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College Station, Texas 77843-3123

May 15, 1995

To: Contestants of the ASHRAE Predictor Shootout II

Re: "The Great Building Energy Predictor Shootout II: Measuring Retrofit Energy savings"

We are happy to announce that we have completed the evaluation of the entries received for the ASHRAE Great Building Energy Predictor Shootout II. The names of the four winners are given below, in the order of best overall CV as calculated by the guidelines established for the competition.

Winner 1:	Robert Dodier and Gregory Henze, University of Colorado.
Winner 2:	Srinivas Katipamula, Battelle, Pacific Northwest Laboratory.
Winner 3:	Y. Chonan, K. Nishida, and Takashi Matsumoto, Waseda University, Japan.
Winner 4:	Kyung Jin Jang, Eric Bartlett, and Ron Nelson, Iowa State University.

A brief report on the evaluation of the entries and plots of the data are enclosed as well as a 1995 ASME paper that gives additional details about the two case study buildings.

We would like to invite all of the Predictor Shootout II contestants to write an ASHRAE symposium paper that details the methods used and discusses the results. If the first draft of these papers can be sent to me by June 23rd, 1995, I will submit them to TC 1.5 and Tc 4.7 for approval for presentation at the Summer 1996 meeting to be held in San Antonio, Texas. We will be writing a summary paper that discusses the overall results and details the two case study buildings. It is anticipated that these papers will also be recommended for a special publications in the same manner as the Predictor Shootout I.

Should you have any additional questions, please feel free to call, FAX, or e-mail: ph#(409)-845-6065, FAX#(409)862-2457, jhaberl@loanstar.tamu.edu.

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Research Associate Professor
Energy Systems Laboratory
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cc (w/encl.): D. E. Claridge, Chairman, TC 4.7 committee
C. Culp, Chairman, TC 1.5 committee
D. Turner (ZEC)
J. Gribou (ARCH)
K. Kissman (# 32548-44910)

encl.: Competition evaluation report.
ESL# ESL-PA-95/04-02

To : Contestants of the Predictor Shootout II.

From: S.Thamilseran and Jeff S. Haberl
Energy Systems Laboratory
Texas Engineering Experiment Station
Texas A & M University

We are pleased to announce the results of the Great Building Energy Predictor Shootout II : Measuring Retrofit Energy Savings. It has taken much longer than the Predictor Shootout I to evaluate the submittals, due to the complexity of the data sets and the extensive evaluations that were performed. We have had four contestants who have successfully completed all the necessary predictions out of 47 people who retrieved the data and instructions. The successful contestants are listed in Table 1. This brief document describes how the contest winner was chosen and discusses the comparison of the savings predictions.

Determining the Contest winner:

Evaluation of the models' ability to predict the removed data.

We evaluated the four models according to their ability to predict the removed data from the training data set for the Zachry Engineering Center at Texas A & M University, College Station, Texas (C Data set) and the Business Building at University of Texas at Arlington, Texas (D Data set). Our analysis was performed on the five energy channels from each site together with the accompanying weather data. The channels evaluated are the Whole Building Electricity (WBE), Motor Control Center (MCC) electricity use, Lights and Equipment Electricity use (LEQ), Cooling energy use (Cooling), and Heating energy use (Heating).

The evaluation was performed using two indicators: The Coefficient of Variation of the Root Mean Square Error (CV-RMSE) and Mean Bias Error (MBE). These were the statistical indicators that were used in the Predictor Shootout I (Kreider and Haberl 1994a, Kreider and Haberl 1994b) with the exception of parameter "p" in the definition of CV (RMSE) and MBE which indicates the total number of regression parameters in the model. For the purpose of this evaluation this parameter was assigned an arbitrary value of 1. The definitions of these two indicators are given below.

Coefficient of Variation CV (%):

$$CV(RMSE) = \frac{\sqrt{\frac{\sum_{i=1}^{n}\left(y_{pred,i} - y_{data,i}\right)^2}{n-p}}}{\bar{y}_{data}} \times 100$$

Mean Bias Error, MBE (%):

$$MBE = \frac{\frac{\sum_{i=1}^{n}\left(y_{pred,i} - y_{data,i}\right)}{n-p}}{\bar{y}_{data}} \times 100$$

where

$y_{data,i}$ = a data value of the dependent variable corresponding to a particular set of the independent variables,

$y_{pred,i}$ = a predicted dependent variable value for the same set of independent variables above,

$\bar{y}_{data}$ = the mean value of the dependent variable of the data set,

n = the number of data points in the data set, and

p = the total number of regression parameters in the model (which was arbitrarily assigned as 1 for all models).

We feel that the CV(RMSE) and MBE are adequate indicators for the prediction of a single channel (i.e., WBE data). However, since the CV(RMSE) is, by definition, normalized to the mean of the data set or channel being evaluated, the comparison of CVs between channels may not be always be beneficial. The CV values were then averaged to arrive at an overall value for all channels from each contestant (equal weight for each channel) to give an indication of the best model that predicted the data that had been removed from the training set. MBE values were used as a secondary indicator in the case of a tie. Based on this analysis we have ranked the accuracy of the four contestants, as shown in Table 2.

Using the CV(RMSE) we have concluded that contestant E4 (R. Dodier and G. Henze, University of Colorado) was the overall winner. Their model predicted the removed data for both the C and D data sets, with overall CV of 16.9%. Followed in second place by contestant E3 (S.Katipamula, Battelle-Pacific Northwest Division) with a overall CV of 18.5%. In third place is contestant E1 (Y. Chonan, K. Nishida and T. Matsumoto, Waseda University, Japan) with a CV of 19.7%. Finally in fourth place is contestant E2 (Kyung Jin Jang, Eric Bartlett and Ron Nelson, Iowa State University) with a CV of 30.2%.

We have taken the liberty of including a fifth entry that represents a schedule/temperature-based modeling method. The fifth entry E5 (Entry#5 in the Table 2) is the prediction of the removed data using an inverse bin method described in the enclosed paper (Thamilseran and Haberl, 1995). E5 was not ranked as an entrant to the competition and is provided for comparative purposes only. However, we are pleased to say that E5 predicted the removed data with a CV(RMSE) of 18.9%.

Calculating the Retrofit Savings:

The second phase of the contest involved the comparison of the calculated retrofit savings. In the second phase the contestants were asked to project the pre-retrofit model into the post-retrofit period. The energy savings were then calculated by subtracting the measured post-retrofit energy use from the predictions made by the models. The annual savings comparisons are given in Figures 1 and 2. Figure 1 presents the comparison of the results of the savings measured for the ZEC building (C Data set) for the 12 month post-retrofit period during 1992. Figure 2 presents the comparison of the results of the savings measured for the BUS building (D Data set) for the 12 month post-retrofit period during 1992. As shown in Table 2 all the entrants predicted the removed data set with remarkably similar CVs. However, a comparison of the savings for the ZEC and BUS by the five methods indicates that there are significant differences that cannot be accounted for by the CV and MBE alone.

ZEC Savings Comparisons

In the ZEC the savings were calculated using the following costs: $0.0278/kWh electricity consumption, $4.67/Mbtu Cooling energy use, and $4.75/Mbtu heating energy use. Electric demand savings were not calculated because this is a university campus building that receives its services from a central plant.

The retrofits implemented for the ZEC building (C data set) included variable speed drives for the MCC, and the conversion of the constant air volume to variable air volume air handler units (CAV to VAV). The savings were calculated by comparing the projections from pre-retrofit models into the post-retrofit period to the actual measured post retrofit period energy use for these channels. For the ZEC building the channels effected by the retrofit included the MCC, Cooling, and Heating channels. Differences in the Lights and Receptacles (LEQ) and whole building electricity (WBE) channels, although significant, could not be attributed to the retrofit. Therefore, the savings for the ZEC considered only the MCC, Cooling, and Heating channels. Table 3 and Figure 1 display the savings for the MCC, Cooling and Heating channels for the ZEC as calculated by the five methods.

Several features are worth pointing out in Table 3 and Figure 1. First, the average of the total savings for all five methods was remarkably close at $163,058. The highest savings, calculated by method #5, were $189,655, which is 16.3% above the average. The lowest savings, calculated by method #2, were $83,399, which is 48.9% below the average.

Under normal circumstances the WBE channel can be used to measure the savings from the MCC channel. However, the WBE channel contains potential confounding factors which are hidden in the form of the Lights and Equipment (LEQ) electricity consumption, for example, personal computers, photocopying machines, etc., which can change from year to year. In the case of the ZEC, all methods predicted small change in Lights and Equipment savings. However, since the major retrofit was a CAV to VAV conversion the whole-building MCC data were used to calculate savings. Entries #5, #4 and #2 appear to have accurately predicted the MCC savings.

BUS Savings Comparisons

In the BUS building, the savings were calculated using the following costs: $0.02931/kWh electricity consumption, $4.417/Mbtu Cooling energy use, and $3.64/Mbtu heating energy use. In this building, the calculation of savings appears to be a much more rigorous test for the models.

The retrofits implemented for the BUS building (D data set) included CAV to VAV conversion of the Air Handler Units (AHU) and control modifications to the lighting. Like the ZEC building, the savings were calculated by comparing the projection of the pre-retrofit models into the post-retrofit period to the actual measured post retrofit period energy use. For the BUS building the channels effected by the retrofit included the Light and Equipment (LEQ), MCC, Cooling, and Heating channels. Table 4 and Figure 2 display the savings for the LEQ, MCC, Cooling and Heating channels as calculated by the five methods. Savings for the Whole-Building Electricity (WBE), were not used to calculate the total dollar savings.

Several features are worth pointing out in Table 4 and Figure 2. First, the average of the total savings for all five methods at $4,761. The highest savings, calculated by method #3, were $22,822, which is 379% above the average. The lowest savings, calculated by method #4, were -$23,223, which is 588% below the average. There seems to be some agreement between methods 2, 3 and 5 with very little agreement between methods 1 and 4.

In relation to the ZEC building the savings in BUS buildings are much smaller (about 15% of the ZEC savings). The per floor area savings varied from a negative value of $0.15/sq.ft. by Entry#4 to a positive savings of $0.15/sq.ft by Entry#3. In a similar calculation, the savings varied from $0.26/sq.ft by Entry#2 to $0.56/sq.ft by Entry#4 for the ZEC.

In general, all four models predicted about the same savings for ZEC building. In BUS building the savings calculated for the MCC, LEQ and heating energy were similar. The cooling savings for the BUS building varied considerably. We believe the reasons for this variation are due to the strong on/off (occupied/unoccupied) operation of the building during this period. In general Entries #2 and #3 and the Bin method predicted similar savings.

Predictability of the removed data from the TRAIN data

One final evaluation that we performed on the data involved the comparison of the removed data set against the training data set. The results of this evaluation can be seen in Figures 3.1 - 3.5 for the ZEC and Figures 4.1 - 4.5 for the BUS building. The data that were removed for the 'removed' data set were formed by extracting every fourth week of data in the training set, thereby leaving missing value indicators (-99) for the removed data in the training set. Although one would like to have achieved a perfect fit to the training set the reality of building operation does not allow for this to occur. Therefore, it was expected that there would be small differences in the mean values of these two set. However, these were kept as small as possible by carefully selecting the data periods.

The variation in the WBE, MCC, L&E, Cooling & Heating for the ZEC and BUS can be seen in the figures and in Table 5. The % difference calculations represent the following:

WBE = average difference for all-day 24 hour bins,
MCC = average difference for all-day 24 hour bins,
L&E = average difference for all-day 24 hour bins,
Cooling = average difference for the 5 F bins
Heating = average difference for the 5 F bins

Table 1: The Completed Entries received for the Predictor Shootout II : Measuring Retrofit Energy Savings

Entry#	Contestants	Address	Method Used:
E1	Y. Chonan, K. Nishida, & T. Matsumoto	Department of Electrical Engineering, Waseda University, 3-4-1 Ohkubo Shinjuku-ku, Tokyo 169 Japan Tel/Fax:01-3-3702-4735 e_mail:chonan@matsumoto.elec.waseda.ac.jp	Preprocessing and multi-layer perceptron
E2	Kyung Jin Jang, Eric Bartlett & Ron Nelson	Mechanical Engineering Dept., H.M.Black Engineering Bldg., Iowa State University, Ames, Iowa, 50011. Tel:(515)294-6886 or Fax: (515)294-3261 e_mail: ronn@iastate.edu	Autoassociative NN
E3	Srinivas Katipamula	Battelle Pacific Northwest Division, P.O.Box 999, Richland, Washington U.S.A. 99352. Tel:(509)372-4592 or Fax: e_mail: s_katipamula@pnl.gov	Sub-hourly and weather dependence
E4	Robert Dodier & Gregor Henze	Joint Center for Energy management, Dept. of Civil Engineering, University of Colorado at Boulder, Boulder, CO 80309. Tel: or Fax: e_mail: dodier@bechtel.colorado.edu henze@bechtel.colorado.edu	Neural Network

To:

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Table 2: The Predictor Shootout II Competition Results

		Coefficient of Variation - CV						Mean Bias Error - MBE				
Entries		E1	E2	E3	E4	E5		E1	E2	E3	E4	E5
C.TRN	wbe	3.1205	13.2116	8.6475	2.9032	3.1647	wbe	0.2722	-1.8049	-6.5555	-0.0907	-0.1237
	mcc	3.2803	3.4728	3.2811	3.5751	3.1796	mcc	0.4817	0.5929	0.4871	0.3613	0.2165
	lteq	4.456	25.6786	3.4384	4.2476	4.3546	lteq	0.5106	-2.6949	0.3971	-0.7068	-0.4096
	cwe	7.1312	8.2585	8.877	7.0312	9.4499	cwe	-0.8917	-3.0309	-3.4214	-1.3372	-1.689
	hwe	21.2758	39.2016	35.3721	16.5914	24.6541	hwe	-3.0988	-15.3095	-10.9781	-2.1426	-2.874
C.average		**7.8528**	**17.9646**	**11.9232**	**6.8697**	**8.9606**		**-0.5452**	**-4.4495**	**-4.0142**	**-0.7832**	**-0.9760**
D.TRN	wbe	17.0462	26.8642	20.8693	16.5368	14.9939	wbe	2.7898	4.2215	-1.6086	2.2887	1.1941
	mcc	17.5371	41.0527	17.7616	22.2904	23.5215	mcc	4.4054	-0.1351	4.1446	0.3206	0.4455
	lteq	21.3187	43.9609	21.1616	17.0489	17.0553	lteq	-3.4806	14.6371	-3.4868	0.6829	0.2512
	cwe	55.9467	53.0195	40.9747	42.0513	51.805	cwe	-3.6721	-16.5221	-8.7733	-11.4627	-19.2526
	hwe	46.0517	47.3523	24.7441	36.8548	33.7135	hwe	-11.1313	-8.31	-4.8605	-12.2519	-6.6527
D.Average		**31.5801**	**42.4499**	**25.1023**	**26.9564**	**28.2178**		**-2.2178**	**-1.2217**	**-2.9169**	**-4.0845**	**-4.8029**
Overall		**19.7164**	**30.2073**	**18.5127**	**16.9131**	**18.5892**		**-1.3815**	**-2.8356**	**-3.4655**	**-2.4338**	**-2.8894**
Rank		3	4	2	1							

Table 3 : Annual Savings for the ZEC building for 1992

Entry#	ZEC Building Savings (C.TST)			
	mcc	Cool	Heat	Total
E1	$45,928	$75,808	$56,487	$178,224
E2	$1,043	$19,922	$62,434	$83,399
E3	$45,933	$54,574	$81,562	$182,069
E4	$45,879	$73,034	$63,028	$181,941
E5-BM	$45,836	$71,330	$72,490	$189,655
Average	$36,924	$58,934	$67,200	$163,058

Table 4 : Annual Savings for the BUS building for 1992

Entry#	BUS Building Savings (D.TST)				
	mcc	L & E	Cool	Heat	Total
E1	$6,478	$111	($28,927)	$13,264	($9,074)
E2	$20	($218)	$2,655	$13,217	$15,673
E3	$5,332	$1,345	$10,464	$5,682	$22,822
E4	$8,120	($494)	($32,920)	$2,071	($23,223)
E5-BM	$5,968	$767	($3,423)	$14,294	$17,606
Average	$5,183	$302	($10,430)	$9,706	$4,761

[1]**where the values within the ( ) indicate a negative value.**

Table 5 : Average difference for the 'removed' data and 'train' data bin mean values

Channel	% difference	
	ZEC	BUS
WBE	0.75	1.96
MCC	0.11	3.29
L&E	1.17	5.96
Cooling	4.65	21.45
Heating	6.65	15.30

NOTE: The unbiased % difference was calculated from the bin means of the 'removed' data and the relevant bin means of the 'train' data. The unbiased difference is the difference between two mean without the associated sign.

