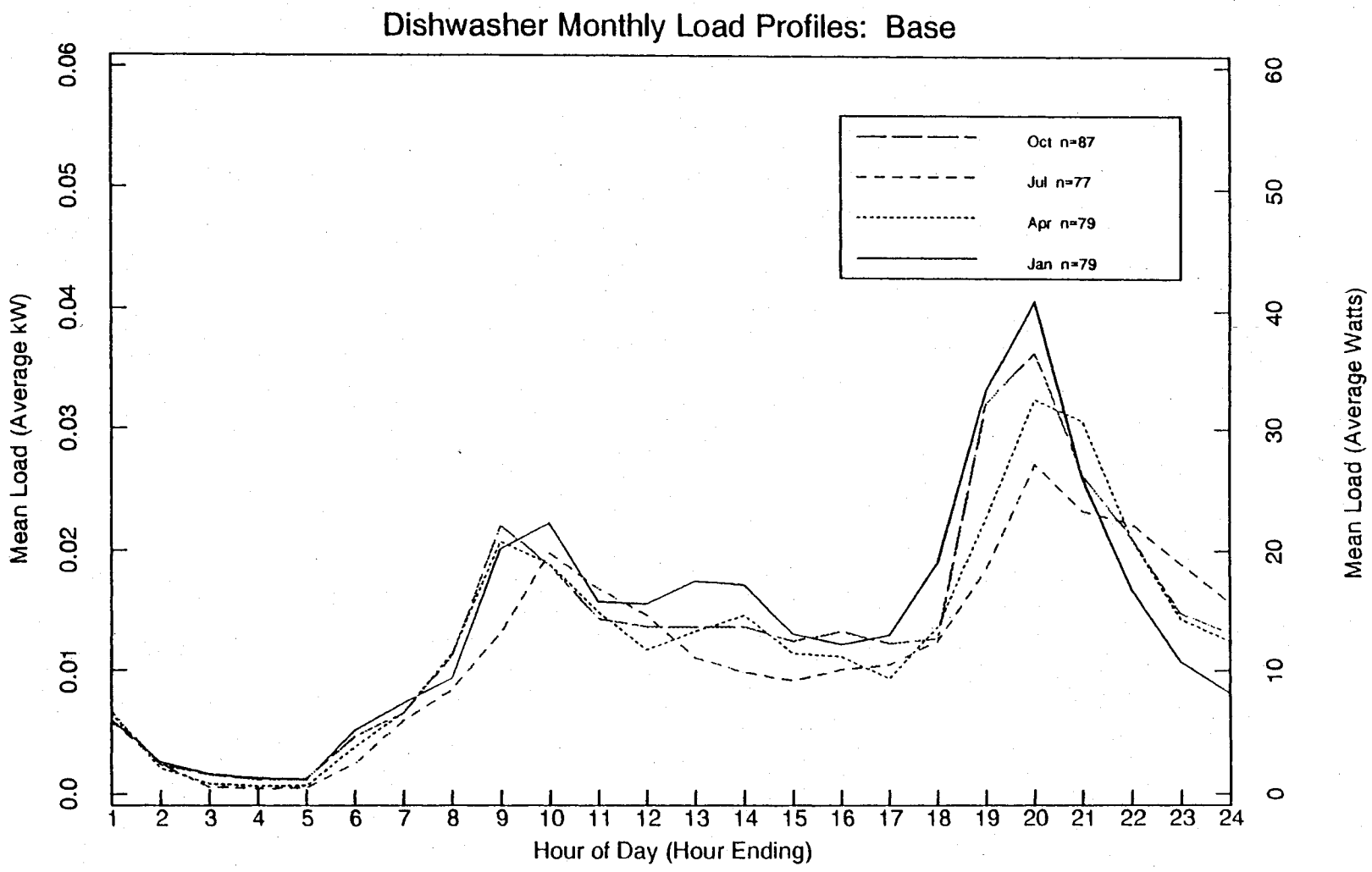
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.8(d)



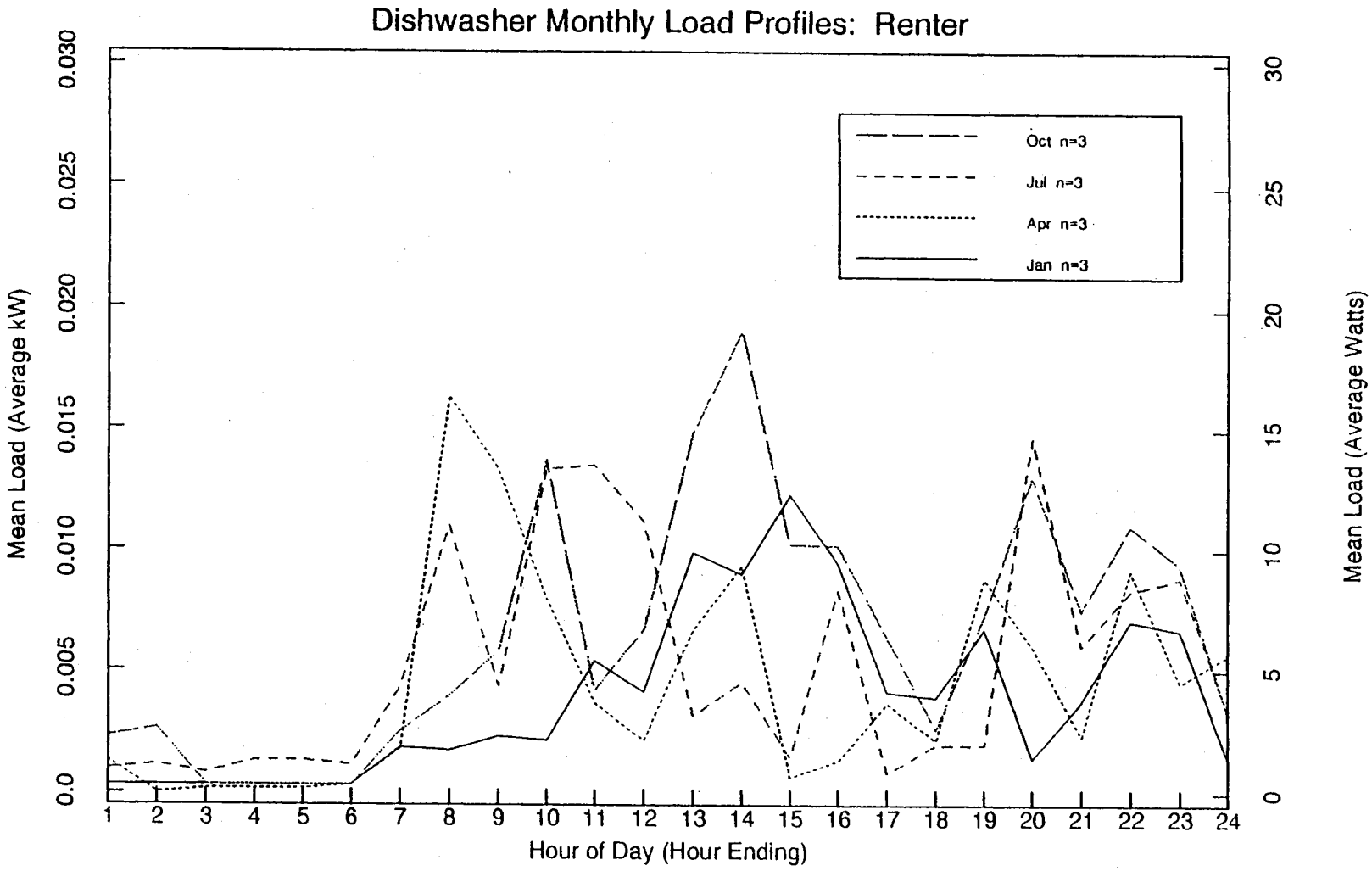
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.9(a)



