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Analysis of Electric Energy Usage in Air Force Houses Equipped With Air-to-Air Heat Pumps

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Analysis of Electric Energy Usage in Air Force Houses Equipped With Air-to-Air Heat Pumps

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Contents

Analysis of Electric Energy Usage in Air Force Houses Equipped With Air-to-Air Heat Pumps

Paul R. Achenbach, Joseph C. Davis, and William T. Smith *

An analysis was made of the electric energy usage for all purposes in 16 samples houses selected from a total of 1,535 houses constructed at Little Rock Air Force Base to domicile Air Force personnel. Of principal interest was the energy used by the air-to-air heat pumps installed for all-year air conditioning and the effect of electric energy used by other appliances on the heating and cooling loads in the houses. The data revealed that the annual energy usage in the 16-house sample averaged 25,300 kilowatt-hours per house, of which approximately half was used by the heat pump and its auxiliary resistance heaters, about one-fourth was used for water heating, and the remaining one-fourth was used for the electric range and miscellaneous devices. It was determined that the energy used by appliances, other than the heat pump, which contributed toward heating the house was about half the amount used by the heat pump during the winter months. An analysis of the demand charts revealed that the monthly maximum power demand for the entire housing area was probably caused by a moderately high sustained demand in many houses rather than a coincidence of the maximum demands in a smaller number of houses. The effect of several types of programing devices on the pattern of power demand is discussed.

1. Introduction

A significant number of the new homes in the United States now employ some air conditioning in them for summer cooling. The use of a heat pump for year-round air conditioning is naturally of interest to any homeowner who has decided upon, or is considering, cooling for his entire house. Within the last few years air-to-air heat pumps of the remote type have been installed in a number of large housing projects at U.S. Air Force bases in several Southern States.

The National Bureau of Standards conducted a study of the heat-pump systems at three airbases and of the gas heating and separate air-conditioning systems at three additional airbases, under the sponsorship of the U.S. Air Force, the Office of the Chief of Engineers, and the Bureau of Yards and Docks, to obtain data on energy usage, system performance, house heating and cooling requirements, and other design data. One part of this study, which is presented in this Monograph, consists of an analysis of electric energy usage and electric power demand data obtained from a sample group of occupied houses at Little Rock Air Force Base in Arkansas, equipped with heat pumps, water heaters, cooking ranges, clothes dryers, and miscellaneous appliances all operated by electricity.

The Arkansas Power and Light Company, the electric utility that serves the Little Rock Air Force Base, collected electric energy consumption data on 16 houses in the housing area from October 1958 until the spring of 1961, using four or more demand meters on each house to record separately the energy and the power demand used for the electric range, the electric water heater, the heat pump, including supplementary heaters, and the total for the house on a 15-min demand interval. Also recorded were the indoor air temperatures in each of the houses and outdoor air temperatures at three separate stations in the housing area. The total monthly energy use indicated by these four meters in each of the 16 houses has been summarized by Arkansas Power and Light Company personnel.

The monthly summaries of the energy usage, the original charts from the recording demand meters, and the temperature records were made available to the National Bureau of Standards for further analysis. The purpose of this analysis was to develop the following information for the sample houses from these records:

(a) The amount of electric energy used by the occupants for cooking, water heating, house heating and cooling, and miscellaneous purposes;

(b) an electric energy usage factor relating the energy used for heating or cooling, the average severity of the weather as indicated by degree-days, and the inside floor area of the house;

(c) a computation of the contribution of the electrical equipment, other than the heat pump, to the heating of the house in the winter and to the cooling load in the summer, based on metered energy values and some assumptions regarding the fraction of the metered energy that was effective in warming the house;

(d) the components of the electrical equipment that contributed significantly to the monthly maximum 15-min power demands in the 16 sample houses;

(e) the frequency of recurrence of 15-min power demands of various magnitudes;

(f) one or more ways to effectively reduce the maximum power demands for the entire housing area without unduly altering the living habits of the house occupants.

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2. Description of Sample Houses

The identification of the 16 houses used for the study with respect to location, type of house, floor area, exterior gross wall area, window and door area, number of bedrooms, and nominal capacity of the supplementary resistance heaters is summarized in table 1. House types A, A_1, B, and B_1 were used to domicile airmen, and house types C, D, E, F, and G were used primarily to domicile officers. House types A_1 and B_1 were of duplex construction with carports adjoining, as illustrated in figure 1; house types A, B, C, and D were of duplex construction with living quarters adjoining and carports at either end; and the remainder were of detached design. All houses were of single-story construction built on concrete slabs on grade. Perimeter insulation of the floor slab consisted of 2 in. of rigid polystyrene foam. The insulation in the walls and ceiling consisted of 4 and 6 in. of glass fiber, respectively. All of the sample houses were equipped with a single heat pump having a nominal cooling capacity of 27,000 Btu/hr, except houses numbered 467 and 468, which had two such heat pumps in them.

There were 1,535 houses in the housing area, so the sample that was used for this study represented about one percent of the total. The sample included six 2-bedroom units, eight 3-bedroom units, and two 4-bedroom units. The entire housing area was comprised of 465 2-bedroom units, 1,067 3-bedroom units, and twelve 4-bedroom units. It is evident from these figures that the proportion of 4-bedroom units was much greater in the sample group of houses than for the entire housing area and that the proportion of 2-bedroom houses was somewhat greater in the sample than for the entire group.

The occupancy of the sample houses for the period from June 8, 1959, to March 8, 1960, as reported by the housing officer at the airbase, is summarized in table 2.

TABLE 2. *Occupancy of sample houses*

House No.	Period	Occupied or vacant	Rank of occupant	Size of family
4	June 8, 1959 to Mar. 8, 1960	Occupied	M/Sgt	2 adults.
14	June 8, 1959 to Mar. 8, 1960	Occupied	M/Sgt	2 adults, 1 child.
74	June 8, 1959 to Mar. 8, 1960	Occupied	M/Sgt	2 adults, 2 children.
163	June 8, 1959 to Mar. 8, 1960	Occupied	T/Sgt	2 adults, 2 children.
172	June 8, 1959 to Nov. 25, 1959.	Occupied	Sgt	2 adults.
	Nov. 25, 1959 to Dec. 1, 1959.	Vacant		
	Dec. 1, 1959 to Mar. 8, 1960	Occupied	M/Sgt	2 adults, 5 children.
180	June 8, 1959 to Mar. 8, 1960	Occupied	T/Sgt	2 adults, 1 child.
263	June 8, 1959 to Mar. 8. 1960	Occupied	T/Sgt	2 adults, 2 children.
301	June 8, 1959 to Mar. 8, 1960	Occupied	S/Sgt	2 adults, 2 children.
467	June 8, 1959 to Mar. 8, 1960	Occupied	Col	2 adults, 3 children.
468	June 8, 1959 to Mar. 8, 1960	Occupied	Col	2 adults, 3 children.
577	June 8, 1959 to Mar. 8, 1960	Occupied	Col	2 adults, 3 children.
585	June 8, 1959 to June 30, 1959.	Occupied	Capt	2 adults, 2 children.
	June 30, 1959 to Aug. 4, 1959.	Vacant		
	Aug. 4, 1959 to Feb. 4, 1960	Occupied	1/Lt	2 adults.
	Feb. 4, 1960 to Mar. 8, 1960	Vacant		
587	June 8, 1959 to Mar. 8, 1960	Occupied	CWO	2 adults.
656	June 8, 1959 to Oct. 30, 1959.	Vacant		
	Oct. 30, 1959 to Mar. 8, 1960.	Occupied	1/Lt	2 adults, 3 children.
770	June 8, 1959 to Mar. 8, 1960	Occupied	Capt	2 adults, 2 children.
843	June 8, 1959 to Nov. 7, 1959	Occupied	1/Lt	2 adults, 1 child.
	Nov. 7, 1959 to Mar. 8, 1960.	Vacant		

TABLE 1. *Identification of sample houses*

Street address of house	Contractor identification No.	House type	No. of bedrooms	Floor area		Ext. gross wall area	Window and door area	Nominal capacity of supplementary resistance heaters
				Gross	Inside			
				ft^2	ft^2	ft^2	ft^2	kw
114 Minnesota Circle	4	B_1	3	1,070	999	1,056	219	5.4
122 Mississippi Loop	14	A_1	2	970	891	992	180	3.6
110 Missouri Circle	74	B	3	1,070	1,013	832	193	5.4
129 Georgia Avenue	163	B_1	3	1,070	999	1,056	219	5.4
189 Pennsylvania Drive	172	B	3	1,070	1,013	832	193	5.4
102 Florida Avenue	180	A	2	970	891	768	153	3.6
115 Idaho Circle	263	A	2	970	891	768	153	3.6
126 Montana Circle	301	A_1	2	970	891	992	180	5.4
103 Arizona Drive	467	F	4	1,680	1,553	1,456	266	7.2
105 Arizona Drive	468	G	4	2,050	1,900	1,604	267	7.2
102 Alabama Drive	577	E	3	1,190	1,115	1,176	267	7.2
122 Illinois Drive	585	C	2	1,050	999	832	166	3.6
130 Illinois Drive	587	D	3	1,100	1,046	916	193	5.4
129 Iowa Circle	656	D	3	1,100	1,046	916	193	5.4
123 Louisiana Drive	770	E	3	1,190	1,115	1,176	267	7.2
127 Michigan Circle	843	C	2	1,050	999	832	166	3 6

FIGURE 1. *A typical type B_1 3-bedroom house with carports adjoining.*

3. Analysis of Data

3.1. Monthly Electric Energy Use

The average monthly electric energy use per house for each of the major components comprising the load and for the entire house was determined for the sample houses as a group and also for the 2-bedroom, 3-bedroom, and 4-bedroom houses as subgroups. These monthly averages have been summarized in table 3 for the period from October 1958 to March 1960, inclusive. The sample consisted of 11 to 15 houses prior to June 1959, since not all of the 16 houses chosen for study were initially occupied. The average monthly energy use for the heat pump, the water heater, the kitchen range, and miscellaneous devices in each subgroup and for the entire sample are also shown as a percentage of the corresponding average total house energy use. Since the miscellaneous devices of the house such as lights, television, clothes dryer, and resistance heater in the bathroom were not metered separately, the energy use of these devices was determined by subtracting the sum of the usages of the heat pump, the water heater, and the range from the total energy use of the house.

The average monthly energy use for the several components of the total load in the sample houses is plotted in figure 2 for the period from October 1958 to February 1960. The average monthly energy use per house for the entire housing area is

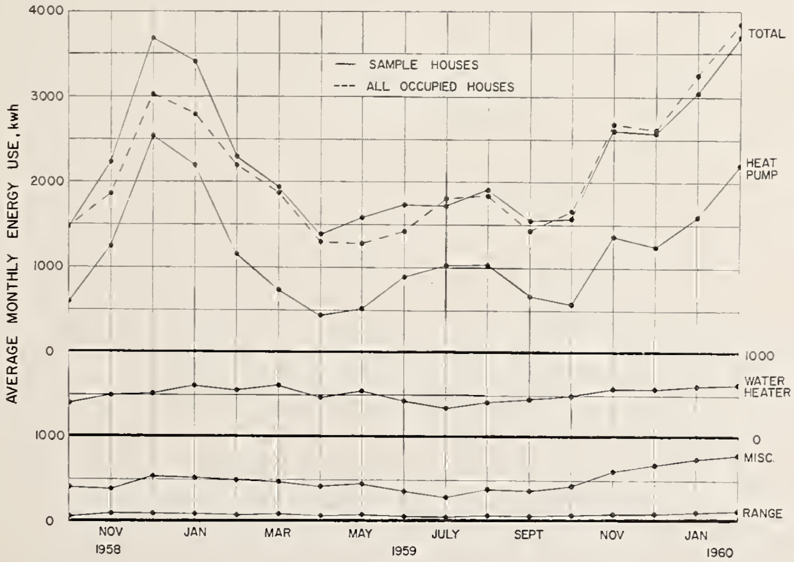

FIGURE 2. *The average monthly electric energy use for the sample houses, all the occupied houses, and for each measured component of the sample houses during the period October 1958–February 1960.*

TABLE 3. *Monthly electric energy usage in the sample houses at Little Rock Air Force Base*

Year	1958			1959												1960		
Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Total energy used for month, kw-hr:																		
Avg for all houses reported	1,469	2,227	3,683	3,409	2,292	1,933	1,379	1,577	1,729	1,718	1,901	1,553	1,570	2,607	2,575	3,040	3,707	2,850
No. of houses reported	11	12	13	13	13	15	15	15	16	16	16	15	16	15	15	16	16	16
Avg for 2-bedroom houses	1,040	1,827	2,800	2,860	1,860	1,432	1,008	1,256	1,473	1,400	1,467	1,300	1,347	2,296	2,352	2,567	3,160	2,313
No. of 2-bedroom houses	3	3	4	4	4	5	5	5	6	6	6	6	6	5	5	6	6	6
Avg for 3-bedroom houses	1,760	2,280	3,943	3,246	2,303	2,030	1,415	1,593	1,633	1,845	1,983	1,483	1,590	2,603	2,468	3,025	3,694	2,885
No. of 3-bedroom houses	6	7	7	7	7	8	8	8	8	8	8	7	8	8	8	8	8	8
Avg for 4-bedroom houses	1,240	2,640	4,540	5,080	3,120	2,800	2,160	2,320	2,880	2,160	2,880	2,560	2,080	3,400	3,560	4,520	5,400	4,320
No. of 4-bedroom houses	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Energy used for heat pump, kw-hr:																		
Avg for all houses reported	582	1,243	2,534	2,200	1,155	773	432	508	881	1,025	1,033	671	571	1,365	1,247	1,589	2,196	1,506
Percent of total	39.6	55.8	68.8	64.5	50.4	40.0	31.3	32.2	51.0	59.7	54.3	43.2	36.4	52.3	48.4	52.3	59.2	52.8
Avg for 2-bedroom houses	320	1,020	2,020	1,945	1,065	716	356	424	750	860	750	520	440	1,188	1,184	1,430	2,000	1,413
Percent of total	30.8	55.8	72.1	68.0	57.3	50.0	35.3	33.8	50.9	61.4	50.8	40.0	32.7	51.7	50.3	55.7	63.3	61.1
Avg for 3-bedroom houses	790	1,209	2,560	1,994	1,103	775	455	478	810	1,018	1,050	620	645	1,368	1,165	1,508	2,089	1,355
Percent of total	44.9	53.0	64.9	61.4	47.9	38.2	32.2	30.0	49.6	55.2	53.0	41.8	40.6	52.5	47.2	49.8	56.5	47.0
Avg for 4-bedroom houses	350	1,700	3,470	3,430	1,520	910	530	840	1,560	1,550	1,810	1,300	670	1,800	1,730	2,390	3,220	2,390
Percent of total	28.2	64.4	76.4	67.5	48.7	32.5	24.5	36.2	54.2	71.8	62.8	50.8	32.2	52.9	48.6	52.9	59.6	55.3
Energy used for water heating, kw-hr:																		
Avg for all houses reported	409	495	515	611	560	609	471	549	430	349	413	452	495	573	573	605	618	626
Percent of total	27.9	22.2	14.0	17.9	24.4	31.5	34.1	34.8	24.9	20.3	21.7	29.1	31.5	22.0	22.2	19.9	16.7	22.0
Avg for 2-bedroom houses	347	420	415	480	425	460	368	460	393	293	353	410	457	492	500	510	477	453
Percent of total	33.4	23.0	14.8	16.8	22.8	32.1	36.5	36.6	26.7	20.9	24.1	31.5	33.9	21.4	21.3	19.9	15.1	19.6
Avg for 3-bedroom houses	403	523	569	600	540	610	450	560	393	403	433	429	470	573	580	633	663	698
Percent of total	22.9	22.9	14.4	18.5	23.4	30.0	31.8	35.2	24.1	21.8	21.8	28.9	29.5	22.0	23.5	20.9	17.9	24.2
Avg for 4-bedroom houses	520	510	530	910	850	980	810	730	690	300	515	660	670	780	730	810	860	860
Percent of total	41.9	19.3	11.7	17.9	27.2	35.0	37.5	31.5	24.0	13.9	17.8	25.8	32.2	22.9	20.5	17.9	15.9	19.9
Energy used for cooking range, kw-hr:																		
Avg for all houses reported	62	103	97	91	83	88	65	81	58	53	68	67	79	88	88	111	118	93
Percent of total	4.2	4.6	2.6	2.7	3.6	4.5	4.7	5.1	3.4	3.1	3.5	4.3	5.0	3.4	3.4	3.6	3.2	3.3
Avg for 2-bedroom houses	53	100	80	80	75	72	36	56	40	30	53	50	47	56	48	50	60	47
Percent of total	5.1	5.5	2.9	2.8	4.0	5.0	3.6	4.5	2.7	2.1	3.6	3.8	3.5	2.4	2.0	1.9	1.9	2.0
Avg for 3-bedroom houses	77	126	126	100	91	95	80	100	70	73	80	80	103	108	110	165	165	130
Percent of total	4.4	5.5	3.2	3.1	3.9	4.7	5.7	6.3	4.3	4.0	4.0	5.4	6.5	4.1	4.5	5.4	4.5	4.5
Avg for 4-bedroom houses	30	30	30	80	70	100	80	70	60	40	60	70	80	88	100	80	100	80
Percent of total	2.4	1.1	0.6	1.6	2.2	3.6	3.7	3.0	2.1	1.9	2.1	2.7	3.9	2.6	2.8	1.7	1.8	1.9
Energy used for misc. devices[a], kw-hr:																		
Avg for all houses reported	409	385	537	523	501	468	411	439	360	291	385	364	425	583	667	735	775	625
Percent of total	27.9	17.3	14.6	15.3	21.9	24.2	29.8	27.8	20.8	16.9	20.2	23.4	27.1	22.4	25.9	24.2	20.9	21.9
Avg for 2-bedroom houses	320	240	285	405	295	280	248	316	290	217	310	320	403	568	620	577	623	400
Percent of total	30.8	13.2	10.2	14.2	15.9	19.5	24.6	25.2	19.7	15.5	21.1	24.6	29.9	24.7	26.4	22.5	19.7	17.3
Avg for 3-bedroom houses	477	443	689	551	569	500	430	455	360	353	420	354	373	555	613	728	778	702
Percent of total	27.1	19.4	17.5	17.0	24.7	24.6	30.4	28.5	22.0	19.1	21.2	23.9	23.4	21.3	24.8	24.1	21.1	24.3
Avg for 4-bedroom houses	340	400	510	660	680	810	740	680	570	270	500	530	660	730	1,000	1,240	1,220	990
Percent of total	27.4	15.2	11.2	13.0	21.8	28.9	34.3	29.3	19.8	12.5	17.3	20.7	31.7	21.5	28.1	27.4	22.6	22.9

[a] Includes electric clothes dryer and bathroom heater.

also plotted as a dashed line in figure 2 for comparison. This latter average represents an increasing number of occupied houses starting with about half of the total in October 1958 and increasing to 1,535 in June 1959.

It will be noted in figure 2 that the energy use for the heat pump and for the entire house reached an annual maximum in the middle of the winter and a smaller maximum during July and August. Two minimums of energy usage for the heat pump and for the house as a whole occurred during the year, in April and October, approximately, when little heating or cooling was required. The winter maximum use of energy was approximately twice the summer maximum. The energy use for the water heater, the kitchen range, and the miscellaneous devices was relatively more stable throughout the year, although the minimum use of energy for water heating and the miscellaneous devices occurred in July and the maximums occurred in the colder months of the year.

Figure 2 shows that the average monthly energy use per house for the 16 houses was very close to that for 1,535 houses for the period from July 1959 to February 1960 when the base was fully occupied, despite the disproportionate number of large houses in the 16-house sample.

