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A REGRESSION METHOD FOR CALCULATING THE THERMAL PERFORMANCE OF BASEMENT, CRAWL SPACE, AND SLAB-ON-GRADE FOUNDATIONS

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ABSTRACT

A set of regression equations has been developed for calculating heating and cooling season loads and energy use for the basement, crawl space, and slab-on-grade constructions described in the Building Foundation Design Handbook (Labs et al. 1988). The building load and energy use data bases were developed for the Handbook using a finite difference computer program coupled with the DOE 2.1C whole building energy-use simulation model. Twenty-seven different insulation configurations and conditions were simulated for 13 U.S. cities representing major climatic regions. The regression equations calculate the annual and seasonal loads and energy use as functions of the local climatological data and the insulation thermal resistance. The general applicability of the regression equations is also discussed.

INTRODUCTION

The energy performance of a building foundation is difficult to simulate due to the thermal coupling between the building and the surrounding subsoil and the long thermal response of the soil. Current building energy simulation programs generally model the building foundation in a very approximate fashion, often as a one-dimensional layer with an effective U-value linked thermally to either the ground or air temperature or both. On the other hand, although several foundation simulation programs using finite element and finite difference methods have been developed (see Sterling et al. [1985] for a discussion of foundation simulation methods), these generally do not simulate the above-ground structure in adequate detail.

In order to provide more accurate energy numbers for the Building Foundation Design Handbook (Labs et al. 1988), an analytical procedure was developed that combines the capabilities of a finite difference program in simulating foundation heat flows with that of the DOE-2.1C program to simulate whole-house performance (Huang et al. 1988). The foundation simulations were done with a two-dimensional, fully implicit, integrated finite difference heat conduction program (Shen et al. 1988). To estimate the changes in space-conditioning energy use due to differing levels of foundation insulation, the developmental DOE-2.1C program (LBL 1980; BESG 1984) was used to simulate a prototypical one-story house of average size and construction under typical operating conditions. The building was tailored to reflect average current construction practices as determined through a review of survey data (NAHB 1981). For details of the whole-building simulation the reader is referred to Huang et al. (1987, 1988).

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Four basic foundation types were considered for the Handbook: deep basements, shallow basements, crawl spaces, and slab-on-grade foundations. A deep basement is typically a fully below-grade space, while a shallow basement has earth placed only against the lower half of the wall. Heated and unheated deep basements were included in the analysis. Vented and unvented crawl spaces and slab-on-grade constructions with both deep and shallow footings were investigated. For each of these foundation types, a wide range of insulation configurations and insulation thermal resistances were considered. This analysis was performed for 13 representative cities in the United States. Table 1 shows the 13 cities with their typical heating degree-day and cooling degree-hour numbers and Table 2 gives a list of the 27 basic insulation measures. The data base provides heating and cooling season loads and energy use for each of these foundation insulation placements. The energy use values take into account heating and cooling system efficiencies.

This paper presents the Handbook data in the form of regression equations that relate the load or energy use of a foundation configuration to the insulation thermal resistance of the foundation and the climate of a particular location. This approach follows an earlier effort by Shipp (1982) to generalize complex technical data and gives users the ability to examine climates and insulation levels not specified in the Handbook.

DERIVATION OF THE REGRESSION EQUATIONS

In following the procedure developed by Shipp (1982), the annual and seasonal loads and energy use data for each of the 27 foundation configurations were described in the form of linear regression equations. These equations provide a more compact and accessible presentation of the simulation results than tables of results from a large number of different cases. Before the regression equations were derived, however, the simulation results were first divided by the foundation perimeter (or floor area, in the cases of underfloor insulation) in order to present results in a format that can be scaled to various house sizes. Adapting the results for a 55 by 28 ft (16.8 by 8.5 m) house to other shapes and sizes introduces errors of approximately 5% to 10% for typical rectangular buildings ranging from approximately 20 by 40 ft (6.1 by 12.2 m) to 40 by 80 ft (12.2 by 24.4 m). Beyond these limits errors increase.

The initial form of the regression equations was based on that developed by Shipp. After numerous investigations, Shipp found that a seven-variable model provided the best fit for his data base using a minimum number of coefficients. The critical parameters for the model are the thermal resistance of the insulated wall or floor (R, in $h\text{-}ft^2\text{-}°F/Btu$), the heating degree-days of the chosen climate (HDD65, in °F-day, base 65 °F), and the cooling degree-hours of the chosen climate (CDH74, in °F-hour, base 74 °F). The value for R is defined as the R-value of the insulation plus an R-value representing the uninsulated foundation configuration (see Table 2). The whole-house loads and energy use were fitted to the following regression equation:

$$Q = B0 + B1/R + B2*(HDD65/100) + B3*(CDH74/100) + B4*(HDD65/100)/R + B5*(CDH74/100)/R + B6*(HDD65/100)*(CDH74/100) + B7*(HDD65/100)*R \quad (1)$$

where Q can be either the annual envelope load or energy use, heating season load or energy use, or cooling season load or energy use. Multiple regression techniques were used to obtain the regression coefficients B0 to B7 for the various load and energy use databases.

Regressions were performed using the entire Handbook data base for each of the basic foundation types. The coefficients in Equation 1 were found for heating season, cooling season, and annual values of load and energy use. The mean multiple regression coefficients (R^2) for all regressions except combined heating and cooling season load are on the order of 0.92, which indicates that 92% of the variability in the measured values is captured by the regression equation. For the total annual load, the R^2 shows that only 81% of the variability in the dependent variable is captured by this equation, indicating that a different regression equation may more accurately predict this value.

Shipp (1982) reported that the regression of his data base produced an R^2 statistic of 0.997 for the annual and heating season loads and an R^2 of 0.978 for the cooling season regressions. This compares to an R^2 of about 0.95 for the heating and cooling season load regressions and an R^2 of about 0.81 for the annual load regression using the 13 Handbook cities. Statistical accuracy, however, may be misleading since the increased variability introduced by regressing over a larger range of cities should provide a wider applicability of the regression equations. For comparison with the Shipp regressions, when the Handbook data were regressed for the same five cities (with the substitution of Kansas City for St. Louis), similar R^2 values were obtained.

While the R^2 statistic gives a measure of the overall fit of the regression equation, it is also important to examine the accuracy of the method by comparing the simulation and regression values for individual configurations. For instance, even though a higher R^2 is obtained by regressing with data from five cities, using a wider range of climatic conditions for the regression should enhance the general use of the regression equations. Figure 1a shows a plot of the HDD65 vs. CDH74 for 3,349 cities in the United States. While most of the data fall within a fairly distinct cloud, there are regions of the United States that obviously do not lie within this cloud. For the Shipp study, the regression runs were performed using five cities: Bismarck, Minneapolis, St. Louis, Fort Worth, and Miami. Figure 1b shows the HDD65 vs. CDH74 plot for the 13 Handbook cities with the 5 Shipp cities highlighted. While the five cities chosen by Shipp cover a large range of heating degree days and cooling degree hours, the climatic regions that do not lie along the line of cities modeled by Shipp may not be represented by the regression equations.

Figure 2 shows the comparison of the 5- and 13-city regressions of the Handbook data for the total annual load of the unheated deep basement case ud2 for Fort Worth and Chicago. The data for Fort Worth were used for both regression methods while Chicago represents a city that falls near the line of cities used by Shipp. The 5-city regression, as expected, gives a better overall fit than the 13-city regression with an error range for Fort Worth of 1% to 4% for the 5-city approach and 3% to 10% for the 13-city regression. For Chicago, the error range is 0% to 6% for the 5-city regression and 4% to 6% for the 13-city approach. However, as the choice of climate moves away from the central line of cities, errors increase dramatically for the 5-city approach.

Figures 3 through 5 show the comparison of the two approaches for predicting the combined annual load for Boston, the cooling season load for Phoenix, and the heating season load for Seattle. For Boston, the 13-city regression has an error range of 1% to 6%, 3% to 10% for Phoenix, and 0% to 7% for Seattle and models the general shape of the curves fairly well. The 5-city approach yields an error range of 17% to 24% for Boston, 13% to 32% for Phoenix, and 45% to 55% for Seattle. Interestingly, Boston, with an HDD65 of 5596 °F-day (3109 °C-day, base 18 °C) and a CDH74 of 2429 °F-day (1349 °C-day, base 23 °C), does not represent a strong departure from the climates that make up the 5-city regression. For Phoenix, even though the 13-city regression will tend to underestimate the savings provided by foundation insulation (on the order of 30% to 40%), the five-city approach incorrectly predicts the shape of the cooling load curve and predicts an increase in load due to insulating the deep basement. Even though the original five cities chosen cover a wide range of HDD and CDH, the use of regression equations for a wide range of climatic conditions necessitates a selection of cities that also includes varied combinations of HDD and CDH.

Comparing the regression predictions to the simulation data over all the foundation configurations, the average percent error for the 13-city regression values is 15% to 21% for the heating load and energy use predictions, 40% to 53% for the cooling load, 13% to 20% for the cooling energy use, and 12-15% for the total annual load and energy use predictions. In order to improve upon the accuracy of the equation, a higher order equation was found by performing a step-wise refinement automatic regression on all observations for a given dependent variable (heating, cooling, or combined load or energy), using the 124 non-constant terms found by the cross-products of powers of R, HDD65, and CDH74 from -2 to 2. A search was made for the best equation of 15 predictors or less, determined by minimizing the coefficient of variation (Younger 1985).

RESULTS AND DISCUSSION

Expanding the climatic descriptors to include the mean daily solar radiation and the deep ground temperature greatly enhances the overall accuracy of the equations. Again comparing the regression predictions to the simulation data over all the foundation configurations, the average percent error is 2% to 6% for the heating load and energy use predictions, 3% to 9% for the cooling load, 2% to 3% for the cooling energy use, and 1% to 2% for the total annual load, and 3% to 15% for the combined energy use predictions.

Large percent errors occur for heating load and energy in Miami (about 15% to 30%) and for cooling load in Seattle (about 10% to 40%). However, since Miami is very cooling dominated and Seattle has no cooling demand, these errors may be ignored. For the slab and crawl space configurations, the accuracy for the combined energy use is worse than the other configurations, with a 19% error for the slab configuration and an average of 15% error for the crawl space. Since the accuracy of the seasonal energy use predictions is within 2% to 4%, on average, summing the heating and cooling season predictions may produce less error than relying on the combined energy regression equation. Some care should also be taken with the cooling load regressions for the slab and unheated deep basement configurations. Even though average errors are 9% and 7%, respectively, cities with an HDD65 greater than 6000 (3333 °C-day) (ie. Bismarck, Minneapolis, Chicago, and Denver) have average percent errors ranging from 10-22%. As a result, the cooling load predictions for these two configurations in these climates may more accurately be found by taking the difference of the annual load and the heating load, which have accuracies within 2.5%. The remaining equations and configurations all have average percent errors less than 10% and most are below 5% error.

An additional caveat should be made when using this equation to predict delta loads. The prediction of delta loads is performed by first using Equation 2 along with the R-value listed in Table 2 to generate the load for an uninsulated building. The effective R-value of the insulation system of interest is then used in Equation 2 to find the load for the entire building with insulation. The form of Equation 2 can be greatly simplified since only those terms containing the effective R-value need be used in calculating delta loads. The difference between the two loads is the delta load or energy savings due to adding the foundation insulation. The accuracy of this estimate is dependent on both the reproduction of the load curve trend and the relative difference between the actual data and the predictions with no insulation and at the insulation of interest. The difference between these two relatively large numbers with small percentage errors can produce large percentage errors in the prediction of the smaller delta load. Figure 6 shows a comparison of delta loads from the Handbook and the regression method for R-10 insulation (RSI-1.8) for the dp2 basement. The results show that the regression method provides a reasonable fit for most cities, although 20% errors are encountered for Denver and Fort Worth. The reproduction of the Handbook delta cooling load data, however, is not as good as for the delta cooling load. In general, the equation should be used with caution for predicting delta cooling loads for crawl spaces and slab foundations, and basements in climates between Washington, DC and Phoenix.