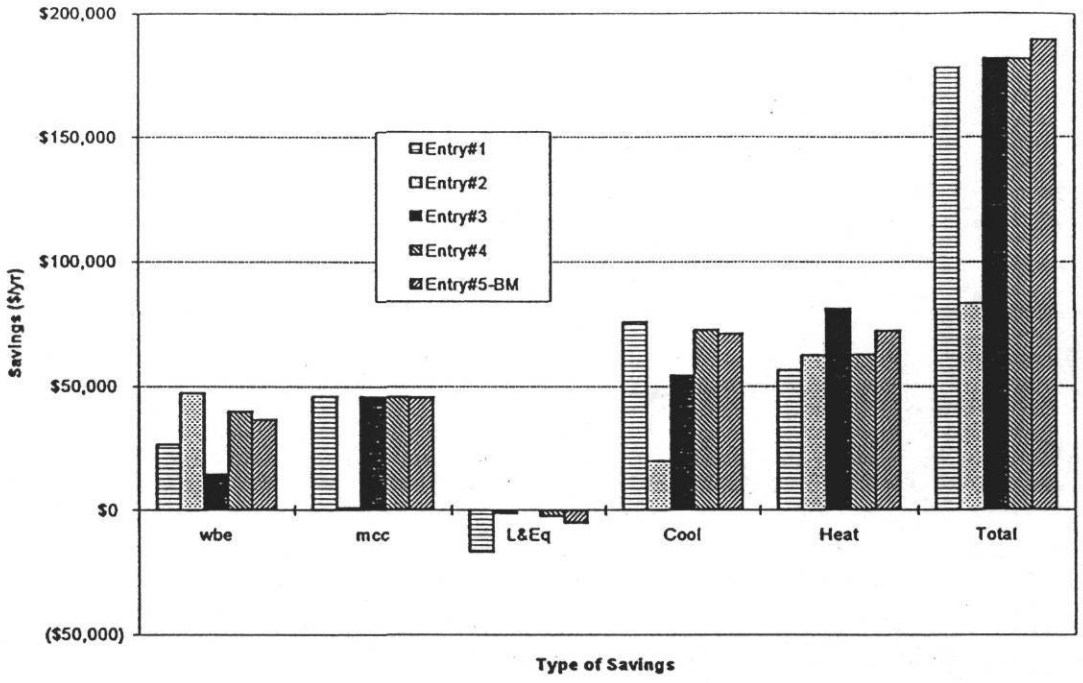

Figure 1: Annual Savings Comparisons for the ZEC building for 1992 (C Data set)

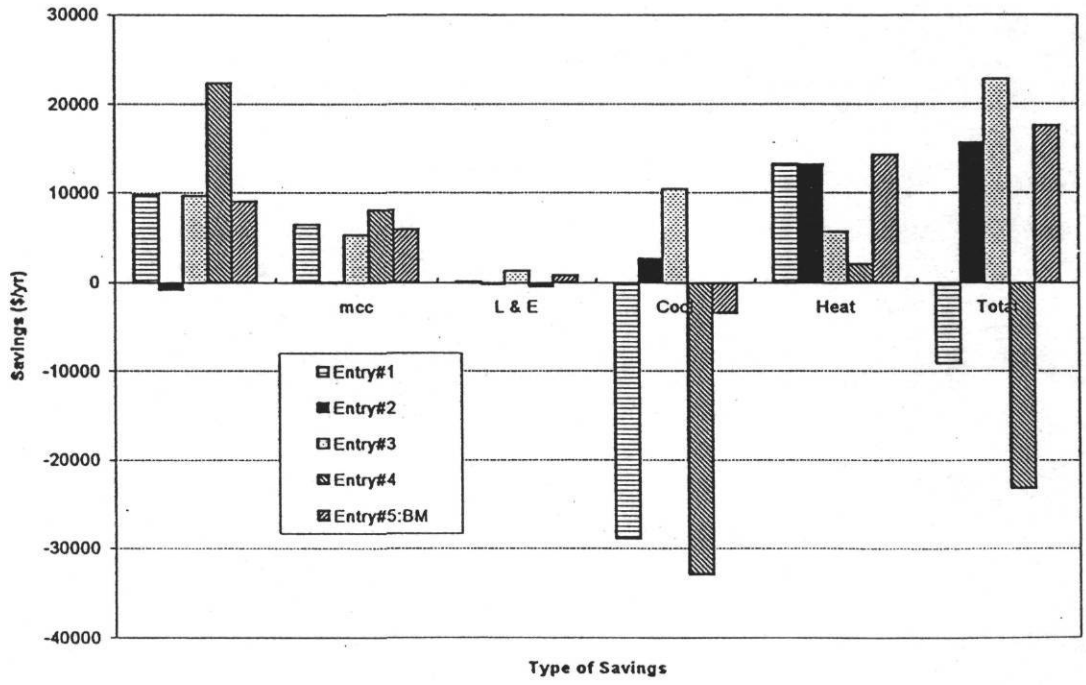

Figure 2 : Annual Savings Comparisons for the BUS building for 1992 (D Data set)

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temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

1.11 Scatter plots of predicted (by Entry #5) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

1.12 Time series plot of measured energy use in ZEC for the period of Nov.28, 1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

1.13 Time series plots of "baseline predicted" energy use by Entry #1 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

1.14 Time series plots of "baseline predicted" energy use by Entry #2 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

1.15 Time series plots of "baseline predicted" energy use by Entry #3 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

1.16 Time series plots of "baseline predicted" energy use by Entry #4 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

1.17 Time series plots of "baseline predicted" energy use by Entry #5 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

Plots for the Business Building (D data set)

2.1 Time series plot of measured energy use in BUS building for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.2 Time series plots of predicted energy use by Entry #1 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.3 Time series plots of predicted energy use by Entry #2 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.4 Time series plots of predicted energy use by Entry #3 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.5 Time series plots of predicted energy use by Entry #4 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.6 Time series plots of predicted energy use by Entry #5 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.7 Scatter plots of predicted (by Entry #1) and measured energy use versus ambient temperature in in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.0

2.8 Scatter plots of predicted (by Entry #2) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

2.9 Scatter plots of predicted (by Entry #3) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

2.10 Scatter plots of predicted (by Entry #4) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

2.11 Scatter plots of predicted (by Entry #5) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

2.12 Time series plot of measured energy use in BUS building for the period of Jul.14, 1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.13 Time series plots of "baseline predicted" energy use by Entry #1 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.14 Time series plots of "baseline predicted" energy use by Entry #2 and energy savings in

BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.15 Time series plots of "baseline predicted" energy use by Entry #3 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.16 Time series plots of "baseline predicted" energy use by Entry #4 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

2.17 Time series plots of "baseline predicted" energy use by Entry #5 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

Plots to check the predictability of the removed data set in C.TRN data

3.1 The box and whisker mean (BWM) plots of WBE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

3.2 The box and whisker mean (BWM) plots of MCC energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

3.3 The box and whisker mean (BWM) plots of LEQ energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

3.4 The box and whisker mean (BWM) plots of CWE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

3.5 The box and whisker mean (BWM) plots of HWE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

Plots to check the predictability of the removed data set in D.TRN data

4.1 The box and whisker mean (BWM) plots of WBE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

4.2 The box and whisker mean (BWM) plots of MCC energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

4.3 The box and whisker mean (BWM) plots of LEQ energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

4.4 The box and whisker mean (BWM) plots of CWE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

4.5 The box and whisker mean (BWM) plots of HWE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) Train data and (c) removed data channels.

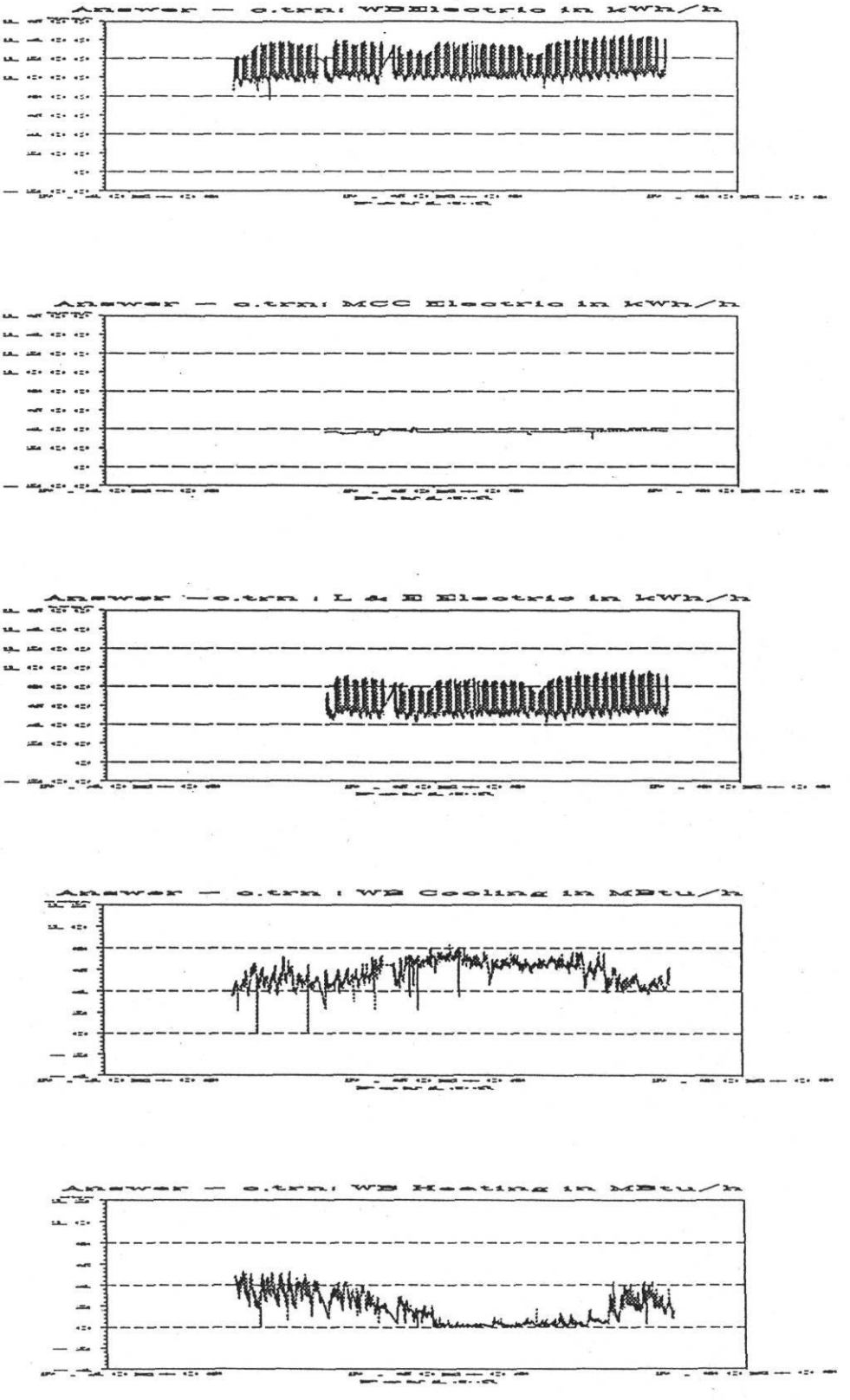


Figure 1.1: Time series plot of measured energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

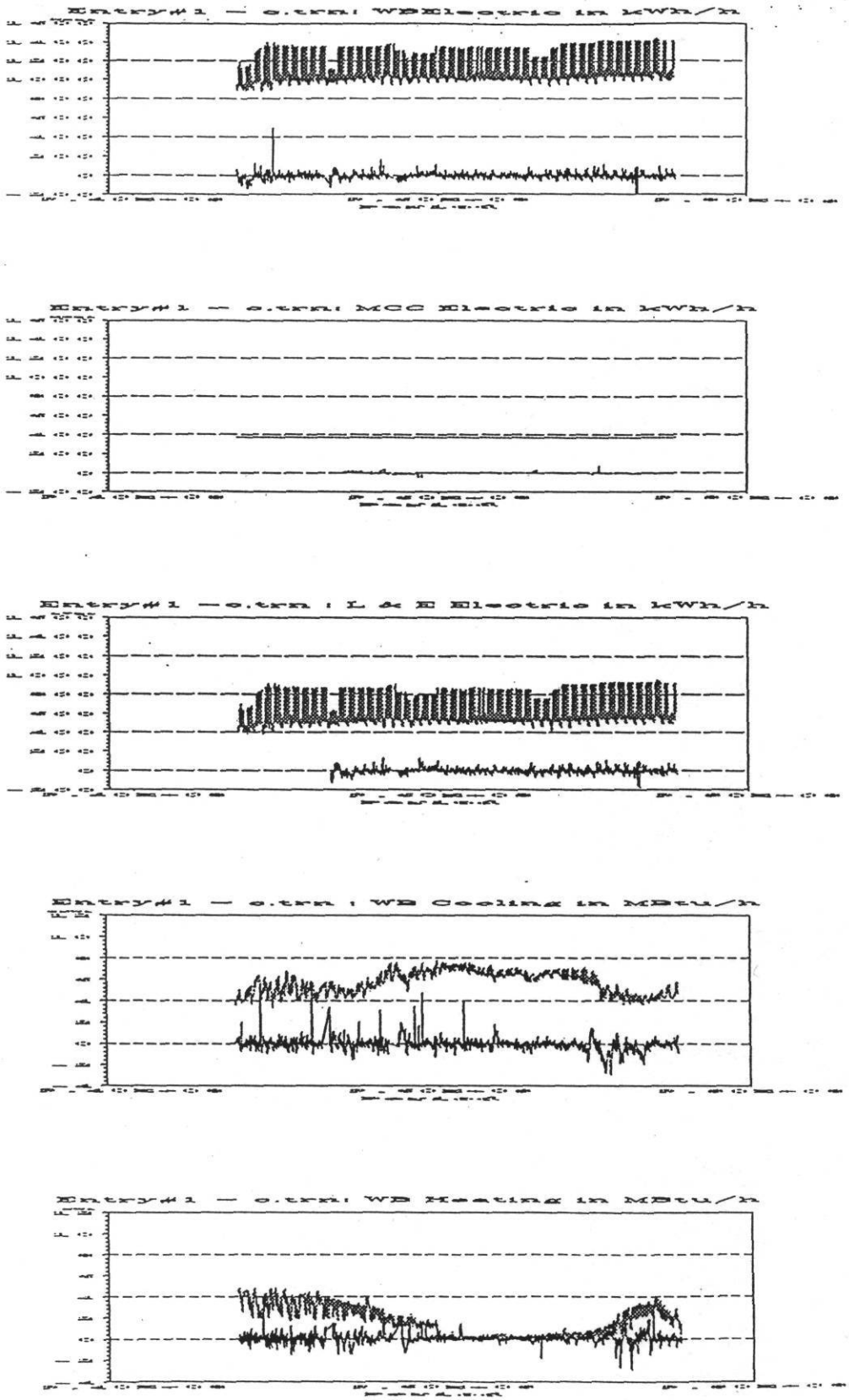


Figure 1.2: Time series plots of predicted energy use by Entry #1 and residual energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

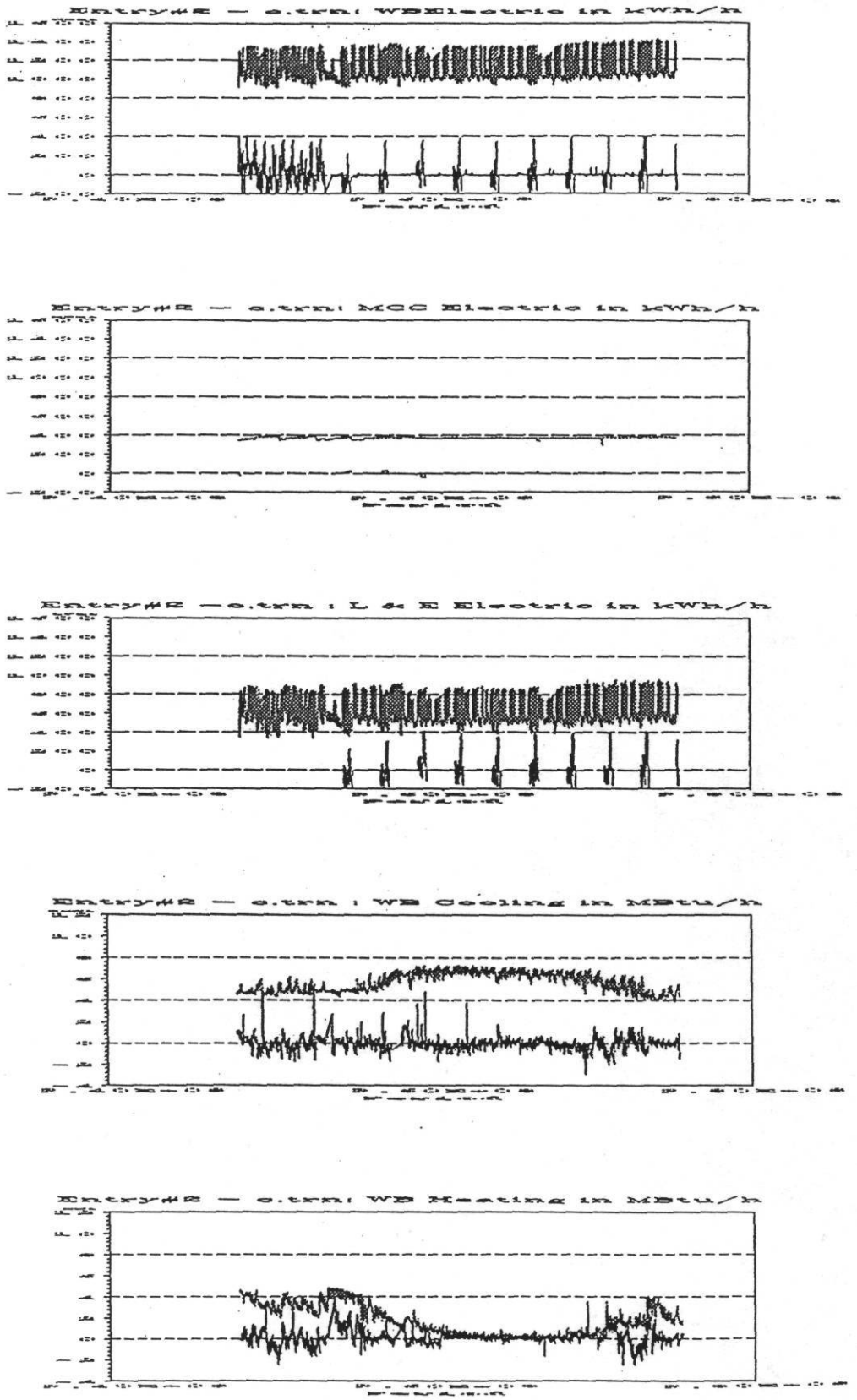


Figure 1.3: Time series plots of predicted energy use by Entry #2 and residual energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