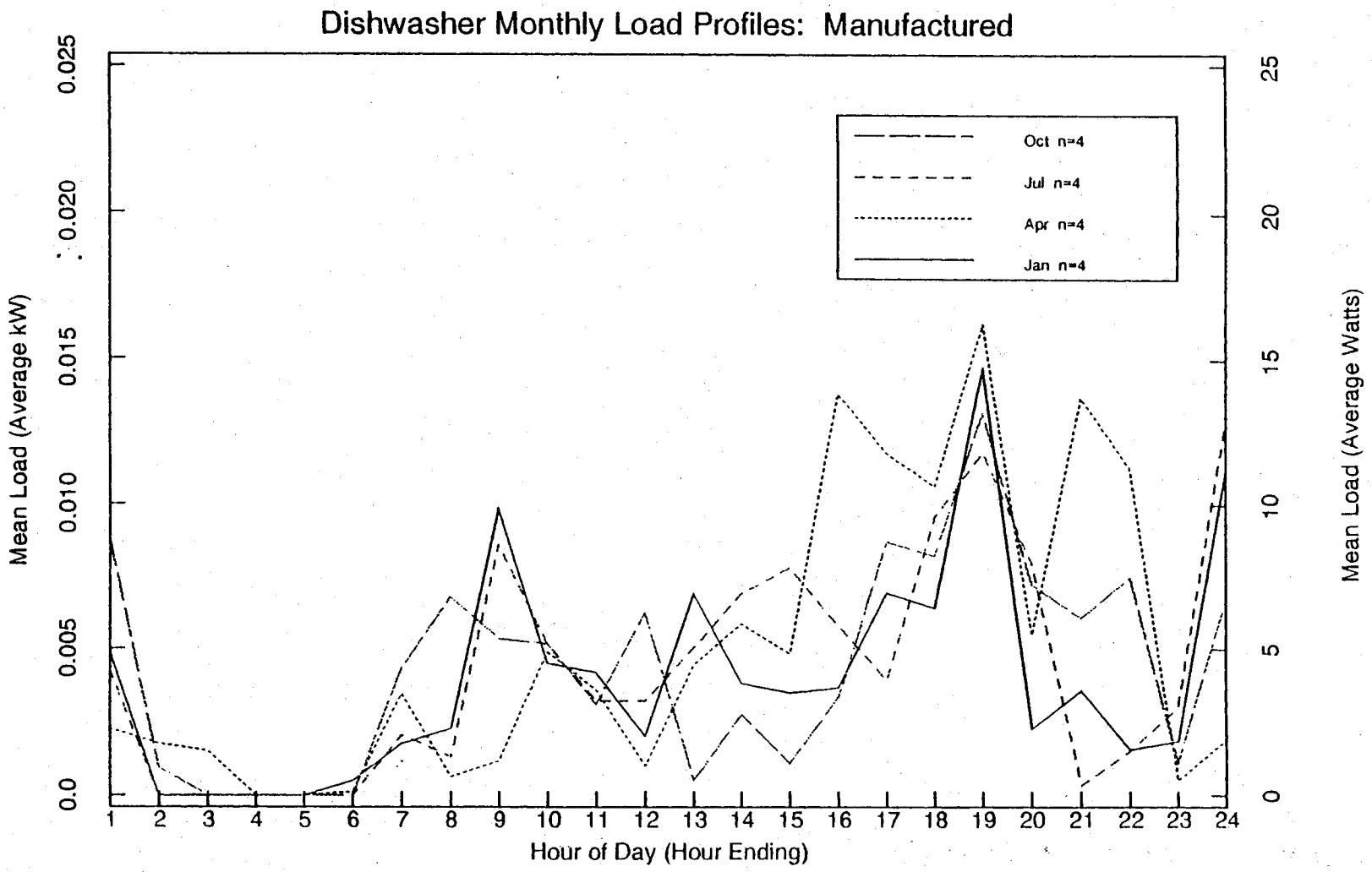
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.9(b)



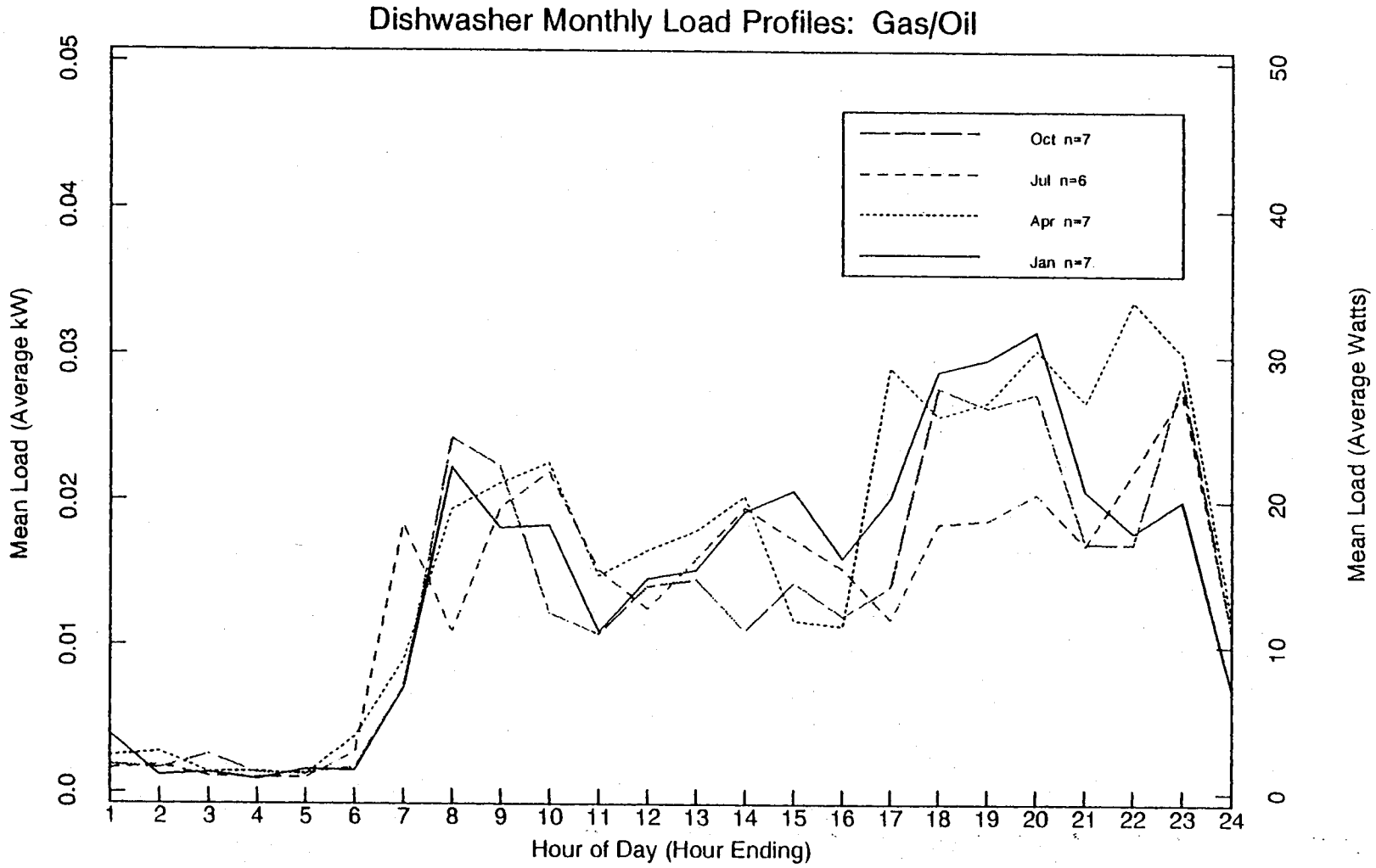
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.9(c)



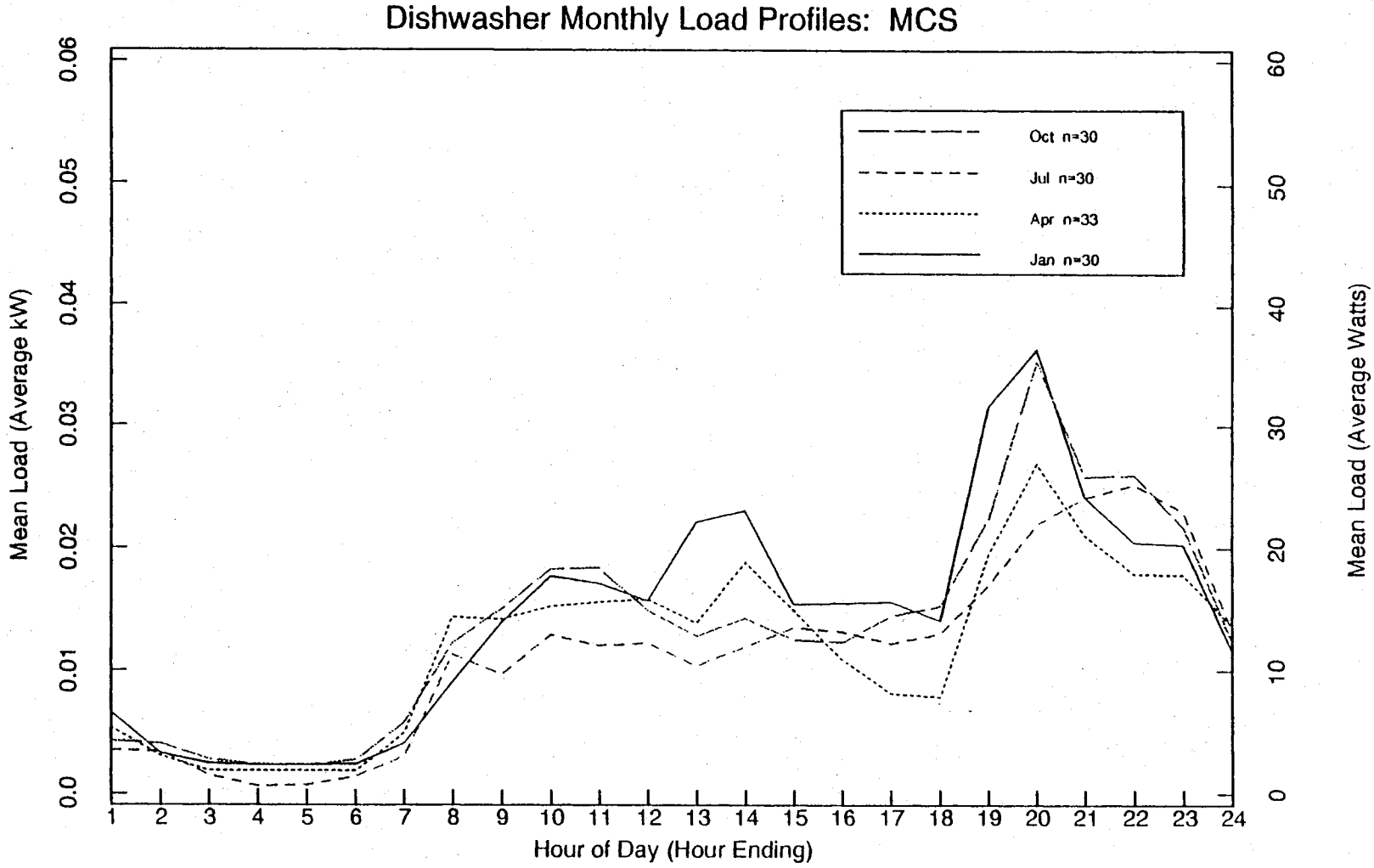
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.9(d)