Considering the average values for all the sample houses after March 1959, table 3 shows that the energy used for the heat pump ranged from a low value of about 30 percent of the total load during spring and fall to a value between 50 and 60 percent during the middle of the summer and winter; the energy used for water heating ranged from about 15 percent in the middle of the winter to a little over 30 percent in the spring and fall; the energy used for the kitchen range was 5 percent or less of the total throughout the year; and the energy used for miscellaneous devices ranged from 20 to 30 percent of the total most of the time.

Considering the 2-bedroom, 3-bedroom, and 4-bedroom houses as separate subgroups, table 3 shows that for most months of the year the energy used for the heat pump and for water heating increased with the number of rooms, whereas the energy used by the electric range was usually the greatest in the 3-bedroom houses, and the energy used for miscellaneous devices was rather inconsistent with respect to house size.

The energy used in the sample houses for each component of the total load and the percent of the total represented by each component is summarized in table 4 for the 12-month period from March 1959 to February 1960, inclusive. It should be noted that only 15 houses were occupied during some months of this period.

Table 4 shows that the total energy used by the heat pump for heating and cooling on an annual basis was slightly less than that used for all other devices combined. The annual energy usages for water heating and miscellaneous devices were each about half as large as that for the heat pump.

Table 4. *Average annual energy use in sample houses*

Component of load	Total energy used	Percent of total
	kw-hr	
Heat pump	12, 290	48. 6
Water heater	6, 135	24. 3
Range	965	3. 8
Miscellaneous (by difference)	5, 905	23. 3
Total	25, 295	100. 0

3.2. House Heating by Range, Water Heater, and Miscellaneous Devices

It is known from experience that the energy used by an electric range, an electric water heater, and the miscellaneous devices in a house makes some contribution toward warming the house in any season of the year. This auxiliary heating reduces the load on the heating system in cold weather and increases the load on the cooling system in hot weather.

It is probable that all of the energy input to the cooking range assists in warming the house with very little time lag except for the water vapor, generated by the cooking processes, that escapes from the house in the wintertime without being condensed. During the cooling season the water vapor produced by cooking would add to the latent cooling load on the heat pump and the sensible heat emitted from the range would add to the sensible cooling load of the heat pump. For this analysis it was assumed that all of the electric energy used by the cooking range was effective in warming the house.

The jacket heat losses from the water heater would warm the house winter and summer, if the heater were located in the occupied space, and a variable fraction of the heat in the warm water used for bathing, dishwashing, and laundry would be transferred to the air in the house as sensible or latent heat. Observations of the electric energy required to maintain storage temperatures in the water tank in some of the sample houses during the night when no water was being drawn indicate that the jacket loss of these water heaters was 8 to 10 percent of the total monthly energy used for water heating. To make some allowance for the heat transferred to the air in the house from the hot water during use, it was assumed for this analysis that 15 percent of all the electric energy supplied to the water heater was effective in warming the house.

It is probable that all of the electric energy used by electric lights, resistance heaters, toasters, radio and television sets, and nearly all of the energy used by an electric iron would be converted into heat that would assist in warming a house. The situation with respect to an electric clothes dryer is less definite. Although there would be some heat transferred to the room from the jacket of the dryer, these devices are usually equipped with a small blower which uses room air to carry the water vapor and some sensible heat outside during the clothes-drying process. Such a blower, when in operation, would increase the infiltration into the house, and create a heating requirement that would probably more than offset the jacket heat loss in cold weather. In summer the clothes dryer would increase the cooling load somewhat. For the purpose of this analysis, it was assumed that the clothes dryer contributed nothing toward heating the sample houses and that all of the remainder of the energy used by miscellaneous devices was converted into heat within the house.

The electric energy used by the electric clothes dryers at Little Rock Air Force Base was not metered separately from the other miscellaneous loads. However, the energy used for this purpose in 15 sample houses at 3 other airbases where it was metered separately averaged about 100 kw-hr per house per month. Accordingly, the energy used for miscellaneous devices in the houses at Little Rock Air Force Base was corrected by subtracting 100 kw-hr from the monthly totals reported in each case where the monthly total exceeded 100 kw-hr.

On the basis of the foregoing assumptions, the monthly contribution of the electric range, water heater, and miscellaneous devices to house heating was determined by the following expression:

$$\text{kw-hr}_A = \text{kw-hr}_R + 0.15\ \text{kw-hr}_W + (\text{kw-hr}_M - 100)$$

where kw-hr_A is the computed contribution of all appliances, other than the heat pump, to house heating in kw-hr/month, kw-hr_R is the metered electric energy use of the electric range in kw-hr/month, kw-hr_W is the metered electric energy use of the electric water heater in kw-hr/month, kw-hr_M is the electric energy used by miscellaneous devices in kw-hr/month.

This formula has been used later in this report for deriving one of the three factors for energy used per degree-day per 1,000 ft^2 of floor area for the sample houses at Little Rock Air Force Base. It is recognized that this formula could probably be improved in accuracy by a careful study of the heat dissipation characteristics of the various electrical appliances, as used in a house.

3.3 Correlation of Energy Requirements for Heating and Heating Degree-Days

Heat requirements for residences of similar construction in different climates and for different months in the same climate have often been compared on the basis of the number of degree-days occurring in each locality or in each time period. The heat requirements of houses of similar size and construction are related to the length of the exterior walls and to the inside floor area. In an effort to correlate the energy requirements of the 16 sample houses at Little Rock Air Force Base during the heating season, 3 different energy-usage factors were determined for the months of October, November, and December of 1959 and for January and February of 1960. These factors relate the electric energy used and the inside floor area for each of the sample houses to the degree-days and have the units kw-hr/degree-day (1,000 ft^2). The data involved in determining the factors and the factors themselves are summarized in tables 5 to 9, inclusive, for the 5 months studied.

The three energy-usage factors shown in tables 5 to 9 each involved the inside floor area of the house, but employed different values for the electric energy used for heating the house or different bases for computing the degree-days. The first factor was computed from the electric energy used by the heat pump plus the contribution to heating made by all other appliances and the degree-days related to a 65 °F base. The second factor was computed from the electric energy used by the heat pump only and the degree-days related to a 65 °F base. The third factor was computed from the electric energy used by the heat pump plus the contribution to heating made by all other appliances and the degree-days based on the difference between the monthly average indoor and outdoor temperatures.

Degree-days based on an indoor temperature of 65 °F were determined by one or both of the following two methods. In one method the maximum and minimum outdoor temperatures for each day were taken from the temperature recorder charts and averaged. Each daily average was subtracted from the value 65 °F, and all such differences for the month were added to determine the degree-days for the month. In the other method the degree-days were determined by evaluating the hourly differences between the recorded outdoor temperature and the 65 °F base. Good agreement was found between the two methods in the several instances when both methods were used for a given month.

An examination of tables 5 to 9 indicates that the methods used to obtain the energy-usage factors provided reasonable consistency among the average values for the 2-, 3-, and 4-bedroom houses as subgroups. Considering all the sample houses as a group, the second factor, obtained from the energy consumption of the heat pump only and the degree-days related to a 65 °F base, did not differ by more than 13 percent in 4 of the 5 months from the third factor, obtained from the total energy used for heating and degree-days based on average indoor-outdoor temperature difference. For the 5 months studied, the second energy-usage factor averaged 2.14 kw-hr/degree-day (1,000 ft^2) whereas the third factor averaged 2.20 in the same units for all the sample houses. The near equality of these two factors indicates that the total energy for heating, including the quantity kw-hr_A, bore the same relationship to the degree-days based on indoor-outdoor temperature difference as the heat-pump energy did to the degree-days based on a 65 °F reference value. Or in other words, it tends to corroborate the validity of the 65 °F base for computing degree-days in relation to the energy used by the heat pump for heating. The second and third energy-usage factors were somewhat more consistent from month to month than the first energy-usage factor, but this was due principally to the high values of the first factor during the month of October when heating was more intermittent.

It will be noted that the appliance contribution, kw-hr$_A$, in tables 5 to 9 ranged from 84 percent of the heat-pump energy in October down to about 40 percent of this item in February based on the averages for 16 houses. Considering the 5 months from October 1959 to February 1960, inclusive, the computed appliance contribution toward heating the houses, kw-hr$_A$, averaged 51.6 percent of the energy used by the heat pump and 34.0 percent of all the energy used for heating the houses.

In those instances where the indoor temperature and the energy usage in tables 5 to 9 indicated that a particular house was probably not occupied during a month, the data for that house were not included in the average. It will be noted that the occupancy, as indicated by the data in tables 5 to 9, was not always consistent with the occupancy information summarized in table 2.

Coefficients of variation are shown in tables 5 to 9 for the three energy-usage factors for the 2-, 3-, and 4-bedroom houses as subgroups and for all the sample houses for the months from October 1959 to February 1960, inclusive. The coefficient of variation is defined as the standard deviation divided by the average of the group of values under consideration and is one method of indicating the consistency within a group of values. Based on the 5-month average from October 1959 to February 1960, the coefficients of variation indicate that the consistency among the individual houses of a given subgroup and within the 16-house sample was about the same for the first and third energy-usage factors, whereas the consistency was a little poorer for the second energy-usage factor. The first and third energy-usage factors involve the total energy used for heating and two different methods for evaluating degree-

Table 5. *Relation of energy usage and degree-days under heating conditions for October 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption			Avg indoor temp	Avg outdoor temp	Degree-days		Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²)		
	Heat pump	Appliance contribution, kw-hr$_A$	Total for heating			Based on 65° F reference	Based on avg indoor-outdoor temp		Total energy, 65 °F base	Heat pump energy, 65 °F base	Total energy, indoor-outdoor, ΔT
2-bedroom houses											
	kw-hr	*kw-hr*	*kw-hr*	*°F*	*°F*			*ft²*			
14	440	469	909	78	59	214	589	891	4.8	2.3	1.7
180	380	529	909	74	59	214	465	891	4.8	2.0	2.2
263	380	484	864	75	59	214	496	891	4.5	2.0	2.0
301	360	423	783	73	59	214	434	891	4.1	1.9	2.0
585	640	366	1,006	78	59	214	589	999	4.7	3.0	1.7
843	440	240	680	70	59	214	341	999	3.2	2.1	2.0
Average	440	419	859	75	59	214	486	927	4.4	2.2	1.9
Coefficient of variation									0.13	0.16	0.11
3-bedroom houses											
4	520	385	905	75	59	214	496	999	4.2	2.4	1.8
74	580	295	875	76	59	214	527	1,013	4.0	2.7	1.6
163	1,240	607	1,847	76	59	214	527	999	8.6	5.8	3.5
172	680	240	920	77	59	214	558	1,013	4.2	3.1	1.6
577	400	623	1,023	74	59	214	465	1,115	4.3	1.7	2.0
587	500	380	880	73	59	214	434	1,046	3.9	2.2	1.9
656	560	486	1,046	77	59	214	558	1,046	4.7	2.5	1.8
770	680	618	1,298	74	59	214	465	1,115	5.4	2.8	2.5
Average	645	454	1,099	75	59	214	504	1,043	4.9	2.9	2.1
Coefficient of variation									0.30	0.39	0.28
4-bedroom houses											
467	380	782	1,162	76	59	214	527	1,553	3.5	1.2	1.4
468	960	699	1,659	73	59	214	434	1,900	4.1	2.4	2.0
Average	670	741	1,411	75	59	214	481	1,727	3.8	1.8	1.7
Coefficient of variation									0.08	0.41	0.18
Average for 16 houses	571	477	1,048	75	59	214	494	1,085	4.6	2.5	2.0
Coefficient of variation, 16 houses									0.26	0.38	0.24

days, whereas the second energy-usage factor is derived from the energy used by the heat pump only. Thus it appears that the energy-usage factors which include the contribution of appliances other than the heat pump to the house-heating function provide a greater consistency in results among a group of houses in the same month than that which makes use of only the heat-pump energy consumption.

3.4. Correlation of Energy Requirements for Cooling and Cooling Degree-Days

A similar relation of energy usage, floor area, and cooling degree-days was determined for the months of June, July, and August 1959 for the sample houses. These data are summarized in tables 10, 11, and 12.

The degree-day concept has been used to some extent for estimating the energy required for air-conditioning residences during the cooling season. However, it has not had the same measure of acceptance for cooling conditions as for heating conditions. Under cooling conditions, the heat contributed by electrical appliances added to the summer cooling load rather than assisting the heat pump as it did during the winter. Also, in the summertime, the outdoor temperature frequently crossed the reference value used for degree-day determinations whether the reference value chosen was 65 or 75 °F. Solar radiation on a house is a much greater factor in the total cooling load than it is for the heating load, and its effect is only partly and indirectly reflected in the indoor-outdoor temperature difference during the summer. In addition, the degree-day concept makes no allowance for the cooling load represented by the humidity in the outdoor air used for ventilation.

Three energy-usage factors were computed based on three different computations of the cooling de-

Table 6. *Relation of energy usage and degree-days under heating conditions for November 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption			Avg indoor temp	Avg outdoor temp	Degree-days		Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²)		
	Heat pump	Appliance contribution, kw-hr A	Total for heating			Based on 65 °F reference	Based on avg indoor-outdoor temp		Total energy, 65 °F base	Heat pump energy, 65 °F base	Total energy, indoor-outdoor, ΔT
2-bedroom houses											
	kw-hr	*kw-hr*	*kw-hr*	*°F*	*°F*			*ft²*			
14	1,140	495	1,635	76	45	640	930	891	2.9	2.0	2.0
180	920	668	1,588	74	45	640	870	891	2.8	1.6	2.0
263	860	805	1,665	76	45	640	930	891	2.9	1.5	2.0
301	1,600	492	2,092	72	45	640	810	891	3.7	2.8	2.9
585	1,420	529	1,949	77	45	640	960	999	3.0	2.2	2.0
843	[a] 620	[a] 3	[a] 623	[a] 60	45	640	[a] 450	[a] 999	[a] 1.0	[a] 1.0	[a] 1.4
Average	1,188	598	1,786	75	45	640	900	927	3.1	2.0	2.2
Coefficient of variation									0.11	0.23	0.17
3-bedroom houses											
4	1,220	502	1,722	73	45	640	840	999	2.7	1.9	2.1
74	1,180	597	1,777	77	45	640	960	1,013	2.7	1.8	1.8
163	2,180	766	2,946	71	45	640	780	999	4.6	3.4	3.8
172	1,320	338	1,658	76	45	640	930	1,013	2.6	2.0	1.8
577	1,300	781	2,081	72	45	640	810	1,115	2.9	1.8	2.3
587	1,060	729	1,789	73	45	640	840	1,046	2.7	1.6	2.0
656	1,160	618	1,778	78	45	640	990	1,046	2.7	1.7	1.7
770	1,520	856	2,376	72	45	640	810	1,115	3.3	2.1	2.6
Average	1,368	648	2,016	74	45	640	870	1,043	3.0	2.0	2.3
Coefficient of variation									0.20	0.26	0.29
4-bedroom houses											
467	1,840	837	2,677	73	45	640	840	1,553	2.7	1.9	2.1
468	1,760	837	2,597	73	45	640	840	1,900	2.1	1.4	1.6
Average	1,800	837	2,637	73	45	640	840	1,727	2.4	1.7	1.9
Coefficient of variation									0.13	0.16	0.14
Average for 15 houses	1,365	657	2,022	74	45	640	876	1,091	3.0	2.0	2.2
Coefficient of variation, 15 houses									0.19	0.25	0.25

[a] House 843 apparently not occupied. These data not included in the averages.

gree-days. The degree-day values in columns 6 and 7 of tables 10, 11, and 12 are based on the differences between hourly values of outdoor temperature taken from the temperature recorder charts and the reference values of 65 and 75 °F, respectively. The degree-day values in column 8 of the tables were computed from the mean of the daily maximum and minimum outdoor temperatures and the daily average indoor temperature.

It will be noted in tables 10 to 12 that the energy-usage factor for cooling varied over a considerable range depending on the basis selected for determining the degree-days of cooling. An examination indicates that the first two energy-usage factors were fairly consistent from month to month in the 2-, 3-, and 4-bedroom houses as subgroups. The percentage variation in each of these two factors in any given month for any group of houses was the same because the factors were related to each other by a fixed ratio: the ratio of the degree-days based on reference temperatures of 65 and 75 °F, respectively. However, the first factor differed less among the 3 separate months than did the second factor. Considering all the sample houses as a group, the three monthly values of the first factor differed by only 10 percent of the average whereas the three monthly values of the second factor differed by 25 percent of the average.

The third energy-usage factor varied more among house subgroups and from month to month than did the other two factors. Basing the degree-days on the difference between mean daily outdoor temperature and average indoor temperature is probably the least suitable of the three methods employed for correlating energy usage, first, because this temperature difference can become vanishingly small, or even negative, and yet the house can have a cooling requirement, and secondly, because a house probably responds with respect to the need for cooling or heating on a cycle of less than 24 hr. Note that the degree-day value for house 585 as used for the third factor was

TABLE 7. *Relation of energy usage and degree-days under heating conditions for December 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption: Heat pump	Energy consumption: Appliance contribution, kw-hr A	Energy consumption: Total for heating	Avg indoor temp	Avg outdoor temp	Degree-days: Based on 65 °F reference	Degree-days: Based on avg indoor-outdoor temp	Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²): Total energy, 65 °F base	Energy-usage factor: Heat pump energy, 65 °F base	Energy-usage factor: Total energy, indoor-outdoor, ΔT
2-bedroom houses											
	kw-hr	*kw-hr*	*kw-hr*	*°F*	*°F*			*ft²*			
14	1,140	535	1,675	77	43	643	1,054	891	2.9	2.0	1.8
180	760	732	1,492	73	43	643	930	891	2.6	1.3	1.8
263	1,080	859	1,939	77	43	643	1,054	891	3.4	1.9	2.1
301	1,742	529	2,271	73	43	643	930	891	4.0	3.0	2.7
585	1,200	560	1,760	77	43	643	1,054	999	2.7	1.9	1.7
843	[a] 1,000	[a] 306	[a] 1,306	[a] 69	43	643	[a] 806	[a] 999	[a] 2.0	[a] 1.6	[a] 1.6
Average	1,184	643	1,827	75	43	643	1,004	927	3.1	2.0	2.0
Coefficient of variation									0.17	0.27	0.18
3-bedroom houses											
4	1,320	390	1,710	74	43	643	961	999	2.7	2.1	1.8
74	980	677	1,657	75	43	643	992	1,013	2.5	1.5	1.6
163	1,700	720	2,420	74	43	643	961	999	3.8	2.6	2.5
172	980	278	1,258	71	43	643	868	1,013	1.9	1.5	1.4
577	1,140	1,016	2,156	71	43	643	868	1,115	3.0	1.6	2.2
587	720	824	1,544	72	43	643	899	1,046	2.3	1.1	1.6
656	1,140	735	1,875	78	43	643	1,085	1,046	2.8	1.7	1.7
770	1,340	1,036	2,376	72	43	643	899	1,115	3.3	1.9	2.4
Average	1,165	710	1,875	73	43	643	942	1,043	2.8	1.8	1.9
Coefficient of variation									0.20	0.24	0.21
4-bedroom houses											
467	1,540	926	2,466	72	43	643	899	1,553	2.5	1.5	1.8
468	1,920	1,293	3,213	74	43	643	961	1,900	2.6	1.6	1.8
Average	1,730	1,110	2,840	73	43	643	930	1,727	2.6	1.6	1.8
Coefficient of variation									0.04	0.06	0.00
Average for 15 houses	1,247	741	1,987	74	43	643	961	1,091	2.9	1.8	1.9
Coefficient of variation, 15 houses									0.18	0.27	0.18

[a] House 843 apparently not occupied. These data not included in the averages.

negative during August because the average indoor temperature was 1 °F higher than the mean daily outdoor temperature even though the heat pump used 380 kw-hr of electric energy during the month, causing the corresponding energy-usage factor to be negative.