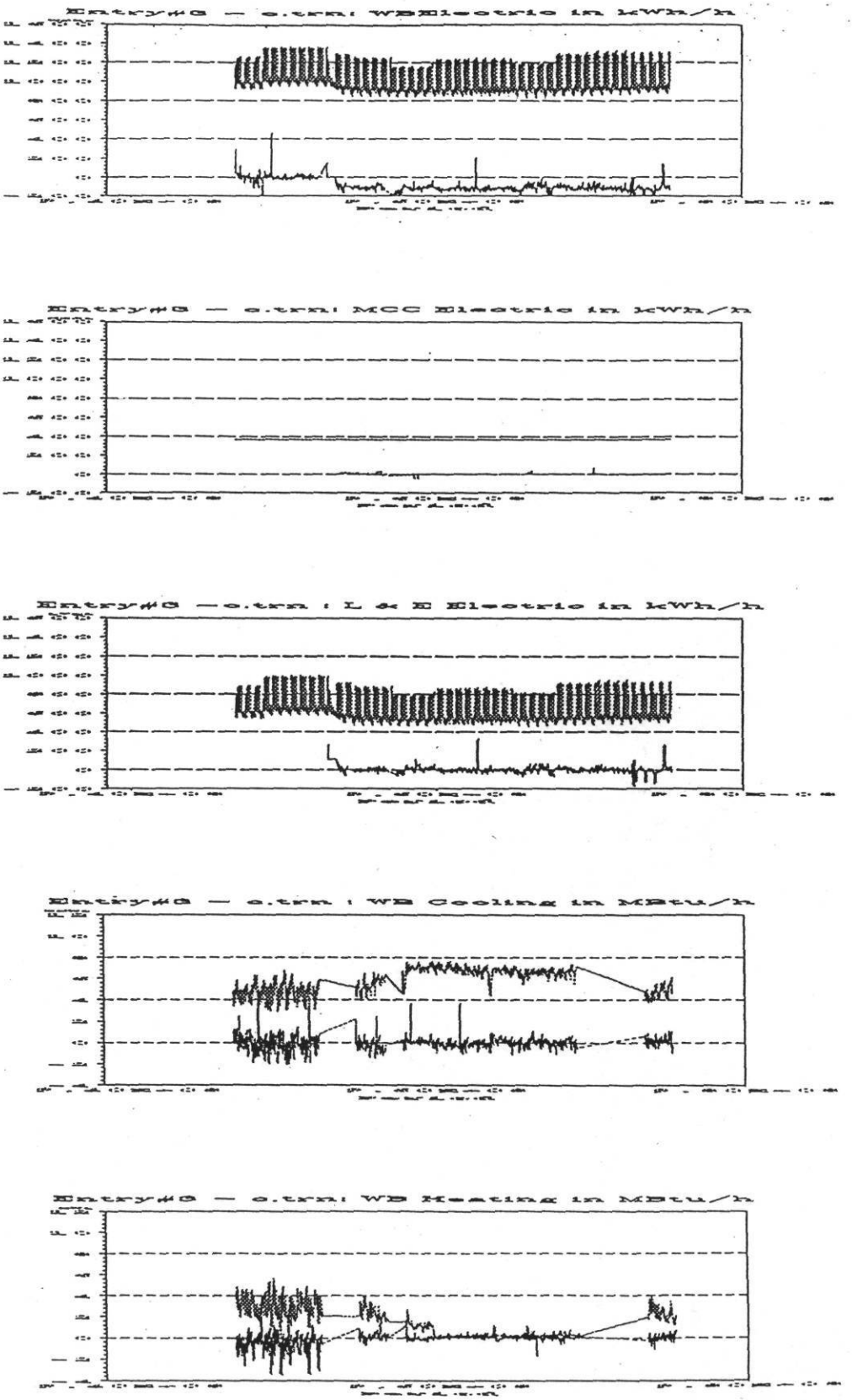


Figure 1.4: Time series plots of predicted energy use by Entry #3 and residual energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

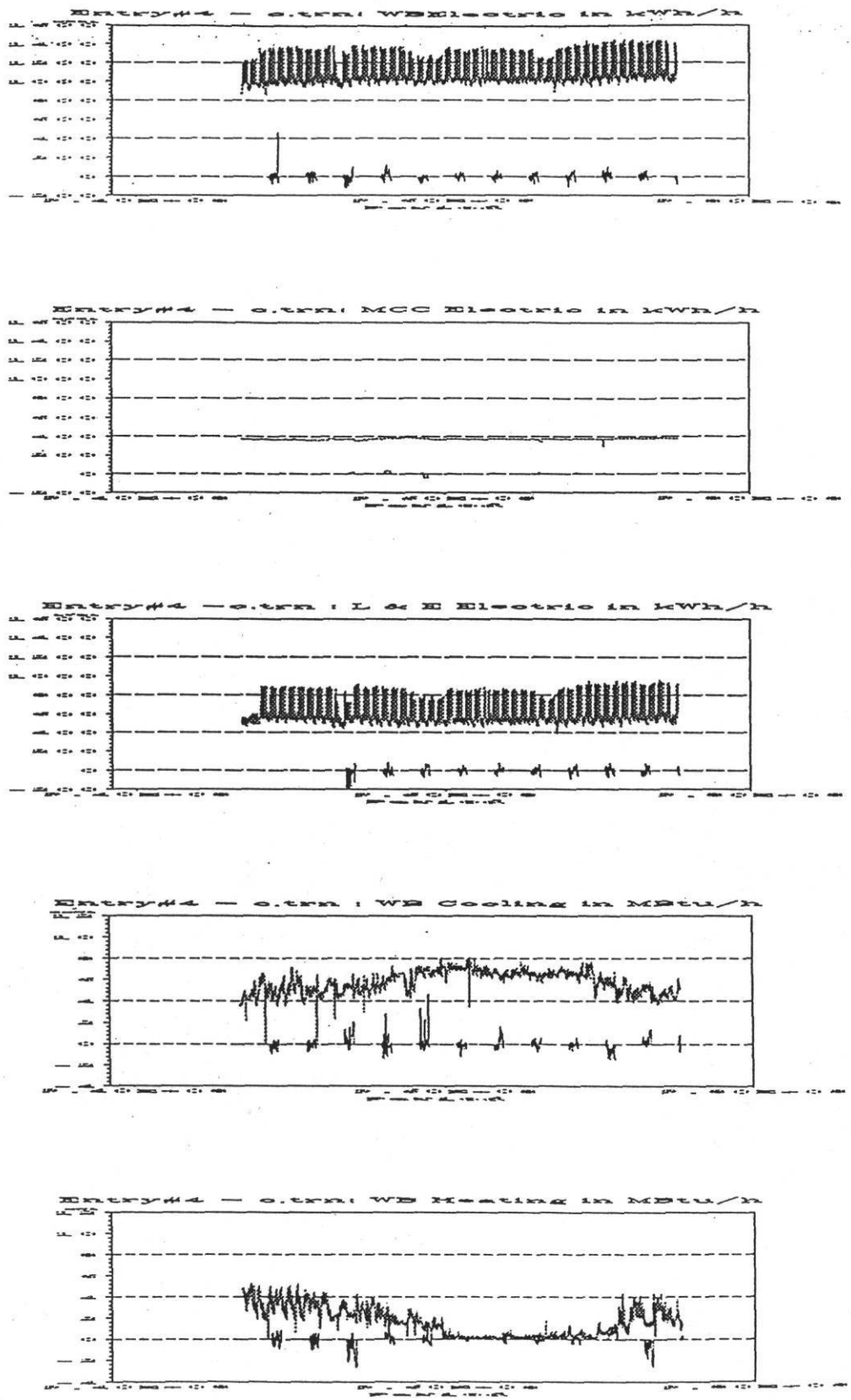


Figure 1.5: Time series plots of predicted energy use by Entry #4 and residual energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

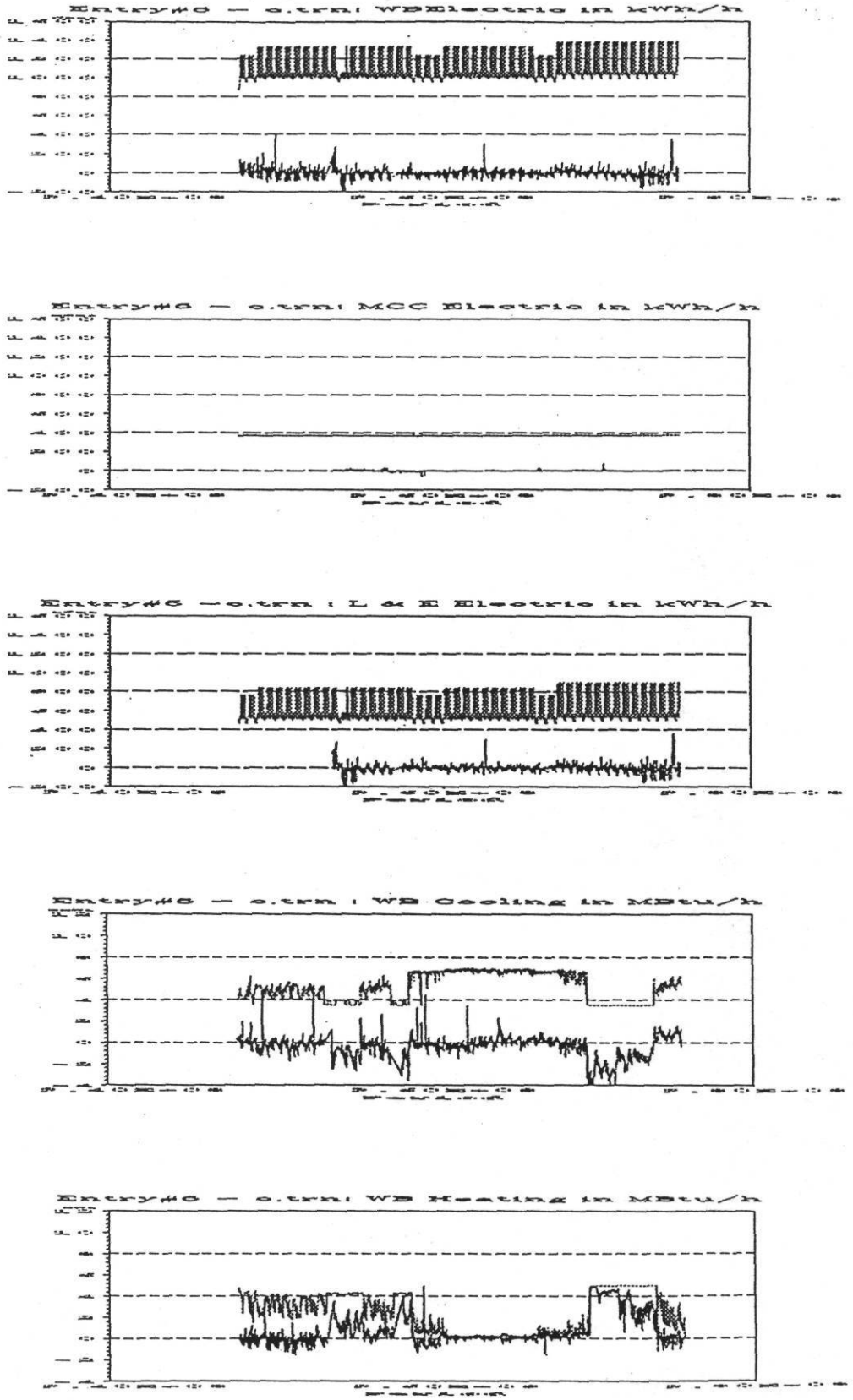
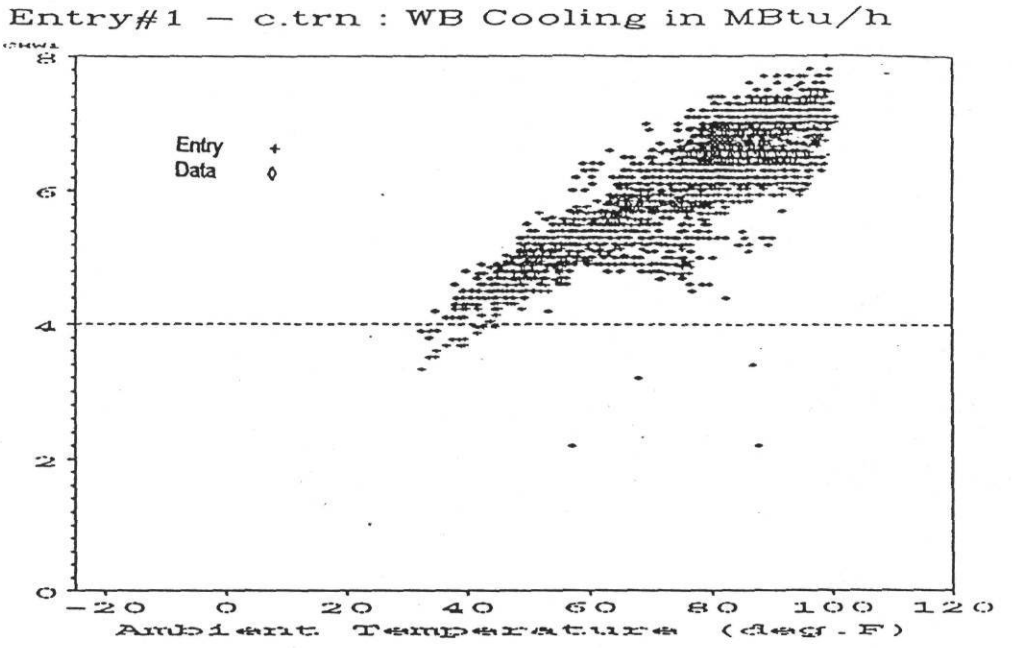


Figure 1.6: Time series plots of predicted energy use by Entry #5 and residual energy use in ZEC for the period of Jan.1,990 to Nov.27,1990 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.



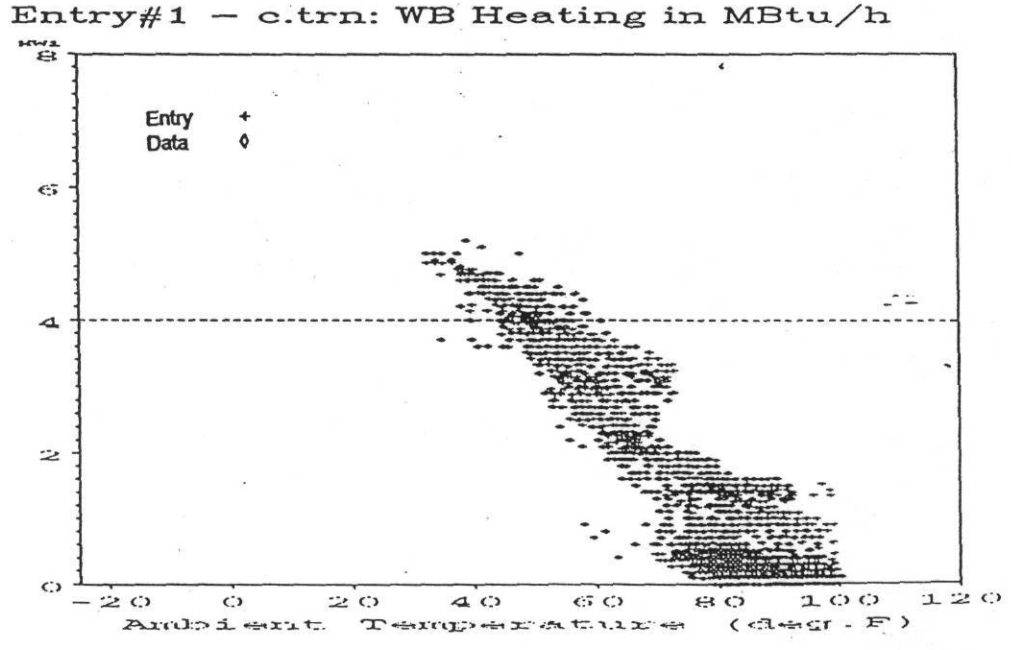
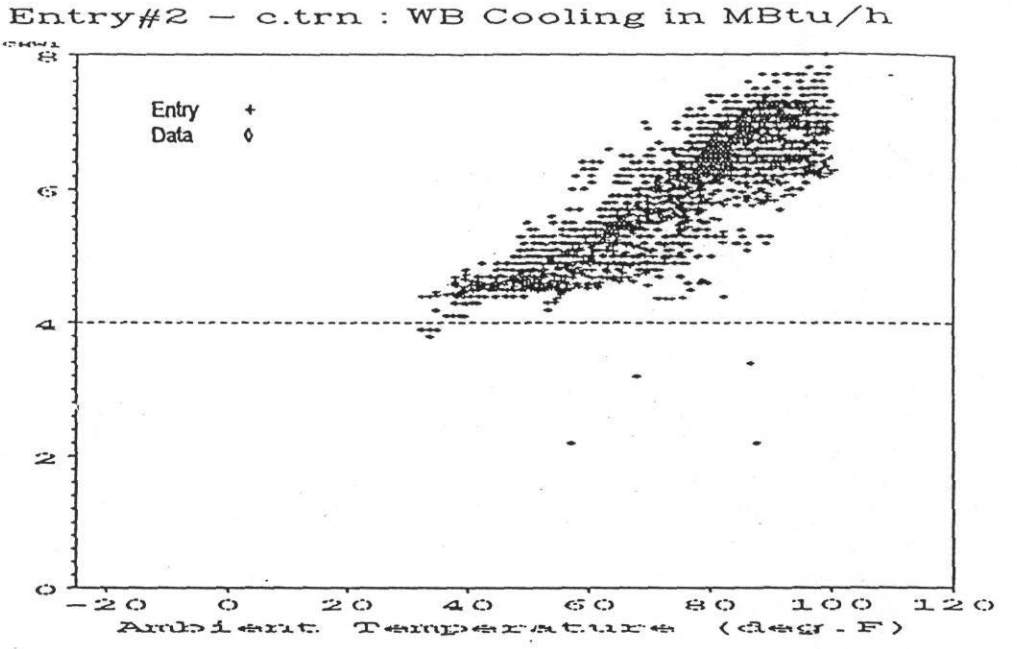