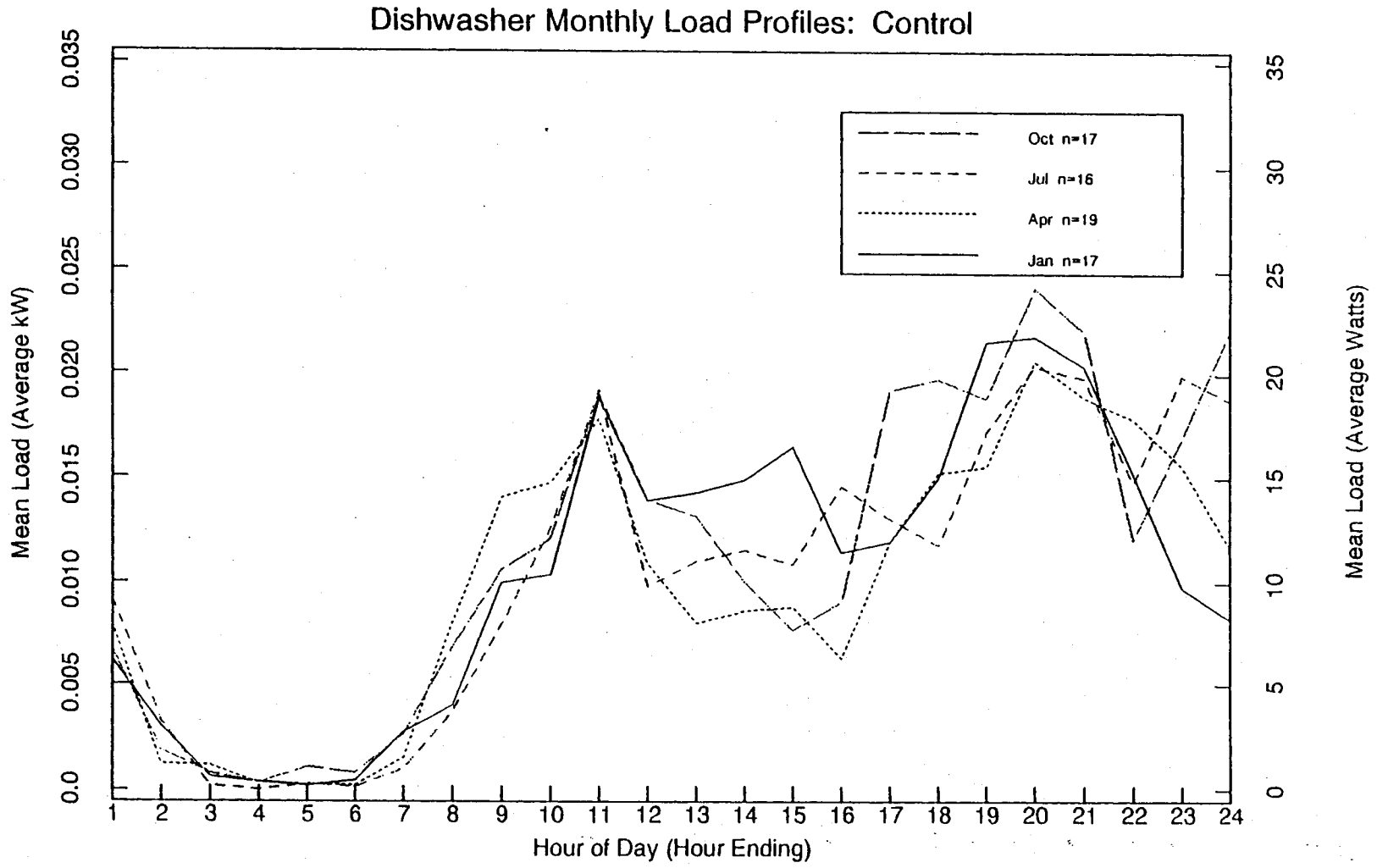
Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

FIGURE 7N.9(e)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

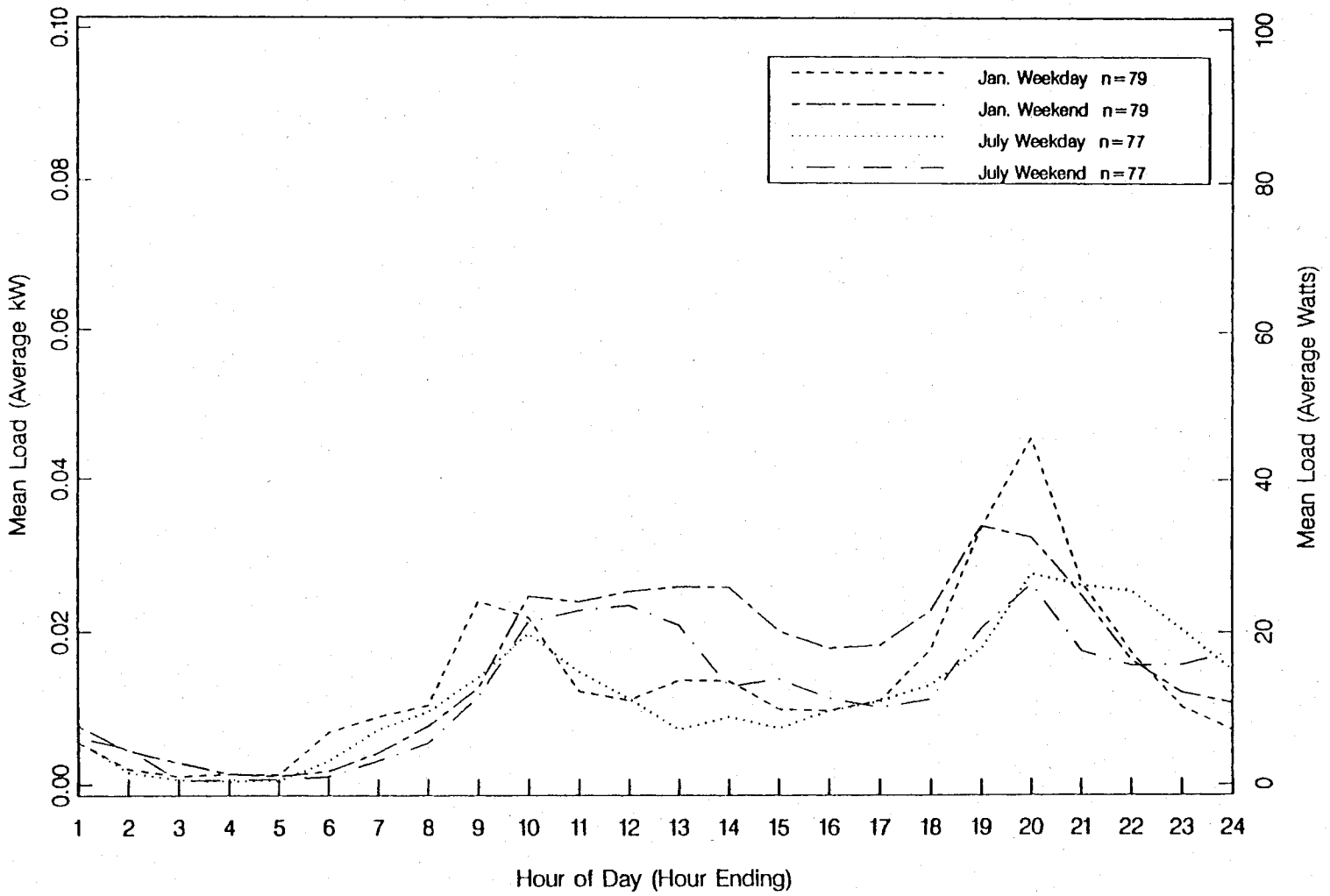
FIGURE 7N.9(f)



