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Statistical Comparison of Energy Requirements for Different Types of Residential Electric Heating

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"STATISTICAL COMPARISON OF ENERGY REQUIREMENTS FOR DIFFERENT TYPES OF RESIDENTIAL ELECTRIC HEATING"

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Abstract

The heat pump can save approximately 40% in energy costs over a central electric furnace and approximately 20% over electric cable heat or baseboard heat installations. Expected demand for any type electric heat is about the same during very cold weather.

1. INTRODUCTION

For many years electric utilities have "pushed" the all-electric home concept in an attempt to increase winter loads. But only recently have electric heating systems been installed on a large scale. The natural gas shortage and relative high expense of other forms of fossil fuels has forced building contractors and homeowners to search for other means of heating their homes. In almost all cases, the only practical alternative to traditional fuels is electricity.

Recognizing consumer problems in heating homes electrically as efficiently and effectively as possible due to increased energy costs and anticipating future winter peak loading, a study was made to determine expected demand and energy usage for all-electric homes and apartments in the central Missouri climate.

Another related subject was a comparison of demands and usage for the different type heating systems. Most recent electric heat installations in central Missouri have been central furnaces. But is there a more efficient means of heating homes than resistance heating?

2. DISCUSSION

Generally the months of January and February will provide the coldest, hardest days of winter in central Missouri. Accordingly this period was chosen to collect demand and usage data for various type heating installations in the area. Thermal demand meters were installed on ten all-electric homes with three different types of heating systems.

The meters were read daily and consistently at the same time of day (early morning). For 29 days the daily peak demand and daily usage data was collected versus the daily low temperature. The demand data should be considered as a 30-minute KVA demand to reflect the time delay characteristic of the meter in registering demand data.

A simple statistical analysis of the data provided expected daily peak demand and energy consumption for various daily low temperatures. Very rarely are low winter temperatures in the area colder than -10^{o}F. Hence this point was selected as the lowest temperature on which to project data.

Originally it was thought the demand and usage would increase exponentially with lower temperatures. The exponential nature of the general heat transfer equation would be reflected in exponentially increasing demands and energy consumption as the temperature dropped. However this was not the case. Plotting the data on semi-log graph paper did not provide a linear relationship between daily low temperature and consumption or demand.

Subsequently plotting the data on linear graph paper did indicate a reasonable straight line relationship for doth daily demand and usage versus daily low temperature. With this relationship determined, a linear regression line was calculated for daily demand and daily usage for the data from each home or apartment monitored. The correlation coefficient, R, for most curves indicated a good "fit" of the linear regression line with the data points. Also the t statistic, t_d, was significant and indicated that demand or usage were dependent variables related to the independent variable, daily low temperature. The second t statistic, t_t, is a measure of the significance of the correlation coefficient. In practically all cases the linear regression line calculated was significant as a tool to forecast the demand or usage for that particular dwelling. A t statistic of 2.0 or greater implies a 94% or greater confidence level for that particular element. For example, if t_t is greater than 2.0, at least 94% confidence can be placed in that particular regression line.

The appendix contains condensed data collected during this study and provides a means of comparing the different types electric heat on a common basis, usage on a 2500 square foot living area base and demand on a 25 KW installed heat base.

3. CONCLUSION

Many variables must be considered in arriving at an expected peak demand or usage for a particular dwelling. This study indicated a straight line relationship exists between daily low temperature and daily peak 30-minute KVA demand or daily energy consumption. However the slope and the intercept describing this relationship vary depending on occupants living style, quality of construction and insulation and type electric heat installed. The more "open" a homeowners living style, the higher will be his demand and power bill. Also the homeowner will pay a premium in high demand and usage for poor construction and insulation practices. A utility has limited control of the above two variables but the utility can recommend a more efficient type heating system than the common central furnace.

The study indicated that, for very cold temperatures, little difference exists between expected peak demands for the different type heating systems. Hence any one type heat system installed on a wide scale will not result in future system "peak shaving". Some form of "load management" and attractive off-peak rates will apparently have to limit peak demands.

This study also indicated heat pump installations in the central Missouri climate could reduce a homeowners expected heating energy consumption about 40% from that expected with a central furnace and about 20% from that expected with cable ceiling heat or baseboard heat. For very mild winter weather (daily low temperatures greater than 30°F) the energy savings from a heat pump installation should be even greater.

Forecasting a peak expected demand for an individual home or apartment is difficult because of the prior mentioned variables. However a conservative demand estimate would be the total installed heat plus 25% or five KVA, whichever is greater. This estimate must be applied with caution for customers having nontypical residential loads, especially in rural area.

Forecasting a peak expected demand, D_n, for a number of homes or apartments is also difficult to determine. This demand is believed to be exponential in nature and to asymptotically approach a value approximately 1/3 the product of the number of dwellings, N, and the expected demand, D_1, for one of the dwellings. The following equation is offered as a suggestion which fits the description and agrees with data collected in the study.

$$D_n = D_1 + ND_1 \left(1 - e^{-.4(N-1)(N+8)/N^2} \right)$$

$$e = \text{natural base} = 2.71823$$

The study was made at a minimal cost and with simple equipment. Using thermal demand meters to monitor demands provided 30-minute KVA demand data which did not reflect total demand. Transient demands were eliminated but actual demand for the dwelling would be slightly greater than that indicated.