Figure 1.7: Scatter plots of predicted (by Entry #1) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



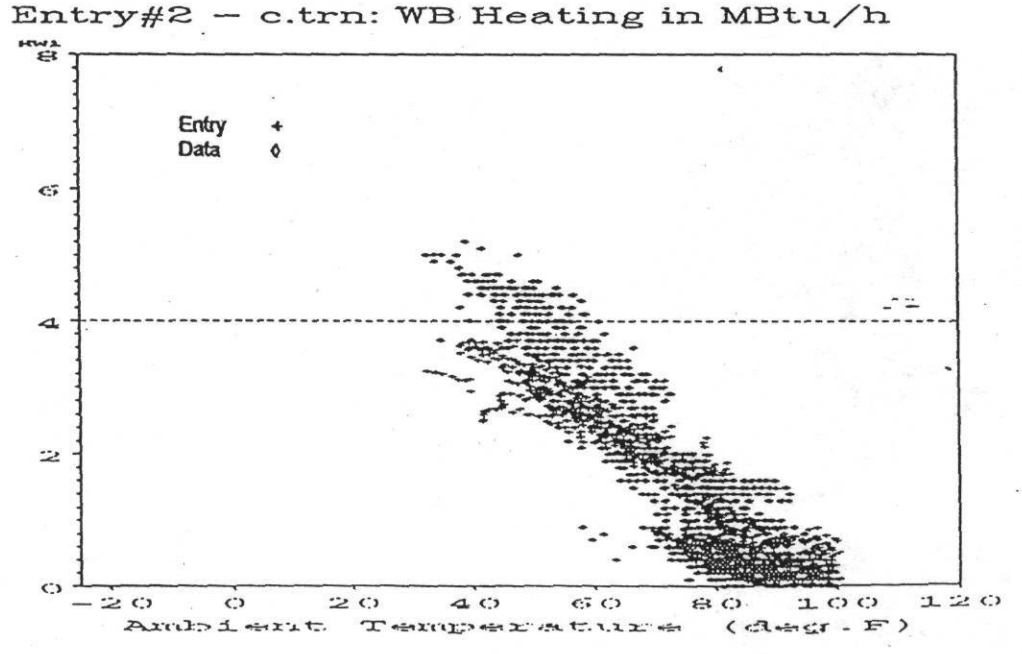
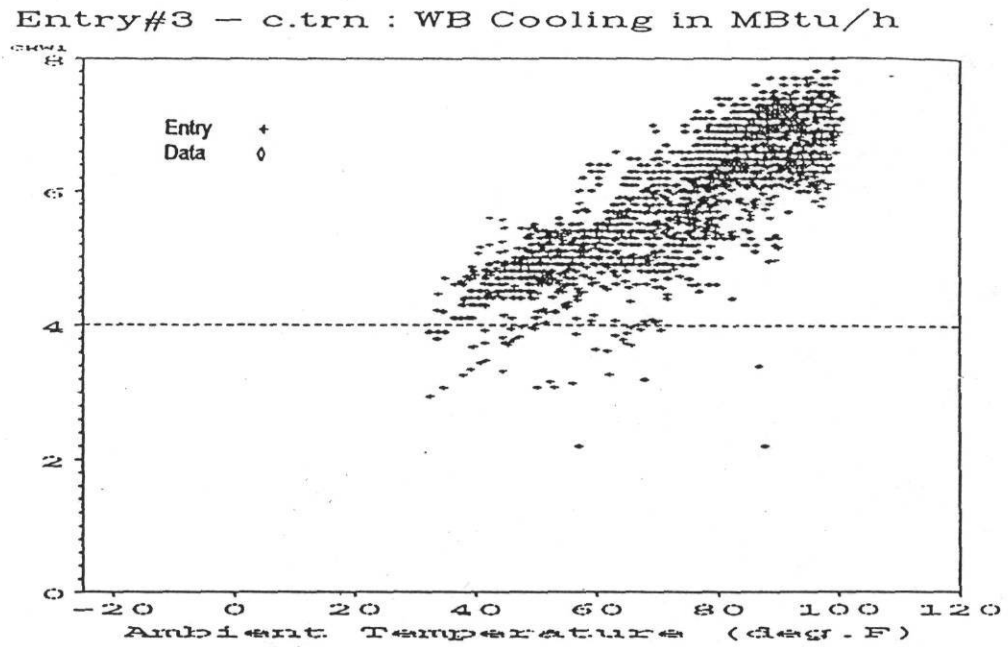


Figure 1.8: Scatter plots of predicted (by Entry #2) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



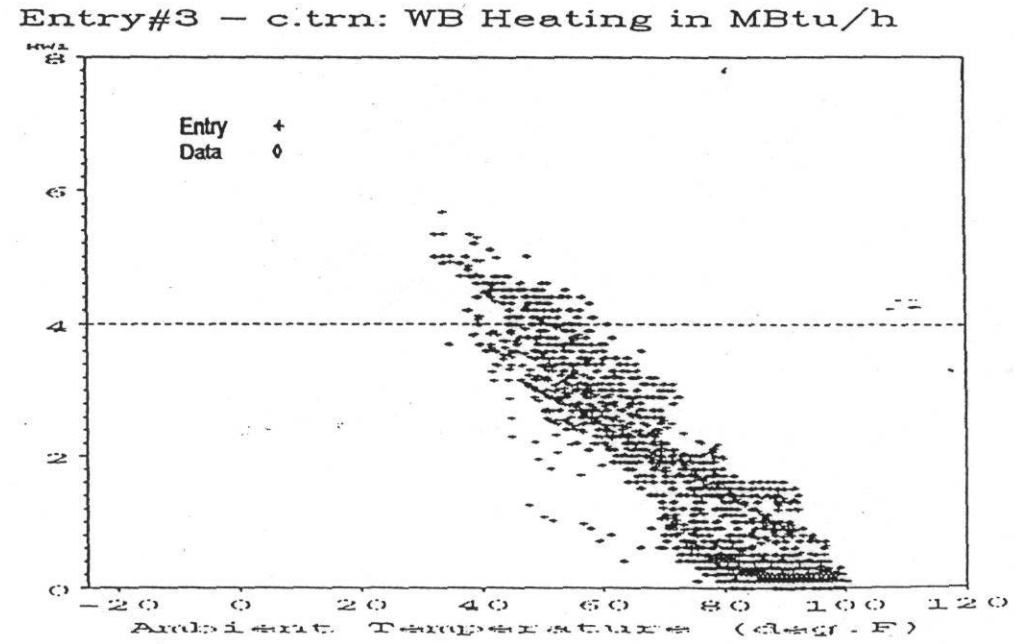
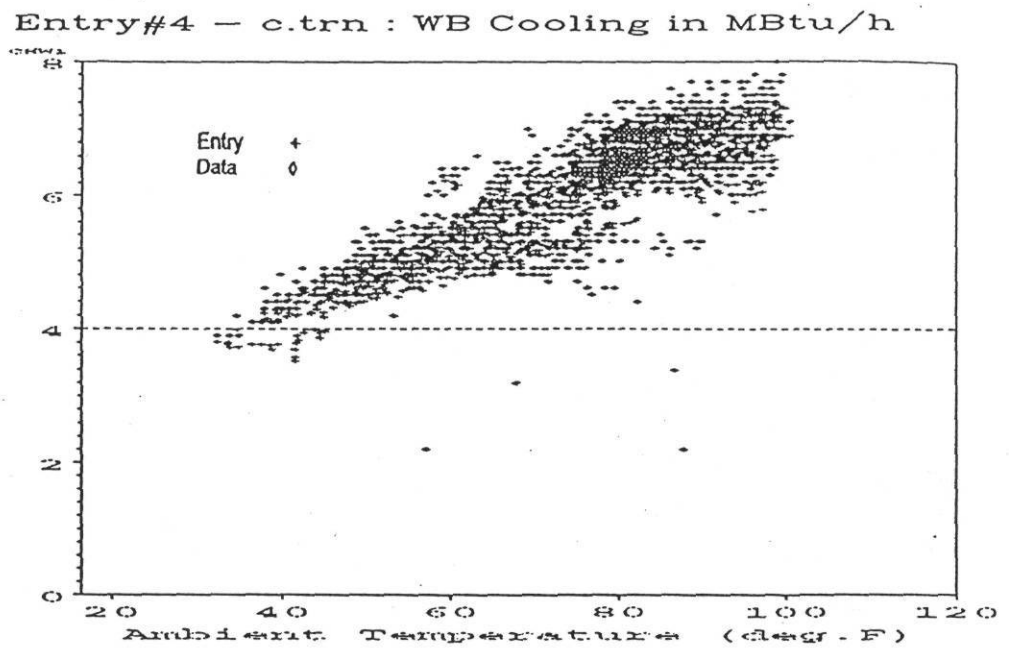


Figure 1.9: Scatter plots of predicted (by Entry #3) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



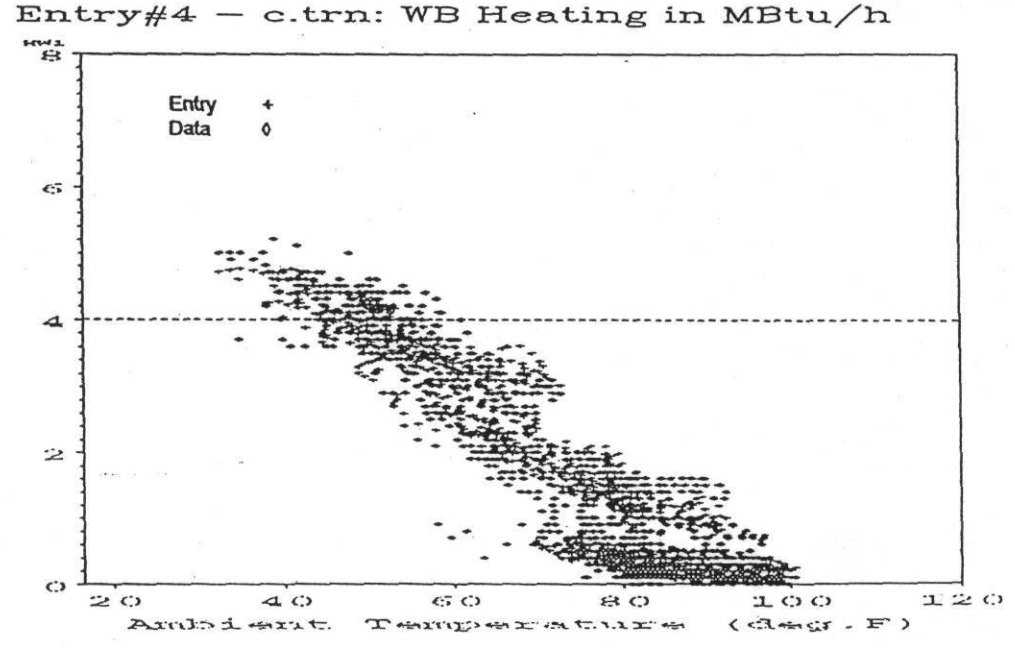
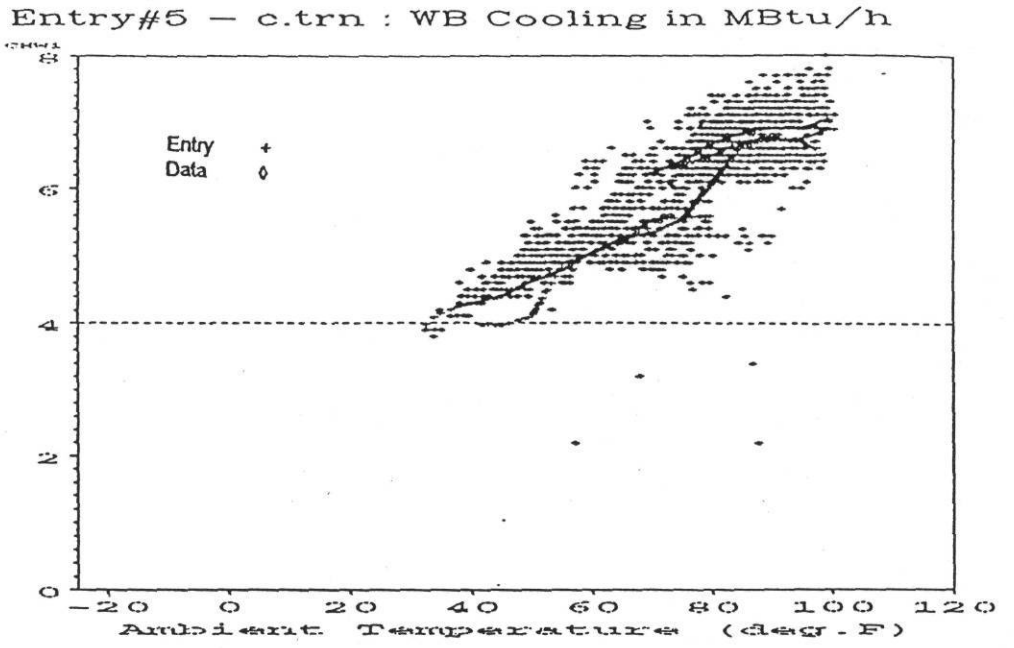


Figure 1.10: Scatter plots of predicted (by Entry #4) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



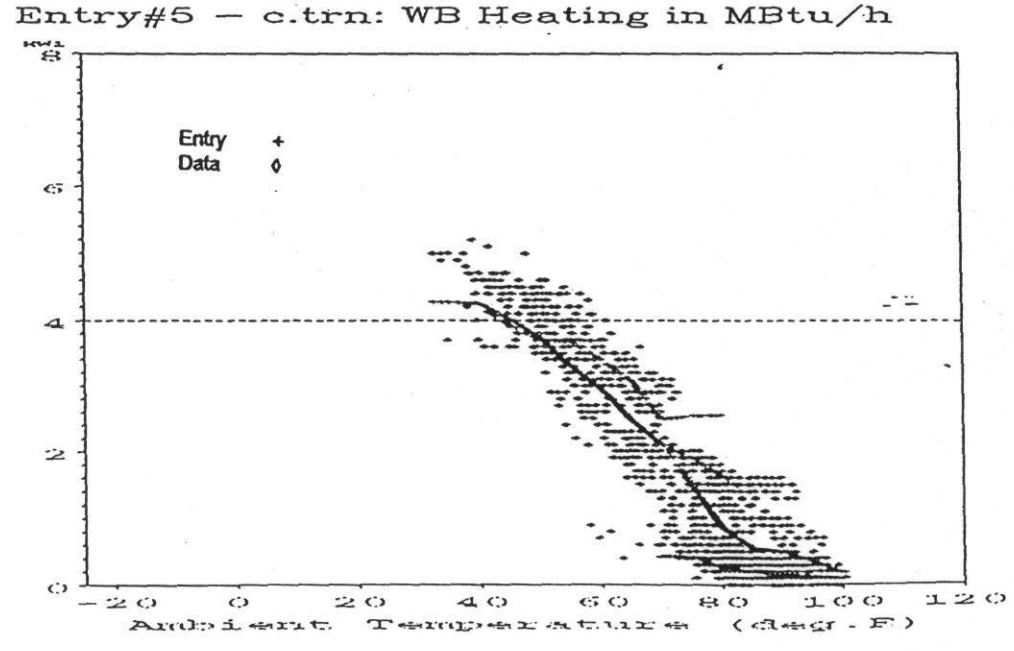


Figure 1.11: Scatter plots of predicted (by Entry #5) and measured energy use versus ambient temperature in ZEC for the removed data from the Jan.1,990 to Nov.27,1990 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