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

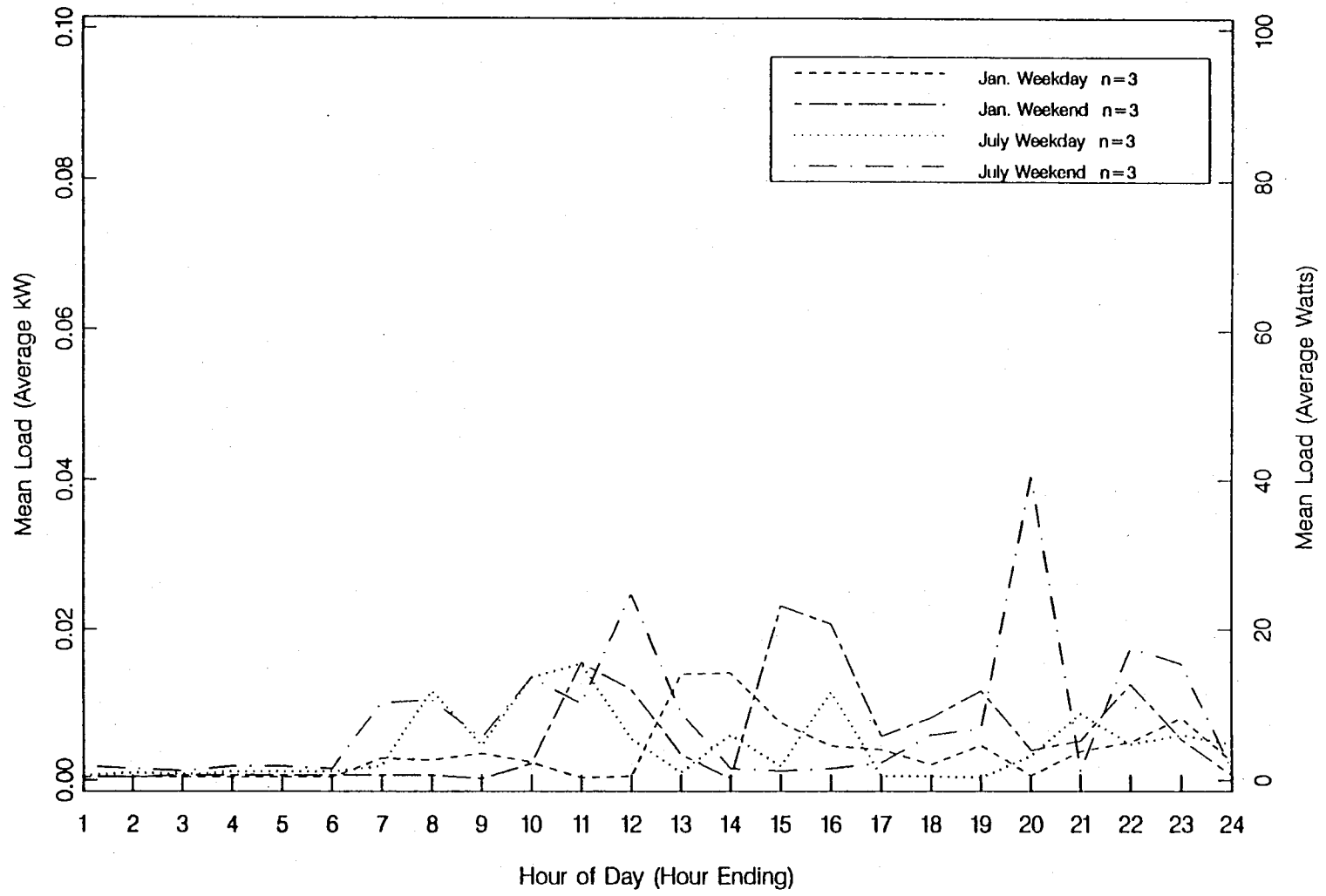
FIGURE 7N.10(a)

Dishwasher January and July Weekday/Weekend Load Profiles: Base



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

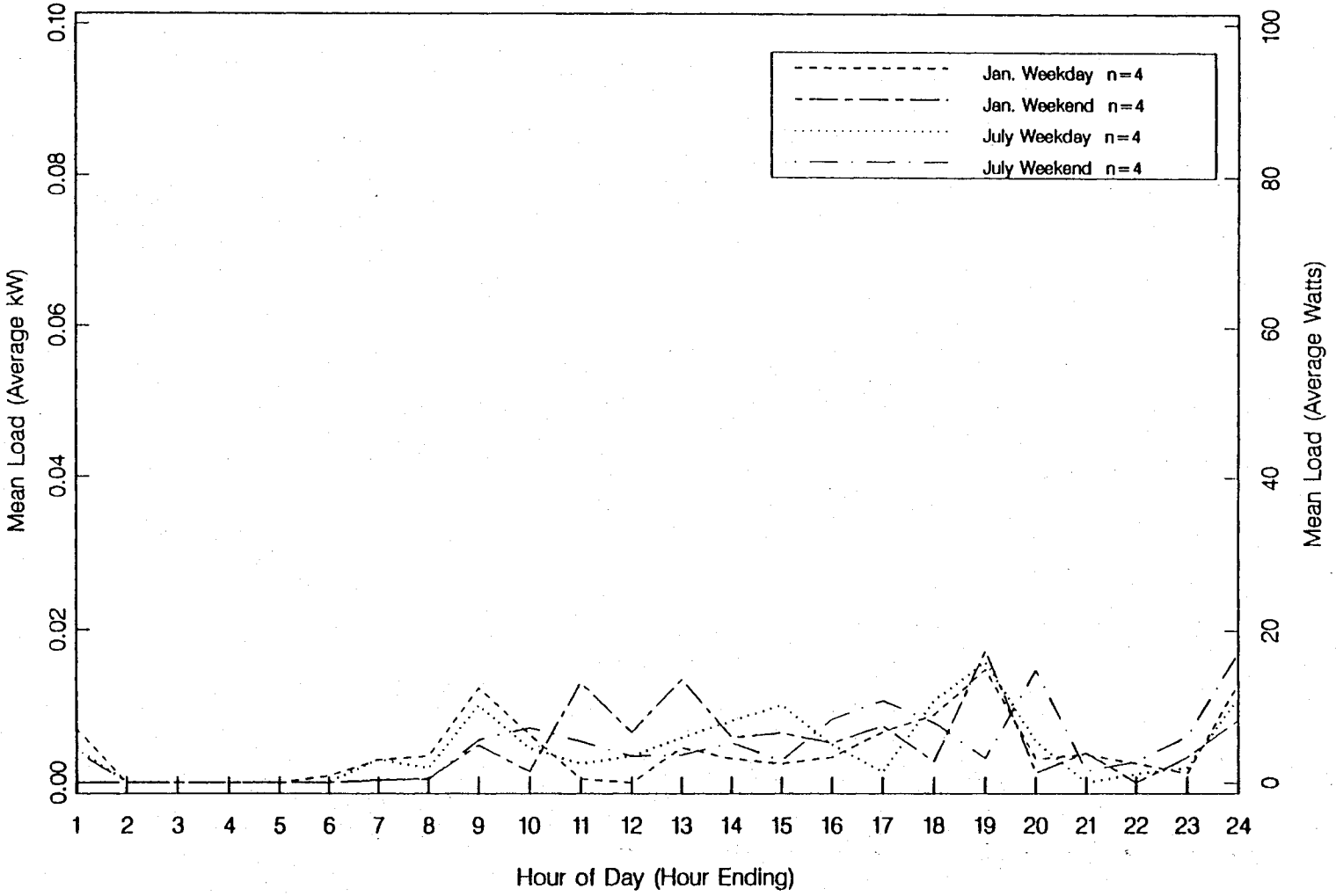
FIGURE 7N.10(b)
Dishwasher January and July Weekday/Weekend Load Profiles: Renter



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

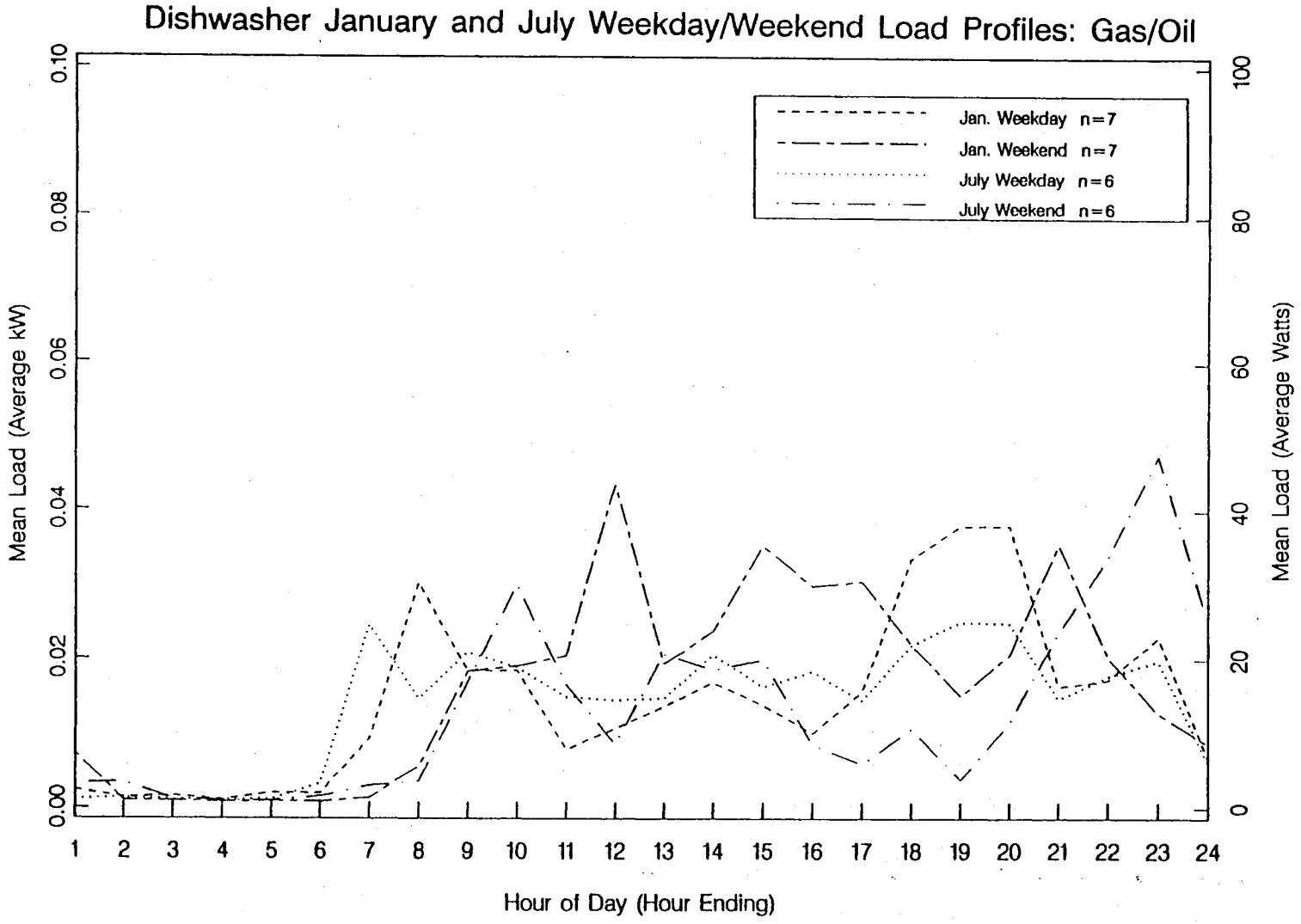
FIGURE 7N.10(c)