Prior to applying Equation 2 for calculating load and energy use numbers or estimating deltas, it is advisable to test the procedure by attempting to reproduce the values for cases of interest similar to those available in the Building Foundation Design Handbook. This will show the accuracy of Equation 2 for the application of most interest and whether any gross user errors have been made in setting up the calculation. The regression equation and coefficients can be installed very easily in a PC spreadsheet, validated against the Handbook data, and numerous cases run with minimal effort.

CONCLUSIONS

The procedures described in this paper represent an update and extension of the methodology first presented by Shipp (1982). The set of regression equations that have been produced provide a more compact and accessible presentation of the load and energy use data published in the Building Foundation Design Handbook. By performing the regression with data from the 13 Handbook cities, the

When regressing with 15 predictors, however, it was observed that the matrices used to determine the regression coefficients could become ill-conditioned. Since the inverses of these matrices are used to determine the statistical measures of accuracy (R^2 and the coefficient of variation), the reliability of these statistical measures is uncertain in these cases and, furthermore, the exactness of the determined regression coefficients cannot be assured. Note that the ill-conditioning only became apparent in extreme cases, and similar problems may plague the other regression as well. For this reason, the absolute percent error, the absolute value of (actual value - predicted value) / actual value, is the preferred measure of accuracy for comparing regression equation predictions.

For the 15-variable regression equation, the average percent error for the regression values is about 11% for the heating load and energy use predictions, 25% for the cooling load, 4% for the cooling energy use, 14% for the total annual load, and 9% for the total annual energy use predictions. Even though the percent error for the cooling load is on average about 25%, it is important to note that the cities with the highest percent error are those that are in heating-dominated climates. For cities with a CDH74 greater than 9000 °F-hour (5000 °C-hour) the percent error for the cooling load regression is 6% and for the four cities above 14000 CDH74 (7778 °C-hour) the error is only 2%.

In spite of the improvement in accuracy provided by using second-order terms, some anomalous results occurred. For the heating load and energy predictions, the regressions for Denver have a percent error in the range of 15% to 31% for all the configurations. Denver has a climate of 6023 HDD65 (3346 °C-day) and 2692 CDH74 (1496 °C-hour) and is quite similar to Boston at 5596 HDD65 (3109 °C-day) and 2429 CDH74 (1349 °C-hour). The percent error range for Boston is between 5% and 10%. While the Denver climate would appear to be slightly harsher than Boston, the simulation data show that Denver normally has heating and cooling demands 10% to 20% lower than Boston. This implies that the regressions are confounded by the lack of other variables and, as suggested by the Denver results, solar gain should be added to the regression model. The regression equations also show errors in the range of 20% for Washington, DC and Atlanta, which suggests further expansion of the regression model. Even though the agreement is quite good for the remainder of the cities (with percent errors of 10% or less), it was decided that total hemispheric mean daily solar radiation and deep ground temperatures should be included in the regression equations. Table 1 gives the values for the mean solar radiation and deep ground temperatures for each of the 13 cities.

The general form of the regression equation to obtain Q, the load or energy use value per lineal foot, was determined to be the summation:

$$Q_{q,f} = B_{q,f,0} + \sum_i B_{q,f,i} \, (R^{r_{q,i}})(\text{kHDD65}^{h_{q,i}})(\text{kCDH74}^{c_{q,i}})(T_{grd}^{g_{q,i}})(Q_{sun}^{s_{q,i}}) \qquad (2)$$

where

q = the dependent variable (heating, cooling, or combined load or energy);
f = the foundation configuration;
R = the R-value of the insulation;
kHDD65 = the number of heating degree days HDD65 (base 65 °F) divided by 1000;
kCDH7 = the number of cooling degree hours CDH74 (base 74 °F) divided by 1000;
T_{grd} = the deep ground temperature (°F);
Q_{sun} = the total hemispheric mean daily solar radiation (Langleys);
$r_{q,i}$, $h_{q,i}$, $c_{q,i}$, $g_{q,i}$, and $s_{q,i}$ = the exponents on R, HDD65, CDH74, T_{grd}, and Q_{sun}, respectively, for the i-th predictive variable for the dependent variable q; and
$B_{q,f,i}$ = the i-th regression coefficient of the predictive equation for dependent variable q in foundation configuration f.

For each dependent variable (the heating, cooling, or combined load or energy), a separate equation was determined and only first-order terms of the independent variables were used for finding each of the six equations. Tables 3 through 8 show the regression equations and coefficients for calculating the loads and energy uses for the various foundation configurations.

regression equations can provide an estimate of the thermal performance of a foundation system, tailored for a particular climate and insulation level. While errors will typically be within 10% of the Handbook data, the regression predictions should be verified against the Handbook data to ensure accuracy of the predictions.

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REFERENCES

Building Energy Simulation Group, Applied Science Division. 1984. "DOE-2 supplement, version 2.1C." Berkeley, CA: Lawrence Berkeley Laboratory.

Huang, Y.J.; Ritschard, R.; Bull, J.C.; Byrne, S.; Turiel, I.; Wilson, D.; Hsui, C.; and Foley, D. 1987. "Methodology and assumptions for evaluating heating and cooling energy requirements in new single-family residential buildings (technical support document for the PEAR microcomputer program)." Lawrence Berkeley Laboratory Report LBL-19128. Berkeley, CA: Lawrence Berkeley Laboratory.

Huang, Y.J.; Shen, L.S.; Bull, J.C.; and Goldberg, L.F. . 1988. "Whole house simulation of foundation heat flows using the DOE-2.1C program." ASHRAE Transactions, Vol. 94, Part 2.

Labs, K.; Carmody, J.; Sterling, R.; Shen, L.; Huang, Y.J.; and Parker, D.. 1988. Building foundation design handbook. Minneapolis, MN: Underground Space Center, University of Minnesota.

Lawrence Berkeley Laboratory and Los Alamos Scientific Laboratory. 1980. DOE2.1B reference manual, parts 1 and 2. Berkeley, CA.

National Association of Home Builders Research Foundation, Inc. 1981. "Sustained builder survey response result in data bank of over one million houses." Rockville, MD: NAHB Research Foundation.

Shen, L.S.; Poliakova, J.; and Huang, Y.J. 1988. "Calculation of foundation heat loss using superposition and numerical scaling." ASHRAE Transactions, Vol. 94, Part 2.

Shipp, P.H. 1982. "Basement, crawlspace, and slab-on-grade thermal performance." Proceedings of the DOE/ASHRAE Conference, Thermal Performance of the Exterior Envelopes of Buildings II, Las Vegas, NV.

Sterling, R.L.; Meixel, Jr., G.D.; Shen, L.S.; Labs, K.; and Bligh, T. 1985. "Assessment of the energy saving potential of building foundations research." Oak Ridge National Laboratory Report ORNL/SUB/84-00240/1, Oak Ridge, TN.

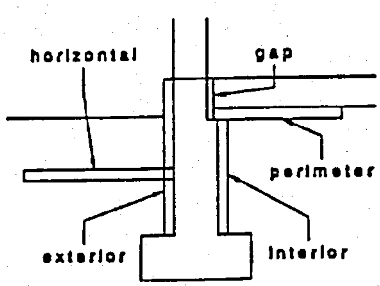
Younger, M.S. 1985. A first course in linear regression. Boston: P.W.S. Publishers.

TABLE 1
Base Cities for Foundation Simulations

City	Avg temp (°F)	Ground temp (°F)	HDD65	CDH74	Mean daily horizontal solar rad (Langley)
Atlanta GA	61	64	3025	12053	365
Bismarck ND	41	42	9080	1966	368
Boston MA	52	48	5596	2429	300
Chicago IL	51	51	6183	5419	330
Denver CO	50	47	6023	2692	425
Fort Worth TX	66	68	2420	30331	398
Kansas City MO	56	54	4814	14865	364
Los Angeles CA	63	62	1595	1414	432
Miami FL	76	77	198	35861	400
Minneapolis MN	45	45	8010	3038	317
Phoenix AZ	71	66	1444	48302	507
Seattle WA	51	52	5122	1	286
Washington DC	58	54	4125	9034	328

TABLE 2
Foundation Configurations

Foundation Configuration	Code	R-value of Unins. Fnd. (h-ft²-F/Btu)
2 ft. Slab Foundations (see sketch for insulation location)		
Exterior	sl1	1
Interior	sl2	1
Perimeter	sl3	1
2 ft. Horizontal	sl4	1
4 ft. Horizontal	sl5	1
4 ft. Slab Foundations (see sketch for insulation location)		
Exterior	sl6	1
Interior	sl7	1
Perimeter	sl8	1
2 ft. Crawl Foundations (see sketch for insulation location)		
Exterior	cr1	1
Interior	cr2	1
Wood	cr3	2.5
Interior, 2 ft. Perimeter	cr4	1
Interior, 4 ft. Perimeter	cr5	1
4 ft. Crawl Foundations (see sketch for insulation location)		
Exterior	cr6	1
Wood	cr7	2.5
Interior, 4 ft. Perimeter	cr8	1
Under floor	cr9	4.8
4 ft. Basement Foundations		
Exterior, Above grade R-11	sh1	1
Exterior, Above grade R-19	sh2	1
Wood	sh3	2.5
8 ft. Basement Foundations (Unconditioned)		
Exterior, half wall	ud1	1
Exterior, full wall	ud2	1
Wood	ud3	2.5
Under floor	ud4	4.8
8 ft. Basement Foundations (Conditioned)		
Exterior, half wall	dp1	1
Exterior, full wall	dp2	1
Wood	dp3	2.5