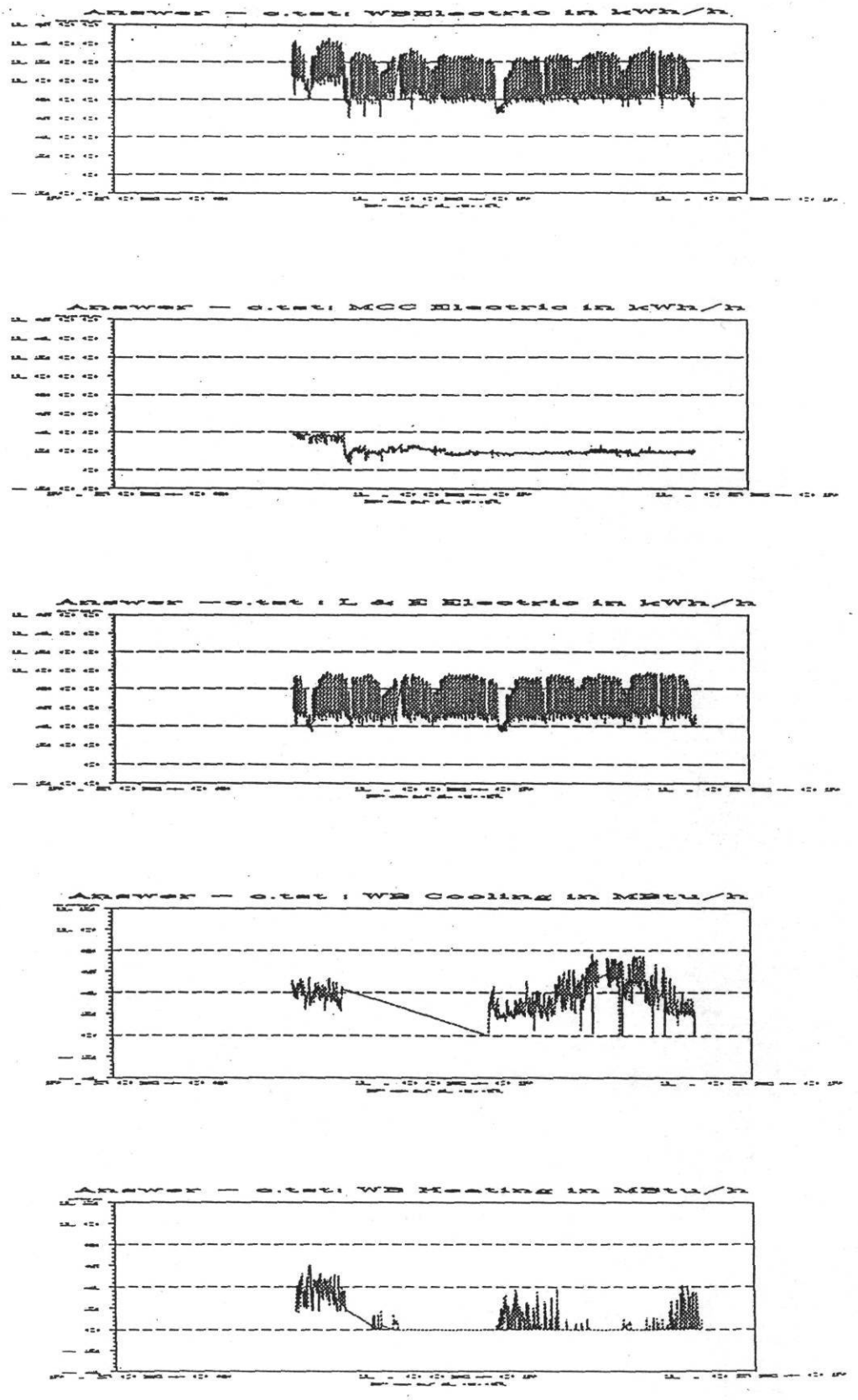


Figure 1.12: Time series plot of measured energy use in ZEC for the period of Nov.28, 1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

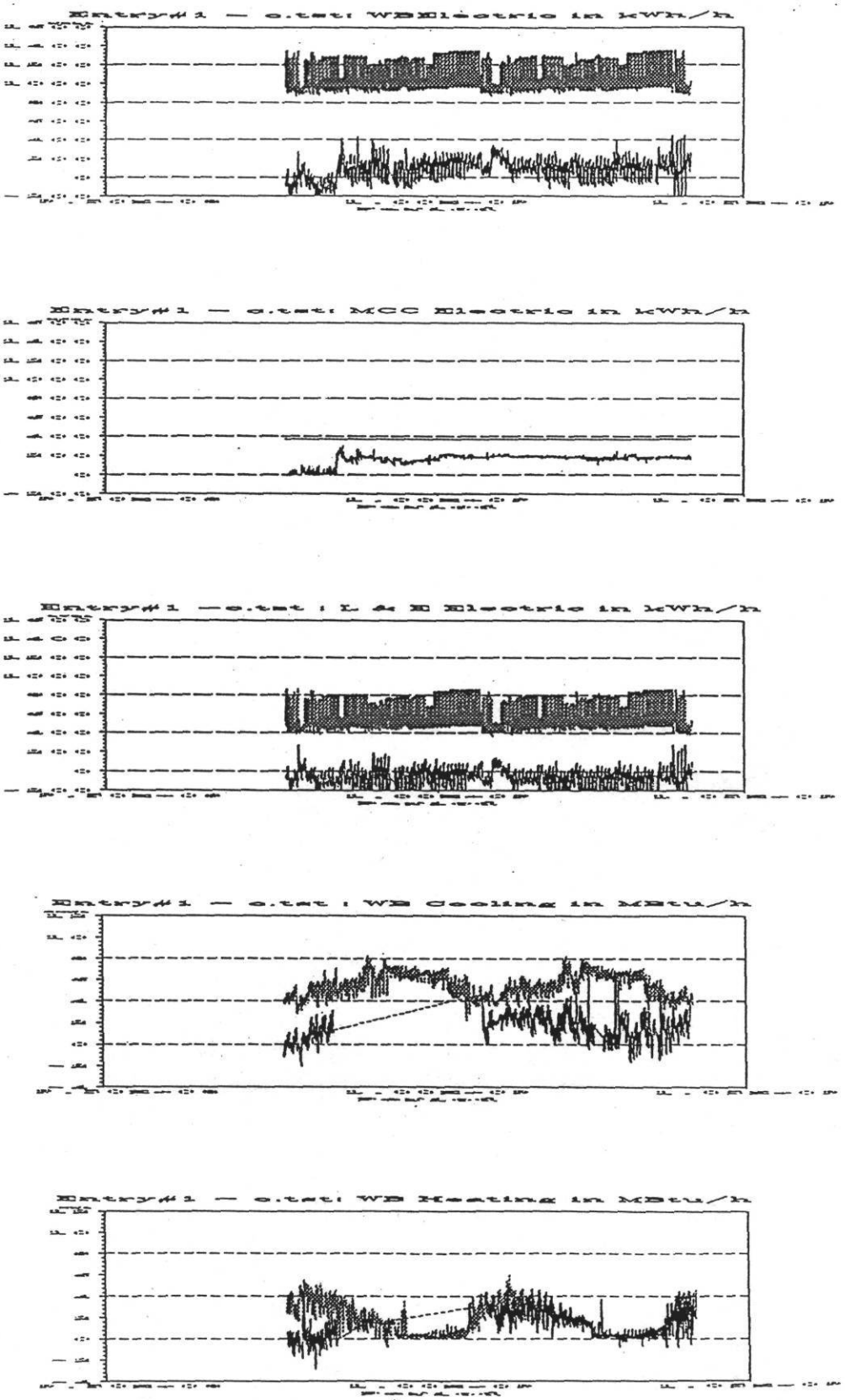


Figure 1.13: Time series plots of "baseline predicted" energy use by Entry #1 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

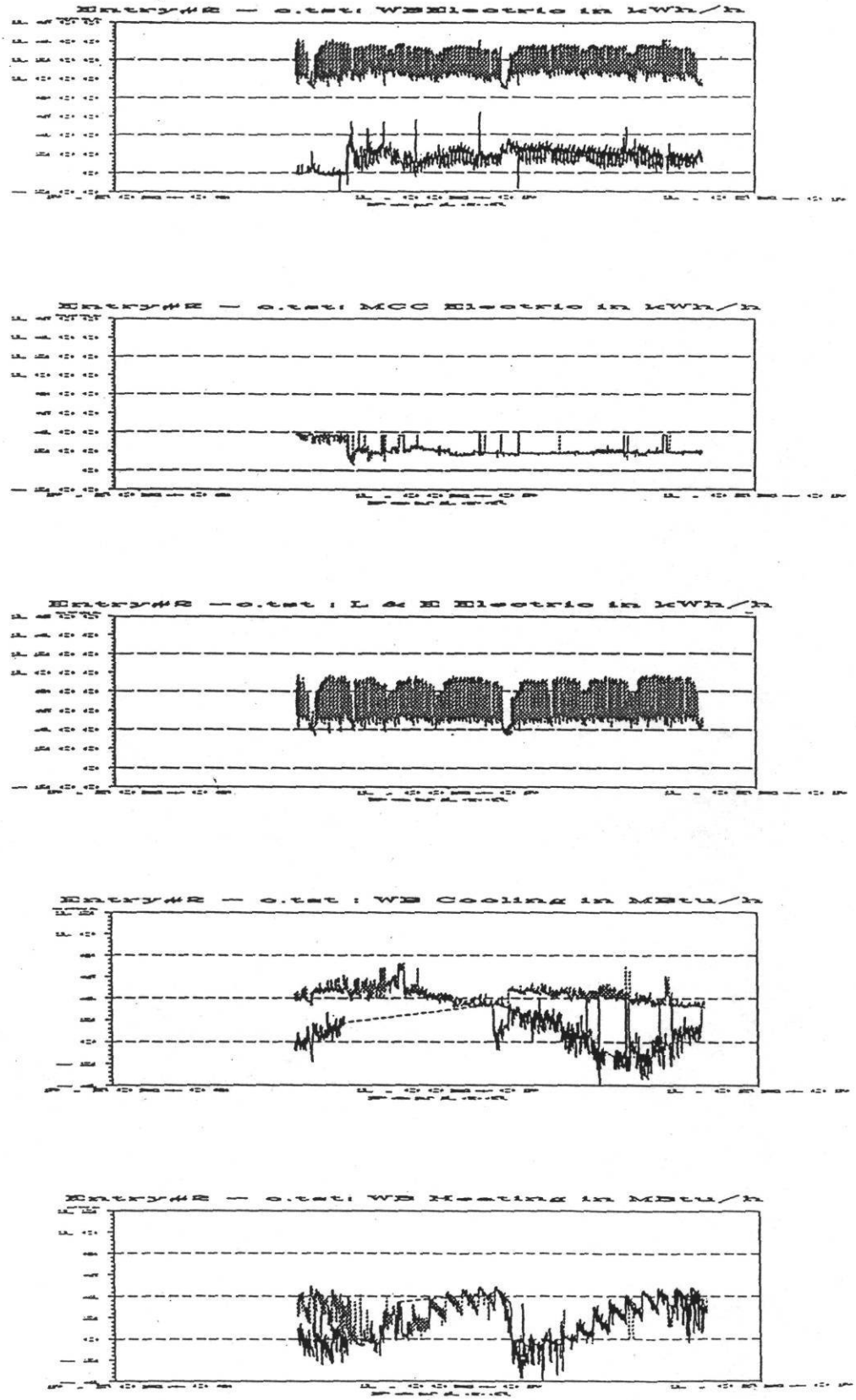


Figure 1.14: Time series plots of "baseline predicted" energy use by Entry #2 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

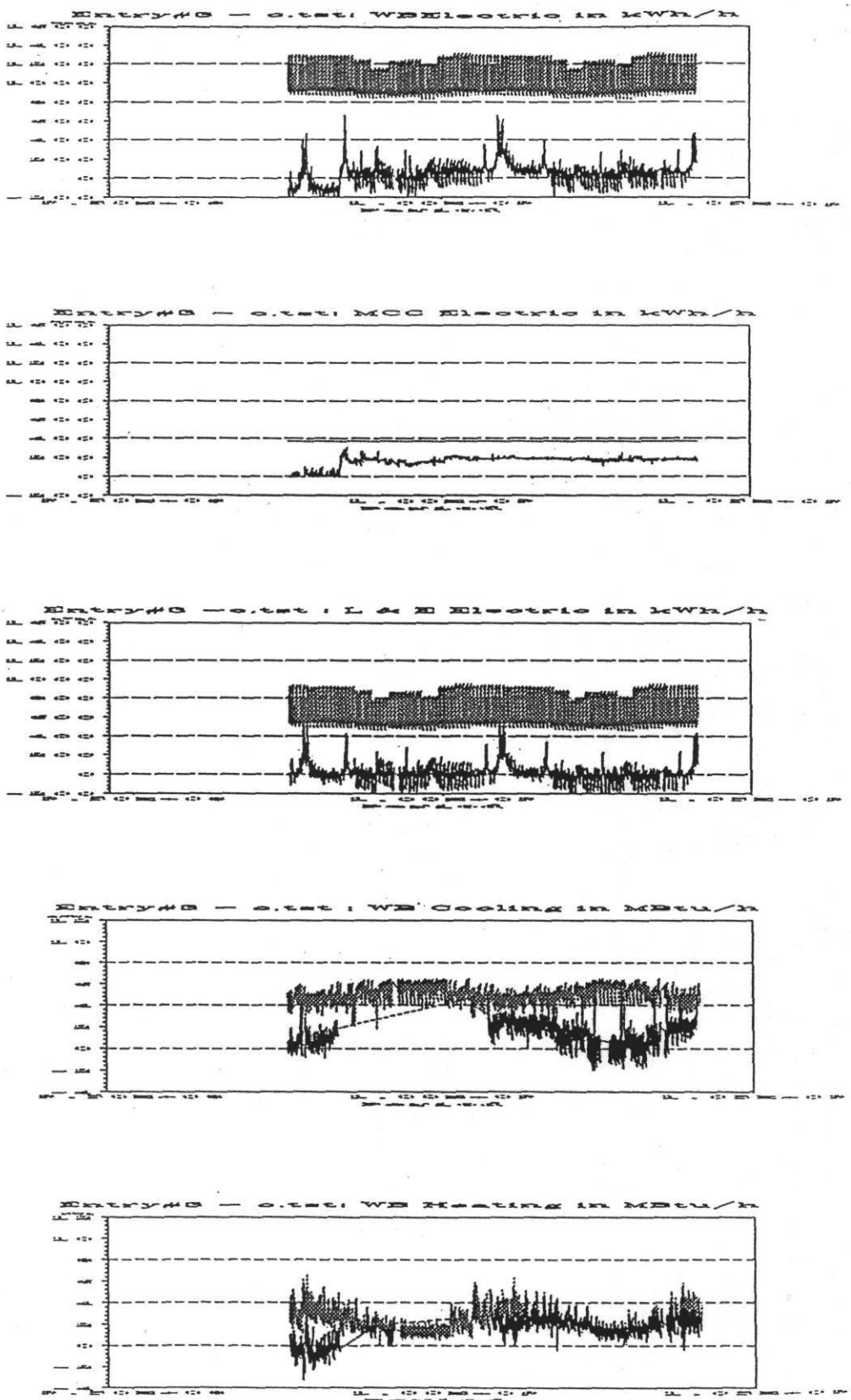


Figure 1.15: Time series plots of "baseline predicted" energy use by Entry #3 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

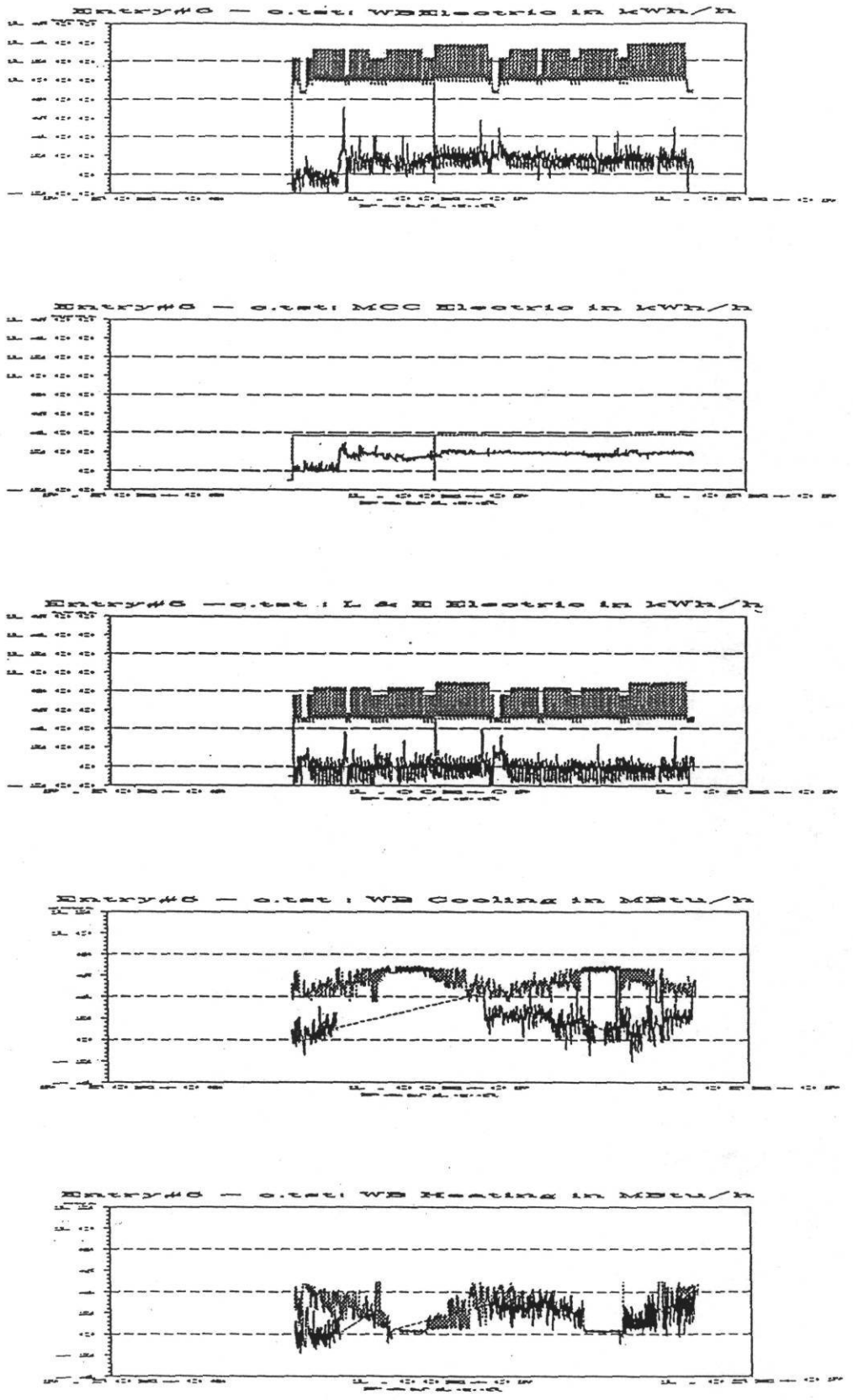


Figure 1.17: Time series plots of "baseline predicted" energy use by Entry #5 and energy savings in ZEC for the period of Nov.28,1990 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