Dishwasher January/July Weekday/Weekend Load Profiles: Manufactured



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

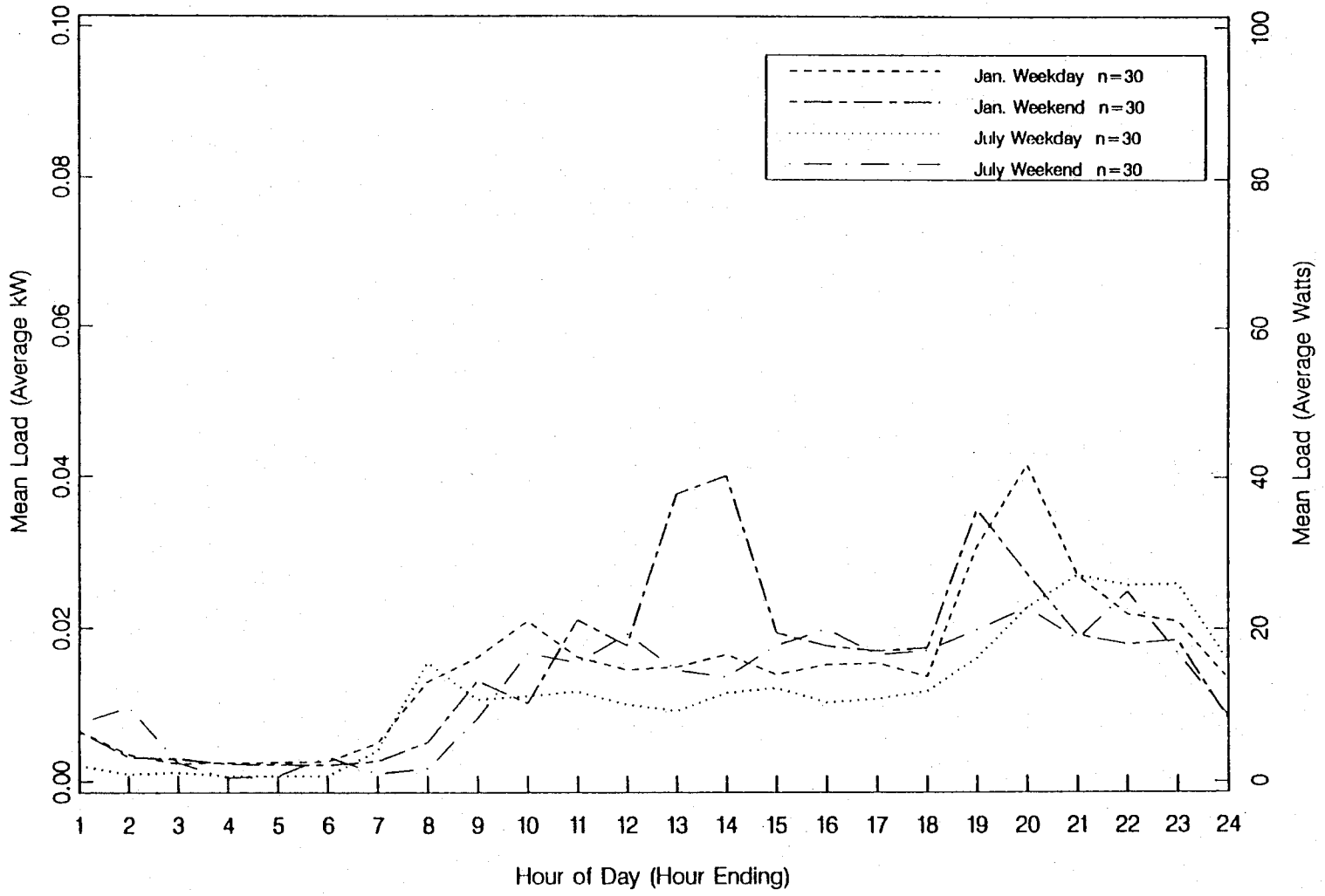
FIGURE 7N.10(d)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

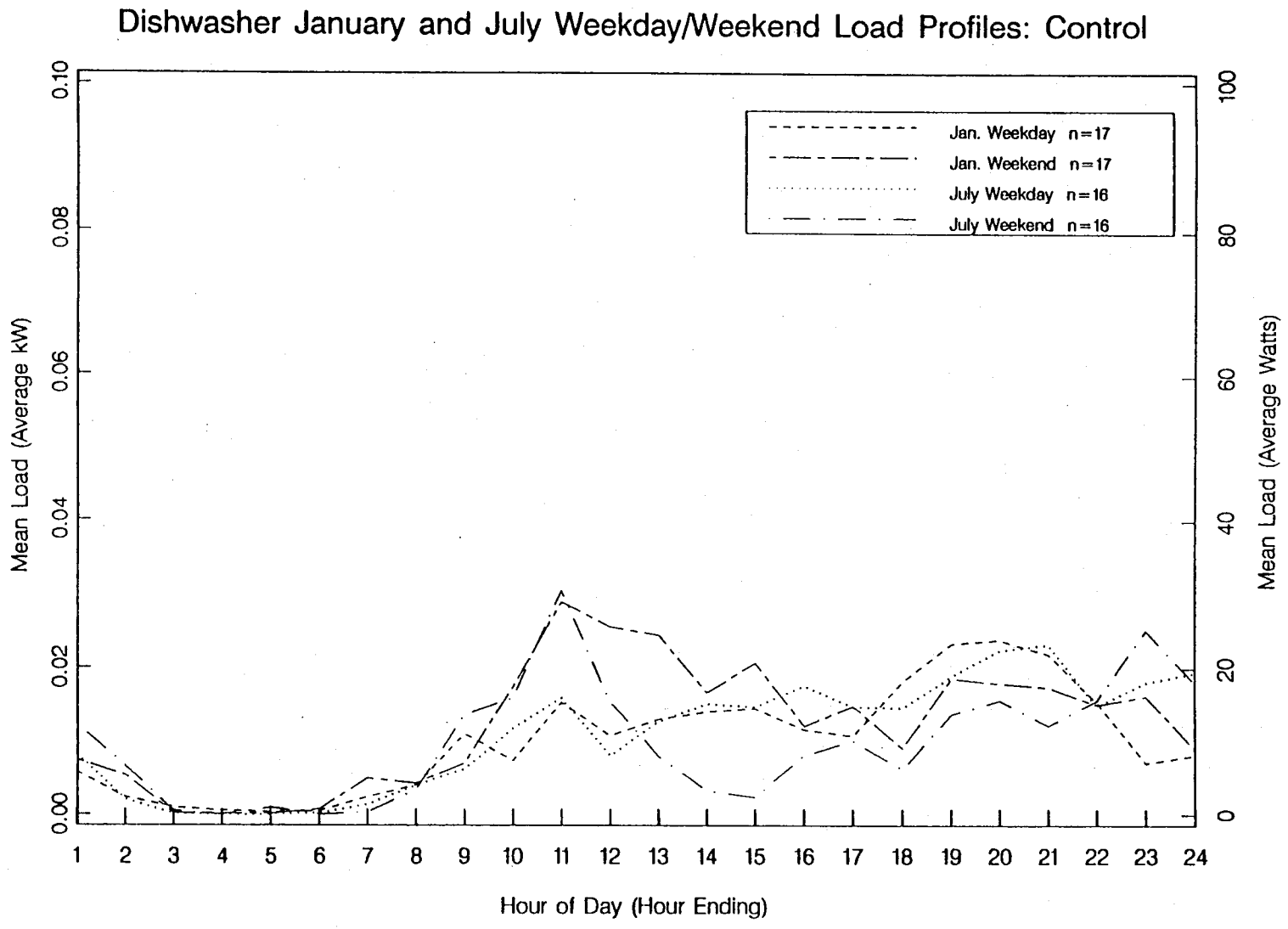
FIGURE 7N.10(e)

Dishwasher January and July Weekday/Weekend Load Profiles: MCS



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7N.10(f)