Any statistical analysis will provide more meaningful results if the sample data is as large as possible. Ideally more total data would have been collected in this study and data would have been collected at very cold temperatures (below 0°F). Although this particular central Missouri winter was mild and only a small computer was required to analyze the data, the results of this study are significant and should prove useful to a utility and its customers.

BIOGRAPHICAL SKETCH

Larry L. Rushing

Larry L. Rushing is District Superintendent for the Jefferson City District of Missouri Power & Light Company. He is very much involved in the design, construction and maintenance of overhead and underground distribution facilities at the district level.

His previous experience includes service in the U.S. Army as an electrical engineer both in Viet Nam and in the United States. He also worked for Pacific Gas & Electric Company and the Shell Oil Company.

He holds a B.A. in Math and Physics from Drury College, a B.S. in Electrical Engineering and an M.S. in Engineering Management from the University of Missouri-Rolla.

He is a Registered Professional Engineer in Missouri, a member of the National and Missouri Societies of Professional Engineers and a member of the Institute of Electrical and Electronics Engineers.

APPENDIX

CONDENSED ALL-ELECTRIC HOME DATA
PAGE ONE

TYPE HEAT	INSTALLED HEAT (KW)	PER UNIT INSTALLED HEAT (25 KW BASE & 1 HP=1 KW)	INSULATION QUALITY (VERY GENERAL DESCRIPTION)	HOME LIVING AREA ($FT.^2$)	PER UNIT LIVING AREA (2500 $FT.^2$ BASE)
Two Furnaces-S	22 + 16.5	1.54	Good	2353	0.9412
One Furnace-P	27.5	1.10	Good-	2618	1.0472
One Furnace-H Heat	25	1.00	Good-	2284	0.9136
One Furnace-P Heat	25	1.00	Good	2696	1.0784
Cable Heat-G	22.5	0.90	Good	2802	1.1208
Cable Heat-L	24.8	0.99	Good	2596	1.0384
	28.2 + 3 HP	1.13			
Heat Pump-A	19.2 + 3 HP		Good-	2367	0.9468
Heat Pump-M Heat	23.5 + 4 HP	0.89	Good+	2550	1.0200
Heat Pump-N Heat	33.6 + 3.5 HP	1.10	Good+	2521	1.0084
Heat Pump-W Heat	2.0 HP	1.564	Excellent	4296	1.7184

CONDENSED ALL-ELECTRIC HOME DATA
PAGE TWO

DEMAND SLOPE (KVA) (KVA/°F)	0° INTERCEPT (KVA)	DEMAND 0° INTERCEPT RELATIVE TO 25 KW	EXPECTED DEMAND 32°F LOW TEMP. (KVA)	EXPECTED DEMAND 32°F LOW TEMP. RELATIVE TO 25 KW (KVA)
-0.082	24.9	16.2	22.3	14.5
-0.041	25.3	23.0	24.0	21.8
-0.0657	15.4		13.3	
-0.0467	10.4	10.4	8.9	8.9
-0.0232	22.0		21.3	
0.0033	18.5	18.5	18.5	18.5
-0.0889	14.8	16.4	12.0	13.3
-0.1609	19.1	19.3	13.9	14.0
0.0322	16.8	14.9	17.9	15.8
.005 & -0.363	21.5		11.7	
- .120 & -0.385	18.5	20.8	6.8	7.6
.153 & -0.259	19.3		11.5	
- .076 & -0.209	15.4	14.0	8.6	7.8
-0.506	34.2		18.0	
-0.566	33.2	21.2	15.9	10.2

CONDENSED ALL-ELECTRIC HOME DATA
PAGE THREE

USAGE SLOPE (KWHR/DAY)	0° INTERCEPT (KWHR/DAY)	USAGE 0° INTERCEPT RELATIVE TO 2500 FT.^{2}	EXPECTED DAILY USAGE $32^{\circ}F$ LOW TEMP. (KWHR)	EXPECTED DAILY USAGE $32^{\circ}F$ LOW TEMP. RELATIVE TO 2500 FT.^{2} (KWHR)	ACTUAL USAGE 29 DAYS JAN. & FEB. (KWHR)	ACTUAL 29 DAYS USAGE RELATIVE TO 2500 FT.^{2} (KWHR)
-4.778	392	416	238	253	7312	7769
-3.550	305	291	191	182	5670	5414
-3.423	271	297	162	177	4915	5380
-3.113	231	253	131	143	4025	4406
-1.779	177	164	120	111	3542	3284
-1.463	136	126	89	83	2645	2453
-2.592	231	206	147	131	4452	3972
-3.798	282	271	160	154	4907	4726
-4.652	256	271	107	113	3494	3690
-1.401	174	171	131	128	3678	3606
-2.134	132	129	65	64	2009	1970
-3.707	234	232	114	113	3630	3600
-4.061	194	192	63	62	2152	2134
-5.396	352	205	178	104	5615	3268
-5.351	302	176	132	77	5273	3069