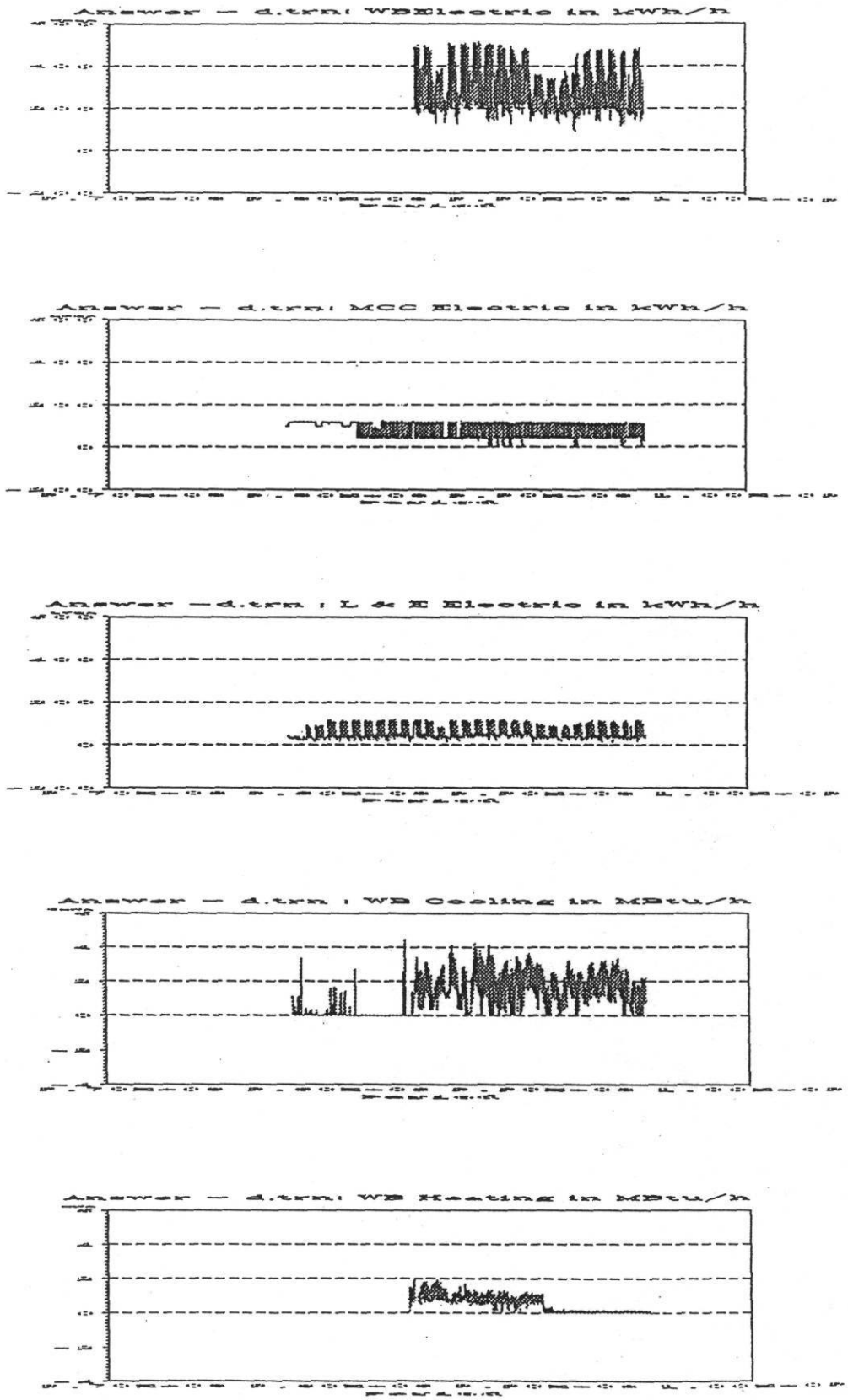


Figure 2.1: Time series plot of measured energy use in BUS building for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

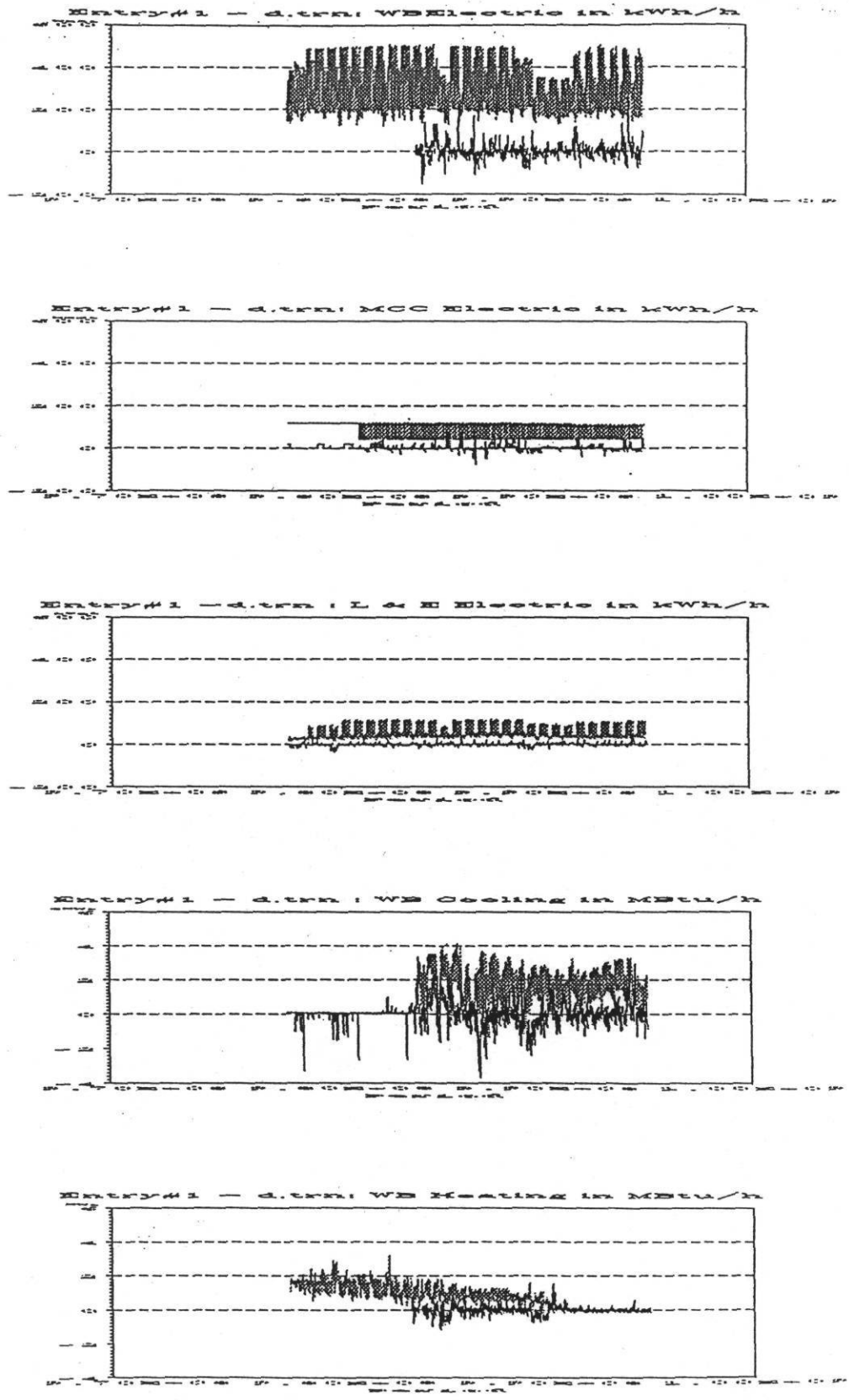


Figure 2.2: Time series plots of predicted energy use by Entry #1 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

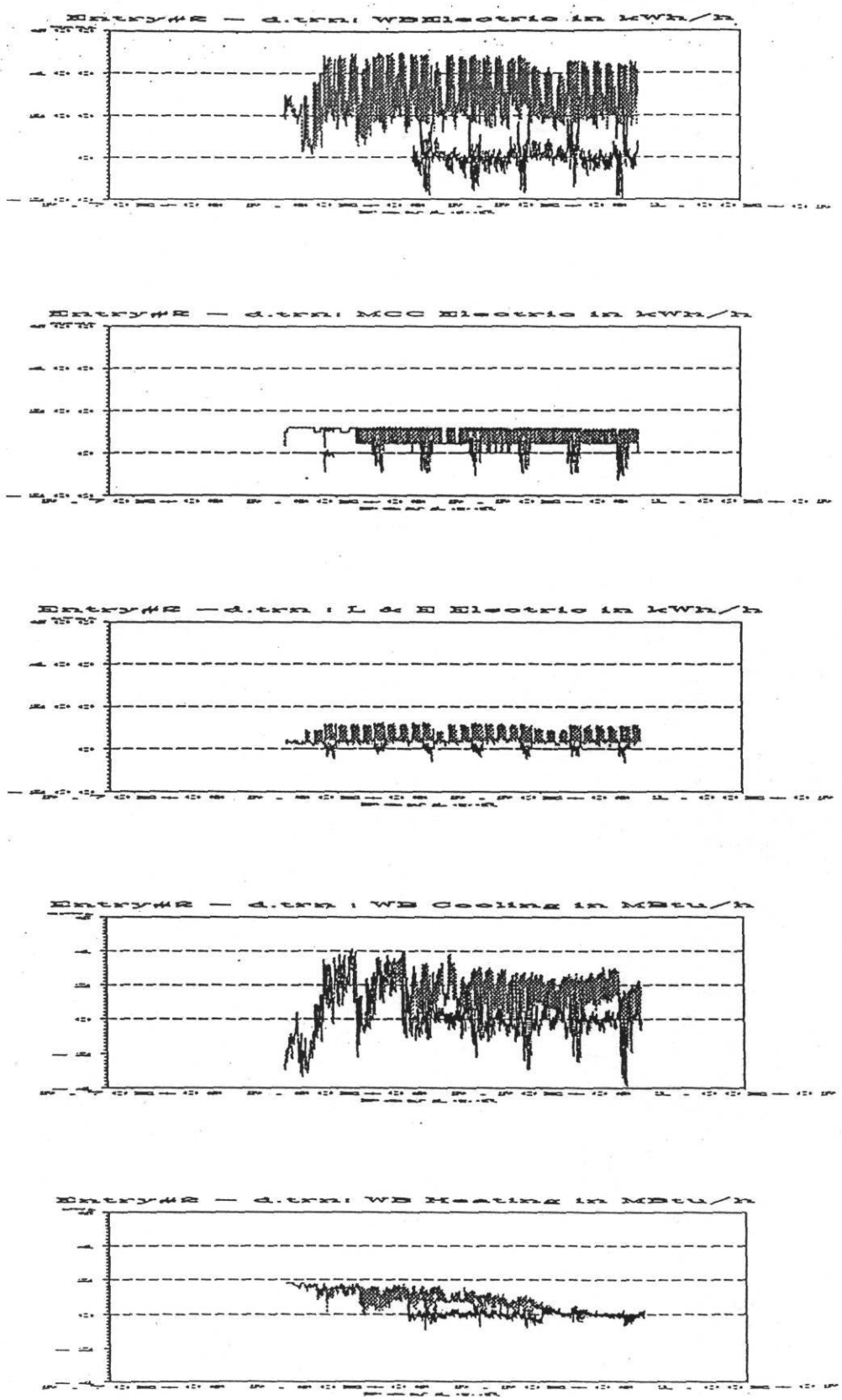


Figure 2.3: Time series plots of predicted energy use by Entry #2 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

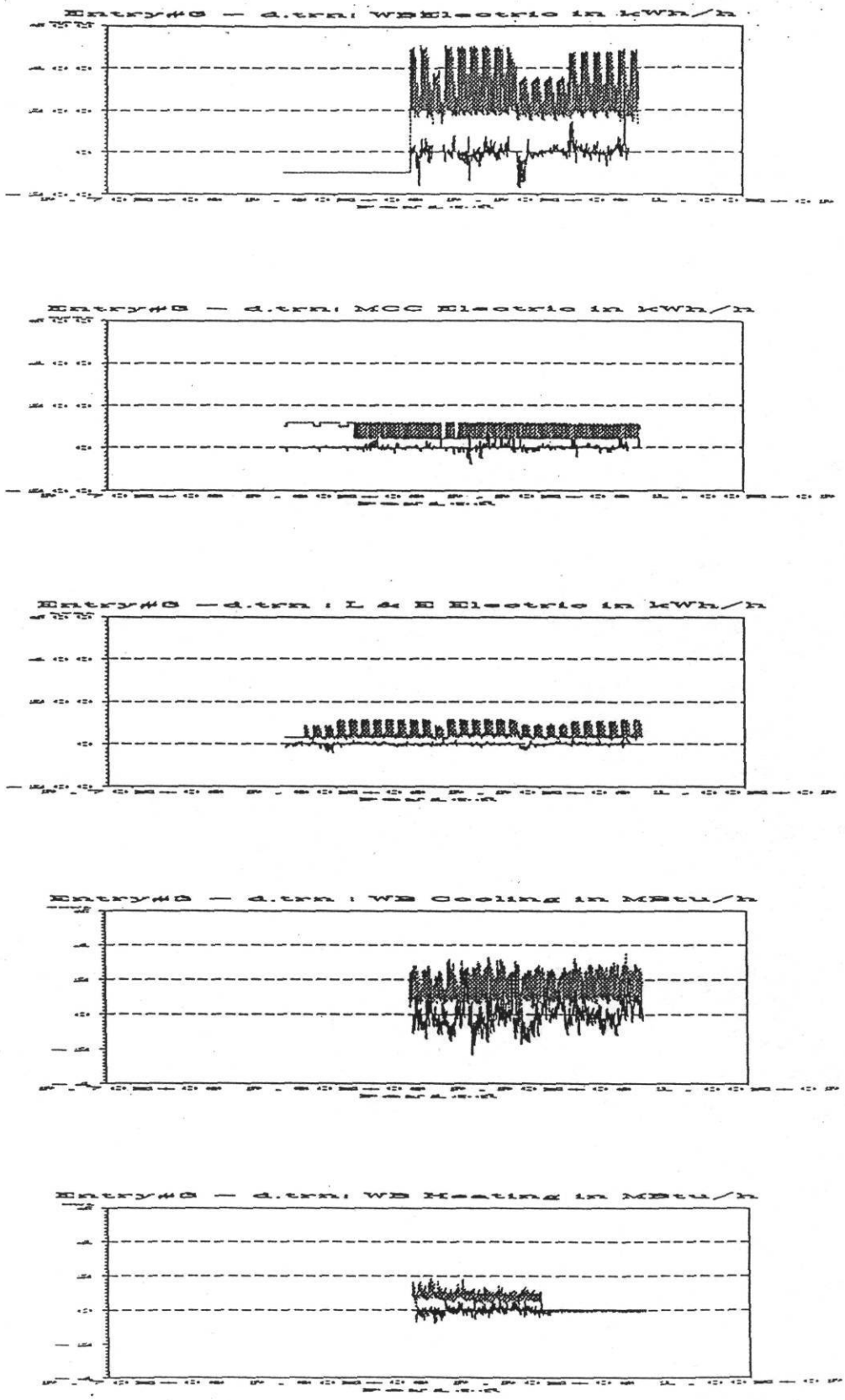


Figure 2.4: Time series plots of predicted energy use by Entry #3 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