Data: ELCAP RES PADS Sept'84 – Mar '88 SAS/PADS November 1988

FIGURE 7N.11

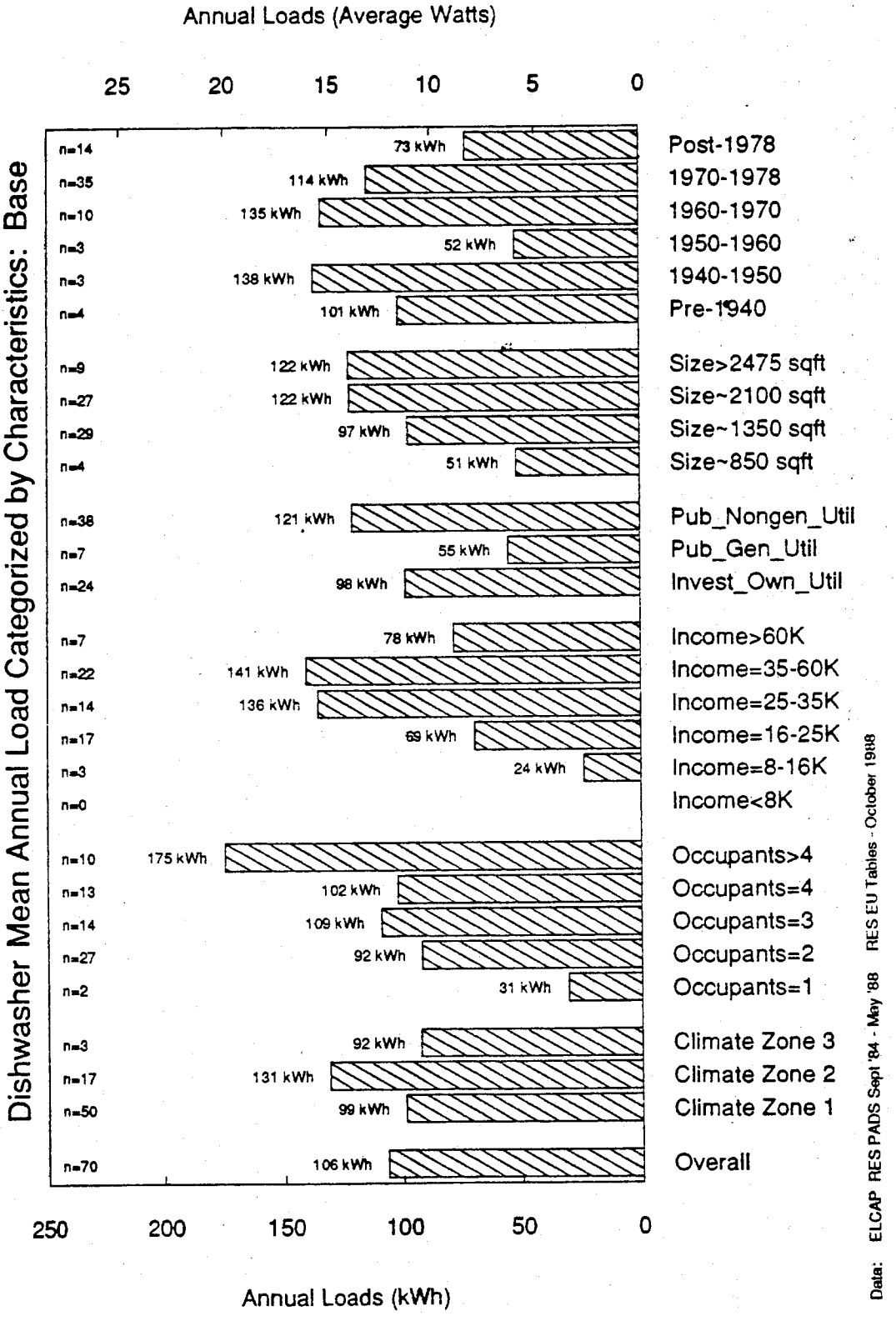
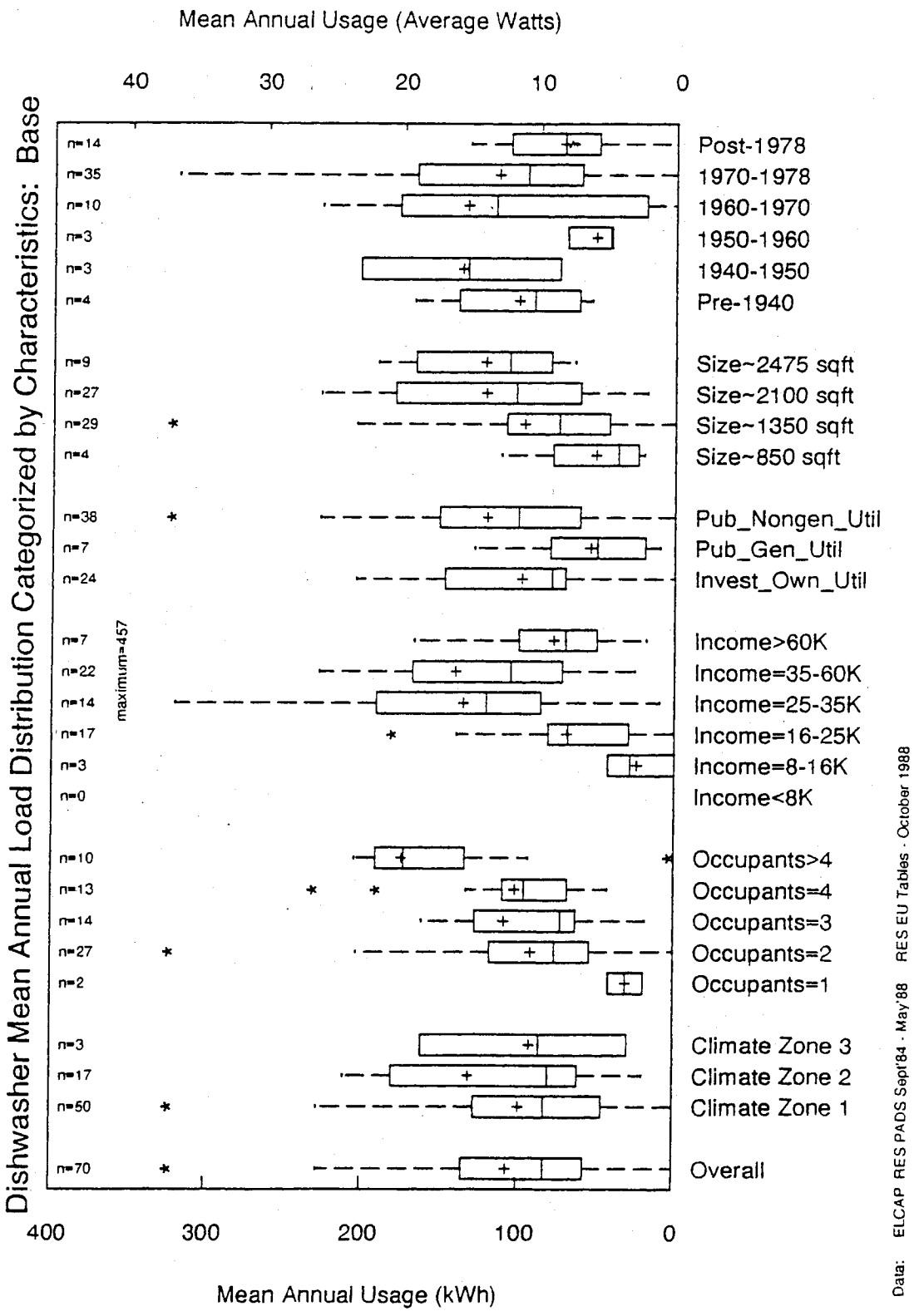

Dishwasher Mean Annual Load Categorized by Characteristics: Base
Annual Loads (Average Watts)
25
20
15
10
5
0
n=14
73 kWh
Post-1978
n=35
114 kWh
1970-1978
n=10
135 kWh
1960-1970
n=3
52 kWh
1950-1960
n=3
138 kWh
1940-1950
n=4
101 kWh
Pre-1940
n=9
122 kWh
Size>2475 sqft
n=27
122 kWh
Size~2100 sqft
n=29
97 kWh
Size~1350 sqft
n=4
51 kWh
Size~850 sqft
n=38
121 kWh
Pub_Nongen_Util
n=7
55 kWh
Pub_Gen_Util
n=24
98 kWh
Invest_Own_Util
n=7
78 kWh
Income>60K
n=22
141 kWh
Income=35-60K
n=14
136 kWh
Income=25-35K
n=17
69 kWh
Income=16-25K
n=3
24 kWh
Income=8-16K
n=0
Income<8K
n=10
175 kWh
Occupants>4
n=13
102 kWh
Occupants=4
n=14
109 kWh
Occupants=3
n=27
92 kWh
Occupants=2
n=2
31 kWh
Occupants=1
n=3
92 kWh
Climate Zone 3
n=17
131 kWh
Climate Zone 2
n=50
99 kWh
Climate Zone 1
n=70
106 kWh
Overall
250
200
150
100
50
0
Annual Loads (kWh)
Data: ELCAP RES PADS Sept '84 - May '88 RES EU Tables - October 1988

FIGURE 7N.12



Data: ELCAP RES PADS Sept'84 - May'88 RES EU Tables - October 1988

TABLE 7N.1

Dishwasher Mean Annual End-Use Loads and Standard Deviations (kWh)

Categorized by Characteristics: Base, Control, and MCS

	Base			Control			MCS			Base + Control + MCS		
Characteristic	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev	N	Mean	SDev
Overall	70	106	88	16	100	71	26	116	120	112	108	94
Climate Zone 1	50	99	83	10	122	67	18	130	141	78	109	98
Climate Zone 2	17	131	103	2	94	127	7	94	36	26	118	90
Climate Zone 3	3	92	86	4	48	33	1	28	0	8	62	49
Occupants=1	2	31	16	1	105	0	1	327	0	4	123	140
Occupants=2	27	92	69	6	52	26	8	70	43	39	82	62
Occupants=3	14	109	109	1	4	0	6	113	59	21	105	95
Occupants=4	13	102	55	2	157	91	3	44	39	18	98	61
Occupants>4	10	175	115	1	184	0	3	182	160	14	173	115
Income<8K	0	-	-	0	-	-	1	78	0	1	78	0
Income=8-16K	3	24	22	1	4	0	0	-	-	4	19	20
Income=16-25K	17	69	51	1	0	0	5	118	123	23	77	73
Income=25-35K	14	136	78	5	108	67	7	95	67	26	119	73
Income=35-60K	22	141	114	3	107	67	5	128	127	30	135	110
Income>60K	7	78	47	1	54	0	1	72	0	9	75	41
Invest_Own_Util	24	98	58	9	92	69	16	140	146	49	111	97
Pub_Gen_Util	7	55	40	6	129	66	5	78	48	18	86	59
Pub_Nongen_Util	38	121	108	1	0	0	5	77	47	44	113	102
Size<850 sqft	4	51	42	0	-	-	0	-	-	4	51	42
Size<1350 sqft	29	97	98	11	92	62	17	107	134	57	99	103
Size<2100 sqft	27	122	90	4	87	77	5	128	62	36	119	84
Size>2475 sqft	9	122	49	0	-	-	3	146	166	12	128	83
Pre-1940	4	101	51	0	-	-	0	-	-	4	101	51
1940-1950	3	138	84	0	-	-	0	-	-	3	138	84
1950-1960	3	52	16	0	-	-	0	-	-	3	52	16
1960-1970	10	135	138	0	-	-	0	-	-	10	135	138
1970-1978	35	114	92	0	-	-	0	-	-	35	114	92
Post-1978	14	73	38	16	100	71	26	116	120	56	101	93