The coefficients of variation of the energy-usage factors during cooling operation, defined in the same way as for heating operation, are shown in tables 10 to 12 for the months of June, July, and August 1959, respectively. These coefficients were the same for the first two energy-usage factors except for differences caused by the arithmetical rounding-off process because the factors themselves for any given house were related to each other in the same ratio as the degree-days based on reference temperatures of 65 and 75 °F, respectively. The coefficient of variation was larger for the third energy-usage factor than for the other two, and especially so in August for the group of 2-bedroom houses because of the one negative value of the energy-usage factor for house 585.

3.5. Conditions Affecting Maximum Power Demand for the Housing Area

The unit rate for electric energy at the Little Rock Air Force Base was related by sliding scales to the following three quantities: (1) the total monthly usage of electric energy; (2) the magnitude of the maximum 15-min power demand during the month; and (3) the load factor, i.e., the ratio of the monthly average use of the electric power to the maximum 15-min demand of power for the month. For this type of rate structure, a reduction of the maximum 15-min demand in any month would tend to lower the unit rate by virtue of its effect on the second and third quantities above, even if the total energy usage remained unchanged.

a. Load Factor

Figure 3 shows the average monthly power use of all the occupied houses from April 1959 to February 1960, inclusive. It also shows the average

TABLE 8. *Relation of energy usage and degree-days under heating conditions for January 1960, Little Rock Air Force Base*

Contractor's house number	Energy consumption: Heat pump	Energy consumption: Appliance contribution, kw-hr A	Energy consumption: Total for heating	Avg indoor temp	Avg outdoor temp	Degree-days: Based on 65 °F reference	Degree-days: Based on avg indoor-outdoor temp	Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft^2): Total energy, 65 °F base	Heat pump energy, 65 °F base	Total energy, indoor-outdoor, ΔT
2-bedroom houses											
	kw-hr	*kw-hr*	*kw-hr*	°*F*	°*F*			ft^2			
14	1,440	458	1,898	76	42	694	1,054	891	3.1	2.3	2.0
180	1,160	601	1,761	73	42	694	961	891	2.8	1.9	2.1
263	1,160	694	1,854	75	42	694	1,023	891	3.0	1.9	2.0
301	2,040	658	2,698	74	42	694	992	891	4.4	3.3	3.1
585	1,400	595	1,995	76	42	694	1,054	999	2.9	2.0	1.9
843	1,380	613	1,993	73	42	694	961	999	2.9	2.0	2.1
Average	1,430	603	2,033	75	42	694	1,008	927	3.2	2.2	2.2
Coefficient of variation									0.18	0.23	0.19
3-bedroom houses											
4	1,400	825	2,225	74	42	694	992	999	3.2	2.0	2.2
74	1,020	934	1,954	73	42	694	961	1,013	2.8	1.5	2.0
163	2,580	858	3,438	74	42	694	992	999	5.0	3.7	3.5
172	1,800	609	2,409	74	42	694	992	1,013	3.4	2.6	2.4
577	1,400	1,076	2,476	71	42	694	899	1,115	3.2	1.8	2.5
587	840	1,040	1,880	73	42	694	961	1,046	2.6	1.2	1.9
656	1,340	729	2,069	77	42	694	1,085	1,046	2.9	1.8	1.8
770	1,680	1,019	2,699	73	42	694	961	1,115	3.5	2.2	2.5
Average	1,508	886	2,394	74	42	694	980	1,043	3.3	2.1	2.4
Coefficient of variation									0.20	0.34	0.22
4-bedroom houses											
467	2,180	1,418	3,598	74	42	694	992	1,553	3.3	2.0	2.3
468	2,600	1,265	3,865	73	42	694	961	1,900	2.9	2.0	2.1
Average	2,390	1,342	3,732	74	42	694	977	1,727	3.1	2.0	2.2
Coefficient of variation									0.06	0.00	0.05
Average for 16 houses	1,589	837	2,426	74	42	694	990	1,085	3.2	2.1	2.3
Coefficient of variation, 16 houses									0.19	0.28	0.18

15-min demand of all the occupied houses occurring at the time of monthly maximum 15-min demand for the entire housing area. The load factor for the entire housing area was determined month by month from these data and plotted in figure 3 for the same period.

Figure 3 shows that the monthly load factor approximated 0.50 from April 1959 to December 1959, with two exceptions, and then rose sharply until it reached a value of about 0.60 during February 1960. That is, the monthly average power demand was about one-half the maximum 15-min demand much of the time, with a higher ratio occurring during the colder months of the winter. A low load factor occurs for a given house when the various pieces of electrical equipment are energized for only a small percentage of the total time, but occasionally many or all of them are simultaneously energized for periods up to 15 min. When the short periods of simultaneous use of many components of the load in a number of houses

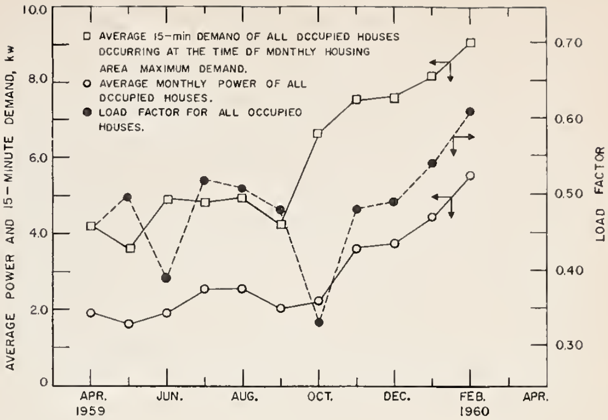

FIGURE 3. *The average monthly power use of all the occupied houses, the average 15-min power demand at the time of the monthly maximum power demand for all occupied houses and the average monthly load factor, for the period April 1959–February 1960.*

TABLE 9. *Relation of energy usage and degree-days under heating conditions for February 1960, Little Rock Air Force Base*

Contractor's house number	Energy consumption: Heat pump	Energy consumption: Appliance contribution, kw-hrA	Energy consumption: Total for heating	Avg indoor temp	Avg outdoor temp	Degree-days: Based on 65 °F reference	Degree-days: Based on avg indoor-outdoor temp	Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²): Total energy, 65 °F base	Energy-usage factor: Heat pump energy, 65 °F base	Energy-usage factor: Total energy, indoor-outdoor, △T
					2-bedroom houses						
	kw-hr	*kw-hr*	*kw-hr*	*°F*	*°F*			*ft²*			
14	1,780	670	2,450	75	34	908	1,189	891	3.0	2.2	2.3
180	1,800	504	2,304	73	34	908	1,131	891	2.8	2.2	2.3
263	1,720	528	2,248	73	34	908	1,131	891	2.8	2.1	2.2
301	3,140	735	3,875	72	34	908	1,102	891	4.8	3.9	3.9
585	1,760	716	2,476	75	34	908	1,189	999	2.7	1.9	2.1
843	1,800	816	2,616	74	34	908	1,160	999	2.9	2.0	2.3
Average	2,000	662	2,662	74	34	908	1,150	927	3.2	2.4	2.5
Coefficient of variation									0.23	0.29	0.24
					3-bedroom houses						
4	3,000	842	3,842	74	34	908	1,160	999	4.2	3.3	3.3
74	1,540	1,158	2,698	73	34	908	1,131	1,013	2.9	1.7	2.4
163	2,800	803	3,603	73	34	908	1,131	999	4.0	3.1	3.2
172	2,080	712	2,792	(a)	34	908	(a)	1,013	3.0	2.3	(a)
577	2,160	1,196	3,356	69	34	908	1,015	1,115	3.3	2.1	3.0
587	1,200	968	2,168	71	34	908	1,073	1,046	2.3	1.3	1.9
656	1,740	757	2,497	75	34	908	1,189	1,046	2.6	1.8	2.0
770	2,180	1,099	3,279	72	34	908	1,102	1,115	3.2	2.2	2.7
Average	2,088	942	3,029	72	34	908	1,114	1,043	3.2	2.2	2.6
Coefficient of variation									0.18	0.28	0.20
					4-bedroom houses						
467	2,720	1,072	3,792	74	34	908	1,160	1,553	2.7	1.9	2.1
468	3,800	1,546	5,346	71	34	908	1,073	1,900	3.1	2.2	2.6
Average	3,260	1,309	4,569	73	34	908	1,117	1,727	2.9	2.1	2.4
Coefficient of variation									0.07	0.08	0.11
Average for 16 houses	2,201	883	3,084	73	34	908	1,129	1,085	3.1	2.3	2.6
Coefficient of variation, 16 houses									0.21	0.28	0.22

[a] Data not available.

occur at the same time, the load factor for the entire group is low.

b. Daily Pattern of Power Demand

In order to determine how the power demand varied throughout the day, the daily pattern of power demand was plotted for 5 of the sample houses for the months of January 1960 and August 1959. For these 2 months, the power used during each 15-min period of the day was tabulated for the 5 houses. From these data the maximum and minimum demands that occurred on any day of the month and the average demand for all days of the month were plotted for each 15-min period of the day. This information is shown in figures 4 to 8, inclusive, for January 1960 and in figures 9 to 13, inclusive, for August 1959.

Of the 5 sample houses evaluated, houses numbered 14, 263, 468, and 587 revealed similar changes in the average and maximum power demands between the day and night hours during the month of January. Starting in the morning at a time ranging from about 0630 to 0900 hr, the average and maximum power demands rose quickly to about twice that observed earlier in the morning and remained at a high level until 1 to 3 hr after noon when they decreased to a value only a little above the night demand. After about 2 hr at a low value, the power demand rose again to a smaller maximum at about 1800 or 1900 hr and then gradually decreased to night level, before midnight in most cases. The daily pattern of power demand for these 4 houses indicates the following conclusions regarding the power demand:

(1) The monthly maximum 15-min power demand often occurred between the hours of 0630 and 2000 and was caused principally by the activities of the occupants of the house during their waking hours.

(2) The monthly maximum 15-min power demand was not directly caused by the heating equipment during the coldest hours in the 24-hr period.

TABLE 10. *Relation of energy usage and degree-days under cooling conditions for June 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption: Heat pump	Energy consumption: Appliance contribution kw-hr A	Avg indoor temp	Avg outdoor temp	Degree-days: Hourly values, 65 °F base	Degree-days: Hourly values, 75 °F base	Degree-days: Daily mean above indoor avg	Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²): Hourly values, 65 °F base	Energy-usage factor: Hourly values, 75 °F base	Energy-usage factor: Daily mean above indoor avg
2-bedroom houses											
	kw-hr	*kw-hr*	*°F*	*°F*				*ft²*			
14	720	354	76	79	390	146	90	891	2.1	5.5	9.0
180	900	489	70	79	390	146	270	891	2.6	6.9	3.7
263	900	262	68	79	390	146	330	891	2.6	6.9	3.1
301	720	470	76	79	390	146	90	891	2.1	5.5	9.0
585	[a] 420	[a] 162	[a] 74	79	390	146	[a] 150	[a] 999	[a] 1.1	[a] 2.9	[a] 2.8
843	840	179	73	79	390	146	180	999	2.2	5.8	4.7
Average	816	351	73	79	390	146	192	912	2.3	6.1	5.9
Coefficient of variation									0.10	0.11	0.44
3-bedroom houses											
4	820	244	75	79	390	146	120	999	2.1	5.6	6.8
74	820	517	71	79	390	146	240	1,013	2.1	5.5	3.4
163	960	555	73	79	390	146	180	999	2.5	6.6	5.3
172	780	289	73	79	390	146	180	1,013	2.0	5.3	4.3
577	660	443	77	79	390	146	60	1,115	1.5	4.1	9.9
587	880	424	71	79	390	146	240	1,046	2.2	5.8	3.5
656	660	562	76	79	390	146	90	1,046	1.6	4.3	7.0
770	900	147	73	79	390	146	180	1,115	2.1	5.5	4.4
Average	810	398	74	79	390	146	161	1,043	2.0	5.3	5.6
Coefficient of variation									0.16	0.14	0.37
4-bedroom houses											
467	1,560	579	74	79	390	146	150	1,553	2.6	6.9	6.7
468	1,560	688	76	79	390	146	90	1,900	2.1	5.6	9.1
Average	1,560	634	75	79	390	146	120	1,727	2.4	6.3	7.9
Coefficient of variation									0.11	0.10	0.15
Average for 15 houses	912	413	73	79	390	146	166	1,091	2.2	5.7	6.0
Coefficient of variation, 15 houses									0.15	0.14	0.38

[a] House 585 apparently occupied only part of the time. These data not included in the averages.

(3) A fairly stable power demand approximating twice the night level occurred from about 0700 to 1400 hr.

(4) Several high 15-min demands occurred during the month that approximated the one monthly maximum value in each house.

(5) There was a high degree of similarity in the daily pattern of power demand in the 4 houses and therefore a good probability of coincidence of high or maximum values in a group of houses.

Despite the similarity in the daily patterns of power demand shown in figures 4 to 7 for houses numbered 14, 263, 468, and 587, the pattern shown in figure 8 for house 74 was significantly different. The variation in power demand between day and night was much less in this house, the monthly maximum 15-min demand was lower, and high values in the maximum demand curve were more or less evenly scattered throughout the 24-hr period. Table 2 indicates that house 74 was not occupied by an unusually small family, and tables 5 to 9 show that the total monthly energy use in this house was of the same order of magnitude as for houses 14, 263, and 587 during the winter months. No reason was found for the power demand pattern being different for house 74 from that observed in the other four houses.

In August, the daily pattern of power demand was similar in all 5 houses studied, as shown in figures 9 to 13. Starting in the morning between 0600 and 0900 hr, the average and maximum power demand increased fairly rapidly for about 2 hr, after which it was reasonably stable until about 1900 hr and then gradually decreased until several hours after midnight. The daily average power demand was quite low from 0200 to 0600 hr ranging from about 0.5 kw in 2 of the houses up to about 1.5 kw in house 263. The daily average power demand during the period from 1000 to 1900 hr was in the range from 3 to 4 kw in some houses and up to 6 kw or more in others.

Unlike the most prevalent daily pattern of power demand in January, there was no period of

TABLE 11. *Relation of energy usage and degree-days under cooling conditions for July 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption: Heat pump	Energy consumption: Appliance contribution kw-hr A	Avg indoor temp	Avg outdoor temp	Degree-days: Hourly values, 65 °F base	Degree-days: Hourly values, 75 °F base	Degree-days: Daily mean above indoor avg	Inside floor area	Energy-usage factor, kw-hr/degree-days (1,000 ft²): Hourly values, 65 °F base	Energy-usage factor: Hourly values, 75 °F base	Energy-usage factor: Daily mean above indoor avg
2-bedroom houses											
	kw-hr	*kw-hr*	*°F*	*°F*				*ft²*			
14	840	354	76	81	488	225	155	891	1.9	4.2	6.1
180	[a]860	[a]6	[a]67	81	488	225	[a]434	[a]891	[a]2.0	[a]4.3	[a]2.2
263	1,140	169	72	81	488	225	279	891	2.6	5.7	4.6
301	1,040	463	76	81	488	225	155	891	2.4	5.2	7.5
585	[a]440	[a]75	[a]74	81	488	225	[a]217	[a]999	[a]0.9	[a]2.0	[a]2.0
843	840	183	74	81	488	225	217	999	1.7	3.7	3.9
Average	965	292	75	81	488	225	202	918	2.2	4.7	5.5
Coefficient of variation									0.17	0.17	0.25
3-bedroom houses											
4	1,140	227	75	81	488	225	186	999	2.3	5.1	6.1
74	1,000	640	72	81	488	225	279	1,013	2.0	4.4	3.5
163	1,360	481	74	81	488	225	217	999	2.8	6.1	6.3
172	720	328	76	81	488	225	155	1,013	1.5	3.2	4.6
577	1,100	569	76	81	488	225	155	1,115	2.0	4.4	6.4
587	1,000	286	72	81	225	279	279	1,046	2.0	4.2	3.4
656	540	276	77	81	488	225	124	1,046	1.1	2.3	4.2
770	1,280	434	71	81	488	225	310	1,115	2.4	5.1	3.7
Average	1,018	405	74	81	488	225	213	1,043	2.0	4.3	4.8
Coefficient of variation									0.25	0.25	0.25
4-bedroom houses											
467	1,540	185	74	81	488	225	217	1,553	2.0	4.4	4.6
468	1,560	325	76	81	488	225	155	1,900	1.7	3.6	5.3
Average	1,550	255	75	81	488	225	186	1,727	1.9	4.0	5.0
Coefficient of variation									0.08	0.10	0.07
Average for 14 houses	1,079	351	74	81	488	225	206	1,105	2.0	4.4	5.0
Coefficient of variation, 14 houses									0.21	0.22	0.25

[a] Houses 180 and 585 apparently not occupied. These data not included in the averages.

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low demand in the middle of the afternoon in August. This variation is probably explained by the high solar load at this time of the day and the fairly steady requirement for heat pump operation.

Figures 9 to 13 show that there were no high values of maximum power demand between 2200 hr in the evening and 0600 hr in the morning that approached the monthly maximum 15-min power demand in these 5 houses. This pattern indicates the high probability that the monthly maximum power demand in the summer months would also occur during the period of the day when the occupants are active.