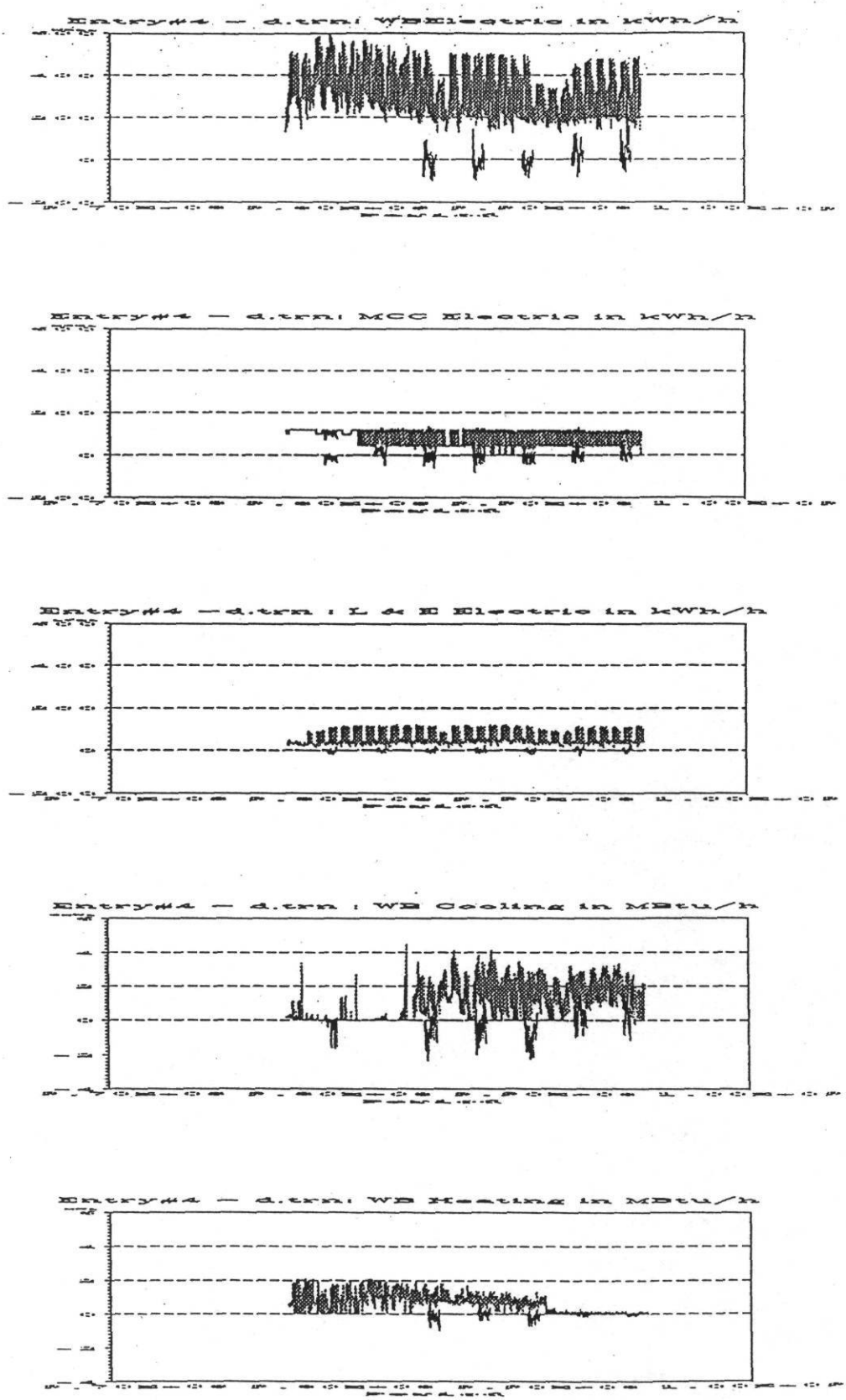


Figure 2.5: Time series plots of predicted energy use by Entry #4 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

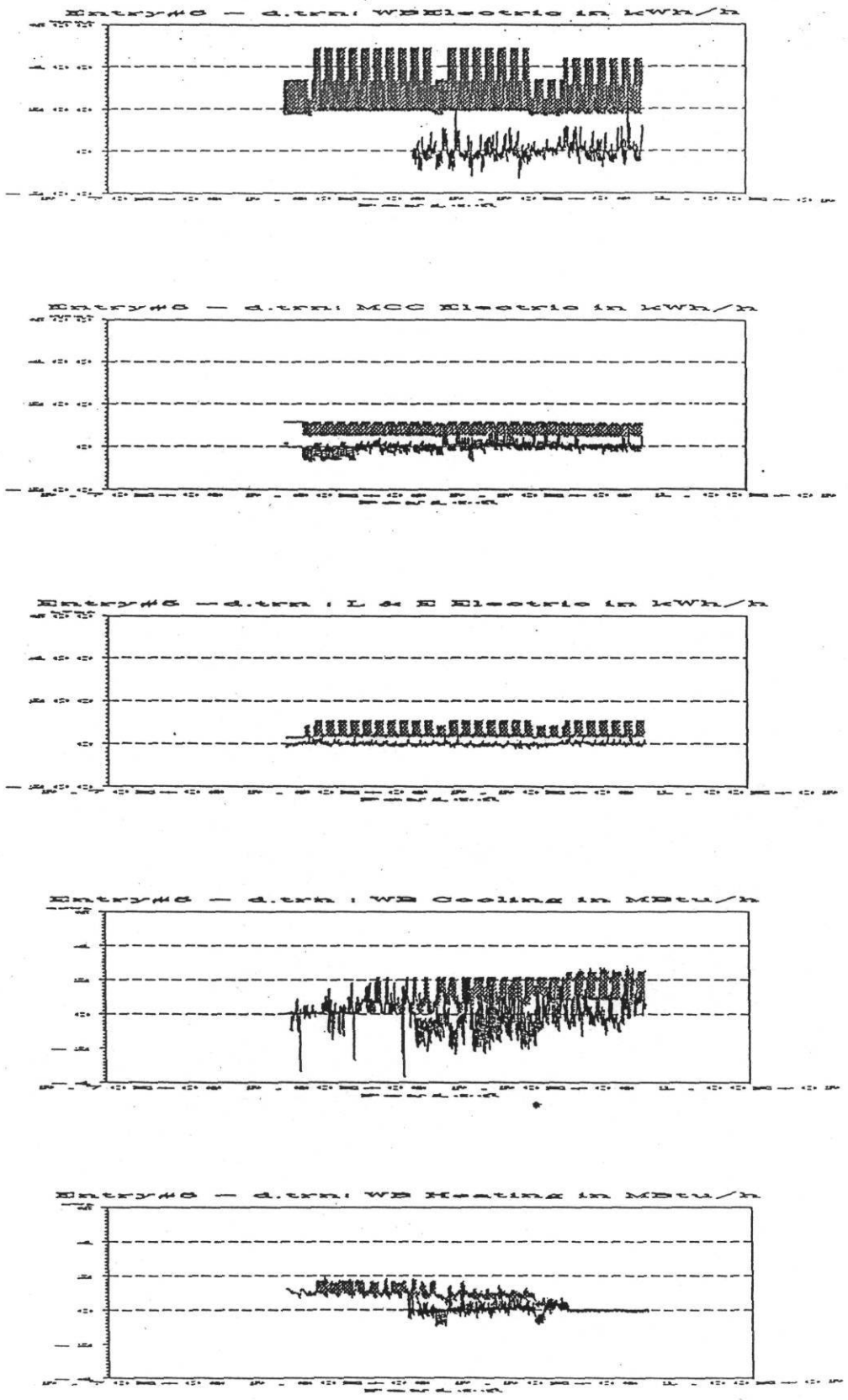
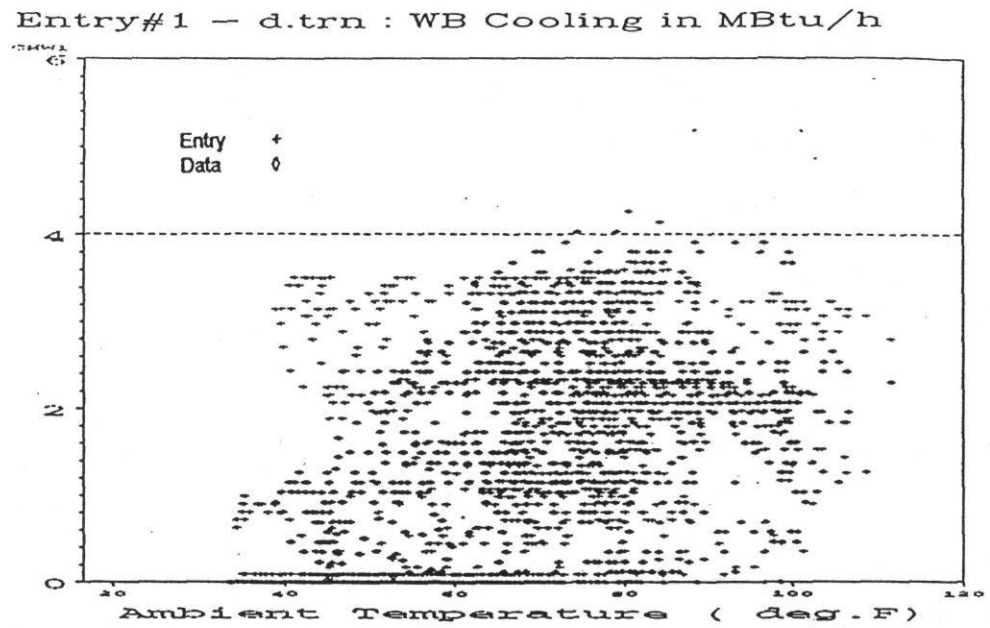


Figure 2.6: Time series plots of predicted energy use by Entry #5 and residual energy use in BUS for the period of Dec.22,990 to Jul.13,1991 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.



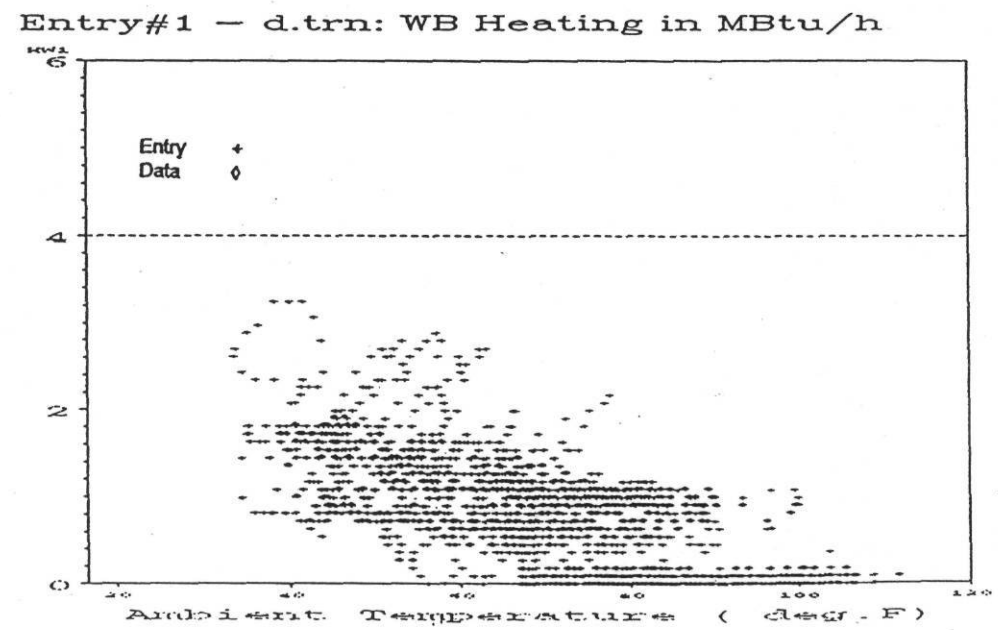
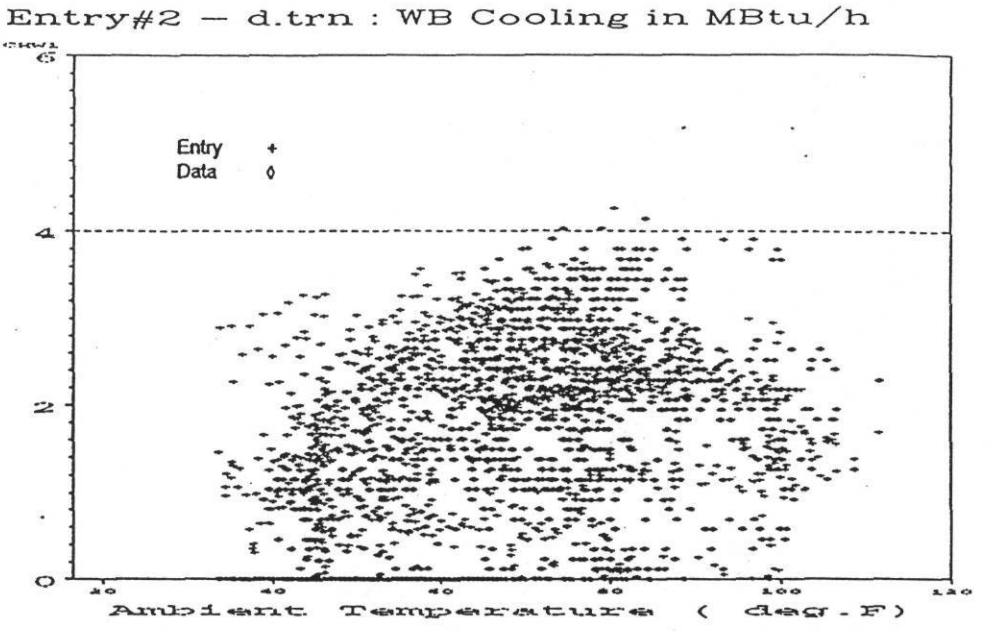


Figure 2.7: Scatter plots of predicted (by Entry #1) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



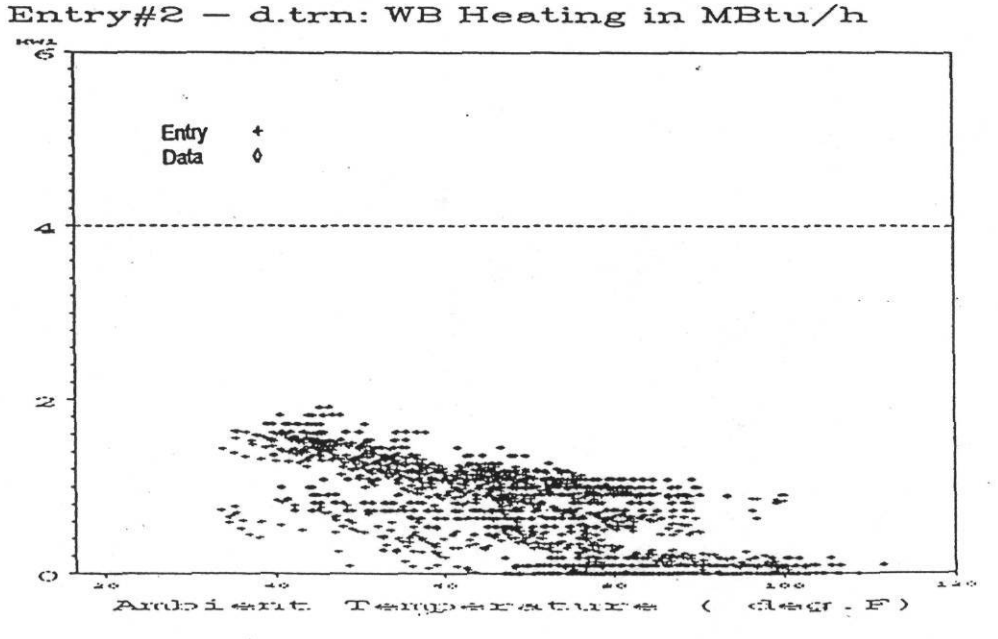
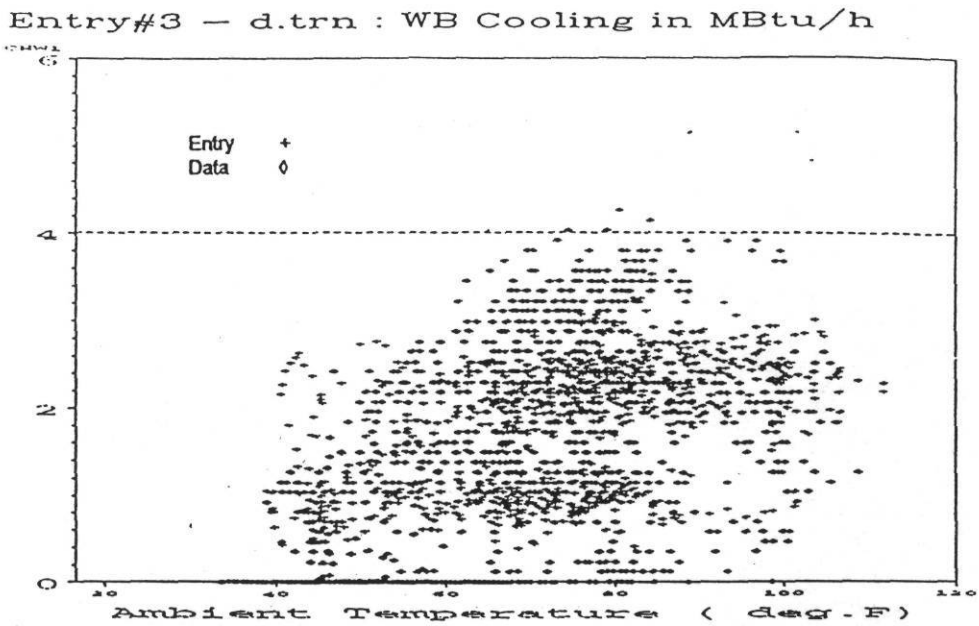


Figure 2.8: Scatter plots of predicted (by Entry #2) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