Data: RES PADS Sept '84 - May '88 RES EU Tables - October 1988

APPENDIX A — TEMPORAL AGGREGATION METHODOLOGY

The ELCAP data set is so large that it is impossible to look at all of the hourly observations for each site and end use. An analyst can work with small portions of the data or can construct aggregations for each site and end use, as is done for this report. The purpose of this appendix is to supplement the basic description of the aggregation process provided in Section 5 with a more detailed, technical description sufficient to document the mathematical procedures used. This appendix introduces the two general forms of the aggregations, the philosophy behind the process used to deal with missing data, and a syntax allowing the aggregations to be expressed as mathematical equations. Then each aggregation used is described by a mathematical expression, and the process involved is discussed.

The aggregations described in this appendix are all used to summarize data from individual sites. Aggregations are averaged across selected sites to produce the plots seen elsewhere in this report. The process of averaging aggregations across sites is not the subject of this appendix, but is described in Section 5.

Two basic types of aggregations are used: average loads (energy totals) and load profiles (average 24-hour load shapes). For any given site and end use, total energy consumed is built from hourly observations. Average loads can be constructed for days, weeks, months, or years. Further, the average loads for a given calendar month or year can be averaged across years to produce, for example, the average load for the month of January.

Missing data is inevitable in any metering project. Most ELCAP sites have some missing data, so a data filling scheme is required to create monthly and annual energy totals. For the aggregations used

here, missing hourly values are filled using the average of available data for that hour, subject to some acceptable criterion. For example, an average monthly load can be constructed only if observations are available for at least 90% of the hours in that month. The derivation of the average loads used in this report will be described in detail later in this appendix. Average loads can be described by either the total energy or by average power over the time period of the aggregation.

Many of the plots constructed for this document describe average consumption for each hour of a 24-hour day, termed an hourly load profile (or simply load profile). The term profile is used in this report exclusively to refer to average hourly loads for the 24 hours of the day. Each hour of the profile is the mean of available data for that hour of day, over the time period of aggregation (a month, or a year). Just as for average loads, the load profiles for a given calendar month or year can be averaged across years to produce, for example, the average load profile for the month of January. Again, missing values must be filled. Average load profiles have units of watt-hours per hour or, equivalently, average watts. The creation of average load profiles is also described later in this appendix.

As noted in Section 5 of this report, and illustrated by Figure 5.1, it is important to understand that <u>average</u> load profiles may differ significantly from <u>typical</u> load shapes for a day. Average load profiles are literally energy-weighted probability distributions, the product of the probability of use and the average intensity of use for each hour of the day. They are indicative of average behavior patterns, whereas hourly loads for a typical day are much more "spiky" and reflect actual behavior on that day.

<u>Treatment of Missing Values</u>

It should be noted that the best possible means of filling missing data is on the basis of the data that is present. Therefore,

the best that any data-filling algorithm can do is match the patterns of information contained in the data with respect to parameters such as temperature and time of day. Any additional or other information added to the data set through filling missing data can only be the result of error in the filling process. Thus a key feature of the methodology used here is that missing data is filled "on the fly" when aggregating. In any case, filling is usually required to have a "complete" data set for higher level aggregations. Any hourly data implicitly "filled" in this manner are not retained in the data archive to avoid potential confusion on the part of future analysts.

By aggregating across time-series data using averages instead of sums, missing data are automatically and implicitly filled with the mean value of the observations with which they are aggregated. Since all the aggregation equations that follow preserve the hourly dimension as long as possible in the aggregation process, the data reported here are implicitly filled with the average for each hour of the day. Missing data at the monthly level are similarly filled with data from the same month but other calendar years, implicitly capturing the seasonal component of energy usage. Although better algorithms can be envisioned (explicitly incorporating the effects of outdoor temperatures and/or day of week, for example), the essentially random pattern of missing values and the multi-year time series in the ELCAP data suggest that the relatively simple time-of-day and time-of-year effects captured in the aggregation process used are appropriate for the view of loads from a large sample of homes presented in this report.

It should also be noted that by aggregating with averages the units of the hourly data (average watts) are maintained when aggregating over any longer time period. This may be convenient to some analysts, since they can build intuition about the relative magnitudes of loads during work with any temporal aggregation, rather than trying to mentally scale loads from a site to "typical" levels for each end use at the hourly, daily, monthly and annual time

intervals. To convert to standard units such as kilowatt-hours, the average power is simply multiplied by the number of hours in the time interval of the aggregation (e.g., 24 hours per day, 8,760 hours per year).

A Syntax for Describing Aggregations

The purpose of adopting a syntax for aggregation equations is to communicate their details in concise, mathematical form and to facilitate discussion of the methods used. Those readers seeking a more general understanding of the aggregation process can skip ahead to the steps of the aggregation methodology. The importance of accurately defining the details of the aggregation methodology used is magnified by its additional function of implicitly filling for any missing data. The syntax used to describe the aggregation equations follows.

A vector (or series) of observations is denoted by the function:

$$\underset{i=1}{\overset{I}{\bigvee}} X_i \equiv (X_1, X_2, \ldots X_I)$$

One convenience of this notation is that the number of possible hourly observations in a vector is always given by the index above the vector symbol. Therefore there are I hourly observations in the vector above. Vectors are used to represent the hourly load profiles, which are a series of 24 hourly loads.

The time series of energy data for a single site is defined as the data set E. Each observation in E is specified using subscripts for the year (y), month (m), day (d) and hour (h) on which it was obtained. When all four subscripts are used an hourly observation is indicated. Vector subsets of E, comprised of multiple hourly observations, are indicated by not specifying one or more of the

subscripts. When one of the subscripts is not used, hourly observations from the data set E for all values of the dropped subscript are indicated. For example, $E_{y,m}$ indicates the hourly observations in year y and month m (a maximum of 31 x 24 = 760 hourly observations), and $E_{y,m,h}$ indicates the observations in year y and month m for hour h (a maximum of 31 observations).

The number of (non-missing) observations in a data set is defined as the function N[E], where subsets of E may be specified by the subscripts. For convenience, N[E] is written simply as N followed by the subscripts specifying the observations of E. For example, $N[E_{y,m,h}]$ is written $N_{y,m,h}$ and indicates the number of non-missing hourly observations in year y and month m, for hour h.

For convenience, the number of calendar days in a calendar month is denoted as D_m.

Mathematical operations involving missing values (<na>) are defined as: any number added to or subtracted from a missing value is equal to the number, and the product or quotient of a number and a missing value is a missing value. An average (mean) of a vector or array (denoted by) is used for aggregating, and is defined in terms of a vector summation as:

$$\overline{X}_i \equiv \sum_{j=1}^{N} X_{i,j} \equiv \frac{1}{N[X]} \sum_{j=1}^{N} X_{i,j}$$

Note that this definition can result in a scalar when X is a vector, or a vector when X is a two-dimensional array, etc. This averaging operation always results in a data set of one less dimension than the data set being averaged.

A function that assigns missing values to a vector or array based on criteria for minimum numbers of observations is defined as:

$$\left\lfloor \overset{N}{\underset{n=1}{\mathbin{\mathrm{V}}}} X_n \right\rceil^{N[\ f(X)\ ] \geq a} \equiv \begin{cases} \overset{N}{\underset{n=1}{\mathbin{\mathrm{V}}}} X_n & ;\text{iff } N[\ f(X)\ ] \geq a \\ \overset{N}{\underset{n=1}{\mathbin{\mathrm{V}}}} \text{<na>} & ;\text{else} \end{cases}$$

When the expressions following the "missing criteria brackets" are false, missing values are assigned to the entire vector. Here f(X) is an arbitrary function of the vector X itself. Hence the vector is defined as valid (not missing) based on the values in the vector X being greater than the constant a (the existence criteria). Note that, by definition, all elements of a vector with one or more missing values also become missing; thus no vector can be partially missing.

Similarly, a function that assigns missing values to an average is defined as:

$$\left\lfloor \frac{\overset{N}{\underset{n=1}{\Sigma}} X_n}{} \right\rceil^{N[\ f(X)\ ] \geq a} \equiv \begin{cases} \overset{N}{\underset{n=1}{\Sigma}} X_n & ;\text{iff } N[\ f(X)\ ] \geq a \\ \text{<na>} & ;\text{else} \end{cases}$$

Aggregation Methodology

Profile for a Year and a Month

The hourly load profile for a year y and month m ($P_{y,m}$) is not used in any of the plots in this report, but rather is calculated for

convenience as an intermediate step used for aggregations across multiple years. This aggregation is defined as:

$$P_{y,m} \equiv \bigvee_{h=1}^{24} P_{y,m,h} \equiv \bigvee_{h=1}^{24} \left[\sum_{d=1}^{Dm} E_{y,m,d,h} \right]^{N_{y,m,h} \geq 7}$$

which describes a three step process:

Step 1. Select a month of hourly energy consumption data for a specific year for site and end use.