An inspection of figures 4 to 13 indicates that the load factor for the individual house could be increased, if some of the electrical load were shifted from the daytime hours to the night hours. Table 13 is a summary of the daily average energy use in 5 sample houses between the hours of 2300 and 0700, and between 0700 and 2300 for the months of August and January. The energy use in these two periods is also expressed as a percent of the total. It will be noted that about 12 percent of the total daily energy use occurred between the hours of 2300 and 0700 in 4 of the sample houses during August, and about 25 percent of the total daily energy use occurred in the same period in four of the sample houses during January. The fifth house in the group used a higher percent of the

Table 13. *Average day and night energy use in 5 sample houses*

Electric energy used, kw-hr

House No.	August 1959				January 1960			
	2300–0700 hr	Percent of total	0700–2300 hr	Percent of total	2300–0700 hr	Percent of total	0700–2300 hr	Percent of total
14	5.8	11.4	45.1	88.6	20.0	24.1	62.9	75.9
74	9.0	12.4	63.7	87.6	10.5	25.2	31.1	74.8
263	12.7	22.4	44.0	77.6	14.7	17.7	68.3	82.3
468	9.9	11.9	73.6	88.1	38.9	27.5	102.6	72.5
587	------	------	------	------	18.4	23.9	58.6	76.1
656	5.5	10.8	45.4	89.2	------	------	------	------

Table 12. *Relation of energy usage and degree-days under cooling conditions for August 1959, Little Rock Air Force Base*

Contractor's house number	Energy consumption		Avg indoor temp	Avg outdoor temp	Degree-days			Inside floor area	Energy-usage factor, degree-days (1,000 ft²)		
	Heat pump	Appliance contribution kw-hr[a]			Hourly values, 65 °F base	Hourly values, 75 °F base	Daily mean above indoor avg		Hourly values, 65 °F base	Hourly values, 75 °F base	Daily mean above indoor avg
					2-bedroom houses						
	kw-hr	*kw-hr*	*°F*	*°F*				*ft²*			
14	840	400	76	79	447	170	93	891	2.1	5.5	10.1
180	900	380	70	79	447	170	279	891	2.3	5.9	3.6
263	680	68	76	79	447	170	93	891	1.7	4.5	8.2
301	1,040	572	75	79	447	170	124	891	2.6	6.9	9.4
585	380	316	80	79	447	170	−31	999	0.9	2.2	[a] −12.3
843	660	162	76	79	447	170	93	999	1.5	3.9	7.1
Average	750	316	76	79	447	170	109	927	1.9	4.8	4.4
Coefficient of variation									0.31	0.31	1.78
					3-bedroom houses						
4	1,240	276	74	79	447	170	155	999	2.8	7.3	8.0
74	1,280	583	73	79	447	170	186	1,013	2.8	7.4	6.8
163	1,080	852	72	79	447	170	217	999	2.4	6.4	5.0
172	680	188	75	79	447	170	124	1,013	1.5	3.9	5.4
577	880	543	77	79	447	170	62	1,115	1.8	4.6	12.7
587	1,360	274	73	79	447	170	186	1,046	2.9	7.6	7.0
656	800	549	77	79	447	170	62	1,046	1.7	4.5	12.3
770	1,080	454	72	79	447	170	217	1,115	2.2	5.7	4.5
Average	1,050	465	74	79	447	170	151	1,043	2.3	5.9	7.7
Coefficient of variation									0.23	0.24	0.39
					4-bedroom houses						
467	1,740	438	74	79	447	170	155	1,553	2.5	6.6	7.2
468	1,880	635	77	79	447	170	62	1,900	2.2	5.8	15.9
Average	1,810	537	76	79	447	170	109	1,727	2.4	6.2	11.6
Coefficient of variation									0.07	0.07	0.38
Average for 16 houses	1,033	418	75	79	447	170	130	1,085	2.1	5.5	6.9
Coefficient of variation, 16 houses									0.26	0.27	0.84

[a] Interior temp. 1 °F *above* exterior temp. Significance of coefficients of variation for 2-bedroom houses and all 16 houses is questionable due to the negative quantity for house 585.

total than the others during August and a lower percent than the average during January in this same time period. If the energy use were uniform, day and night, one-third of the total daily use would have occurred during the 8-hr period between 2300 and 0700 hr.

c. Coincidence of Component and Total Power Demands in the Sample Houses

In order to study the contributions of the various house appliances to the maximum demands for electric power, the simultaneous demands in the sample houses at the time of the maximum demand for the entire housing area were graphed for a 4-hr period, bracketing the time of the maximum value for the months of August 1959 and January 1960. The data used for these graphs were taken from the strip recorder charts of the demand meters which recorded the average power demand in kilowatts in 15-min increments for the heat pump, the water heater, the range, and the total house load. The miscellaneous load in the house, which consisted of the lights, the toaster, the television and radio sets, the refrigerator, the clothes dryer, etc., was not metered separately, but was calculated by subtracting the sum of the range, water

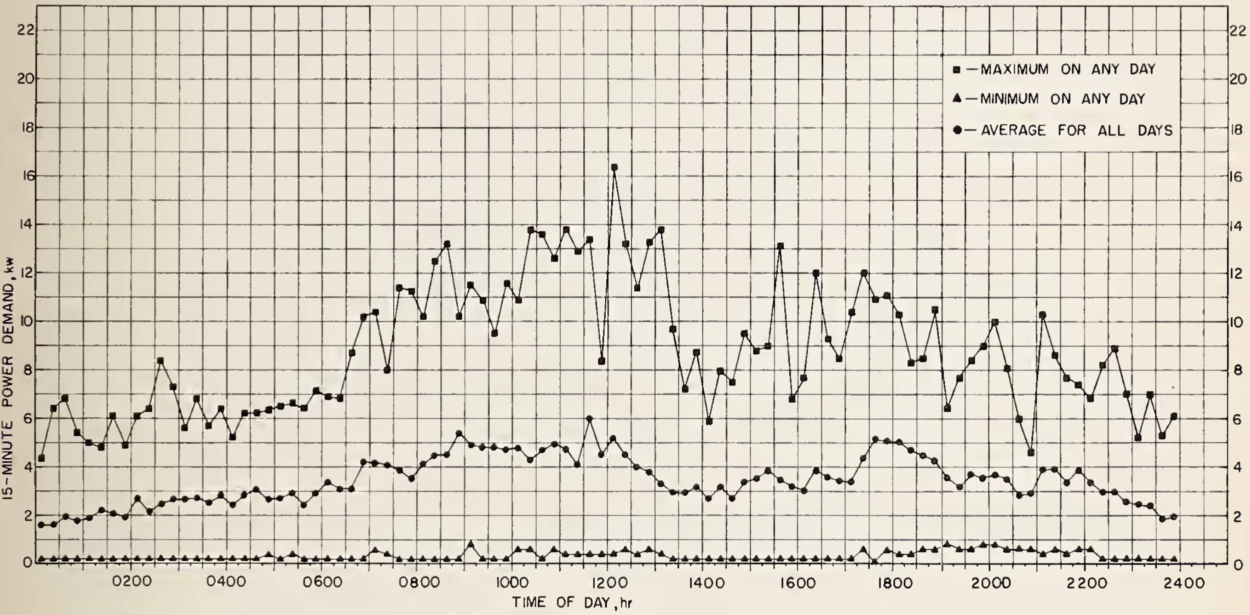

FIGURE 4. *Daily pattern of power demand in house 14, type A_1 for the period January 8, 1960–February 8, 1960.*

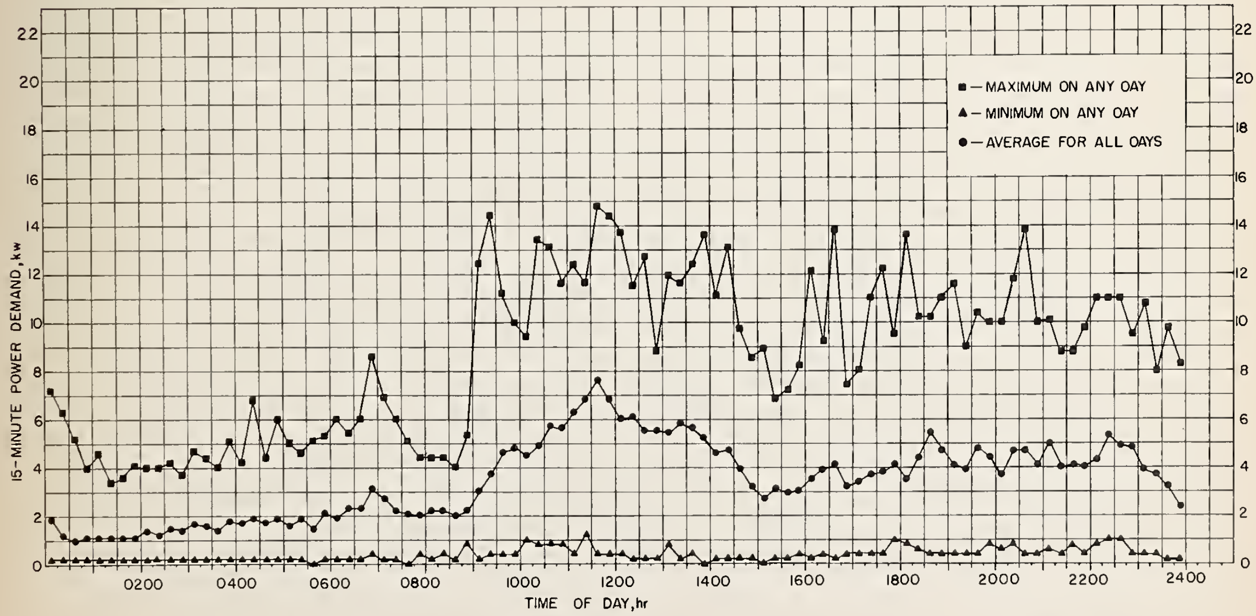

FIGURE 5. *Daily pattern of power demand in house 263, type A, for the period January 8, 1960–February 8, 1960*

heater, and heat pump demands from the total house meter demand.

These graphs for houses numbered 14, 163, and 467 are shown in figure 14 for January 1960 and in figure 15 for August 1959. The demands of the various components of the load in each house were plotted against the same time scale such that the center of the time scale coincided with the time of the maximum power demand for the entire housing area, i.e., for 1,535 houses. For the 4-hour period in January, represented in figure 14, it will be seen that the water heater was energized continuously for several hours in each house, that the heat pump was operating intermittently on a time cycle that resulted in some power demand during every 15-min period, that the range contributed very little to the total demand, and that the power demand of the miscellaneous devices varied widely from one 15-min period to the next. The total power demand in house 163 varied widely during the 4-hr period, ranging from 1 to 16.5 kw, whereas it was reason-

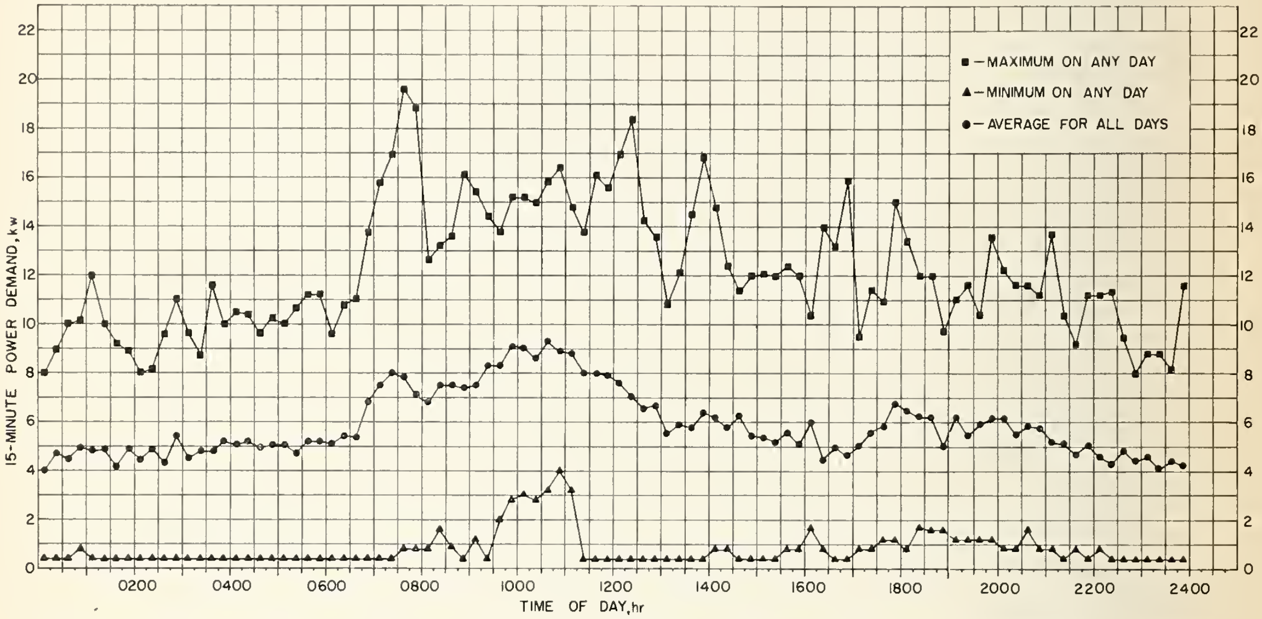

FIGURE 6. *Daily pattern of power demand in house 468, type G, for the period January 8, 1960–February 8, 1960.*

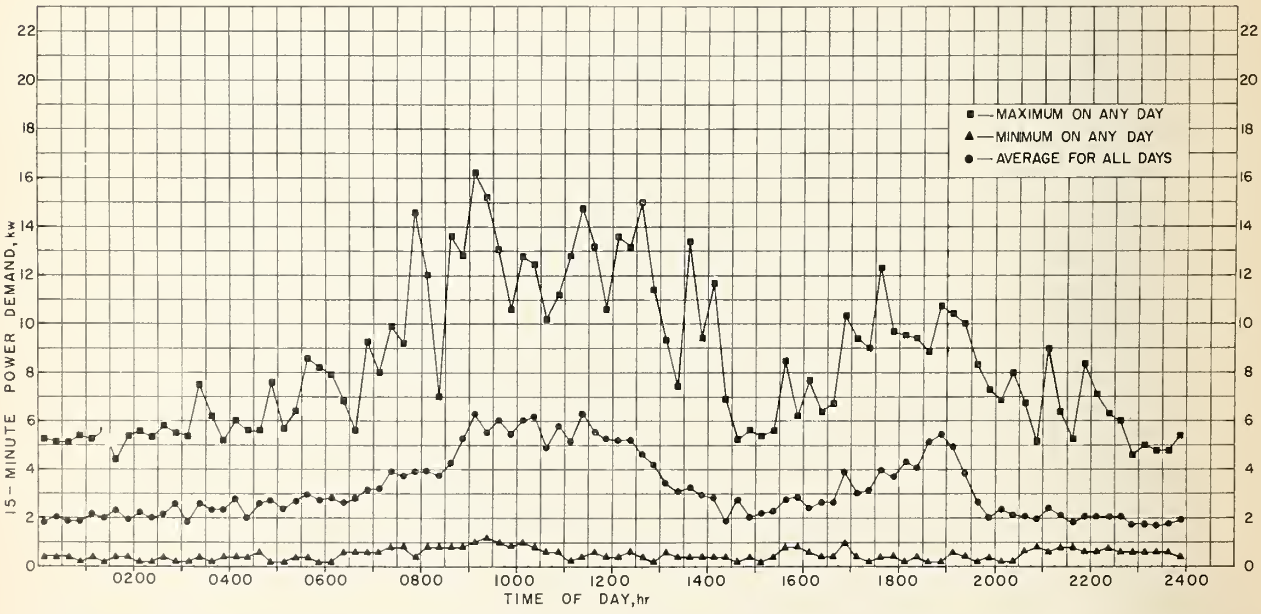

FIGURE 7. *Daily pattern of power demand in house 587, type D, for the period January 8, 1960–February 8, 1960.*

ably steady at a high level in house 467, ranging from 12.5 to 18 kw. One of the three houses had a maximum demand at 1100 hr coincident with the maximum for the entire housing area.

It should be noted that some of the graphs for miscellaneous power demand show negative values, which is a physical impossibility. It is believed that these negative values resulted from imperfect synchronization of the time clocks and the 15-min demand intervals of the four recorders from which the miscellaneous demands were determined by calculation.

In figure 15, the component power demands in the same houses are shown for a 4-hr period bracketing the time of the monthly maximum demand for the entire housing area on August 24, 1959. In each of these houses the power demand of the heat pump was fairly steady, ranging from about 2 to 6 kw for the 3 houses. The water heaters in 2 houses were energized for 1½ to 3½ hr, the miscellaneous devices varied in demand from 0 to 7 kw, but none of the cooking ranges was used. The maximum demand in each of these houses during the 4 hr was noncoincident with that for the entire housing area.

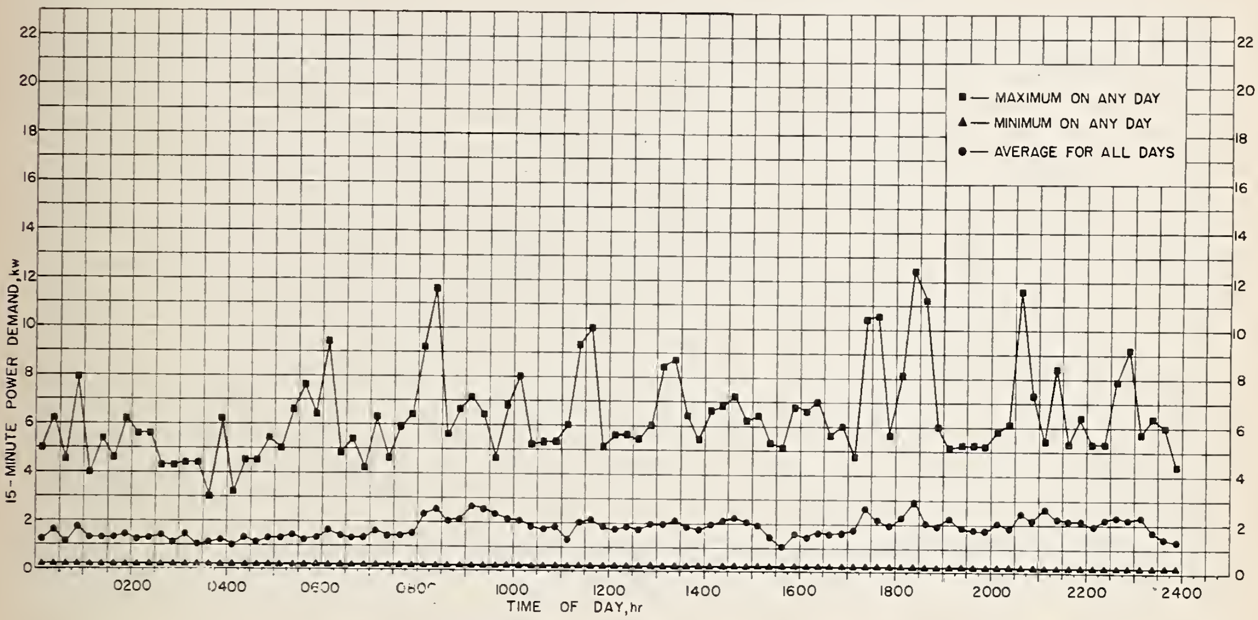

FIGURE 8. *Daily pattern of power demand in house 74, type B, for the period January 8, 1960–February 8, 1960.*

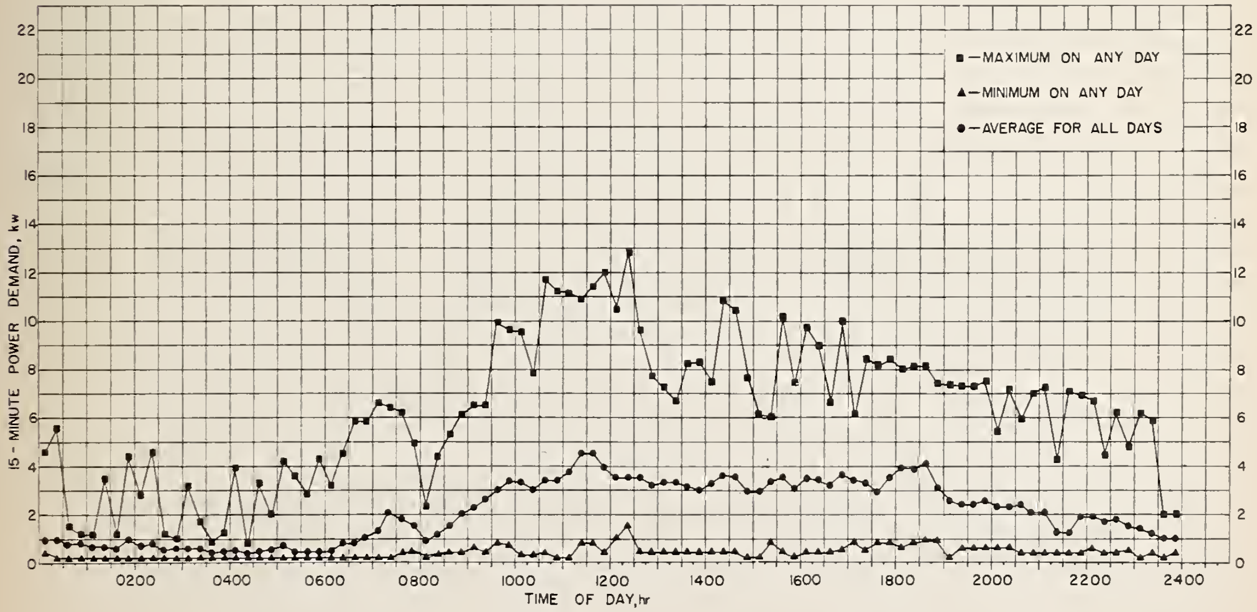

FIGURE 9. *Daily pattern of power demand in house 14, type A_1, for the period August 7, 1959–September 8, 1959.*

Figure 16 shows the averages of the demands for the house and each component for all 16 of the sample houses for the same 4-hr periods in January and August. This figure shows that there was sufficient diversity, or noncoincidence of high demands, within this group to produce a fairly steady total for each component and for the house total. On January 18 there was about a 2 kw variation during the 4-hr period related to an average value of about 8 kw for the house total, and on August 24 a variation of about 1½ kw related to an average value of about 5½ kw. This graph shows how the diversity in a group of houses reduces the wide variations in demand that are characteristic of a single house.