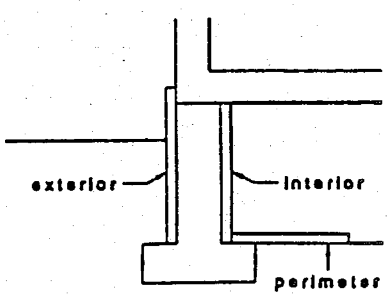


TABLE 3
Regression Coefficients for Heating Season Loads (in MBtu/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
sl1	-6.522	1.107E-7	3.897E-1	8.571E+1	-2.417E-8	1.160E+2	2.770	2.282E+1	5.518E+2	-7.747	-1.833	2.206E-5	-1.379E-3	4.382E-4	9.192E-4
sl2	-6.537	1.833E-7	3.906E-1	8.886E+1	-2.436E-8	1.164E+2	2.744	2.286E+1	5.554E+2	-7.769	-1.848	2.229E-5	-1.140E-3	4.535E-4	9.072E-4
sl3	-6.553	1.856E-7	3.918E-1	9.273E+1	-2.444E-8	1.166E+2	2.731	2.291E+1	5.588E+2	-7.781	-1.861	2.248E-5	-1.161E-3	4.561E-4	8.893E-4
sl4	-6.469	1.341E-7	3.866E-1	1.134E+2	-2.418E-8	1.149E+2	2.745	2.267E+1	5.365E+2	-7.677	-1.777	2.121E-5	-9.927E-4	3.907E-4	1.398E-3
sl5	-6.490	9.982E-8	3.879E-1	1.186E+2	-2.445E-8	1.153E+2	2.732	2.274E+1	5.346E+2	-7.707	-1.768	2.105E-5	-1.126E-3	3.905E-4	1.385E-3
sl6	-6.567	4.309E-8	3.917E-1	1.183E+2	-2.558E-8	1.176E+2	2.740	2.302E+1	5.394E+2	-7.859	-1.784	2.132E-5	-1.004E-3	4.051E-4	1.142E-3
sl7	-6.583	8.857E-8	3.926E-1	1.189E+2	-2.571E-8	1.181E+2	2.709	2.305E+1	5.455E+2	-7.888	-1.809	2.170E-5	-8.865E-4	4.309E-4	1.106E-3
sl8	-6.588	1.028E-7	3.940E-1	1.163E+2	-2.536E-8	1.171E+2	2.676	2.304E+1	5.541E+2	-7.821	-1.842	2.219E-5	-1.551E-3	4.484E-4	1.022E-3
cr1	-6.740	-8.700E-8	4.073E-1	8.537E+1	-2.071E-8	1.135E+2	3.306	2.384E+1	5.656E+2	-7.641	-1.864	2.200E-5	-8.354E-4	4.802E-5	8.631E-4
cr2	-6.743	-8.561E-8	4.083E-1	8.744E+1	-2.044E-8	1.123E+2	3.379	2.389E+1	5.659E+2	-7.574	-1.863	2.196E-5	-8.267E-4	-1.739E-5	8.469E-4
cr3	-6.717	7.628E-8	4.047E-1	1.222E+2	-2.201E-8	1.142E+2	3.288	2.380E+1	5.471E+2	-7.691	-1.791	2.095E-5	-4.187E-4	2.037E-6	1.133E-3
cr4	-6.774	-8.387E-9	4.098E-1	1.257E+2	-2.188E-8	1.136E+2	3.236	2.398E+1	5.560E+2	-7.652	-1.824	2.137E-5	-8.322E-4	1.161E-5	9.945E-4
cr5	-6.866	1.611E-8	4.150E-1	1.397E+2	-2.298E-8	1.164E+2	3.103	2.423E+1	5.687E+2	-7.825	-1.877	2.219E-5	-8.849E-4	1.002E-4	1.053E-3
cr6	-6.749	-4.285E-8	4.063E-1	1.247E+2	-2.265E-8	1.156E+2	3.203	2.389E+1	5.457E+2	-7.776	-1.787	2.089E-5	-6.300E-4	5.889E-5	1.102E-3
cr7	-6.729	-9.169E-9	4.045E-1	1.257E+2	-2.330E-8	1.157E+2	3.215	2.384E+1	5.383E+2	-7.788	-1.758	2.049E-5	-4.036E-4	3.334E-5	9.338E-4
cr8	-6.817	1.068E-8	4.121E-1	1.417E+2	-2.275E-8	1.150E+2	3.132	2.409E+1	5.591E+2	-7.741	-1.837	2.159E-5	-7.856E-4	6.305E-5	1.016E-3
cr9	-8.220E-1	1.693E-8	4.958E-2	2.713E+2	-3.372E-9	1.406E+1	2.816E-1	2.902	5.835E+1	-9.445E-1	-1.893E-1	2.137E-6	-1.452E-4	2.623E-5	1.589E-3
sh1	-8.318	-1.395E-6	5.129E-1	3.812E+2	-1.682E-8	1.262E+2	4.289	2.925E+1	7.074E+2	-8.521	-2.317	2.704E-5	-8.982E-4	1.745E-4	4.260E-3
sh2	-8.340	-6.723E-7	5.100E-1	4.183E+2	-2.045E-8	1.312E+2	4.206	2.937E+1	6.835E+2	-8.839	-2.225	2.582E-5	-5.289E-4	1.456E-4	4.600E-3
sh3	-8.480	-8.424E-7	5.168E-1	8.669E+2	-2.330E-8	1.357E+2	4.182	2.990E+1	6.673E+2	-9.140	-2.155	2.458E-5	-1.447E-3	2.388E-4	6.610E-3
ud1	-6.662	-2.006E-7	4.042E-1	8.811E+1	-1.801E-8	1.107E+2	3.394	2.352E+1	5.733E+2	-7.456	-1.887	2.226E-5	-8.766E-4	-1.830E-5	6.654E-4
ud2	-6.703	-1.652E-7	4.052E-1	1.275E+2	-2.061E-8	1.133E+2	3.258	2.368E+1	5.513E+2	-7.622	-1.800	2.098E-5	-9.974E-4	1.083E-5	6.173E-4
ud3	-6.736	-2.925E-8	4.061E-1	1.918E+2	-2.206E-8	1.150E+2	3.192	2.380E+1	5.418E+2	-7.737	-1.762	2.044E-5	-4.830E-4	9.229E-6	6.950E-4
ud4	-7.578E-1	-6.470E-8	4.590E-2	7.775E+1	-2.629E-9	1.270E+1	3.360E-1	2.674	6.201E+1	-8.542E-1	-2.046E-1	2.433E-6	-2.182E-4	1.411E-5	-8.925E-5
dp1	-6.377	-1.775E-6	4.079E-1	3.929E+2	1.124E-9	8.064E+1	3.944	2.233E+1	6.244E+2	-5.511	-2.067	2.441E-5	8.982E-5	-2.916E-5	4.904E-3
dp2	-6.667	-1.214E-6	4.175E-1	5.325E+2	-8.278E-9	9.492E+1	3.664	2.340E+1	5.689E+2	-6.436	-1.846	2.105E-5	-8.791E-4	3.769E-5	6.282E-3
dp3	-6.723	-4.932E-7	4.143E-1	6.003E+2	-1.336E-8	1.028E+2	3.629	2.368E+1	5.412E+2	-6.943	-1.737	1.961E-5	-3.358E-4	9.942E-6	6.367E-3

where the regression coefficients are multiplied by the following terms:

B0	1.0
B1	$kHDD65 * Q_{sun} * R$
B2	Q_{sun}/T_{grd}
B3	$kHDD65/(Q_{sun} * T_{grd} * R)$
B4	$Q_{sun} * T_{grd}/(kHDD65 * kCDH74)$
B5	$1.0/(kHDD65 * T_{grd})$
B6	$kHDD65/T_{grd}$
B7	T_{grd}/Q_{sun}
B8	$kHDD65 * kCDH74/(Q_{sun} * T_{grd})$
B9	$T_{grd}/(kHDD65 * Q_{sun})$
B10	$kHDD65 * kCDH74/T_{grd}$
B11	$kHDD65 * kCDH74 * Q_{sun}$
B12	$kHDD65 * T_{grd} * R/Q_{sun}$
B13	$kHDD65 * T_{grd}$
B14	$kHDD65 * kCDH74 * T_{grd}/(Q_{sun} * R)$

TABLE 4

Regression Coefficients for Heating Season Energy Use (in MBtu/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
sl1	-2.164E+1	-2.063E-8	1.364	1.245E+2	-4.030E-8	3.244E+2	8.154	7.233E+1	4.226E+3	-1.390E+1	-1.798E+1	3.980E-4	-2.099E-3	-6.183E-1	-2.136E-5
sl2	-2.206E+1	7.731E-8	1.392	1.289E+2	-4.070E-8	3.298E+2	8.252	7.367E+1	4.342E+3	-1.403E+1	-1.849E+1	4.100E-4	-1.740E-3	-6.382E-1	-2.187E-5
sl3	-2.200E+1	8.119E-8	1.388	1.345E+2	-4.063E-8	3.282E+2	8.208	7.350E+1	4.325E+3	-1.405E+1	-1.840E+1	4.077E-4	-1.756E-3	-6.340E-1	-2.131E-5
sl4	-2.098E+1	1.092E-8	1.320	1.640E+2	-4.044E-8	3.167E+2	7.883	7.019E+1	4.036E+3	-1.368E+1	-1.714E+1	3.789E-4	-1.875E-3	-5.874E-1	-2.084E-5
sl5	-2.082E+1	-3.828E-8	1.310	1.715E+2	-4.058E-8	3.141E+2	7.806	6.969E+1	3.981E+3	-1.368E+1	-1.690E+1	3.730E-4	-2.052E-3	-5.781E-1	-2.020E-5
sl6	-2.138E+1	-5.450E-9	1.346	1.794E+2	-4.229E-8	3.213E+2	7.921	7.160E+1	4.094E+3	-1.415E+1	-1.738E+1	3.839E-4	-1.448E-3	-5.966E-1	-1.948E-5
sl7	-2.208E+1	5.436E-8	1.392	1.800E+2	-4.276E-8	3.305E+2	8.108	7.384E+1	4.291E+3	-1.436E+1	-1.825E+1	4.044E-4	-1.261E-3	-6.304E-1	-2.045E-5
sl8	-2.136E+1	-5.137E-8	1.347	1.684E+2	-4.100E-8	3.168E+2	7.900	7.150E+1	4.126E+3	-1.399E+1	-1.750E+1	3.860E-4	-2.364E-3	-5.986E-1	-1.856E-5
cr1	-1.365E+1	-1.475E-7	8.423E-1	1.221E+2	-3.353E-8	2.224E+2	5.982	4.692E+1	1.909E+3	-1.186E+1	-7.610	1.504E-4	-1.736E-3	-1.984E-1	-1.035E-5
cr2	-1.204E+1	-1.239E-7	7.378E-1	1.249E+2	-3.250E-8	2.003E+2	5.524	4.178E+1	1.457E+3	-1.140E+1	-5.587	1.021E-4	-1.770E-3	-1.168E-1	-7.686E-6
cr3	-1.219E+1	1.118E-7	7.452E-1	1.649E+2	-3.439E-8	2.030E+2	5.466	4.229E+1	1.478E+3	-1.167E+1	-5.688	1.052E-4	-1.025E-3	-1.251E-1	-6.698E-6
cr4	-1.247E+1	-3.465E-8	7.658E-1	1.797E+2	-3.418E-8	2.039E+2	5.453	4.318E+1	1.549E+3	-1.165E+1	-5.989	1.117E-4	-1.824E-3	-1.351E-1	-6.816E-6
cr5	-1.418E+1	-4.090E-8	8.779E-1	2.002E+2	-3.566E-8	2.244E+2	5.831	4.869E+1	2.013E+3	-1.228E+1	-8.040	1.596E-4	-1.822E-3	-2.147E-1	-7.861E-6
cr6	-1.393E+1	-4.553E-8	8.588E-1	1.876E+2	-3.617E-8	2.262E+2	5.882	4.789E+1	1.941E+3	-1.223E+1	-7.754	1.543E-4	-1.117E-3	-2.083E-1	-9.172E-6
cr7	-1.238E+1	-2.482E-8	7.571E-1	1.719E+2	-3.564E-8	2.040E+2	5.434	4.293E+1	1.514E+3	-1.189E+1	-5.841	1.088E-4	-7.525E-4	-1.333E-1	-5.385E-6
cr8	-1.348E+1	-3.153E-8	8.323E-1	2.028E+2	-3.537E-8	2.157E+2	5.640	4.645E+1	1.820E+3	-1.203E+1	-7.187	1.398E-4	-1.706E-3	-1.825E-1	-7.255E-6
cr9	-1.895	1.777E-8	1.184E-1	3.925E+2	-4.926E-9	2.779E+1	6.352E-1	6.494	2.823E+2	-1.557	-1.149	2.373E-5	-2.502E-4	-3.501E-2	-4.132E-7
sh1	-2.003E+1	-2.023E-6	1.262	4.997E+2	-3.165E-8	3.149E+2	8.729	6.723E+1	3.547E+3	-1.233E+1	-1.491E+1	3.243E-4	-3.136E-3	-4.789E-1	-3.340E-5
sh2	-1.935E+1	-8.637E-7	1.212	5.811E+2	-3.580E-8	3.076E+2	8.258	6.517E+1	3.278E+3	-1.287E+1	-1.369E+1	2.956E-4	-1.332E-3	-4.347E-1	-2.888E-5
sh3	-1.947E+1	-1.245E-6	1.221	1.098E+3	-3.715E-8	3.049E+2	8.412	6.577E+1	3.279E+3	-1.319E+1	-1.368E+1	2.950E-4	-2.612E-3	-4.384E-1	-2.583E-5
ud1	-1.245E+1	-2.673E-7	7.650E-1	1.254E+2	-2.976E-8	2.068E+2	5.698	4.289E+1	1.604E+3	-1.136E+1	-6.240	1.175E-4	-1.786E-3	-1.418E-1	-9.349E-6
ud2	-1.230E+1	-2.114E-7	7.549E-1	1.871E+2	-3.229E-8	2.017E+2	5.437	4.257E+1	1.512E+3	-1.167E+1	-5.814	1.076E-4	-1.592E-3	-1.296E-1	-5.901E-6
ud3	-1.149E+1	-3.296E-8	7.015E-1	2.765E+2	-3.315E-8	1.894E+2	5.078	4.004E+1	1.264E+3	-1.168E+1	-4.696	8.093E-5	-7.644E-4	-8.681E-2	-2.676E-6
ud4	-1.293	-9.478E-8	7.980E-2	1.105E+2	-3.550E-9	1.895E+1	5.459E-1	4.528	1.439E+2	-1.321	-5.290E-1	8.801E-6	-3.041E-4	-9.398E-3	6.684E-7
dp1	-1.849E+1	-2.413E-6	1.180	5.146E+2	-1.537E-8	3.022E+2	8.492	6.090E+1	3.704E+3	-8.143	-1.592E+1	3.578E-4	-2.519E-3	-5.335E-1	-5.138E-5
dp2	-1.735E+1	-1.528E-6	1.099	7.431E+2	-2.340E-8	2.809E+2	7.570	5.770E+1	3.188E+3	-9.416	-1.355E+1	3.006E-4	-2.109E-3	-4.490E-1	-3.845E-5
dp3	-1.485E+1	-6.269E-7	9.291E-1	8.142E+2	-2.665E-8	2.468E+2	6.701	4.997E+1	2.423E+3	-9.776	-1.010E+1	2.180E-4	-8.081E-4	-3.163E-1	-2.792E-5