Step 2. Construct a 24-hour profile by averaging data for each hour of the day across the days in that month.

Step 3. Check that, for each of the 24 hours, at least seven observations are available. If less than seven observations are available for any hour, consider that hour in the hourly profile (and hence the entire profile) to be missing.

All of the other aggregations that follow start with these profiles for individual years and months.

Profile for Average Month

The hourly load profile for the average calendar month (P_m) is defined as the average of the profiles for the specified month for each of the years in the time series data:

$$P_m \equiv \left[\bigvee_{h=1}^{24} \left[\sum_{y=1}^{Y} P_{y,m,h} \right]^{N_{m,h} \geq .5*Dm} \right]^{N_m \geq .9*24*Dm}$$

which describes a four step process:

Step 1. Select a month, say January, for a site and end use. Collect the monthly profiles for that month for all years of data. For example, January profiles may be available for 1986, 1987 and 1988.

Step 2. Average the monthly profiles for all three years to form one profile for the month. For example, the average January profile consists of the 24 hourly averages for each hour of the day from the three January profiles. That is, the noon value in the profile is the average of the three average noon loads for each of the years, and the 1 P.M. value is the average of the three average 1 P.M. values, and so on.

Step 3. Check that, for each of the 24 hours, a total of at least 50% of the possible observations in a single month are available from the sum of the observations from all years. In the example using January data from three years, at least 50% of the possible observations must be available for each hour of the day. If not, the profile for January is considered missing.

Step 4. Check that at least 50% of the total possible hourly observations in 1 month are available from the sum of the observations from all years. In the example, for three years of January data there are 2,232 (3 x 31 x 24) possible hourly observations. If 90% of 1 month's (31 x 24 = 744) observations are not available, then the average profile for January is considered missing.

Note that in this process the profiles from each year are weighted equally, rather than each hourly observation being weighted equally.

Average Load for Month

The monthly average load for calendar month m (M_m) is defined as the average of the hours in the average of the monthly profiles across the years in the data time series (Y):

$$M_m \equiv \left[\sum_{h=1}^{24} \sum_{y=1}^{Y} P_{y,m,h}\right]^{N_m \geq .9*24*Dm}$$

which describes a four step process:

Step 1. Select a month (say January) for a site and end use. Collect the monthly profiles for that month for all years of data. For example, there may be January data available for 1986, 1987, and 1988.

Step 2. Average the monthly profiles for all years to form one profile for the month. In the example, the average January profile consists of the 24 hourly averages for each hour of the day from the three profiles. That is, the noon value in the profile is the average of the three average noon loads for each of the years, and the 1 P.M. value is the average of the three average 1 P.M. values, and so on.

Step 3. Average the 24 hourly loads in the single profile to form the average power for the month (in average watts) across all hours of the day. In the example, the average January load is thus the average of the 24 hourly loads in the profile for the average January.

Step 4. Check that at least 90% of the total possible hourly observations in 1 month are available. In the example, for three years of January data there are 2,232 (3 x 31 x 24) possible hourly observations. If 90% of one month's (31 x 24 = 744) observations are not available, then the average load for January is considered missing.

The average power for the month can be converted to a monthly energy total (in kilowatt-hours) by multiplying by the number of hours in the month, in this case 744 (31 x 24).

Profile for Average Year

The load profile for the average year (P), is the average of the monthly profiles for all years of the data set (Y), weighted by the number of days in each month:

$$P \equiv \bigvee_{h=1}^{24} \frac{12}{365} \sum_{m=1}^{12} \left\lfloor \sum_{y=1}^{Y} P_{y,m,h} * Dm \right\rfloor^{N_{m,h} \geq .5*Dm}$$

which describes a six step process:

Step 1. For a given site and end use, collect the monthly profiles for all years and months for which they are available.

Step 2. Multiply each of the twelve monthly profiles by the number of days in the calendar month, to weight the loads from each month of the year in proportion to the number of days in the month.

Step 3. For each calendar month, average the monthly profiles across years, providing twelve average monthly profiles. For example, if monthly profiles for January are available from three years, then the average January profile consists of the 24 hourly averages for each hour of the day from the three profiles. That is, the noon value in the profile is the average of the three January average noon loads for each of the years, and the 1 P.M. value is the average of the three average 1 P.M. values, and so on.

Step 4. Check that, for each calendar month, at least 50% of the possible observations in a single (31) month are available for each hour from the combination of data from all years. For the example with three years of January data, the total possible observations for each hour is 93 (3 x 31). If 50% of the possible observations in a single month (31) are not available from all January profiles combined, the average profile for January is considered missing, and therefore the entire profile will be considered missing.

Step 5. Average the twelve monthly profiles to obtain an average annual profile. That is, the average profile consists of the 24 hourly averages for each hour of the day from the twelve average monthly profiles.

(The noon value in the profile is the average of the twelve average noon loads for each of the months, and the 1 P.M. value is the average of the twelve average 1 P.M. values, and so on.

Step 6. Divide by the number of days in the average month (365/12) to return the units of the calculation to average watts (Step 2 changed the units by multiplying by the days in each month to properly weight the profiles).

Annual Load for Average Year

The annual load for the average year (A) is the average of the hours in the average of the monthly profiles for year y, weighted by the number of days in each month, and averaged across all years:

$$A \equiv \left\lfloor \sum_{m=1}^{12} \frac{12}{365} \sum_{h=1}^{24} \left\lfloor \sum_{y=1}^{Y} P_{y,m,h} * Dm \right\rfloor^{N_{m,h} \geq .5*Dm} \right\rfloor^{N \geq .9*24*365}$$

which describes an eight step process:

Step 1. For a given site and end use, collect the monthly profiles for all years and months for which they are available.

Step 2. Multiply the twelve monthly profiles by the number of days in the calendar month to weight the hourly loads from each month of the year in proportion to the number of days in the month.

Step 3. For each calendar month, average the monthly profiles across years, providing average monthly profiles. For example, if monthly profiles for January are available from three years, the average January profile consists of the 24 hourly averages for each hour of the day from the three profiles. That is, the noon value in the profile is the average of the three January average noon loads for each of the years, and the 1 P.M. value is the average of the three average 1 P.M. values, and so on.

Step 4. Check that, for each calendar month, at least 50% of the possible observations in a single month are available for each hour from the combination of data from all years. For the example with three years of

January data, the total possible observations for each hour is 93 (3 x 31). If 50% of the possible observations in a single month (31) are not available for all January profiles combined, the average profile is considered missing and therefore the average load will be considered missing.

Step 5. Average the 24 hourly values for each of the twelve months to obtain an average monthly load for each month. For example, the average January load consists of the average of the 24 hourly averages for each hour of the day in the average January profile.

Step 6. Divide by the number of days in the average month (365/12) to return the units of the calculation to average watts (Step 2 changed them by multiplying by the days in each month to properly weight the profiles).

Step 7. Average the twelve monthly loads to obtain an average annual load. That is, the average load consists of the average of the 12 monthly average loads.

Step 8. Check that at least 90% of the possible hourly observations in one year of data (365 x 24 = 8760) are available from the combination of data from all years. If not, the average annual load is considered to be missing.

The average annual load (in average watts) can be converted to an annual energy total (in kilowatt-hours) by multiplying by the number of hours in a year, 8,760.

SELECTED BIBLIOGRAPHY

Harris, L., and Associates. 1983. 1983 Pacific Northwest Residential Energy Survey: Sample Selection Activities Report. Bonneville Power Administration, Portland, Oregon.

Lee, A.D., Z.T. Taylor, G.B. Parker, G.L. Wilfert, J.W. Callaway, S.A. Onisko. 1986. Energy and Indoor Air Quality Measurements from Five Energy Conserving Manufactured Homes. DOE/BP-803, Bonneville Power Administration, Portland, Oregon.

Northwest Power Planning Council. 1986. Northwest Conservation and Electric Power Plan. Vol. II, Chapter 5. Northwest Power Planning Council, Portland, Oregon.

Parker, G.B., E.W. Pearson, and W.F. Sandusky. 1985. The Residential Pilot Study. DOE/BP-13795-7, Bonneville Power Administration, Portland, Oregon.

Parker, G.B., and R.A. Stokes. 1985. "An Overview of ELCAP." Presented at Conservation in Buildings: Northwest Perspective, May 20, 1985, Butte, Montana. PNL-SA-13179, Pacific Northwest Laboratory, Richland, Washington.

Parker, G.B., G.M. Stokes, M.A. Halverson, and W.F. Sandusky. 1989. Lessons Learned from Monitoring Electricity Use in Multifamily Residences. DOE/BP-13795-20, Bonneville Power Administration, Portland, Oregon.

Pearson, E.W., G.M. Stokes, and S. Crowder. 1985. "Data Verification in End-Use Metering." Electric Power Research Institute Metering Workshop Papers. DOE/BPA-13795-3, Bonneville Power Administration, Portland, Oregon.

Stovall, T.K. 1987. Hood River Conservation Project: Load Analysis. ORNL/CON-240, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Windell, P.A. 1987. ELCAP: Residential Sector Sample Design. DOE/BP-13795-16, Bonneville Power Administration, Portland, Oregon.

Windell, P.A. 1985. "Overview of ELCAP Study Objectives." Workshop II Abstracts. DOE/BP-13795-10, Bonneville Power Administration, Portland, Oregon.