In order to study the factors that caused the monthly maximum demands in individual houses, the power demands of each component of the load and of the house as a whole were plotted for a 4-hr period bracketing the time of the monthly maximum demand for that house. Such graphs are shown for houses 14, 163, and 467 for 1 winter month in figure 17 and for 1 summer month in figure 18. The time at which the monthly maxi-

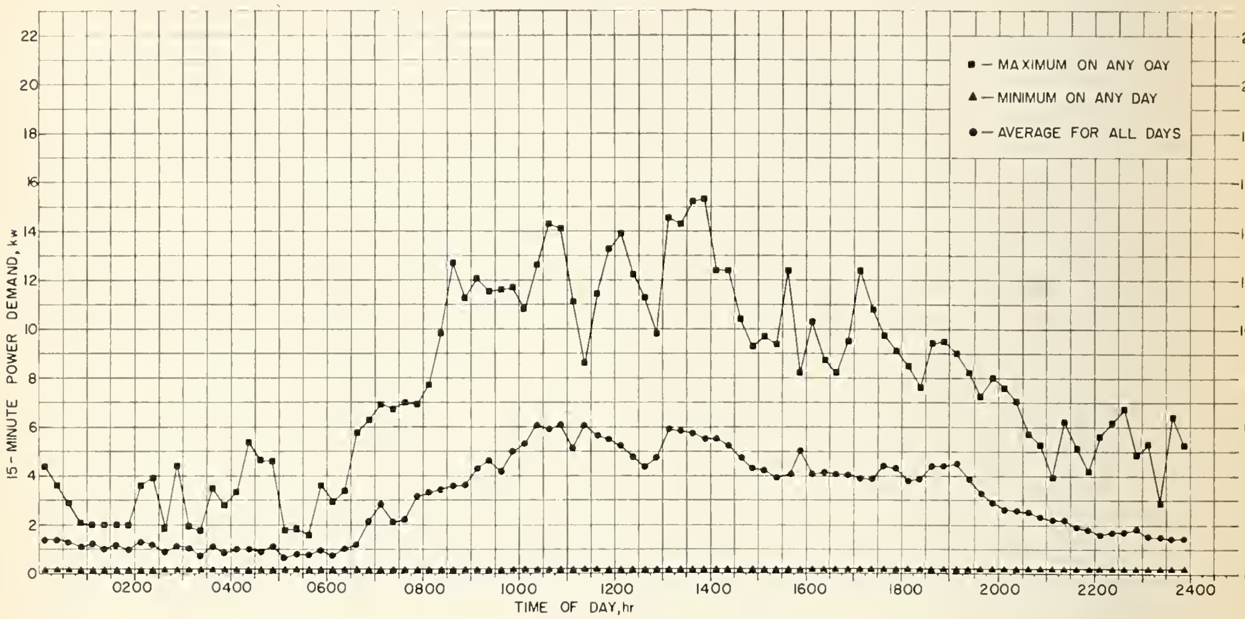

Figure 10. *Daily pattern of power demand in house 74, type B, for the period August 7, 1959–September 8, 1959.*

Figure 11. *Daily pattern of power demand in house 263, type A, for the period August 7, 1959–September 8, 1959.*

mum demand occurred in each house was placed at the center of the 4-hr time scale in each graph.

In figure 17 it will be noted that the heat pump, water heater, and miscellaneous devices contributed significantly to the maximum in each case and that the electric range contributed little or nothing in power demand. The power demand of the heat pump in houses 163 and 467 was such that use of the supplementary resistance heaters was indicated even though the outdoor temperature averaged 53 °F in the case of house 163. A sustained demand in excess of 15 kw for 3 hr occurred in house 163 as a result of long steady operation of the heat pump and water heater. The high demands in the other two houses were of much shorter duration.

A comparison of figures 17 and 18 shows that the maximum total power demand in each of the three sample houses was higher during January than during August. However, the same three components; namely, the heat pump, water heater, and miscellaneous devices, were the principal contributors to the maximum power demands during both seasons. The water heater

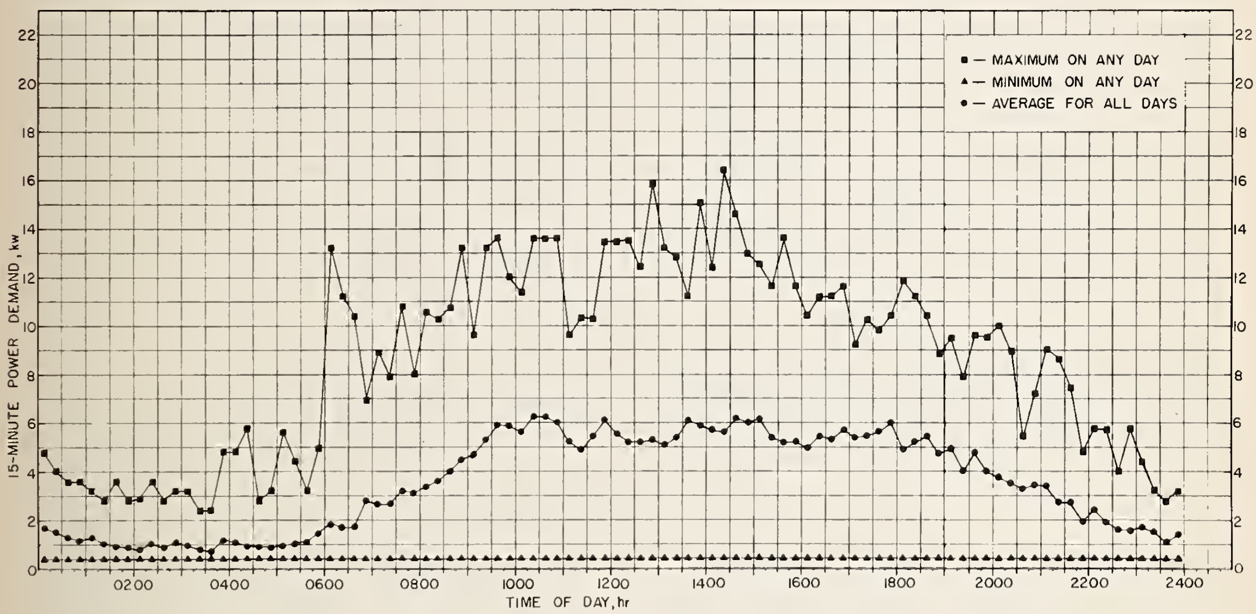

FIGURE 12. *Daily pattern of power demand in house 468, type G, for the period August 7, 1959–September 8, 1959.*

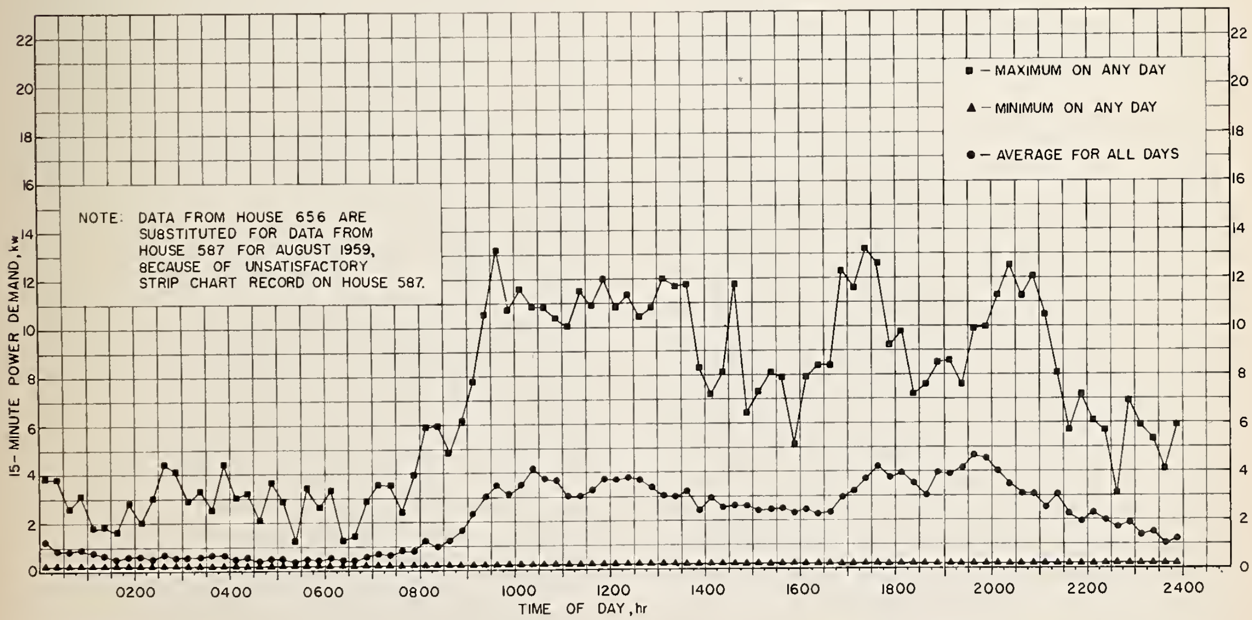

FIGURE 13. *Daily pattern of power demand in house 656, type D, for the period August 7, 1959–September 8, 1959.*

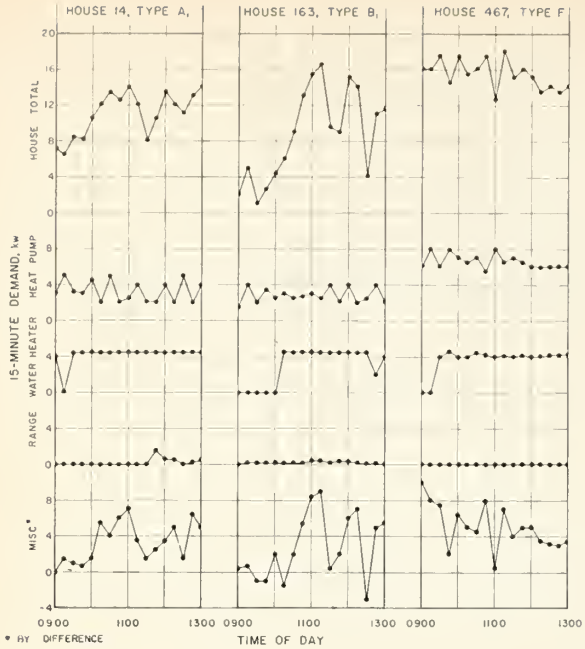

FIGURE 14. *Total and component 15-min power demands in 3 sample houses for a 4-hr period bracketing the time of maximum demand for the entire housing area which occurred during the period January 8–February 8, 1960.*

Time of maximum demand for the housing area, 1100 hr, on January 18, 1960. Average outdoor temperature during 4-hr period, 31.4 °F.

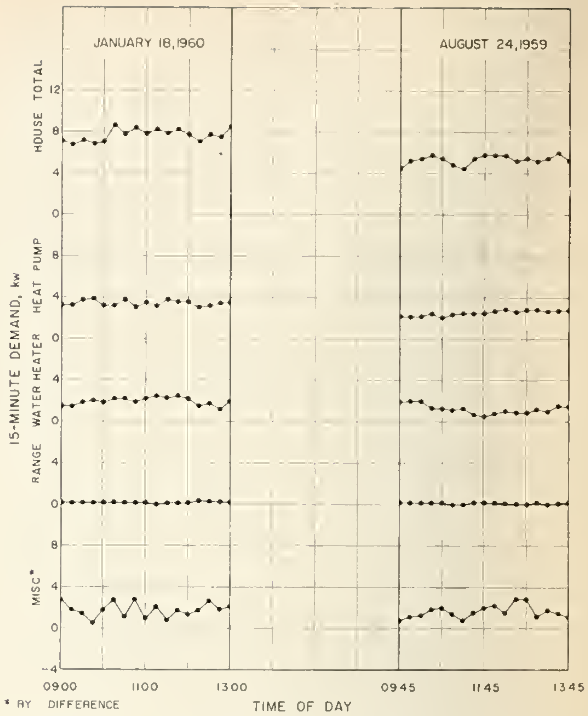

FIGURE 16. *Average of the total and component 15-min power demands for 16 sample houses during a 4-hr period bracketing the time of maximum demand for the entire housing area which occurred during the periods January 8–February 8, 1960, and August 7–September 8, 1959.*

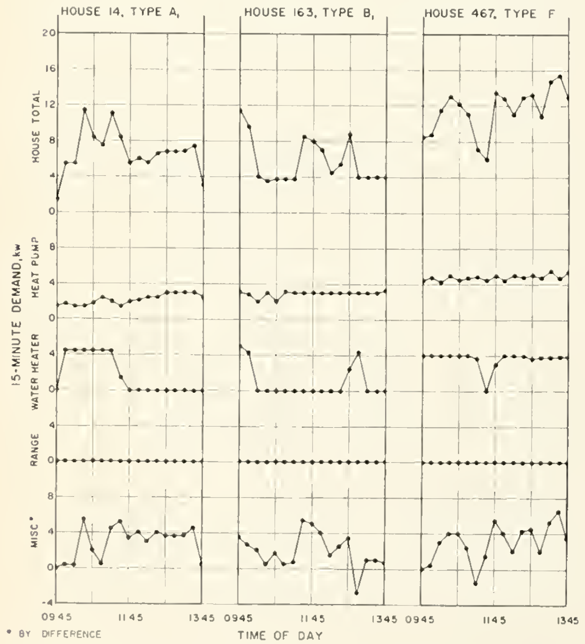

FIGURE 15.—*Total and component 15-min power demands in 3 sample houses for a 4-hr period bracketing the time of maximum demand for the entire housing area which occured during the period August 7–September 8, 1959.*

Time of maximum demand for the housing area, 1145 hr, on August 24, 1959. Average outdoor temperature during 4-hr period, 92.2 °F.

FIGURE 17. *Total and component 15-min power demands in 3 sample houses for a 4-hr period bracketing the time of maximum total demand for each house occurring during the period January 8–February 8, 1960.*

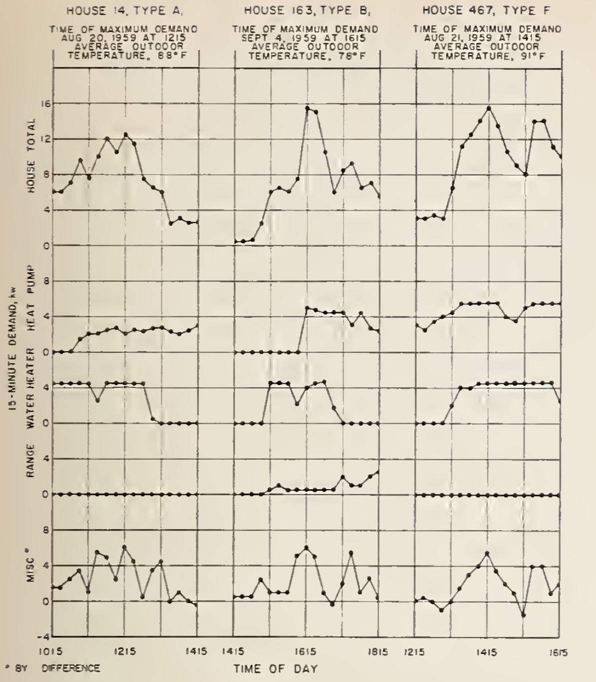

FIGURE 18. *Total and component 15-min power demands in 3 sample houses for a 4-hr period bracketing the time of maximum total demand for each house occurring during the period August 7–September 8, 1959.*

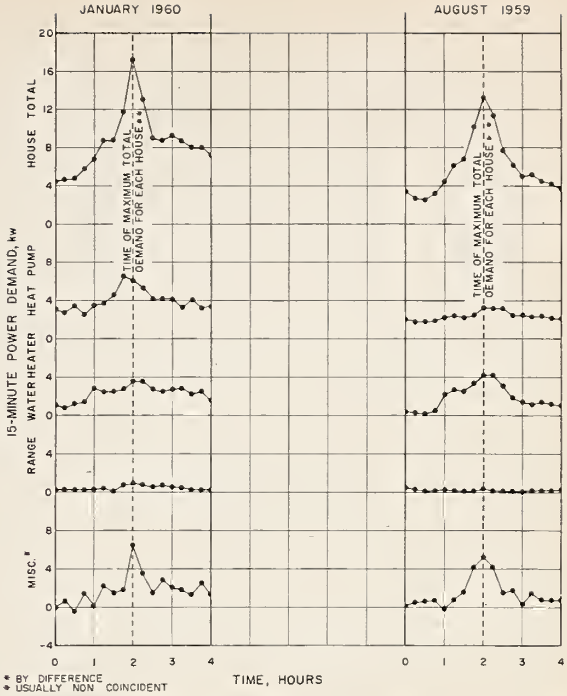

FIGURE 19. *Average of the total and component 15-min power demands for 15 sample houses during a 4-hr period bracketing time of maximum total demand for each house which occurred during the periods January 8–February 8, 1960, and August 7–September 8, 1959.*

provided a fixed demand whenever it was energized, winter or summer, whereas the heat pump provided a somewhat lower maximum demand in the summer because the supplementary resistance heaters would ordinarily never be used during the summer.

Figure 19 shows the type of maximum demands that would have occurred if the maximum demand in all of the 15 sample houses represented by the figure had occurred coincidentally. The data for house 263 were not continuous throughout the 4-hr period and for this reason were not included in the averages plotted in figure 19. Figure 19 shows that the average of the maxima for the 15 houses was about 17 kw whereas figure 16 shows that the average demand of the 16 houses at the time of the maximum demand for the entire housing area was only about 8 kw during the month of January 1960. During the month of August 1959, the maximum 15-min demands in the 16 sample houses averaged about 13 kw whereas the average 15-min demand at the time of the maximum demand in the entire housing area was about 5½ kw. Figure 19 shows a high degree of coincidence between the maximum demands of each of the components of the load in the sample houses and the maximum for the house as a whole during both the winter and summer months used for illustration.

In order to evaluate the magnitude of the component and total power demands in each of the sample houses in a more comprehensive way than was possible with the limited graphical presentation in figures 14 to 19, tables 14 to 19 were prepared to show coincident power demands in all the sample houses for 3 winter months and 3 summer months at the time of the monthly maximum power demand for the entire housing area.

Considering winter operation first, tables 14 to 16 show that the average total house demand for the 16-house sample approximated the average for the entire housing area during 2 of the winter months studied, viz, January and February. Based on averages for the 16-house sample, the heat pump contributed from 48 to 62 percent of the total house load, the water heater from 19 to 29 percent, the miscellaneous devices from 12 to 21 percent, and the electric range from ½ to 3 percent. It will be noted that the heat pump in every house used some energy during the 15-min period representing the maximum demand for each of the 3 months, and that the average power demand for the heat pump in all the sample houses ranged from 3.6 to 5.0 kw for the 3 months. The water heaters in 5 to 8 houses, in different months, were energized at the time of the maximum demand, and in only a few cases were the electric ranges using a significant amount of energy. Tables 14 to 16 show that the maximum demand for the entire housing area occurred between 0900 and 1100 hr for the 3 winter months represented.

Tables 17 to 19 show that in the summer months of June and August 1959 the average total house demand for the 16-house sample exceeded the average for the entire housing area by amounts up to 16 percent and was less than the average for the entire housing area by 17 percent in July. Based on averages for the 16 sample houses, the heat pump contributed from 35 to 58 percent of the total house load, the water heater from 9 to 25 percent, the miscellaneous devices from 20 to 49 percent, and the electric range from 1 to 4 percent. The tables show that the heat pump in a large majority of the houses operated during a part of the 15-min period representing the maximum demand, water heaters in 3 to 7 houses were energized at the time of maximum demand, and very few of the electric ranges contributed a significant amount to the total load. Tables 17 to 19 show that the maximum demand for the entire housing area occurred between 1000 hr and noon for the 3 summer months studied.