where the regression coefficients are multiplied by the following terms:

B0	1.0
B1	$kHDD65 * Q_{sun} * R$
B2	Q_{sun}/T_{grd}
B3	$kHDD65/(Q_{sun} * T_{grd} * R)$
B4	$Q_{sun} * T_{grd}/(kHDD65 * kCDH74)$
B5	$1.0/(kHDD65 * T_{grd})$
B6	$kHDD65/T_{grd}$
B7	T_{grd}/Q_{sun}
B8	$kHDD65 * kCDH74/(Q_{sun} * T_{grd})$
B9	$T_{grd}/(kHDD65 * Q_{sun})$
B10	$kHDD65 * kCDH74/T_{grd}$
B11	$kHDD65 * kCDH74 * Q_{sun}$
B12	$kHDD65 * T_{grd} * R/Q_{sun}$
B13	$kCDH74 * T_{grd}/Q_{sun}$
B14	$T_{grd} * Q_{sun}/kHDD65$

TABLE 5
Regression Coefficients for Cooling Season Loads (in kWh/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
sl1	5.616	-7.100E-1	1.403E-1	2.192E+2	6.715E-2	-1.590E-1	-1.669E-2	2.266E-5	-5.742E-4	-9.345E+2	2.179E+4	-4.627E-2
sl2	5.618	-7.094E-1	1.407E-1	2.190E+2	6.702E-2	-2.002E-1	-1.680E-2	-2.664E-5	-4.502E-4	-9.306E+2	2.175E+4	-4.624E-2
sl3	5.672	-7.132E-1	1.420E-1	2.202E+2	6.732E-2	-2.694E-1	-1.694E-2	-7.243E-5	-3.764E-4	-9.336E+2	2.208E+4	-4.685E-2
sl4	5.410	-6.722E-1	1.278E-1	2.071E+2	6.351E-2	4.333E-1	-1.566E-2	3.281E-4	-3.712E-4	-8.767E+2	2.090E+4	-4.431E-2
sl5	5.421	-6.759E-1	1.289E-1	2.084E+2	6.388E-2	3.506E-1	-1.568E-2	2.871E-4	-3.650E-4	-8.843E+2	2.103E+4	-4.433E-2
sl6	5.789	-7.221E-1	1.432E-1	2.234E+2	6.845E-2	-1.048E-1	-1.650E-2	2.380E-5	-2.308E-4	-9.672E+2	2.284E+4	-4.740E-2
sl7	5.822	-7.235E-1	1.443E-1	2.238E+2	6.848E-2	-1.476E-1	-1.667E-2	-2.646E-6	-1.283E-4	-9.648E+2	2.307E+4	-4.792E-2
sl8	5.833	-7.091E-1	1.424E-1	2.193E+2	6.684E-2	-4.016E-1	-1.687E-2	-1.224E-4	-3.078E-4	-9.281E+2	2.253E+4	-4.755E-2
cr1	2.040	-5.441E-1	9.126E-2	1.675E+2	5.137E-2	-1.343E-1	-1.350E-2	6.792E-6	-6.179E-4	-6.702E+2	9.337E+3	-1.599E-2
cr2	1.494	-5.430E-1	8.736E-2	1.670E+2	5.119E-2	-1.524E-1	-1.336E-2	-1.982E-5	-4.453E-4	-6.629E+2	7.455E+3	-1.061E-2
cr3	1.740	-5.358E-1	8.853E-2	1.655E+2	5.052E-2	-4.056E-1	-1.314E-2	-1.243E-5	-3.216E-4	-6.614E+2	8.115E+3	-1.219E-2
cr4	1.798	-5.482E-1	9.184E-2	1.692E+2	5.157E-2	-4.860E-1	-1.362E-2	-1.464E-4	-5.834E-4	-6.706E+2	8.647E+3	-1.331E-2
cr5	2.143	-5.776E-1	9.680E-2	1.783E+2	5.447E-2	-6.111E-1	-1.383E-2	-2.222E-4	-5.462E-4	-7.196E+2	1.114E+4	-1.756E-2
cr6	2.170	-5.561E-1	9.442E-2	1.718E+2	5.265E-2	-9.405E-2	-1.330E-2	-4.562E-7	-2.210E-4	-7.035E+2	1.021E+4	-1.685E-2
cr7	1.859	-5.425E-1	9.007E-2	1.679E+2	5.117E-2	-5.543E-1	-1.303E-2	-3.162E-5	-1.983E-4	-6.767E+2	9.091E+3	-1.338E-2
cr8	2.105	-5.629E-1	9.623E-2	1.739E+2	5.296E-2	-6.433E-1	-1.385E-2	-2.262E-4	-5.572E-4	-6.944E+2	1.031E+4	-1.665E-2
cr9	1.852E-1	-5.111E-2	8.543E-3	1.599E+1	4.783E-3	-4.942E-1	-1.304E-3	6.822E-6	-6.551E-5	-6.052E+1	9.644E+2	-1.144E-3
sh1	8.913E-1	-6.252E-1	1.048E-1	1.918E+2	5.836E-2	-4.638E-2	-1.678E-2	3.094E-5	-1.764E-3	-7.051E+2	1.310E+4	-1.154E-2
sh2	1.239	-6.230E-1	1.052E-1	1.917E+2	5.816E-2	2.856E-1	-1.619E-2	5.681E-5	-6.038E-4	-7.200E+2	1.451E+4	-1.462E-2
sh3	9.328E-1	-6.025E-1	9.913E-2	1.854E+2	5.627E-2	1.329	-1.590E-2	1.218E-5	-1.560E-3	-6.775E+2	1.308E+4	-1.080E-2
ud1	2.105	-5.657E-1	9.964E-2	1.750E+2	5.353E-2	-2.173E-1	-1.496E-2	-5.023E-5	-5.756E-4	-7.083E+2	8.580E+3	-1.597E-2
ud2	2.115	-5.844E-1	1.025E-1	1.813E+2	5.525E-2	-2.805E-1	-1.475E-2	-7.881E-5	-5.757E-5	-7.440E+2	9.472E+3	-1.592E-2
ud3	1.981	-5.933E-1	1.027E-1	1.842E+2	5.600E-2	-6.584E-1	-1.453E-2	-5.268E-5	-4.394E-5	-7.561E+2	9.870E+3	-1.504E-2
ud4	2.646E-1	-6.149E-2	1.100E-2	1.916E+1	5.701E-3	-4.898E-1	-1.629E-3	-1.125E-5	5.975E-5	-7.463E+1	1.085E+3	-1.761E-3
dp1	2.122	-7.098E-1	1.291E-1	2.179E+2	6.717E-2	2.003E-1	-1.720E-2	2.340E-4	-1.833E-3	-8.922E+2	1.590E+4	-2.117E-2
dp2	2.378	-7.208E-1	1.324E-1	2.223E+2	6.841E-2	4.927E-1	-1.669E-2	1.890E-4	-8.512E-4	-9.353E+2	1.705E+4	-2.322E-2
dp3	2.372	-7.151E-1	1.329E-1	2.215E+2	6.780E-2	2.019E-1	-1.659E-2	5.075E-5	-3.191E-4	-9.375E+2	1.689E+4	-2.274E-2

where the regression coefficients are multiplied by the following terms:

B0	1.0
B1	$kCDH74 * T_{grd}$
B2	$kHDD65 * kCDH74 * Q_{sun} / T_{grd}$
B3	$kCDH74 * T_{grd} / Q_{sun}$
B4	$kCDH74 * Q_{sun}$
B5	$kCDH74 * T_{grd} / (Q_{sun} * R)$
B6	$kHDD65 * kCDH74 * T_{grd}$
B7	$kCDH74 * Q_{sun} * R / (kHDD65 * T_{grd})$
B8	$kCDH74 * Q_{sun} * R / T_{grd}$
B9	$kCDH74 / T_{grd}$
B10	$kHDD65 / (Q_{sun} * T_{grd})$
B11	$kHDD65 * T_{grd}$