The negative values that appear for the power demand of the miscellaneous devices in tables 14 to 19 indicate that the demand periods were not perfectly synchronized and that the reported demand values do not represent simultaneous occurrences in some cases. However, the demands reported for the heat pump, water heater, electric range, and the house total are recorded values that certainly occurred within a few minutes of each other.

Table 14. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, December 10, 1959–January 8, 1960*

(Time of housing area maximum demand: 0915, January 8, 1960)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	9.5	3.5	4.2	0	1.8
180	5.4	5.4	0	0	0
263	3.5	2.8	0	0	0.7
301	6.0	2.4	0	0	3.6
585	4.3	2.0	0	0	2.3
843	[b] 0	[b] 0.2	[b] 0	[b] 0	[b] −0.2
3-bedroom houses					
4	3.3	2.5	2.7	0	−1.9
74	(c)	(c)	(c)	(c)	(c)
163	6.0	(c)	0	.01	(c)
172	3.5	1.2	0	0	2.3
577	6.5	5.6	0	0	0.9
587	4.8	3.6	0	0	1.2
656	2.0	0.2	4.2	0.4	−2.8
770	5.1	3.0	3.0	0	−0.9
4-bedroom houses					
467	12.6	7.9	4.0	0	0.7
468	8.0	6.7	0	0	1.3
Average for sample houses	5.8	3.6	1.3	.03	0.7
Average for 1,535 houses	7.6				

[a] Calculated by difference.
[b] House No. 843 apparently not occupied. These data not included in the average.
[c] Not available.

Table 15. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, January 8–February 8, 1960*

(Time of housing area maximum demand: 1100, Jan. 18, 1960)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	13.8	2.1	4.8	0	6.9
180	1.2	3.7	0	0	−2.5
263	7.5	3.5	4.4	0	−0.4
301	8.0	4.0	0	0	4.0
585	4.3	2.2	0	0	2.1
843	4.4	4.0	0	0	0.4
3-bedroom houses					
4	3.0	2.7	0	0	0.3
74	2.2	1.8	0	0	0.4
163	15.5	3.6	4.5	0.8	6.6
172	6.0	1.8	4.7	0.4	−0.9
577	10.8	9.0	0	0	1.8
587	8.5	1.8	5.0	0.2	1.5
656	1.4	4.0	0	0.1	−2.7
770	7.0	1.8	4.2	0	1.0
4-bedroom houses					
467	13.3	8.0	4.0	0	1.3
468	13.4	3.7	3.5	0	6.2
Average for sample houses	7.5	3.6	2.2	0.1	1.6
Average for 1,535 houses	8.1				

[a] Calculated by difference.

Table 16. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, February 8 to March 8, 1960*

(Time of housing area maximum demand: 1015, March 2, 1960)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	6.7	5.9	0.0	0.0	1.7
180	12.7	3.5	4.7	.0	4.5
263	9.5	8.5	2.4	.0	−1.4
301	14.0	6.0	3.1	.0	4.9
585	7.0	4.2	0.0	.2	2.8
843	3.5	3.7	.0	.0	−0.2
3-bedroom houses					
4	6.0	6.1	0.0	0.0	−0.1
74	1.2	3.5	.0	3.0	−5.3
163	13.9	2.7	4.0	0.2	7.0
172	13.5	3.5	4.4	.0	5.6
577	8.9	7.0	0.0	1.2	0.7
587	6.4	4.6	.0	0.0	1.8
656	3.2	2.2	.0	.0	1.0
770	11.9	3.4	4.0	.4	4.1
4-bedroom houses					
467	10.9	7.9	0.2	0.0	2.8
468	11.4	7.8	4.4	.0	−0.8
Average for sample houses	8.8	5.0	1.7	0.3	1.8
Average for 1,535 houses	9.0				

[a] Calculated by difference.

The total and coincident component 15-min demands occurring at the time of the monthly maximum total demand in each sample house are summarized for 3 winter months in tables 20 to 22 and for 3 summer months in tables 23 to 25. It will be noted in these tables that none of the maximum demands of the sample houses during either winter or summer occurred coincidentally with the maximum demand of the entire housing area listed in tables 14 to 19. In the 3 winter months, the average of these maximum values ranged from 17.2 to 18.2 kw, of which about 35 percent was power used by the heat pump, about 20 percent was used by the water heater, about 5 percent was used by the electric range, and about 39 percent was used by the miscellaneous devices. Tables 20 to 22 also show that, for the 3 winter months, the 15-min power demand exceeded 1 kw for 12 to 16 heat pumps, for 13 to 15 water heaters, and for 3 to 4 electric ranges in the sample houses at the time of the maximum 15-min monthly power demand in each house. At the same time, the miscellaneous devices in 14 to 16 of the sample houses were using more than 1 kw of electric power.

For the 3 summer months, the average of the maximum monthly power demands of the 16 sample houses ranged from 13.8 to 13.9 kw, of which about 23 percent was power used by the heat pump, about 26 percent was used by the water heater, about 3 percent was used by the electric range, and about 45 percent was used by the mis-

Table 17. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, June 8 to July 7, 1959*

(Time of housing area maximum demand: 1045, June 29, 1959)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	12.2	1.8	0.6	0.0	9.8
180	3.1	1.5	.0	.0	1.6
263	5.4	0.0	3.4	.0	2.0
301	2.7	2.7	0.0	.0	0.0
585	3.2	0.0	.0	.0	3.2
843	7.0	2.8	3.8	.0	0.4
3-bedroom houses					
4	4.2	2.1	3.6	0.0	−1.5
74	2.5	2.0	0.0	.0	0.5
163	5.8	3.0	.0	.0	2.8
172	3.3	1.5	.8	.5	0.5
577	2.0	2.0	.0	.1	−.1
587	3.2	2.1	.0	.0	1.1
656	0.9	1.1	.0	.0	−0.2
770	8.0	0.0	.0	.0	8.0
4-bedroom houses					
467	9.4	4.2	3.7	0.0	1.5
468	9.4	([b])	4.1	0.0	([b])
Average for sample houses	5.1	1.8	1.3	0.04	2.0
Average for 1,535 houses	4.9				

[a] Calculated by difference.
[b] Not available.

Table 18. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, July 7 to August 7, 1959*

(Time of housing area maximum demand: 1145, August 3, 1959)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	8.5	2.1	4.5	0	1.9
180	2.0	2.1	0	0	−0.1
263	7.8	1.9	4.9	0	1.0
301	2.8	2.1	0	0	0.7
585	2.4	2.0	0	0	0.4
843	2.0	0.8	0	0	1.2
3-bedroom houses					
4	3.0	2.0	0	0	1.0
74	8.2	2.4	0.7	0.4	4.7
163	4.5	3.0	0	0	1.5
172	2.5	3.0	0	0.5	−1.0
577	2.8	2.7	0	0	0.1
587	3.4	2.4	3.0	0.2	−2.2
656	0.9	2.3	0	0	−1.4
770	3.4	0	0	0	3.4
4-bedroom houses					
467	5.5	3.8	0	0	1.7
468	4.8	4.4	0	0	0.4
Average for sample houses	4.0	2.3	0.8	0.1	0.8
Average for 1,535 houses	4.8				

[a] Calculated by difference.

Table 19. *Total and component 15-min power demands in each sample house at the time of monthly maximum demand for the entire housing area, August 7 to September 8, 1959*

(Time of housing area maximum demand: 1145, August 24, 1959)

Contractor's house No.	House total	Heat pump	Hot water heater	Range	Misc.[a]
2-bedroom houses					
	kw	*kw*	*kw*	*kw*	*kw*
14	5.7	2.0	0	0	3.7
180	1.6	2.0	0	0	−0.4
263	3.3	0	0	0	3.3
301	5.3	3.0	0	0	2.3
585	0.4	0	0	0	0.4
843	2.6	2.0	0	0.4	0.2
3-bedroom houses					
4	2.8	2.3	0	0	0.5
74	11.4	2.8	0	1.0	7.6
163	8.0	3.0	0	0	5.0
172	9.4	2.0	2.0	0.5	4.9
577	4.6	2.4	2.1	0	0.1
587	--------	--------	--------	--------	--------
656	6.7	3.4	0	0.2	3.1
770	3.2	2.0	0	0	1.2
4-bedroom houses					
467	13.5	5.2	3.2	0	5.1
468	6.3	0.7	0	1.0	4.6
Average for sample houses	5.7	2.2	0.5	0.2	2.8
Average for 1,535 houses	4.9				

[a] Calculated by difference.

cellaneous devices. Tables 23 to 25 show that the heat pumps in 14 to 15 sample houses, the water heaters in 13 to 14 sample houses, and the electric ranges in 1 to 2 sample houses were each using more than 1 kw of electric power at the time of the maximum summer power demand. At the same time the miscellaneous devices in 14 to 16 of the sample houses were using more than 1 kw of electric power.

The power demand data shown in tables 20 to 25 show that the miscellaneous devices, with one exception, made a larger contribution to the monthly maximum demand in the sample houses on the average than any of the other components of the load during both winter and summer conditions.

Tables 20 to 25 show that maximum demands in the individual houses occurred on different days and at different times of the day in most cases, both winter and summer. A study of the demand charts and the charts from the outdoor temperature recorders also showed that the maximum demands in the individual houses occurred at various outdoor temperatures. In the period from January 8 to February 8, 1960, the outdoor temperatures, rounded to the nearest degree at the time of the monthly maximum demands in the 16 sample houses, ranged from 21 to 58 °F, distributed as follows:

Outdoor temperature range, °F	*Number of cases*
21 to 30	2
31 to 40	8
41 to 50	4
51 to 60	2

In the period from August 7 to September 8, 1959, the outdoor temperatures, rounded to the nearest degree, at the time of the monthly maximum demands in the 16 sample houses, ranged from 78 to 93 °F, distributed as follows:

Outdoor temperature range, °F	*Number of cases*
71 to 80	2
81 to 90	10
91 to 100	4

These results indicate that the maximum demands in individual houses during winter and summer were not directly related to the magnitude of the heating and cooling loads and confirm the findings that the miscellaneous loads contributed more to the maximum demand than do the heat pumps.

Tables 26 to 31 show the monthly maximum power demand for each of the 16 sample houses and the monthly maximum power demand of each of the four components comprising the total house load. The monthly maximum power demands of the components did not necessarily

TABLE 20. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, December 10, 1959 to January 8, 1960*

Contractor's house No.	Time of maximum total demand for house		Maximum total demand for house	Coincident component demand			
	Date	Time		Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	Jan. 1, 1960	1130	16.8	5.8	4.5	0.1	6.4
180	Jan. 7, 1960	1730	16.7	4.0	4.5	2.5	5.7
263	Jan. 6, 1960	1230	17.1	7.2	5.0	0	4.9
301	Jan. 1, 1960	0845	17.6	7.0	4.2	0	6.4
585	Dec. 16, 1959	0600	18.8	7.9	4.4	0.7	5.8
843	Jan. 6, 1960	1145	[b] 11.6	[b] 8.4	[b] 3.7	[b] 0	[b] −0.5
			3-bedroom houses				
4	Jan. 8, 1960	0730	16.6	7.6	4.5	3.8	0.7
74	Dec. 18, 1959	0800	12.0	6.0	0	2.9	3.1
163	Jan. 6, 1960	1300	20.8	4.4	2.7	0.1	13.6
172	Jan. 7, 1960	1145	18.2	7.0	4.8	.4	6.0
577	Jan. 8, 1960	0700	19.2	9.0	3.5	0	6.7
587	Dec. 30, 1959	1015	15.9	2.3	4.9	0	8.7
656	Jan. 5, 1960	1045	17.0	4.6	4.4	0.1	7.9
770	Dec. 30, 1959	2015	16.2	9.1	4.4	.5	2.2
			4-bedroom houses				
467	Dec. 28, 1959	0830	17.9	9.4	4.2	0.2	4.1
468	Dec. 28, 1959	1045	17.9	4.5	2.9	0	10.5
Average for 15 houses			17.2	6.4	3.9	0.8	6.2

[a] Calculated by difference.
[b] House No. 843 apparently not occupied. These data not included in the average.

TABLE 21. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, January 8 to February 8, 1960*

Contractor's house No.	Time of maximum total demand for house		Maximum total demand for house	Coincident component demand			
	Date	Time		Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	Jan. 17, 1960	1215	16.1	3.0	4.5	0	8.6
180	Jan. 20, 1960	1330	17.9	0	4.5	1.0	12.4
263	Jan. 20, 1960	1145	14.8	0	5.0	0	9.8
301	Jan. 29, 1960	0915	16.9	2.5	4.2	0	10.2
585	Jan. 20, 1960	1715	18.8	6.0	4.8	0.9	7.1
843	Jan. 25, 1960	1000	16.2	8.5	0	0	7.7
			3-bedroom houses				
4	Jan. 31, 1960	0900	17.6	1.0	2.4	4.0	10.2
74	Feb. 5, 1960	1815	12.4	4.0	3.0	3.0	2.4
163	Feb. 6, 1960	1430	19.6	9.2	4.5	1.0	4.9
172	Jan. 16, 1960	1815	18.6	5.9	4.5	4.0	4.2
577	Jan. 17, 1960	0845	19.4	4.0	2.0	2.0	11.4
587	Feb. 6, 1960	0900	16.2	10.0	4.0	1.0	1.2
656	Jan. 25, 1960	0915	15.8	1.0	4.5	0.2	10.1
770	Jan. 18, 1960	1300	14.6	4.0	4.0	0.2	6.4
			4-bedroom houses				
467	Jan. 22, 1960	0715	20.8	13.9	3.8	0	3.1
468	Jan. 21, 1960	0730	19.4	14.0	2.8	0	2.6
Average for 16 houses, where applicable			17.2	5.4	3.7	1.1	7.0

[a] Calculated by difference.

TABLE 22. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, February 8 to March 8, 1960*

Contractor's house No.	Time of maximum total demand for house: Date	Time	Maximum total demand for house	Coincident component demand: Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	Mar. 3, 1960	1145	16.7	5.7	4.6	0	6.4
180	Feb. 27, 1960	1030	17.7	7.4	4.5	0	5.8
263	Feb. 19, 1960	1330	18.1	5.5	5.0	0	7.6
301	Feb. 15, 1960	0845	17.6	(b)	(b)	(b)	(b)
585	Feb. 17, 1960	0545	19.1	5.6	4.4	0	9.1
843	Feb. 26, 1960	0700	17.6	8.1	3.4	3.1	3.0
			3-bedroom houses				
4	Mar. 3, 1960	0730	17.6	2.0	4.7	4.4	6.5
74	Feb. 14, 1960	2145	17.2	13.8	3.0	3.8	−3.4
163	Mar. 3, 1960	1115	18.2	0.4	3.5	0.1	14.2
172	Mar. 3, 1960	1145	17.6	0	4.7	0	12.9
577	Feb. 29, 1960	0715	20.1	10.2	4.5	(b)	5.4
587	Mar. 2, 1960	0900	17.2	10.4	0	0	6.8
656	Mar. 6, 1960	1645	17.8	0	4.5	0.4	12.9
770	Feb. 24, 1960	1000	16.8	3.3	0	.4	13.1
			4-bedroom houses				
467	Feb. 29, 1960	0815	20.8	10.8	4.3	0	5.7
468	Mar. 1, 1960	1115	20.2	7.8	3.0	0	9.4
Average for 15 houses			18.1	6.1	3.6	0.9	7.7

[a] Calculated by difference.
[b] Not available.

TABLE 23. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, June 8 to July 7, 1959*

Contractor's house No.	Time of maximum total demand for house: Date	Time	Maximum total demand for house	Coincident component demand: Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	June 21, 1959	1430	13.9	3.1	0.6	0.4	9.8
180	July 4, 1959	1230	14.7	2.8	4.9	1.8	5.2
263	June 26, 1959	1100	13.4	2.8	4.4	0	6.2
301	July 1, 1959	1630	13.4	3.1	4.5	0	5.8
585	June 10, 1959	1015	13.4	3.0	5.0	0	5.4
843	June 22, 1959	1030	12.2	2.8	4.2	0.2	5.0
			3-bedroom houses				
4	June 29, 1959	0830	11.8	0.9	4.8	0	6.1
74	July 1, 1959	2000	13.4	13.2	3.0	0	−2.8
163	June 8, 1959	1145	15.1	4.8	5.0	0.5	4.8
172	July 4, 1959	2045	14.4	3.0	4.5	0	6.9
577	June 22, 1959	2030	12.5	1.6	3.3	0	7.6
587	July 6, 1959	1130	14.1	2.6	4.7	0.9	5.9
656	July 5, 1959	1715	13.0	1.3	2.0	0	9.7
770	June 8, 1959	2100	14.2	1.1	4.5	0	8.6
			4-bedroom houses				
467	June 28, 1959	1430	15.4	5.4	0	0	10.0
468	June 27, 1959	1215	15.9	(b)	0	0.5	(b)
Average for 16 houses, where applicable			13.8	3.4	3.5	0.3	6.3

[a] Calculated by difference.
[b] Not available.

TABLE 24. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, July 7–August 7, 1959*

Contractor's house No.	Time of maximum total demand for house: Date	Time	Maximum total demand for house	Coincident component demand: Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	July 20, 1959	1145	12.7	2.5	4.2	2.4	3.6
180	Aug. 5, 1959	0900	11.7	1.0	(b c)	0	(b)
263	Aug. 3, 1959	1230	14.0	2.7	4.8	0	6.5
301	July 20, 1959	0845	13.8	3.0	4.8	0	6.0
585	Aug. 6, 1959	1890	14.9	2.0	2.4	3.2	7.3
843	July 17, 1959	1830	11.7	2.0	2.8	0.5	6.4
			3-bedroom houses				
4	July 10, 1959	1600	13.7	3.7	0	0	10.0
74	Aug. 1, 1959	1145	13.2	3.2	4.2	0	5.8
163	July 11, 1959	1445	17.7	2.8	0	0.5	14.4
172	Aug. 5, 1959	1145	14.4	2.4	4.2	1.0	6.8
577	July 25, 1959	1500	14.0	2.5	4.6	0.4	7.5
587	July 8, 1959	1900	13.2	6.5	4.6	0	2.1
656	July 9, 1959	1145	13.6	0.6	4.4	0	8.6
770	Aug. 6, 1959	1330	12.6	2.9	4.0	0	5.7
			4-bedroom houses				
467	July 16, 1959	1130	13.6	2.5	4.0	0.6	6.5
468	Aug. 6, 1959	1630	16.8	6.0	4.0	0.6	6.2
Average for 16 houses, where applicable			13.9	2.9	3.5	0.6	6.9

[a] Calculated by difference.
[b] Not available.
[c] Water heater not in use.

TABLE 25. *Total and component 15-min power demand occurring at the time of the monthly maximum total demand in each sample house, August 7–September 8, 1959*

Contractor's house No.	Time of maximum total demand for house: Date	Time	Maximum total demand for house	Coincident component demand: Heat pump	Hot water heater	Range	Misc.[a]
			2-bedroom houses				
			kw	*kw*	*kw*	*kw*	*kw*
14	Aug. 20, 1959	1215	12.8	2.0	4.5	0	6.3
180	Sept. 2, 1959	1315	13.4	2.8	4.4	1.4	4.8
263	Sept. 7, 1959	1200	13.5	3.0	4.4	0	6.1
301	Aug. 16, 1959	1030	14.0	3.0	4.5	0	6.5
585	Aug. 25, 1959	1745	13.7	5.0	4.6	2.7	1.4
843	Aug. 28, 1959	1245	11.5	0	0.5	0	11.0
			3-bedroom houses				
4	Sept. 8, 1959	0930	15.6	2.8	0.8	0	12.0
74	Aug. 23, 1959	1400	15.3	4.5	4.4	0	6.5
163	Sept. 4, 1959	1615	15.6	5.0	4.2	0.5	5.9
172	Aug. 17, 1959	1845	12.8	2.0	4.5	1.0	5.3
577	Aug. 20, 1959	2015	13.6	2.2	4.6	0.5	6.3
587	Aug. 10, 1959	1130	12.4	2.1	4.7	0.5	5.1
656	Sept. 1, 1959	0945	13.4	3.0	4.4	0	6.0
770	Aug. 17, 1959	0645	13.2	1.2	4.2	0	7.8
			4-bedroom houses				
467	Aug. 21, 1959	1415	15.2	5.5	4.3	0	5.4
468	Aug. 29, 1959	1415	16.8	7.2	4.4	0	5.2
Average for 16 houses			13.9	3.2	4.0	0.4	6.4

[a] Calculated by difference.

coincide with the monthly maximums for the house as a whole. The degree of coincidence between the monthly component maximums and the monthly maximum for the entire house is shown as a coincidence factor in these tables. For the purpose of these tables, the coincidence factor is defined as the ratio of the measured maximum power demand of the house to the sum of the maximum power demands of the appliance components in the house over a period of a month. The time at which the maximum 15-min power demand occurred for each house is reported in tables 20 to 25, inclusive, for these same months.

Tables 26 to 28, for the 3 winter months used for analysis, show that the maximum power demands for the various components were fairly consistent from month to month when comparing averages for all of the sample houses. The maximum power demands for the heat pump ranged from 5.6 to 14.8 kw in different houses with the 3-month average for all houses being 9.2 kw. Individual houses cannot reasonably be compared because different house types were equipped with different amounts of supplementary resistance heating, and houses 467 and 468 were equipped with two heat pumps whereas the others in the sample contained only one. The maximum power demand of the water heaters varied from 4.4 to 5.4 kw, probably due to voltage variations at different houses. The maximum

TABLE 26. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, December 10, 1959–January 8, 1960*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	16.8	6.6	4.8	3.7	6.4	.78
180	16.7	7.7	4.8	4.0	5.2	.77
263	17.1	8.6	5.2	[b] 1.0	11.7	[b] .65
301	17.6	7.5	4.5	7.6	7.6	.65
585	18.8	8.4	5.0	3.7	7.4	.77
843	[c] 11.6	[c] 8.6	[c] 5.2	[c] 0	[c] 5.0	[c] .62
3-bedroom houses						
4	16.6	8.4	4.8	5.1	5.1	.71
74	12.0	8.1	4.6	6.2	3.1	.55
163	20.8	11.2	5.2	4.3	4.7	.82
172	18.2	9.3	5.0	4.5	6.1	.73
577	19.2	10.3	5.0	5.6	5.8	.72
587	15.9	10.2	5.1	4.2	6.9	.60
656	17.0	9.9	4.8	4.1	9.9	.59
770	16.2	9.8	4.8	3.6	6.7	.65
4-bedroom houses						
467	17.9	12.2	4.6	3.0	5.0	.72
468	17.9	14.0	4.8	4.3	5.7	.62
Average for 15 houses	17.2	9.5	4.9	4.6	6.5	.69

[a] From table 20.
[b] Range meter incorrectly wired. These data not included in the average.
[c] House No. 843 apparently vacant. These data not included in the average.

TABLE 27. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, January 8–February 8, 1960*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	16.1	6.8	4.8	5.7	8.2	.63
180	17.9	7.7	4.8	2.8	8.5	.75
263	14.8	8.7	5.2	[b] 0.6	8.8	[b] .64
301	16.9	7.4	4.6	4.0	7.2	.73
585	18.8	8.4	4.9	3.9	6.0	.81
843	16.2	8.3	5.4	4.2	6.2	.67
3-bedroom houses						
4	17.6	8.4	4.8	6.3	6.5	.68
74	12.4	7.6	4.5	5.7	5.2	.54
163	19.6	10.8	5.2	4.9	8.2	.67
172	18.6	6.6	5.0	5.4	6.0	.81
577	19.4	10.5	4.9	5.0	8.4	.67
587	16.2	10.1	5.1	4.4	5.4	.65
656	15.8	9.7	4.8	4.3	7.4	.60
770	14.6	10.1	4.6	3.6	7.5	.57
4-bedroom houses						
467	20.8	14.0	4.7	3.0	5.8	.76
468	19.4	14.2	4.7	4.0	4.5	.71
Average for 16 houses, where applicable	17.2	9.3	4.9	4.5	6.9	.68

[a] From table 21.
[b] Range meter incorrectly wired. These data not included in the average.

TABLE 28. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, February 8–March 8, 1960*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	16.7	6.6	4.7	3.1	5.7	.83
180	17.7	7.8	4.7	4.1	5.3	.81
263	18.1	8.6	5.3	[b] 0.7	9.0	[b] .77
301	17.6	7.4	4.4	3.8	5.6	.83
585	19.1	8.1	5.0	5.0	4.2	.86
843	17.6	8.6	5.4	4.3	5.2	.75
3-bedroom houses						
4	17.6	7.4	4.8	5.5	9.4	.65
74	17.2	7.5	4.5	5.9	8.8	.64
163	18.2	5.6	4.6	5.3	9.1	.74
172	17.6	9.7	5.0	4.6	5.7	.70
577	20.1	10.6	4.9	5.8	5.1	.76
587	17.2	10.5	5.2	2.8	7.0	.67
656	17.8	9.4	4.7	4.4	7.9	.67
770	16.8	9.5	4.5	3.6	8.2	.65
4-bedroom houses						
467	20.8	14.8	4.7	4.0	9.8	.62
468	20.2	8.2	4.7	6.7	9.2	.70
Average for 16 houses, where applicable	18.1	8.8	4.8	4.6	7.2	.73

[a] From table 22.
[b] Range meter incorrectly wired. These data not included in the average

power demands of the electric ranges varied widely depending on the habits of the individual occupant. Probably none of the recorded maximum power demands for the electric ranges represents the full connected load of this appliance. The miscellaneous devices provided the second largest maximum power demand on the average. The biggest single electrical load included in the miscellaneous group was the clothes dryer, with a power consumption of about 5 kw. Other significant loads in the miscellaneous group were the resistance heater in the bathroom, the washing machine, and such appliances as electric irons and toasters.

The coincidence factor for individual houses ranged from 0.54 to 0.87 during the 3 winter months, but the average value for all houses in the sample varied only between 0.68 and 0.73 in the 3-month period.

Tables 29 to 31, for the 3 summer months used for analysis, show that the maximum power demands for the various components were fairly consistent from month to month based on the averages for all the sample houses. The average of the maximum values for the total house load in all houses was 3 to 4 kw lower for the summer months than for the winter months, due almost entirely to a corresponding decrease in the maximum power demands for the heat pump in the summer. The maximum power demands of

Table 29. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, June 8–July 7, 1959*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	13.9	5.6	4.8	5.0	10.1	.55
180	14.7	3.2	5.4	3.5	6.8	.78
263	13.4	3.1	5.1	[b] 1.0	6.0	[b] .88
301	13.4	3.5	5.1	3.5	10.2	.60
585	13.4	3.1	5.0	3.4	5.5	.79
843	12.2	4.4	5.4	3.8	6.3	.61
3-bedroom houses						
4	11.8	4.4	5.3	5.4	6.2	.55
74	13.4	3.3	4.7	4.0	7.2	.70
163	15.1	7.7	5.2	4.4	11.4	.53
172	14.4	3.2	4.8	4.3	6.9	.75
577	12.5	3.2	5.1	5.4	7.6	.59
587	14.1	3.2	5.0	2.9	6.9	.78
656	13.0	7.8	5.0	3.9	7.6	.53
770	14.2	3.1	4.8	2.4	8.1	.77
4-bedroom houses						
467	15.4	5.8	4.8	3.4	9.6	.65
468	15.9	5.9	4.8	5.0	6.1	.73
Average for 16 houses, where applicable	13.8	4.4	5.0	4.0	7.7	.66

[a] From table 23.
[b] Range meter incorrectly wired. These data not included in the average.

Table 30. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, July 7–August 7, 1959*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	12.7	3.2	4.9	4.4	8.8	.60
180	11.7	3.1	[b] 0	2.0	9.8	.79
263	14.0	3.1	4.9	[c] 1.0	6.4	[c] .91
301	13.8	3.5	5.1	4.1	6.1	.73
585	14.9	3.4	4.8	3.2	6.2	.85
843	11.7	3.3	5.2	4.8	7.5	.56
3-bedroom houses						
4	13.7	5.0	5.1	3.1	10.5	.58
74	13.2	5.5	4.7	4.9	5.9	.63
163	17.7	3.3	5.0	5.3	9.8	.76
172	14.4	3.2	4.6	3.0	5.8	.87
577	14.0	3.4	4.8	6.9	6.5	.65
587	13.2	3.3	4.9	2.7	6.2	.77
656	13.6	3.5	4.7	2.5	8.6	.70
770	12.6	6.4	4.8	3.5	7.1	.58
4-bedroom houses						
467	13.6	5.5	4.6	3.0	6.6	.69
468	16.8	6.0	4.7	4.3	5.5	.82
Average for 16 houses, where applicable	13.9	4.0	4.9	3.8	7.3	.71

[a] From table 24.
[b] House No. 180 apparently unoccupied during most of this period. Water heater not in use.
[c] Range meter incorrectly wired. These data not included in the average.

Table 31. *Maximum total and component 15-min power demands occurring at any time during the month in each sample house, August 7–September 8, 1959*

Contractor's house No.	Maximum noncoincident power demands for month					Monthly coincidence factor for the house
	House [a]	Heat pump	Hot water heater	Range	Misc.	
2-bedroom houses						
	kw	*kw*	*kw*	*kw*	*kw*	
14	12.8	3.1	4.9	4.0	6.1	.71
180	13.4	3.1	5.1	3.9	4.6	.80
263	13.5	3.1	4.9	[b] 0.5	5.8	[b] .94
301	14.0	3.5	5.1	3.8	6.3	.75
585	13.7	5.4	4.9	5.1	5.1	.67
843	11.5	1.6	5.2	4.1	7.7	.62
3-bedroom houses						
4	15.6	5.0	5.0	3.9	8.4	.70
74	15.3	4.9	4.6	4.2	7.5	.72
163	15.6	5.1	5.0	4.5	6.1	.75
172	12.8	3.2	4.6	3.3	5.6	.77
577	13.6	3.2	4.8	6.1	5.8	.68
587	12.4	5.6	4.9	1.9	5.1	.71
656	13.4	3.4	4.7	4.0	6.2	.73
770	13.2	3.1	4.5	3.8	7.1	.71
4-bedroom houses						
467	15.2	5.8	4.6	4.3	5.4	.76
468	16.8	7.2	4.6	4.6	5.5	.77
Average for 16 houses, where applicable	13.9	4.1	4.8	4.1	6.1	.72

[a] From table 25.
[b] Range meter incorrectly wired. These data not included in the average.

the water heater, electric range, and miscellaneous devices were comparable, winter and summer.

Excepting house 263, the coincidence factor for the sample houses ranged from 0.53 to 0.87 during the 3 summer months, but the monthly average for all houses varied only from 0.66 to 0.72 for the 3-month period. It will be noted in tables 29 to 31 that the coincidence factor for house 263 was significantly higher than those for all other houses in the sample. Investigation revealed that the demand meter on the electric range for this house was incorrectly wired causing the meter to indicate a low value most of the time. Therefore, the coincidence factors for house 263 were not used in determining either the summer or winter average values.

d. Frequency Distribution of Power Demand Values

It was noted in figures 4 to 13 that high 15-min power demand values, somewhat lower than the monthly maximum value, occurred at various times throughout the day, usually during the period from 0630 to 2000 hr. The exact number of these occurrences cannot be counted in figures 4 to 13 because these graphs show only the one highest value of power demand occurring at each 15-min interval of the day. Information on the frequency of these high power demands is of importance in determining the requirements of the distribution system and in selecting possible devices for limiting the magnitude of the maximum power demand in the houses.

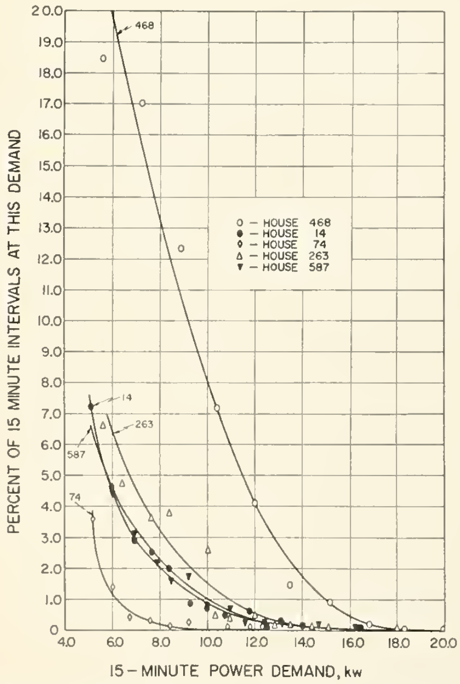

Figure 20. *Frequency distribution of 15-min power demand greater than 5 kw for 5 houses during the period January 8–February 8, 1960.*

Figures 20 and 21, representing data for January 1960 and August 1959, respectively, were plotted to show the frequency of recurrence of 15-min power demands at various levels of demand. The curves are plotted for the same 5 houses for which the daily pattern of power demand was illustrated in figures 4 to 13. Because the higher values were of primary interest, only demands greater than 5 kw were used.

An inspection of figures 20 and 21 indicates that the frequency distribution curves are approximately exponential in shape for the range of power demand values of 5 kw and higher. A mathematical expression of the form $y=Ce^{-kx}$ was used to fit curves to some of the observed data. The values of constants C and k differed somewhat for different houses; x represented the 15-min power demand in kilowatts, and y represented the percent of the total monthly demand intervals at this value of power demand.

The number of 15-min intervals in the month for which the power demand would be expected to be at any selected value from 5 kw to the maximum can be derived from figures 20 and 21 for this group of sample houses. Tables 32 and 33 show the power demands corresponding to frequencies of 0.1, 1.0, and 5.0 percent for the period January 8, 1960–February 8, 1960, and to frequencies of 0.1, 1.0, and 3.0 percent for the period August 7, 1959–September 8, 1959, taken from figures 20 and 21. Since there are ninety-six 15-min periods in a day, a frequency of 1 percent corresponds to about one 15-min period per day on the average. These tables show that the demands of houses 14, 263, and 587 were similar during January and that those for houses 14, 263, and 656 were similar during August. The de-

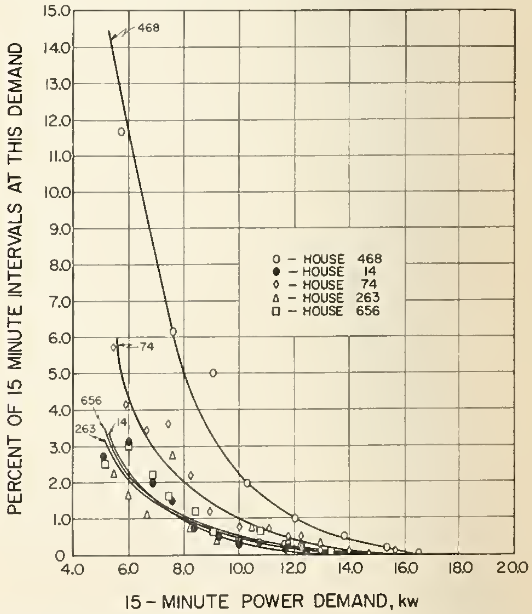

Figure 21. *Frequency distribution of 15-min power demands greater than 5 kw for 5 houses during the period August 7–September 8, 1959.*

mands for house 468, a 4-bedroom house, were larger than the others for both months whereas the demands for house 74 were the lowest of the group during January and second highest in August.

TABLE 32. *Power demands at selected frequencies of recurrence, January 8, 1960–February 8, 1960*

Selected frequency of recurrence	15-min power demand, kw, for house No.				
	14	74	263	468	587
%					
0.1	15.0	9.2	15.0	18.0	15.0
1.0	9.8	6.2	10.9	15.0	10.0
5.0	5.8	>5.0	6.8	11.5	5.8

TABLE 33. *Power demands at selected frequencies of recurrence, August 7, 1959–September 8, 1959*

Selected frequency of recurrence	15-min power demand, kw, for house No.				
	14	74	263	468	656
%					
0.1	11.6	14.3	13.5	16.0	13.7
1.0	7.9	10.0	8.0	12.0	8.2
3.0	5.5	6.9	5.2	9.3	5.4

The data obtained from house 14 for the months of January and August were plotted to show the frequency of recurrence of all power demands from zero to the maximum. Exponential curves of the form $y=Ce^{-kx}$ fit the data approximately for both months over a part or the whole of the range of demand values. The curve drawn through the observed data in figure 22 fits the values calculated from the exponential equation reasonably well from 6 kw to the maximum of about 18 kw, but bends to the right of the exponential curve for demand values from 3.5 to 6 kw. In contrast, the curve in figure 23 fits both observed and calculated values throughout the range of power demand.

The reasons for the significant difference in the shape of the frequency curves for January and August for demand levels below 3.5 kw are not fully understood. The double reversal of the slope of the frequency curve from negative to positive and back to negative again for power demands below 5 kw in figure 22 was probably related to the number and size of the more or less fixed components of the house load. Close examination of the plotted points in figures 20 and 21 for houses 263 and 587 during January and for houses 263, 14, and 74 during August, indicates that similar changes in slope of equal or lesser magnitude may have occurred in the frequency curves for some other houses. Table 34 shows the frequency of recurrence of outdoor temperatures in consecutive 5-degree temperature bands from 20 to 75 °F, based on readings to the nearest degree from the chart of one of the outdoor temperature recorders. This table indicates that the outdoor temperature was at 40 °F or lower

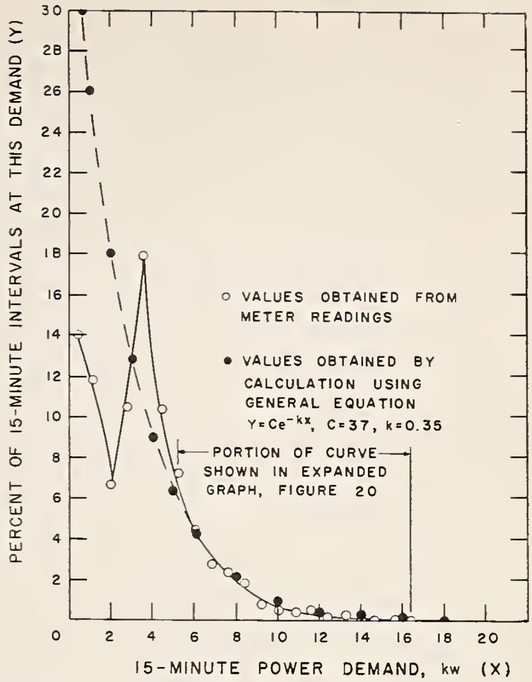

FIGURE 22. *Frequency distribution of 15-min power demands for house 14 during the period January 8–February 8, 1960.*

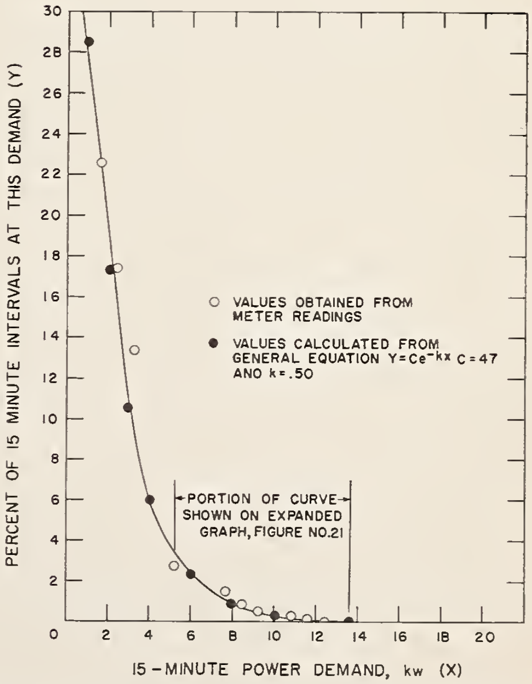

FIGURE 23. *Frequency distribution of 15-min power demands for house 14 during the period August 7–September 8, 1959.*

for nearly one-half of the total hours in the 1-month period represented by the table, thus entailing many 15-min demand periods when the heat pump operated steadily.