TABLE 6
Regression Coefficients for Cooling Season Energy Use (in kWh/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
sl1	-2.239E+2	-1.667E-2	9.263E-9	9.971E-2	-7.240E-2	-2.825E+3	2.291	6.411E+3	-7.055E+1	5.911E+4	-2.011	-2.251E-1	4.269E-2	1.728E-6	-6.816E-4
sl2	-2.230E+2	-1.689E-2	2.431E-8	9.969E-2	-6.565E-2	-2.863E+3	2.286	6.388E+3	-7.039E+1	5.962E+4	-2.028	-2.390E-1	4.394E-2	1.393E-6	-2.696E-3
sl3	-2.250E+2	-1.728E-2	3.259E-8	1.002E-1	-4.962E-2	-2.897E+3	2.307	6.444E+3	-7.085E+1	6.043E+4	-2.050	-2.279E-1	4.475E-2	1.052E-6	-5.670E-3
sl4	-2.160E+2	-1.542E-2	-6.035E-8	9.581E-2	-1.423E-2	-2.420E+3	2.191	6.178E+3	-6.846E+1	5.701E+4	-1.979	-7.150E-2	3.142E-2	4.990E-6	1.642E-2
sl5	-2.183E+2	-1.539E-2	-4.268E-8	9.673E-2	-3.638E-2	-2.395E+3	2.213	6.242E+3	-6.883E+1	5.673E+4	-1.953	-1.398E-1	3.030E-2	5.221E-6	1.531E-2
sl6	-2.359E+2	-1.591E-2	3.149E-9	1.014E-1	-1.097E-2	-2.579E+3	2.390	6.778E+3	-7.478E+1	5.576E+4	-1.827	-9.349E-2	3.451E-2	9.624E-7	-3.935E-3
sl7	-2.343E+2	-1.631E-2	1.349E-8	1.016E-1	-2.806E-3	-2.647E+3	2.378	6.735E+3	-7.437E+1	5.670E+4	-1.853	-1.027E-1	3.666E-2	8.665E-7	-5.932E-3
sl8	-2.284E+2	-1.708E-2	5.781E-8	1.008E-1	-4.089E-2	-2.790E+3	2.331	6.559E+3	-7.250E+1	5.938E+4	-1.963	-3.014E-1	4.149E-2	1.699E-6	-9.400E-3
cr1	-1.263E+2	-1.183E-2	1.500E-8	7.708E-2	-6.699E-2	-2.527E+3	1.411	3.465E+3	-3.189E+1	5.326E+4	-2.123	-2.669E-1	4.286E-2	1.766E-6	-1.341E-4
cr2	-1.188E+2	-1.172E-2	2.022E-8	7.737E-2	-3.653E-2	-2.515E+3	1.357	3.199E+3	-2.637E+1	5.291E+4	-2.128	-2.463E-1	4.236E-2	2.137E-6	-1.376E-3
cr3	-1.315E+2	-1.113E-2	7.699E-9	7.889E-2	-2.626E-1	-2.386E+3	1.451	3.617E+3	-3.309E+1	5.014E+4	-1.927	-1.743E-1	3.822E-2	1.628E-6	7.162E-3
cr4	-1.281E+2	-1.195E-2	5.530E-8	7.836E-2	-8.743E-2	-2.471E+3	1.433	3.502E+3	-3.076E+1	5.310E+4	-2.063	-3.707E-1	4.090E-2	1.674E-6	-9.300E-3
cr5	-1.451E+2	-1.230E-2	7.134E-8	7.966E-2	-1.164E-1	-2.285E+3	1.588	3.970E+3	-3.371E+1	5.441E+4	-2.125	-4.318E-1	3.364E-2	1.994E-6	-1.041E-2
cr6	-1.420E+2	-1.120E-2	1.315E-8	7.920E-2	2.933E-3	-2.302E+3	1.543	3.937E+3	-3.714E+1	4.993E+4	-1.930	-1.292E-1	3.512E-2	8.937E-7	-4.257E-3
cr7	-1.423E+2	-1.093E-2	1.424E-8	7.985E-2	-2.904E-1	-2.184E+3	1.541	3.930E+3	-3.557E+1	4.926E+4	-1.855	-1.433E-1	3.140E-2	1.322E-6	9.433E-3
cr8	-1.391E+2	-1.231E-2	7.401E-8	7.937E-2	-9.681E-2	-2.398E+3	1.531	3.825E+3	-3.400E+1	5.387E+4	-2.070	-4.041E-1	3.791E-2	1.445E-6	-1.308E-2
cr9	-1.582E+1	-8.900E-4	-1.492E-9	8.602E-3	-1.017E-1	-2.009E+2	1.651E-1	4.570E+2	-4.967	4.778E+3	-1.530E-1	-1.114E-2	2.486E-3	1.252E-7	-1.282E-2
sh1	-5.037E+1	-9.141E-3	3.647E-8	6.665E-2	-1.536E-1	-2.699E+3	7.140E-1	1.361E+3	-9.743E-1	6.133E+4	-2.560	-6.346E-1	5.370E-2	4.059E-6	7.789E-3
sh2	-6.101E+1	-8.518E-3	8.932E-9	6.516E-2	7.115E-2	-2.384E+3	8.001E-1	1.680E+3	-4.392	5.711E+4	-2.359	-1.861E-1	4.485E-2	1.247E-6	1.742E-4
sh3	-6.563E+1	-7.905E-3	-1.325E-8	6.611E-2	4.564E-1	-2.365E+3	8.324E-1	1.833E+3	-7.199	5.800E+4	-2.320	-3.538E-1	4.322E-2	2.078E-6	1.725E-2
ud1	-1.290E+2	-1.208E-2	3.716E-8	8.288E-2	-5.197E-2	-2.577E+3	1.461	3.472E+3	-3.044E+1	5.347E+4	-2.215	-3.320E-1	4.264E-2	1.909E-6	-2.983E-3
ud2	-1.474E+2	-1.180E-2	4.454E-8	8.580E-2	2.241E-2	-2.283E+3	1.616	4.021E+3	-3.590E+1	5.090E+4	-2.013	-2.136E-1	3.240E-2	1.261E-6	-1.063E-2
ud3	-1.567E+2	-1.172E-2	2.331E-8	8.702E-2	-6.829E-2	-2.151E+3	1.695	4.298E+3	-3.796E+1	4.998E+4	-1.892	-1.122E-1	2.778E-2	6.381E-7	-1.371E-2
ud4	-1.635E+1	-1.369E-3	7.256E-9	1.005E-2	-4.201E-2	-1.811E+2	1.754E-1	4.451E+2	-3.907	5.619E+3	-2.048E-1	-2.205E-2	1.221E-3	4.184E-7	-5.421E-3
dp1	-8.001E+1	-1.320E-2	-6.513E-9	8.136E-2	-1.383E-2	-3.379E+3	1.035	2.163E+3	-9.641	6.154E+4	-2.532	-5.218E-1	6.890E-2	3.783E-6	6.404E-3
dp2	-1.055E+2	-1.186E-2	-2.747E-8	8.584E-2	9.522E-2	-2.858E+3	1.246	2.911E+3	-1.837E+1	5.428E+4	-2.089	-2.644E-1	5.161E-2	2.602E-6	4.222E-3
dp3	-1.220E+2	-1.118E-2	5.301E-9	8.826E-2	-3.350E-1	-2.518E+3	1.386	3.384E+3	-2.354E+1	5.096E+4	-1.895	-2.448E-1	4.043E-2	1.474E-6	1.425E-2

where the regression coefficients are multiplied by the following terms:

B0	1.0
B1	$kCDH74 * T_{grd}$
B2	$kHDD65 * kCDH74 * Q_{sun} * T_{grd} * R$
B3	$kCDH74 * Q_{sun} / (kHDD65 * T_{grd})$
B4	$kCDH74 * T_{grd} / (Q_{sun} * R)$
B5	$1.0 / (kHDD65 * T_{grd})$
B6	T_{grd}
B7	$1.0 / T_{grd}$
B8	$kHDD65 / T_{grd}$
B9	$kCDH74 / (Q_{sun} * T_{grd})$
B10	$kHDD65 * kCDH74 * T_{grd} / Q_{sun}$
B11	$kCDH74 * R / T_{grd}$
B12	$Q_{sun} / kHDD65$
B13	$Q_{sun} * T_{grd} * R$
B14	T_{grd} / R

TABLE 7
Regression Coefficients for Total Annual Loads (in MBtu/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
sl1	3.441	1.881E+3	4.109E+1	2.740E-1	-2.571E-3	-4.247E-2	-3.846E+1	6.347E-4	-3.322E+4	-2.865E-2	-1.092E-2	-7.780E-5	-1.651E-3	-1.756E-9
sl2	3.488	1.884E+3	4.097E+1	2.801E-1	-2.580E-3	-2.301E-2	-3.568E+1	6.418E-4	-3.364E+4	-2.902E-2	-8.493E-3	-7.894E-5	-1.670E-3	-1.450E-9
sl3	3.489	1.885E+3	4.122E+1	2.858E-1	-2.595E-3	-2.442E-2	-3.581E+1	6.449E-4	-3.366E+4	-2.915E-2	-6.519E-3	-7.894E-5	-1.671E-3	-1.284E-9
sl4	3.407	1.843E+3	4.050E+1	4.105E-1	-2.534E-3	-1.138E-4	-3.791E+1	6.276E-4	-3.276E+4	-2.836E-2	-2.019E-2	-7.707E-5	-1.683E-3	-2.509E-9
sl5	3.386	1.837E+3	4.068E+1	4.214E-1	-2.541E-3	-1.048E-2	-3.851E+1	6.275E-4	-3.259E+4	-2.835E-2	-1.871E-2	-7.657E-5	-1.677E-3	-2.411E-9
sl6	3.289	1.856E+3	4.233E+1	3.698E-1	-2.612E-3	-3.756E-2	-4.523E+1	6.304E-4	-3.199E+4	-2.836E-2	-5.098E-3	-7.395E-5	-1.619E-3	-1.435E-9
sl7	3.368	1.866E+3	4.208E+1	3.672E-1	-2.619E-3	-2.650E-2	-4.094E+1	6.401E-4	-3.268E+4	-2.887E-2	-3.666E-3	-7.583E-5	-1.651E-3	-1.186E-9
sl8	3.421	1.863E+3	4.174E+1	3.496E-1	-2.616E-3	-5.012E-2	-3.710E+1	6.458E-4	-3.306E+4	-2.919E-2	-4.747E-3	-7.726E-5	-1.664E-3	-1.301E-9
cr1	2.661	1.758E+3	4.725E+1	2.688E-1	-2.748E-3	-3.909E-2	-8.464E+1	5.973E-4	-2.658E+4	-2.620E-2	-1.501E-2	-5.923E-5	-1.233E-3	-2.747E-9
cr2	2.577	1.751E+3	4.845E+1	2.689E-1	-2.795E-3	-3.955E-2	-9.087E+1	5.980E-4	-2.594E+4	-2.613E-2	-1.259E-2	-5.714E-5	-1.185E-3	-2.571E-9
cr3	2.696	1.765E+3	4.702E+1	4.006E-1	-2.742E-3	-1.919E-3	-8.244E+1	5.982E-4	-2.694E+4	-2.627E-2	-7.584E-3	-5.983E-5	-1.304E-3	-6.466E-9
cr4	2.618	1.734E+3	4.796E+1	3.617E-1	-2.784E-3	-3.723E-2	-8.513E+1	6.025E-4	-2.621E+4	-2.643E-2	-8.985E-3	-5.809E-5	-1.239E-3	-2.435E-9
cr5	2.762	1.750E+3	4.839E+1	3.988E-1	-2.858E-3	-3.799E-2	-7.803E+1	6.364E-4	-2.751E+4	-2.814E-2	-6.625E-3	-6.146E-5	-1.301E-3	-2.263E-9
cr6	2.645	1.743E+3	4.734E+1	3.834E-1	-2.766E-3	-3.084E-2	-8.159E+1	6.046E-4	-2.646E+4	-2.659E-2	-5.790E-3	-5.863E-5	-1.269E-3	-1.727E-9
cr7	2.718	1.767E+3	4.715E+1	3.914E-1	-2.767E-3	-1.602E-2	-7.889E+1	6.089E-4	-2.716E+4	-2.683E-2	-3.060E-3	-6.020E-5	-1.332E-3	-4.210E-9
cr8	2.684	1.735E+3	4.792E+1	3.967E-1	-2.807E-3	-3.731E-2	-8.037E+1	6.163E-4	-2.679E+4	-2.715E-2	-5.739E-3	-5.966E-5	-1.275E-3	-2.152E-9
cr9	3.370E-1	1.827E+2	5.187	7.963E-1	-3.195E-4	-4.895E-3	-5.399	7.734E-5	-3.230E+3	-3.505E-3	-8.961E-4	-7.579E-6	-1.734E-4	-3.348E-9
sh1	2.966	2.057E+3	5.386E+1	1.223	-2.938E-3	-1.697E-1	-1.194E+2	5.960E-4	-2.935E+4	-2.546E-2	-6.645E-2	-6.803E-5	-9.988E-4	-9.364E-9
sh2	2.940	2.071E+3	5.468E+1	1.354	-3.010E-3	-8.696E-2	-1.172E+2	6.119E-4	-2.938E+4	-2.621E-2	-2.636E-2	-6.680E-5	-1.115E-3	-5.140E-9
sh3	3.270	2.165E+3	5.368E+1	2.734	-3.022E-3	-1.476E-1	-1.006E+2	6.467E-4	-3.193E+4	-2.808E-2	-3.953E-2	-7.459E-5	-1.334E-3	-1.773E-8
ud1	2.812	1.822E+3	4.510E+1	2.667E-1	-2.621E-3	-5.375E-2	-8.343E+1	5.737E-4	-2.789E+4	-2.514E-2	-1.063E-2	-6.294E-5	-1.352E-3	-1.969E-9
ud2	2.768	1.802E+3	4.588E+1	3.633E-1	-2.672E-3	-6.164E-2	-8.170E+1	5.845E-4	-2.756E+4	-2.567E-2	-1.341E-3	-6.165E-5	-1.365E-3	-7.062E-010
ud3	2.853	1.813E+3	4.612E+1	5.335E-1	-2.706E-3	-2.502E-2	-7.769E+1	5.982E-4	-2.840E+4	-2.635E-2	-9.795E-5	-6.348E-5	-1.437E-3	-1.113E-9
ud4	3.025E-1	1.943E+2	5.294	2.253E-1	-3.149E-4	-1.524E-2	-7.971	7.113E-5	-2.989E+3	-3.168E-3	1.010E-3	-6.741E-6	-1.514E-4	5.606E-012
dp1	1.623	1.528E+3	4.494E+1	1.276	-2.098E-3	-1.616E-1	-1.587E+2	3.105E-4	-1.708E+4	-1.171E-2	-8.334E-2	-3.769E-5	-3.837E-5	-1.243E-8
dp2	1.951	1.611E+3	4.516E+1	1.747	-2.255E-3	-1.588E-1	-1.340E+2	3.875E-4	-1.995E+4	-1.565E-2	-3.868E-2	-4.464E-5	-4.845E-4	-7.942E-9
dp3	2.336	1.753E+3	4.435E+1	1.936	-2.306E-3	-6.602E-2	-1.192E+2	4.257E-4	-2.363E+4	-1.763E-2	-1.297E-2	-5.292E-5	-8.659E-4	-1.343E-8

where the regression coeffcients are multiplied by the following terms:

B0	1.0
B1	$kHDD65/(Q_{sun}*T_{grd})$
B2	$kCDH74/Q_{sun}$
B3	$kHDD65/(T_{grd}*R)$
B4	$kCDH74*T_{grd}$
B5	$kHDD65*R/Q_{sun}$
B6	$kHDD65*kCDH74/(Q_{sun}*T_{grd})$
B7	$kCDH74*Q_{sun}$
B8	$1.0/(Q_{sun}*T_{grd})$
B9	$kCDH74*Q_{sun}/T_{grd}$
B10	$kCDH74*R/Q_{sun}$
B11	$Q_{sun}*T_{grd}$
B12	$kHDD65*T_{grd}$
B13	$kCDH74*Q_{sun}*T_{grd}/(kHDD65*R)$

TABLE 8

Regression Coefficients for Total Annual Energy Use (in MBtu/ft)

Id	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
sl1	-1.202E+1	-4.255E+3	4.965E+2	-3.215E-1	-1.618E-2	-3.021E+1	-1.263	7.445E+4	-3.474E-1	2.488E-2	8.675E-1	-6.549E-3	6.267E+1	-1.092E-1	4.302E+2	5.588
sl2	-1.233E+1	-4.381E+3	4.907E+2	-3.294E-1	1.209E-2	-3.086E+1	-1.230	7.703E+4	-2.430E-1	2.558E-2	8.861E-1	-6.688E-3	6.395E+1	-1.116E-1	4.368E+2	5.729
sl3	-1.254E+1	-4.455E+3	4.907E+2	-3.247E-1	1.357E-2	-3.130E+1	-1.221	7.884E+4	-1.617E-1	2.608E-2	8.985E-1	-6.781E-3	6.493E+1	-1.133E-1	4.401E+2	5.816
sl4	-1.151E+1	-4.072E+3	5.019E+2	-2.720E-1	3.224E-2	-2.885E+1	-1.317	6.919E+4	-7.144E-1	2.339E-2	8.290E-1	-6.261E-3	5.984E+1	-1.029E-1	4.206E+2	6.452
sl5	-1.148E+1	-4.064E+3	5.007E+2	-2.584E-1	1.606E-2	-2.876E+1	-1.310	6.878E+4	-6.593E-1	2.327E-2	8.264E-1	-6.241E-3	5.960E+1	-1.024E-1	4.205E+2	6.475
sl6	4.107	1.171E+3	6.389E+2	1.103E-1	-5.132E-2	1.604	-2.492	-7.011E+4	-2.461E-1	-1.329E-2	-4.038E-2	3.007E-4	-8.023	1.352E-2	1.878E+2	3.172
sl7	4.172	1.165E+3	6.358E+2	1.104E-1	-3.543E-2	1.627	-2.483	-7.078E+4	-1.835E-1	-1.343E-2	-4.117E-2	3.089E-4	-8.310	1.357E-2	1.892E+2	3.172
sl8	-1.270E+1	-4.511E+3	4.858E+2	-2.778E-1	-2.222E-2	-3.144E+1	-1.192	7.973E+4	-1.193E-1	2.626E-2	9.028E-1	-6.814E-3	6.523E+1	-1.131E-1	4.429E+2	6.213
cr1	-8.517	-2.780E+3	6.324E+2	-2.318E-1	-2.551E-2	-2.291E+1	-1.986	4.486E+4	-4.697E-1	1.712E-2	6.616E-1	-5.031E-3	5.006E+1	-8.297E-2	3.545E+2	4.785
cr2	-8.451	-2.711E+3	6.450E+2	-2.471E-1	-2.539E-2	-2.261E+1	-2.039	4.393E+4	-3.492E-1	1.689E-2	6.534E-1	-4.973E-3	4.983E+1	-8.156E-2	3.516E+2	4.934
cr3	-8.263	-2.691E+3	6.259E+2	-1.256	3.483E-2	-2.195E+1	-1.980	3.988E+4	-1.796E-3	1.584E-2	6.345E-1	-4.826E-3	4.771E+1	-7.705E-2	3.572E+2	1.435E+1
cr4	-8.727	-2.864E+3	6.275E+2	-1.947E-1	-7.776E-3	-2.306E+1	-1.946	4.553E+4	-2.036E-1	1.726E-2	6.660E-1	-5.065E-3	5.035E+1	-8.232E-2	3.597E+2	5.740
cr5	-1.032E+1	-3.463E+3	6.090E+2	-2.052E-1	-3.145E-3	-2.638E+1	-1.828	5.935E+4	-1.020E-1	2.097E-2	7.606E-1	-5.775E-3	5.722E+1	-9.487E-2	3.888E+2	6.276
cr6	3.866	1.341E+3	7.257E+2	1.135E-1	-4.144E-2	1.505	-2.861	-6.647E+4	-2.562E-1	-1.231E-2	-3.537E-2	2.314E-4	-4.676	1.162E-2	1.714E+2	3.299
cr7	-8.894	-2.949E+3	6.043E+2	-7.179E-1	-6.672E-3	-2.331E+1	-1.858	4.639E+4	-1.618E-2	1.740E-2	6.730E-1	-5.113E-3	5.032E+1	-8.239E-2	3.656E+2	1.012E+1
cr8	-9.436	-3.153E+3	6.132E+2	-1.783E-1	-6.439E-4	-2.454E+1	-1.863	5.156E+4	-6.502E-2	1.887E-2	7.082E-1	-5.380E-3	5.325E+1	-8.776E-2	3.737E+2	6.094
cr9	3.762E-1	1.016E+2	7.859E+1	2.395E-1	-4.197E-3	1.049E-1	-3.153E-1	-7.660E+3	-2.071E-2	-1.424E-3	-2.185E-3	1.407E-5	-6.001E-1	1.704E-3	2.314E+1	7.185
sh1	-5.777	-1.699E+3	8.012E+2	2.565E-1	-1.510E-1	-1.894E+1	-2.524	2.516E+4	-2.701	1.271E-2	5.479E-1	-4.187E-3	4.356E+1	-7.590E-2	3.079E+2	1.048E+1
sh2	4.495	1.713E+3	8.700E+2	5.132E-1	-1.006E-1	1.409	-3.236	-6.817E+4	-1.295	-1.202E-2	-3.258E-2	1.962E-4	-2.324	3.927E-3	1.594E+2	9.335
sh3	-6.677	-2.093E+3	7.585E+2	6.528E-1	-1.503E-1	-2.051E+1	-2.329	2.975E+4	-1.387	1.376E-2	5.928E-1	-4.516E-3	4.539E+1	-7.834E-2	3.390E+2	2.334E+1
ud1	-7.317	-2.304E+3	6.624E+2	-1.541E-1	-5.316E-2	-2.072E+1	-2.144	3.634E+4	-3.047E-1	1.494E-2	5.994E-1	-4.571E-3	4.622E+1	-7.697E-2	3.248E+2	4.180
ud2	3.981	1.437E+3	7.438E+2	2.013E-1	-8.942E-2	1.469	-2.913	-6.505E+4	-4.471E-2	-1.186E-2	-3.388E-2	2.116E-4	-3.599	8.779E-3	1.583E+2	2.502
ud3	3.567	1.235E+3	7.236E+2	1.812E-1	-3.534E-2	8.658E-1	-2.812	-6.328E+4	2.673E-2	-1.144E-2	-1.690E-2	8.940E-5	-3.016	8.353E-3	1.730E+2	4.582
ud4	4.259E-1	1.462E+2	7.874E+1	2.995E-1	-2.429E-2	1.050E-1	-3.148E-1	-7.036E+3	4.159E-2	-1.292E-3	-2.162E-3	1.251E-5	-3.964E-1	8.814E-4	1.821E+1	1.441E-1
dp1	-7.081E-1	2.270E+2	7.726E+2	4.210E-1	-1.489E-1	-7.673	-2.609	-8.310E+3	-3.566	2.936E-3	2.247E-1	-1.760E-3	2.188E+1	-3.927E-2	1.549E+2	9.707
dp2	3.596	1.522E+3	7.667E+2	7.163E-1	-1.880E-1	9.037E-1	-2.780	-5.050E+4	-2.115	-8.362E-3	-1.963E-2	9.391E-5	8.996E-1	-2.482E-3	1.092E+2	1.160E+1
dp3	3.300	1.325E+3	7.193E+2	8.988E-1	-7.877E-2	5.341E-1	-2.652	-5.140E+4	-6.951E-1	-8.692E-3	-8.994E-3	2.292E-5	1.864E-1	-4.359E-4	1.304E+2	1.225E+1

where the regression coeffcients are multiplied by the following terms:

B0	1.0
B1	$kHDD65/(Q_{sun} * T_{grd})$
B2	$kCDH74/(Q_{sun} * T_{grd})$
B3	$kHDD65/(T_{grd} * R)$
B4	$kHDD65 * R/Q_{sun}$
B5	$Q_{sun}/(kHDD65 * T_{grd})$
B6	$kHDD65 * kCDH74/Q_{sun}$
B7	$1.0/(Q_{sun} * T_{grd})$
B8	$kCDH74 * R/(Q_{sun} * T_{grd})$
B9	Q_{sun}
B10	$Q_{sun}/kHDD65$
B11	$Q_{sun} * T_{grd}/kHDD65$
B12	$T_{grd}/(kHDD65 * Q_{sun})$
B13	T_{grd}
B14	$1.0/T_{grd}$
B15	$kHDD65/(Q_{sun} * R)$

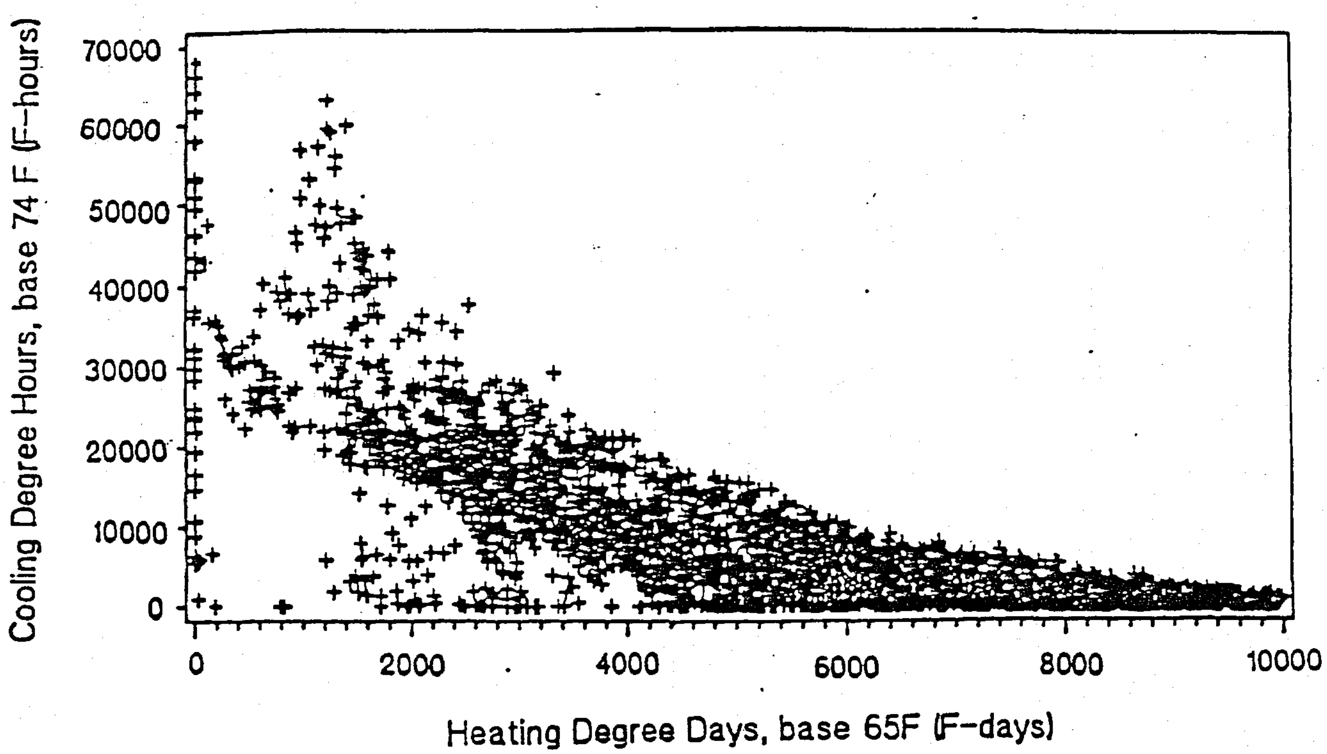


Figure 1a Cooling degree hours, base 74 F, versus heating degree days, base 65 F, for 3,349 cities in the United States.

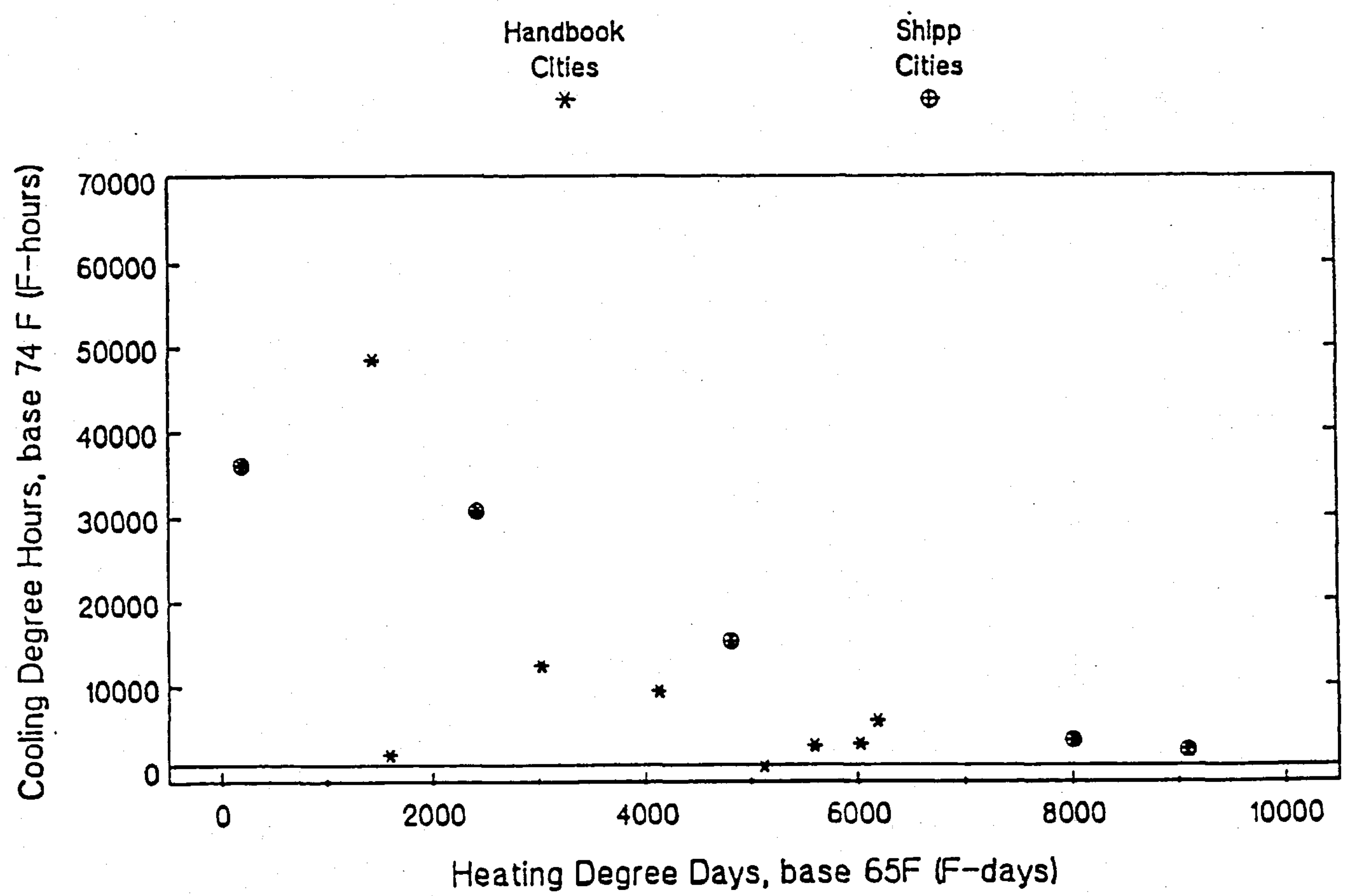


Figure 1b Cooling degree hours, base 74 F, versus heating degree days, base 65 F, for 13 Handbook cities and the 5 Shipp cities.

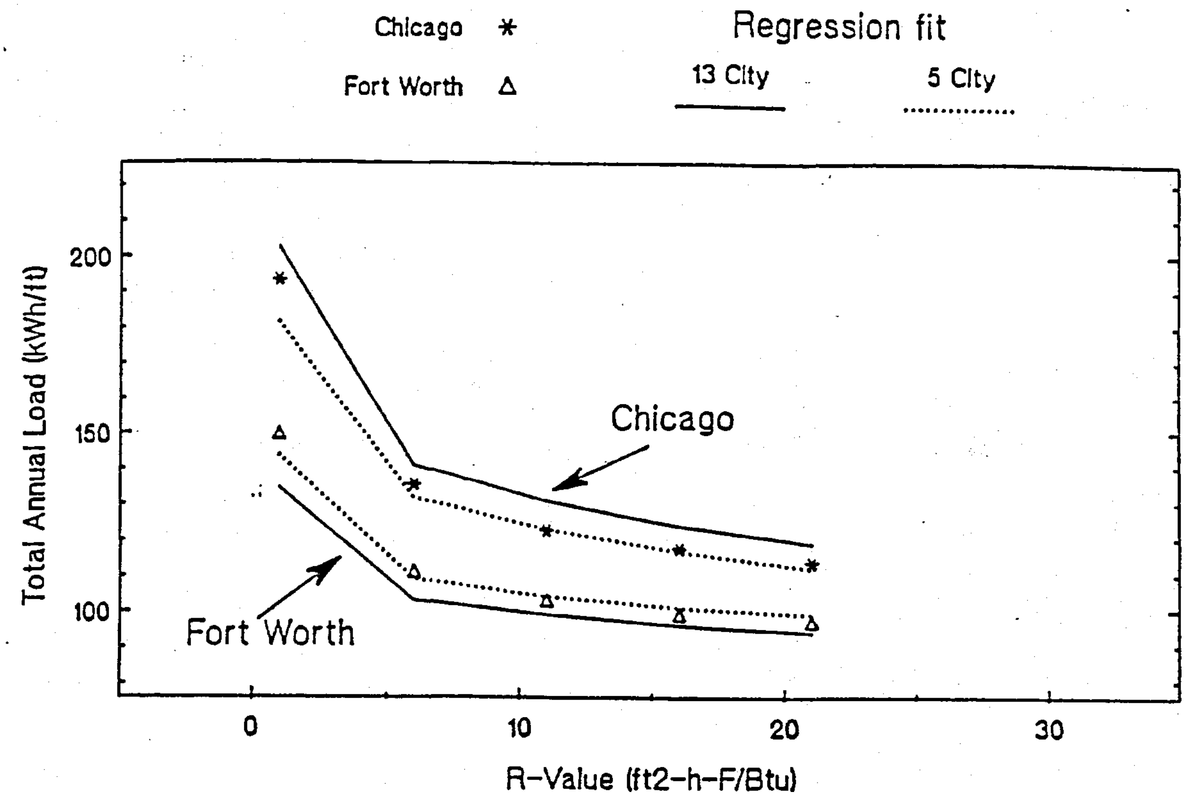


Figure 2 Comparison of the total annual load predictions from the 13 and 5 city regressions with the actual data for an unheated deep basement in Chicago and Fort Worth.

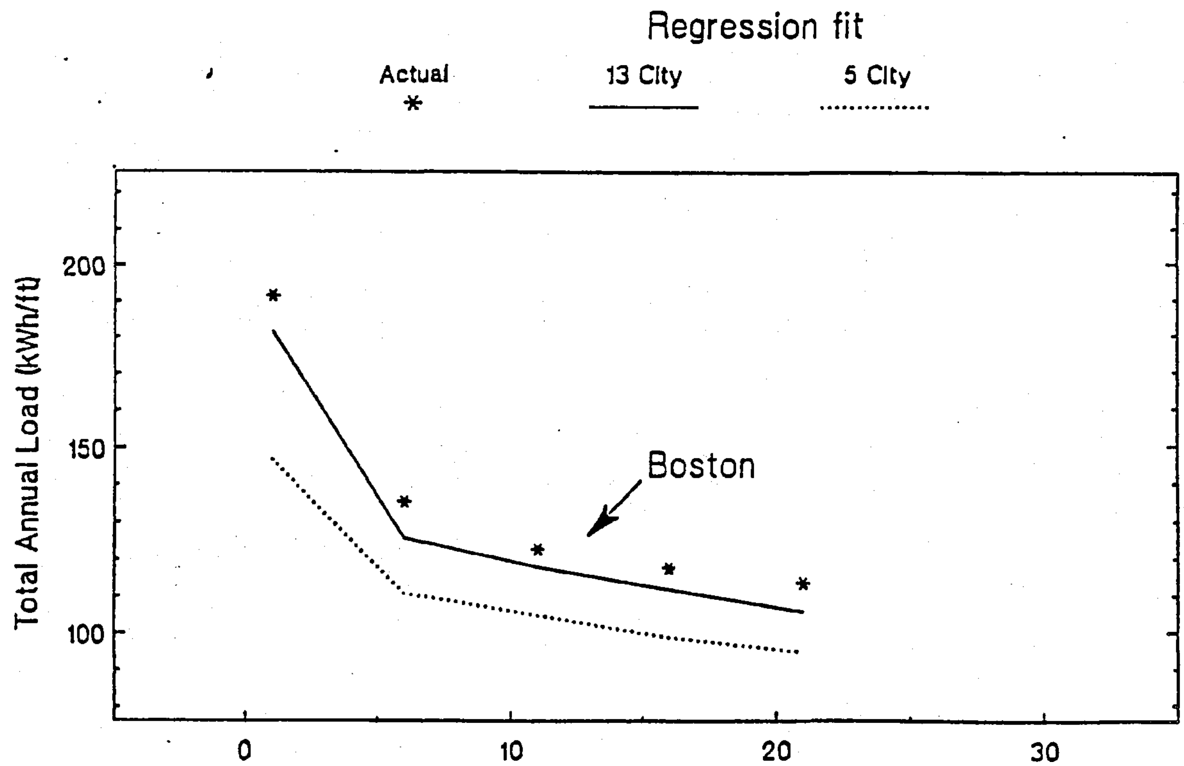


Figure 3 Comparison of the total annual load predictions from the 13 and 5 city regressions with the actual data for an unheated deep basement in Boston.