Table 34. *Frequency of recurrence of outdoor temperatures in selected temperature ranges at Little Rock Air Force Base, January 8–February 8, 1960*

Temperature range	No. of hours with temperatures in this range
°F	
20 to 25	45
26 to 30	70
31 to 35	90
36 to 40	150
41 to 45	120
46 to 50	95
51 to 55	75
56 to 60	40
61 to 65	35
66 to 70	20
71 to 75	5

The frequencies of recurrence of 15-min power demands at or above selected levels of demand from about 5 kw to the maximum are shown in figures 24 and 25. The same data were used for these figures as for figures 20 and 21, but in this case the frequencies shown as ordinates were plotted on a cumulative basis. The data for 5 houses are shown in figure 24 for the month of January 1960, and the data for 4 of the same houses and 1 other house are shown in figure 25 for the month of August 1959. These curves can

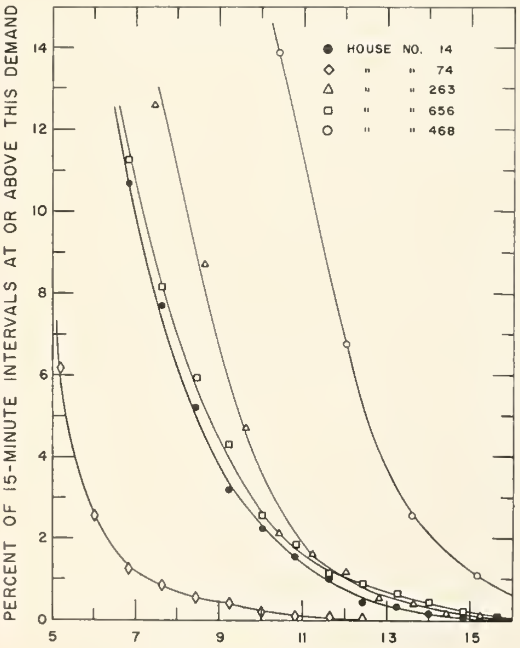

Figure 24. *Cumulative frequency of recurrence of 15-min power demands greater than 5 kw for 5 houses during the period January 8–February 8, 1960.*

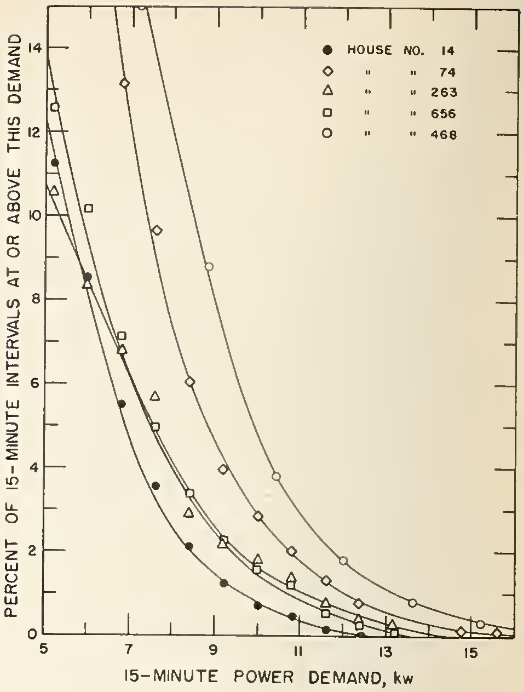

Figure 25. *Cumulative frequency of recurrence of 15-min power demands greater than 5 kw for 5 houses during the period August 7–September 8, 1959.*

be used to determine what part of a day or a month, on the average, will correspond to 15-min power demands at any selected value or higher. For example, figure 24 shows that the 15-min power demand for house 468 will be 15.2 kw or higher, 1 percent of the time, or about one 15-min period per day on the average in the month of January. In figure 25, it is shown that the 15-min power demands that will be equaled or exceeded 1 percent of the time in August, range from 9.6 to 13.2 kw in the 5 sample houses. Curves of this type can be used to evaluate the probable amount of time that the energy-use habits in a given house would be affected by a device which limited the 15-min demand to any selected value.

3.6. Relation of Maximum Demand for the Entire Airbase to That for the Housing Area Only

Table 35 shows the magnitudes of the monthly 15-min maximum demands from March 1959 through February 1960, for both the housing area by itself and the entire airbase. It also shows the times that the monthly maximum demands occurred for both the housing area and the entire airbase. Comparison of the magnitude of the two maximum demands and the time of occurrence of these demands, shows that the demand of the housing area was the predominant factor determining the time of the monthly maximum demands for the entire airbase. For these months, the maximum demand for the housing area ranged from 59 percent to 81 percent of that for the entire airbase, with the higher percentages occurring in the winter months. For all months but 5, the time of the maximum demand for the housing area was coincident with that for the total base. In four of these five exceptions, both maximum demands occurred on the same morning.

It should be noted that the lack of coincidence of the housing area and total airbase maximum power demands occurred during the summer months when the power usage for air conditioning was not as great as for winter operation. In agreement with much of the data given on the sample houses, the data in these tables show that in every instance, except one, the maximum demand for the housing area occurred during the morning hours.

Table 35. *Maximum 15-min demands for entire airbase and housing area only*

Time Period	Magnitude of monthly maximum demand			Time of monthly maximum demand	
	Entire airbase	Housing area only	Ratio of housing demand to total demand	Entire airbase	Housing area only
	kw	*kw*	%		
Mar. 6–Apr. 7, 1959	9,856	7,224	73	1100 3–6–59	1100 3–6–59
Apr. 7–May 7, 1959	7,728	5,712	74	0930 4–9–59	0700 4–13–59
May 7–June 8, 1959	8,949	5,292	59	1045 5–29–59	1230 5–29–59
June 8–July 7, 1959	10,600	7,560	71	1030 6–29–59	1045 6–29–59
July 7–Aug. 7, 1959	11,200	7,308	65	1100 8–3–59	1145 8–3–59
Aug. 7–Sept. 8, 1959	11,200	7,476	67	1100 8–24–59	1145 8–24–59
Sept. 8–Oct. 8, 1959	9,968	6,384	64	1115 9–28–59	1115 9–28–59
Oct. 8–Nov. 9, 1959	12,656	10,080	80	0915 11–6–59	0915 11–6–59
Nov. 9–Dec. 10, 1959	14,448	11,508	80	0930 11–17–59	0930 11–17–59
Dec. 10, 1959–Jan. 8, 1960	14,672	11,676	80	0915 1–8–60	0915 1–8–60
Jan. 8–Feb. 8, 1960	15,568	12,432	80	1100 1–18–60	1100 1–18–60
Feb. 8–Mar. 8, 1960	17,024	13,860	81	1015 3–2–60	1015 3–2–60

4. Summary and Conclusions

The more significant data developed by this analysis and the conclusions derived therefrom may be summarized as follows:

(a) The annual use of electric energy by the sample houses averaged 25,300 kw-hr per house based on the 12-month period from March 1959 to February 1960, inclusive (table 4). Of this total, 48.6 percent was used by the heat pump, including the supplementary resistance heaters, for heating and cooling; 24.3 percent was used for water heating; 23.3 percent was used for miscellaneous devices, including a resistance heater in the bathroom; and 3.8 percent was used by the electric range. Annual costs can be derived from these data by applying appropriate rate schedules.

(b) Three energy-usage factors were computed to correlate the electric energy used for heating, the severity of the weather, and the floor area of the sample houses (tables 5 to 9). These factors were expressed in the units kw-hr/degree-day (1,000 ft^2 of floor area). The first factor was based on the total electric energy used for heating, including the contribution made by appliances other than the heat pump, the degree-days related to a 65 °F base, and the inside floor area of the house in thousands of square feet. This factor averaged 3.4 for the 16 sample houses during the 5-month period from October 1959 through February 1960. The second energy-usage factor was similar to the first except that only the electric energy used by the heat pump was included. The third energy-usage factor employed the total electric energy used for heating, as for the first factor, but the degree-days were based on the average indoor and outdoor temperatures. The second and third factors averaged 2.1 and 2.2, respectively, for the same 5-month period. Within a given month the first and third factors provided a better correlation of the energy use, the weather, and the size of the sample houses. However, the third factor was less variable from month to month than the other two factors for the 5-month period used in the comparison.

(c) Three energy-usage factors were computed to correlate the electric energy used by the heat pump for cooling, the severity of the weather, and the floor area of the sample houses (tables 10 to 12). These factors were expressed in the units kw-hr/degree-day (1,000 ft^2 of floor area) and were alike except for the method used to determine the cooling degree-days. The degree-days were based on hourly values of outdoor temperature and reference temperatures of 65 and 75 °F for the first and second factors, respectively, whereas the degree-days were computed from the mean daily outdoor temperatures and the average daily indoor temperatures for the third factor. The best correlation was obtained by the first energy-usage factor employing a 65 °F reference value for determining degree-days, for which an average value of 2.1 was observed for the 16 sample houses from June through August 1959.

(d) Appliances other than the heat pump contributed significantly toward the heating of the sample houses in the winter (tables 5 to 9). For the assumptions made, the computed appliance contribution toward heating averaged 34 percent of all of the energy used for heating in the sample houses for the period from October 1959 to February 1960, inclusive. The computed appliance contribution to the summer cooling load averaged about 12.9 kw-hr per day per house, equivalent to a 24-hr average of about 1,830 Btu/hr (tables 10 to 12).

(e) The maximum electric power demand for the entire housing area was apparently caused by a moderately high average demand in many houses rather than a coincidence of the maximum or very high demand in a minority of the houses, as indicated in tables 14 to 19. None of the 16 sample houses exhibited a monthly maximum demand coincident with the monthly maximum demand for the entire housing area, yet the average demand in the sample houses at the time of the monthly maximum for the entire housing area was about equal to the average for all of the houses at that time. These facts suggest that a program device which simply reduced the individual house maximum demand by 4 or 5 kw probably would not have a significant effect on the maximum demand for the entire housing area.

(f) The average electric power demand during the hours from about 0630 to 2000 was significantly higher than during the night hours (figs. 4 to 13). This difference was more significant in the summer than in the winter. For 4 of the 5 sample houses on which this comparison was evaluated, the average rate of energy use during the hours from 0700 to 2300 was about 1½ times that during the night hours from 2300 to 0700 in the month of January, and this day-to-night ratio of energy use rates was about 4 to 1 for the same time intervals in the month of August (table 13). The difference between the day and night rates of energy use was not as great as this in the fifth house, i.e., house 263 during August and house 468 during January. These results indicate that a program device which transferred some of the load from the daytime hours to the night hours would probably provide a lower maximum demand for the housing area.

(g) The maximum electric power demands for the individual houses averaged about 14 kw in the summer and about 17.5 kw in the winter with the heat pump, water heater, and miscellaneous devices being the principal contributors to these maximum demands (tables 20 to 25). The monthly coincidence factors between the maximum demands of the load components in each house and the maximum demand for the entire house load averaged about 0.70 both winter and summer (tables 26 to 31).

(h) An exponential curve of the form $y=Ce^{-kx}$ approximated the relation between the frequency of recurrence, y, of power demands from about 5 kw upward, and the numerical value of the 15-min power demand, x (figs. 22 and 23). Cumulative curves for frequency of recurrence of high power demands (figs. 24 and 25) showed that power demands of 11.5 kw or more occurred only about 1 percent of the time, or about 15 min per day, on the average, during a typical summer or winter month, except in the large 4-bedroom houses with two heat pumps. These cumulative frequency curves also indicated that power demands in excess of 7 kw occurred for no more than 3½ hr per day, on the average, except in the large 4-bedroom houses.

5. Methods of Limiting Maximum Power Demand in the Housing Area

Various devices and methods have been used to limit the power demand in houses designed for electric heating and all-electric appliances. These usually take the form of some type of programing system and could either be administrative or mechanical-electrical. Certain intermittent operations in a house, such as laundering, could be staggered throughout the week by administrative order to provide diversity among a large group of houses. This type of programing has the advantage that no equipment is required to implement it, but it depends on voluntary cooperation in most cases and would cause inconvenience at times. The practicability of administrative programing can best be evaluated by the personnel at an airbase and will not be further considered in this discussion.

Mechanical-electrical devices for programing a group of component loads in a house might take any of the following forms:

(1) A nonpreferential total load-limiting device;

(2) a total load-limiting device that gave preference to certain appliances;

(3) a load selector that permitted either of two appliances, but not both, to be energized at the same time;

(4) a device which permitted one or more appliances to be energized, only if the load already energized was below some selected value;

(5) an off-peak water heating control on a time clock;

(6) a device to reduce the applied voltage from 230 to 115 v on resistance elements such as the water heater and the supplementary resistance heaters in the heat pumps whenever the power demand reached some selected value;

(7) a control that prevented operation of the water heater for intervals of 2 hr, more or less, during the time of the day when other loads were high, but with these 2-hr periods staggered throughout the period from about 0800 to 2000 hr.

In considering the type of programer that would provide the best combination of reduction of maximum demand and minimum of inconvenience to the house occupants, the principal conclusions indicated by the foregoing analysis of the energy usage and power demand in the sample houses and the priority of the several load components in the house from a convenience standpoint should be taken into account.

From a convenience standpoint it is believed that the various functions occurring in a house that require electric energy should be placed in the following order of decreasing priority:

(1) Cooking;
(2) heating and cooling;
(3) miscellaneous uses, laundering, ironing, etc.;
(4) water heating.

Cooking was given priority over heating partly because it can effectively substitute for heating for limited periods of time. Heating and cooling were given priority over miscellaneous uses because they are continuous requirements over rather long periods of time whereas the occupant has considerable choice in performing the miscellaneous functions of laundering, ironing, etc. Water heating was given the lowest priority because it is both possible and conventional to provide some storage of hot water whereas only very limited storage of heating and cooling effect is practical, and the other functions cannot be stored.

The foregoing analysis and conclusions, regarding the average pattern of daily power demand, the coincidence factor within individual houses and among groups of houses, the probable cause of the maximum demand for the entire housing area, the frequency of recurrence of high demands, and the convenience considerations associated with the various energy-using activities in a house, indicate that some type of programer that caused the water heater to be energized only during periods of low or moderate demand by other appliances offers the best possibility of decreasing the maximum 15-min power demands for the entire housing area. Program devices 3 through 7, listed at the beginning of section 5 of this report, are variations of this type of device.

Of all the devices listed it is believed that a relay which permitted one or more appliances to be energized only if the load already energized was below some selected value, identified as (4) in the earlier listing, offers the best possibility of distributing the total daily energy use evenly over the 24-hr period. This type of relay, with a current coil in the lines serving the house, would interrupt the circuit to the water heater or possibly to the water heater and dryer, whenever the current reached some selected value. In this arrangement the electric service to the water heater, or water heater and dryer, would be connected on the line side of the current relay. This device would not limit the power demand or time of use of any component of the load, except the one or two interrupted by the current relay, and would not prevent these from being energized except at times of high demand. The data on frequency of recurrence of high demands indicate that such a relay should be activated at a load somewhat above that caused by the compression system of the heat pump, but somewhat below the load when the compression system and supplementary resistance heaters were both energized. That is, in the houses with one heat pump the relay should be energized at a load somewhere between 5 and 8 kw and in the houses with two heat pumps at a load somewhere between 9 and 12 kw. This type of program device might require a water heater sized for off-peak heating to provide greater storage of hot water than is now possible.

An off-peak water heating schedule controlled by a time clock could also be used to shift the water heating load to the night hours, but unless the hours of water heating were staggered after midnight, the time of maximum demand for the entire housing area might only be shifted to a new hour without reduction in magnitude. This device might still be practical, if it were found that the power demand of the airbase outside the housing area became quite low at night.

The type of device which permitted either of two devices to be energized as required, but not both simultaneously, would probably reduce the maximum power demand in each house appreciably, but it might not reduce the high average that appears to have caused the maximum demand for the entire housing area.

This analysis indicates that water heaters with storage tanks suited to off-peak heating are desirable and that some types of programing devices for water heating would probably be better than others in this installation. The program devices identified by the numbers (4), (5), (6), and (7) appear to offer the best possibilities for reduction of maximum power demand.

6. Comparison of Annual Energy Use in 16 Sample Houses With Other Published Information

Table 36 provides a comparison between annual energy usage of some of the appliances in the 16 sample houses and of the same type of appliances in homes elsewhere in the United States. Information is shown for the heat pump, the hot water heater, and the electric range only. Comparable information is published for other individual home appliances, but it has not been included because the energy use by these appliances was not metered separately in the sample houses at Little Rock Air Force Base.

A literature search revealed that there are very few published data available on energy usage for individual appliances obtained by meter readings. Most of the information on individual appliances consists of estimates by electric light and power

Table 36. *Comparison of annual energy use in 16 sample houses with other published data*

Source of information	Geographical area	Heating degree-days	Size of sample	Annual energy usage (kw-hr)		
				Heat pump	Water heater	Range
A. Private homes, nonmilitary						
Edison Electric Institute Study, 1957[a]	Entire nation, without geographical weighting of samples.	----------	Unknown. Data from more than 30 electric light and power companies.	15,450	3,950	1,225
Edison Electric Institute Study, 1959[b]	Same	----------	Same	14,635	3,675	1,200
Edison Electric Institute Study, 1961[c]	Same	----------	Same	15,840	4,070 4,475 (Quick recovery)	1,225
Southeastern Electric Exchange Economic Study, June 1958.[d]	Southeastern States	3,500	20–40 nonmilitary private homes, large and small towns.	----------	3,376	1,206
B. 1- and 2-family structures, Little Rock Air Force Base						
National Bureau of Standards Study for period March 1959–March 1960.	Arkansas	3,000	16 dwelling units	12,290	6,135	965

[a] Edison Electric Institute; Wattage Rating and Estimated Average Annual KWH Consumption of Electrical Household Appliances Assuming Normal Use, January 1, 1957.
[b] Ibid., January 1, 1959.
[c] Ibid., January 1, 1961.
[d] Southeastern Electric Exchange; Economic Study of Electric, Gas and Oil Usage for Capehart and Other Public Housing Projects, June 1958.

companies based on meter readings of the total house load. The information cited in table 36 from the Edison Electric Institute studies of 1957, 1959, and 1961 is of this type. The estimates are based on information obtained by the Institute from over 30 different electric light and power companies, and the data have not been weighted geographically. Since over 90 percent of the electric light and power companies in the United States are members of the Edison Electric Institute, the data from which the estimates were made are probably representative of the entire nation.

The data shown in table 36 from the Southeastern Electric Exchange study, however, were obtained from actual meter readings of appliance energy usage.

A study of the table shows that the average annual energy usage of the heat pumps in the 16 houses at Little Rock Air Force Base was lower than the estimates published by the Edison Electric Institute by amounts ranging from 16 to 22 percent. The average annual energy usage for the hot water heaters in the 16 sample houses was appreciably higher than any of the published data. The hot water heaters at Little Rock Air Force Base can probably be considered to be of the quick-recovery type. Thus, the observed average energy use of 6,135 kw-hr water heating at the airbase should be compared with the value of 4,475 kw-hr published by the Edison Electric Institute in 1961 for quick-recovery heaters. The observed annual energy use by the electric ranges in the 16 sample houses was about 80 percent of the values cited from the other sources.

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