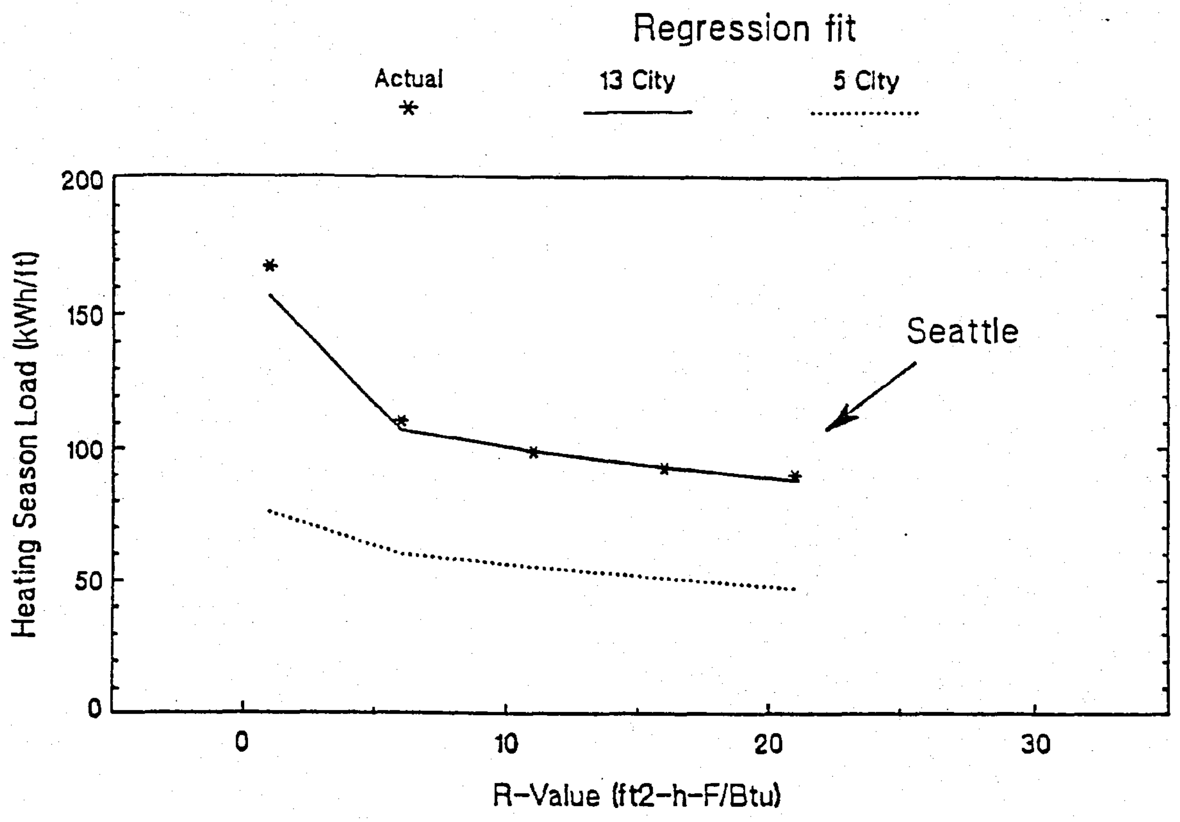


Figure 4 Comparison of the heating season load predictions from the 13 and 5 city regressions with the actual data for an unheated deep basement in Seattle.

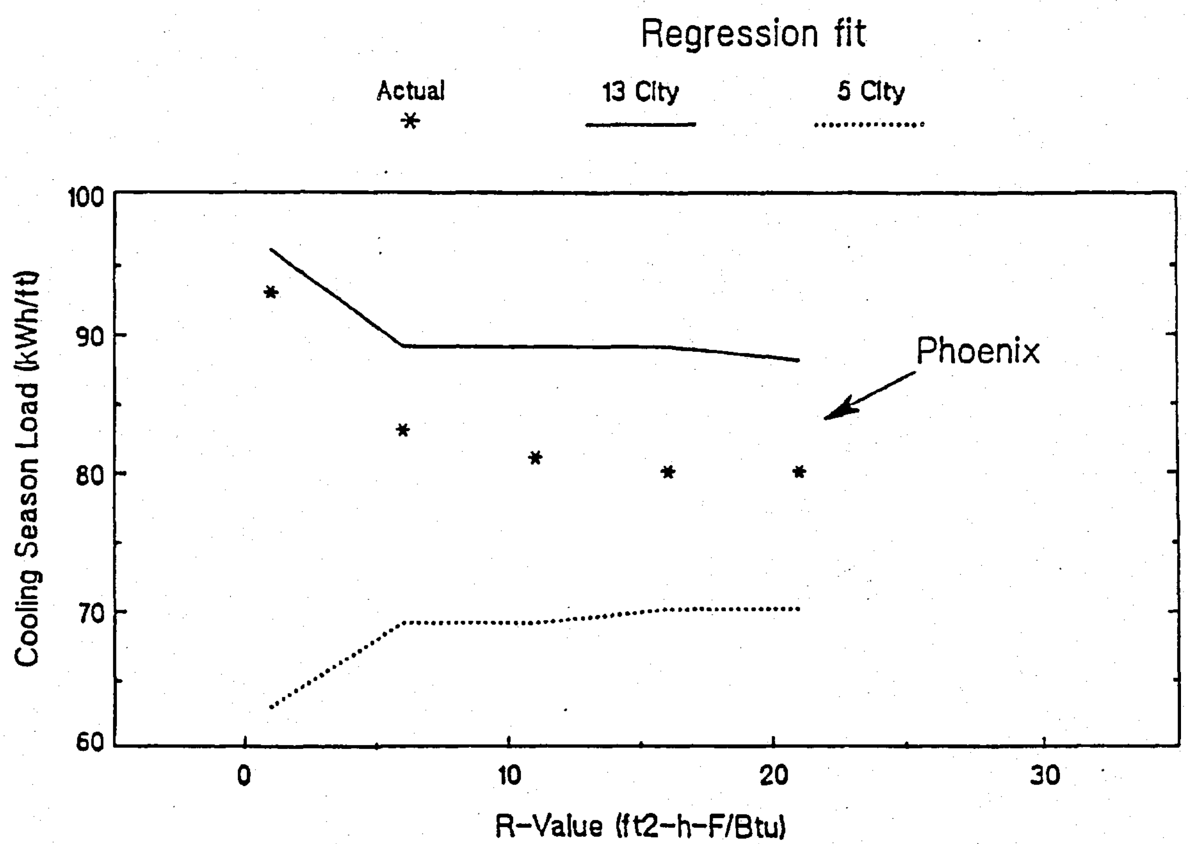


Figure 5 Comparison of the cooling season load predictions from the 13 and 5 city regressions with the actual data for an unheated deep basement in Phoenix.

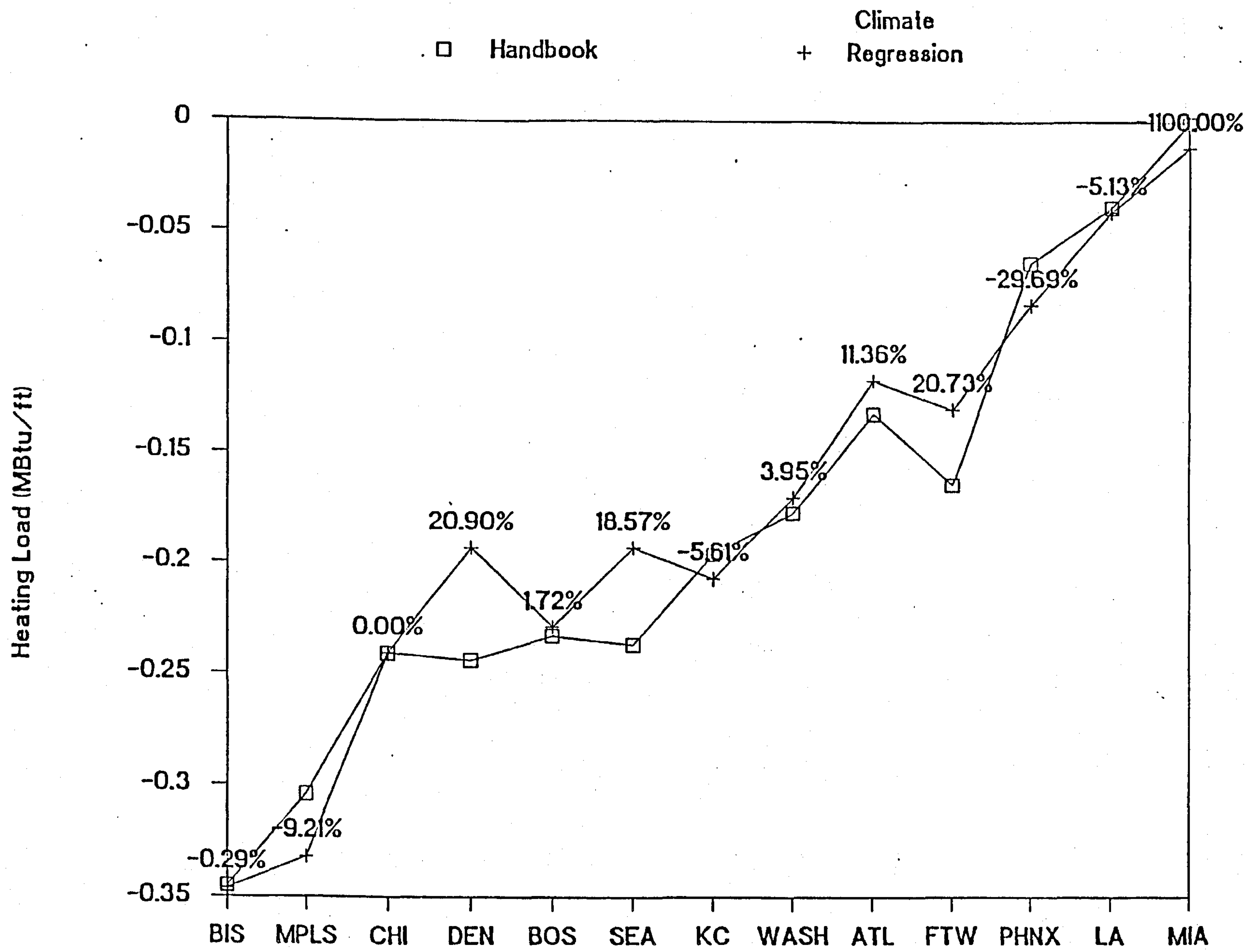


Figure 6 Comparison of the cooling season load predictions from the 13 and 5 city regressions with the actual data for an unheated deep basement in Phoenix.