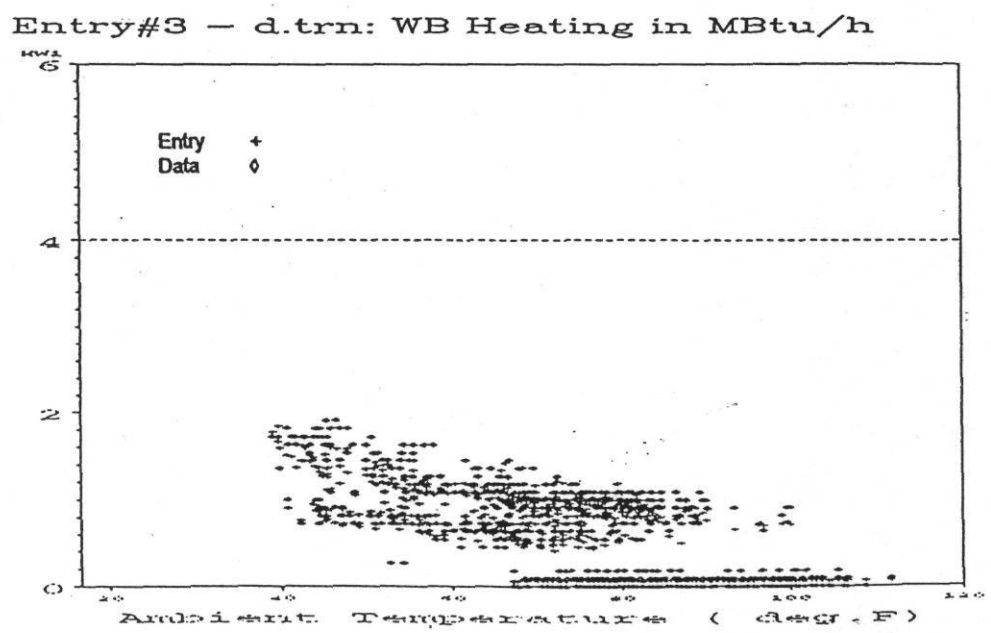
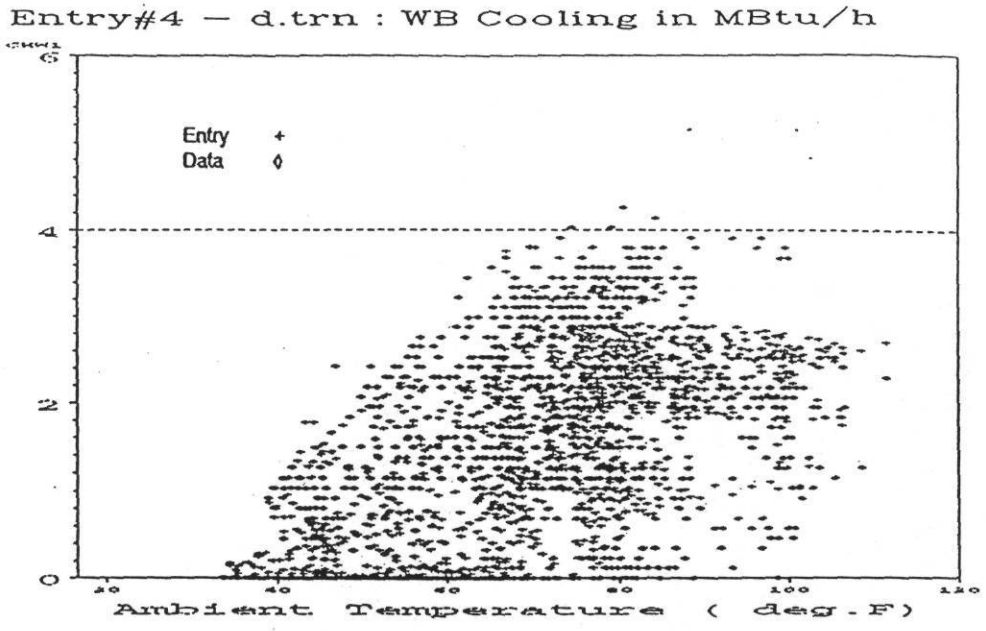


Figure 2.9: Scatter plots of predicted (by Entry #3) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



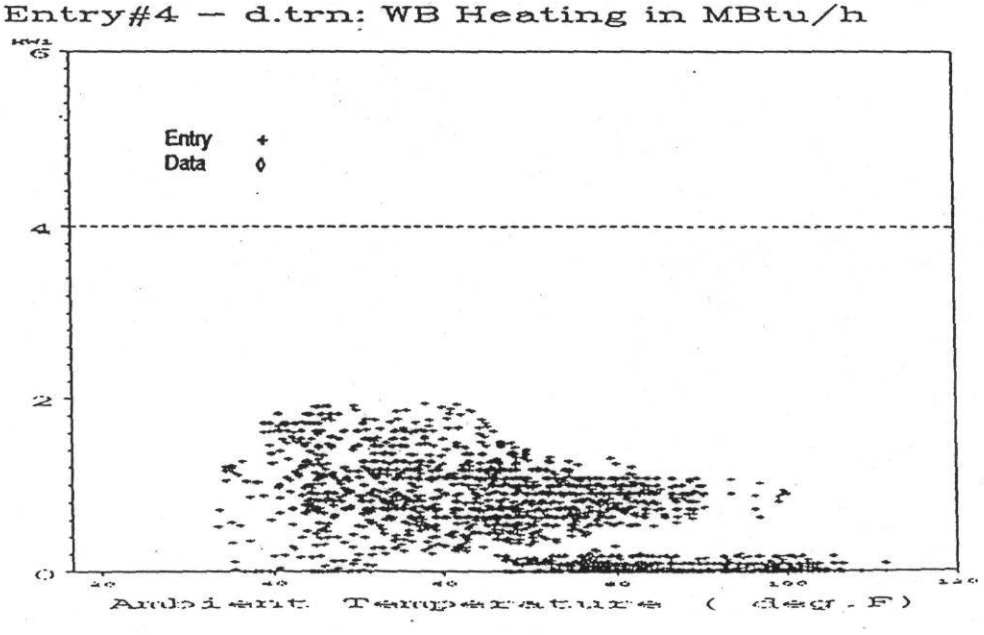
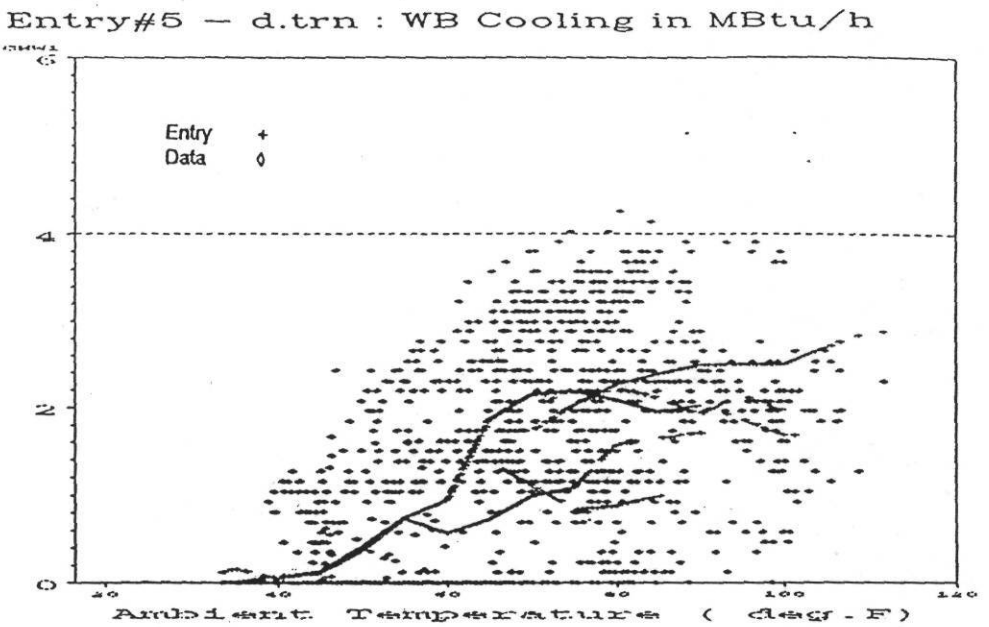


Figure 2.10: Scatter plots of predicted (by Entry #4) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.



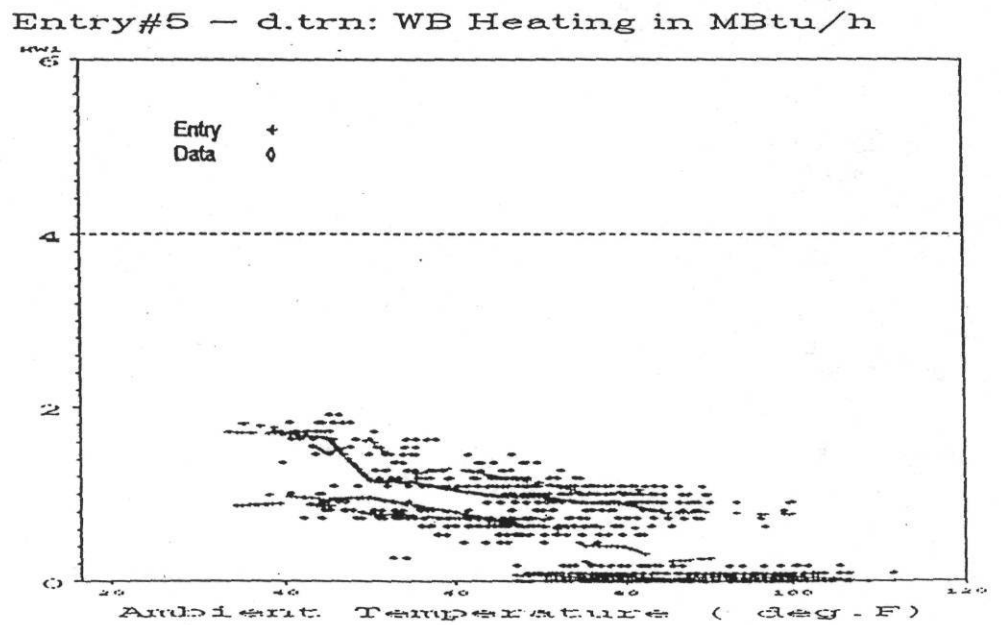


Figure 2.11: Scatter plots of predicted (by Entry #5) and measured energy use versus ambient temperature in BUS building for the removed data from the Dec.22,1990 to Jul.13,1991 period for (a) Whole-Building Cooling, (b) Whole-Building Heating channels.

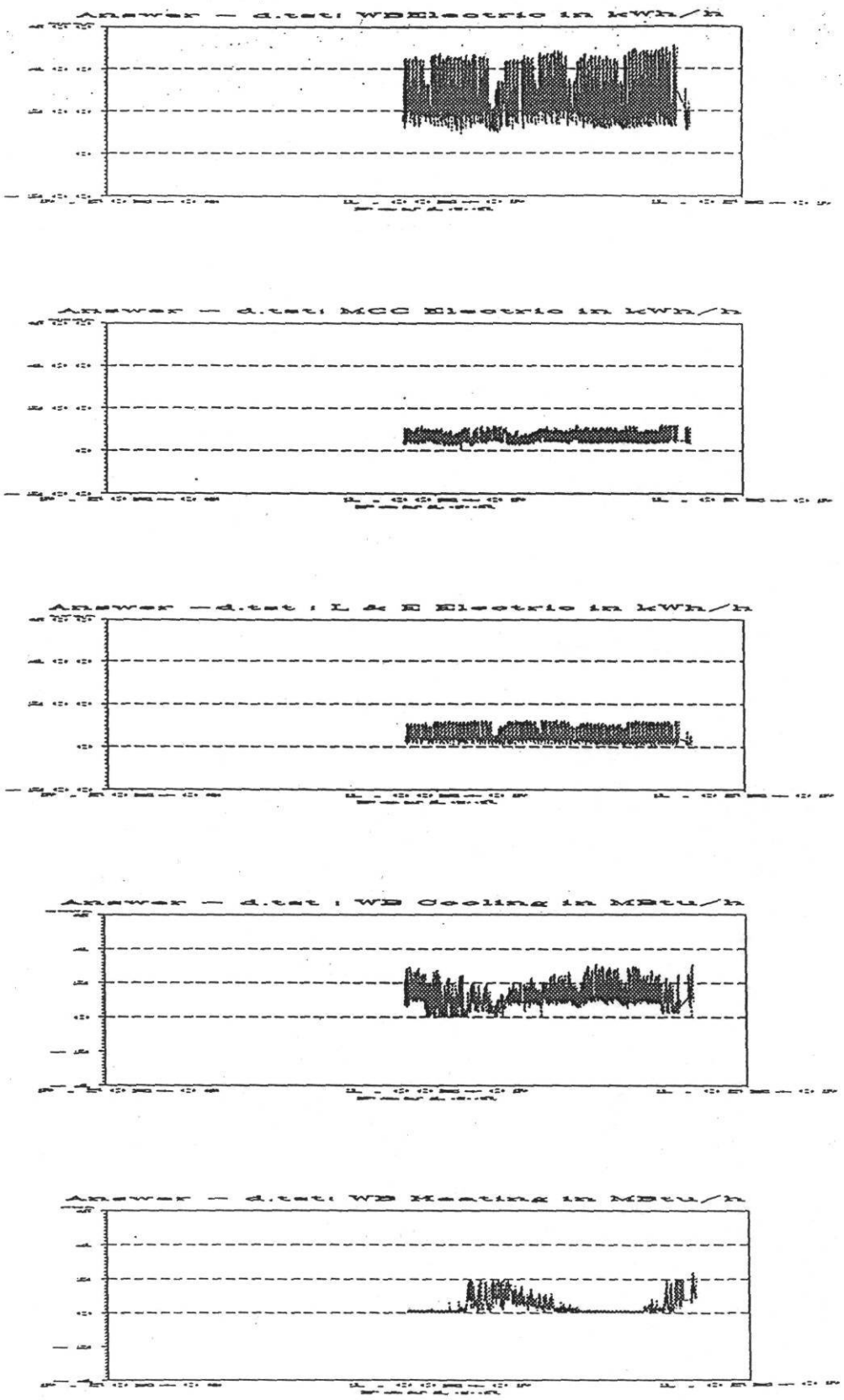


Figure 2.12: Time series plot of measured energy use in BUS building for the period of Jul.14, 1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

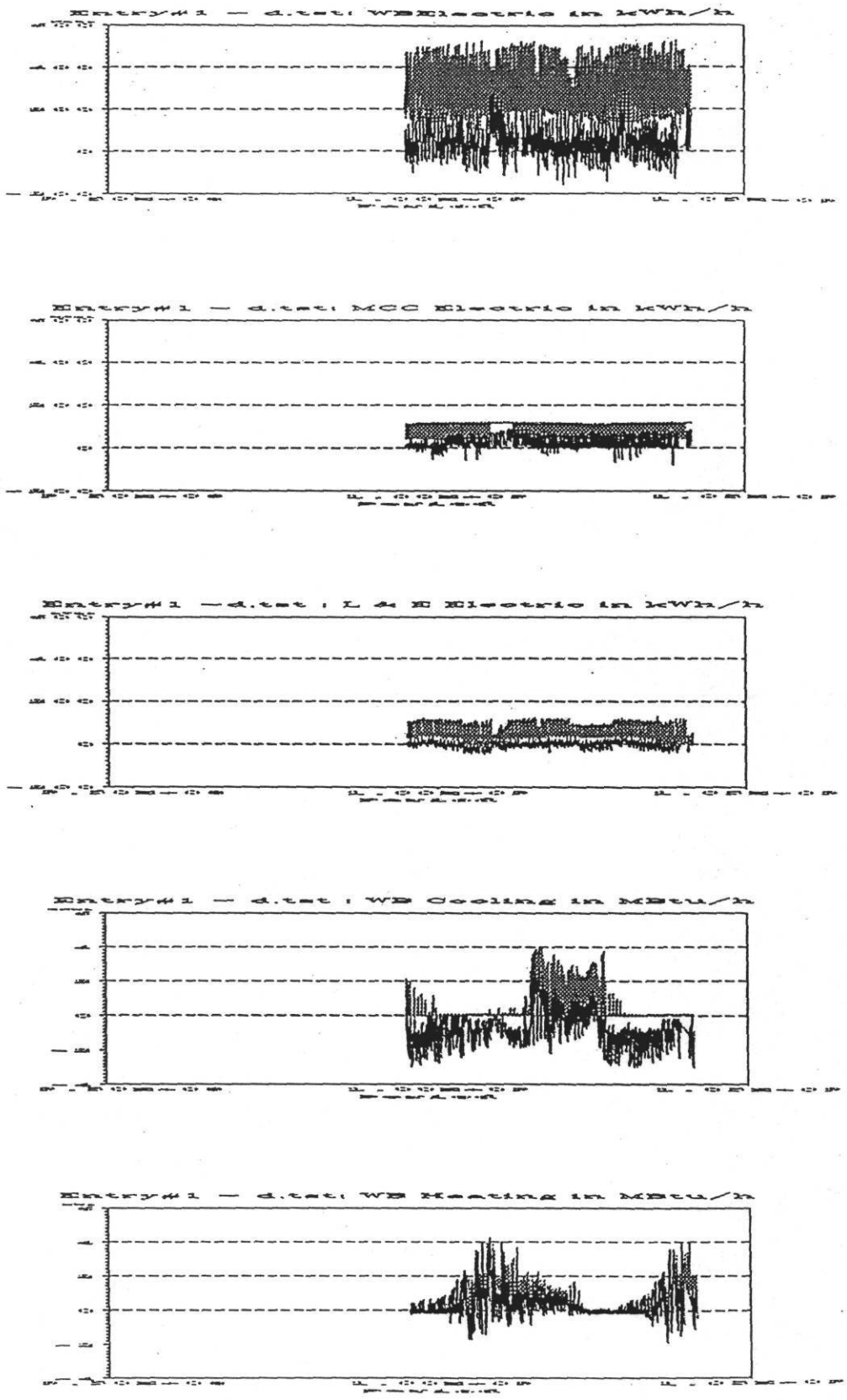


Figure 2.13: Time series plots of "baseline predicted" energy use by Entry #1 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

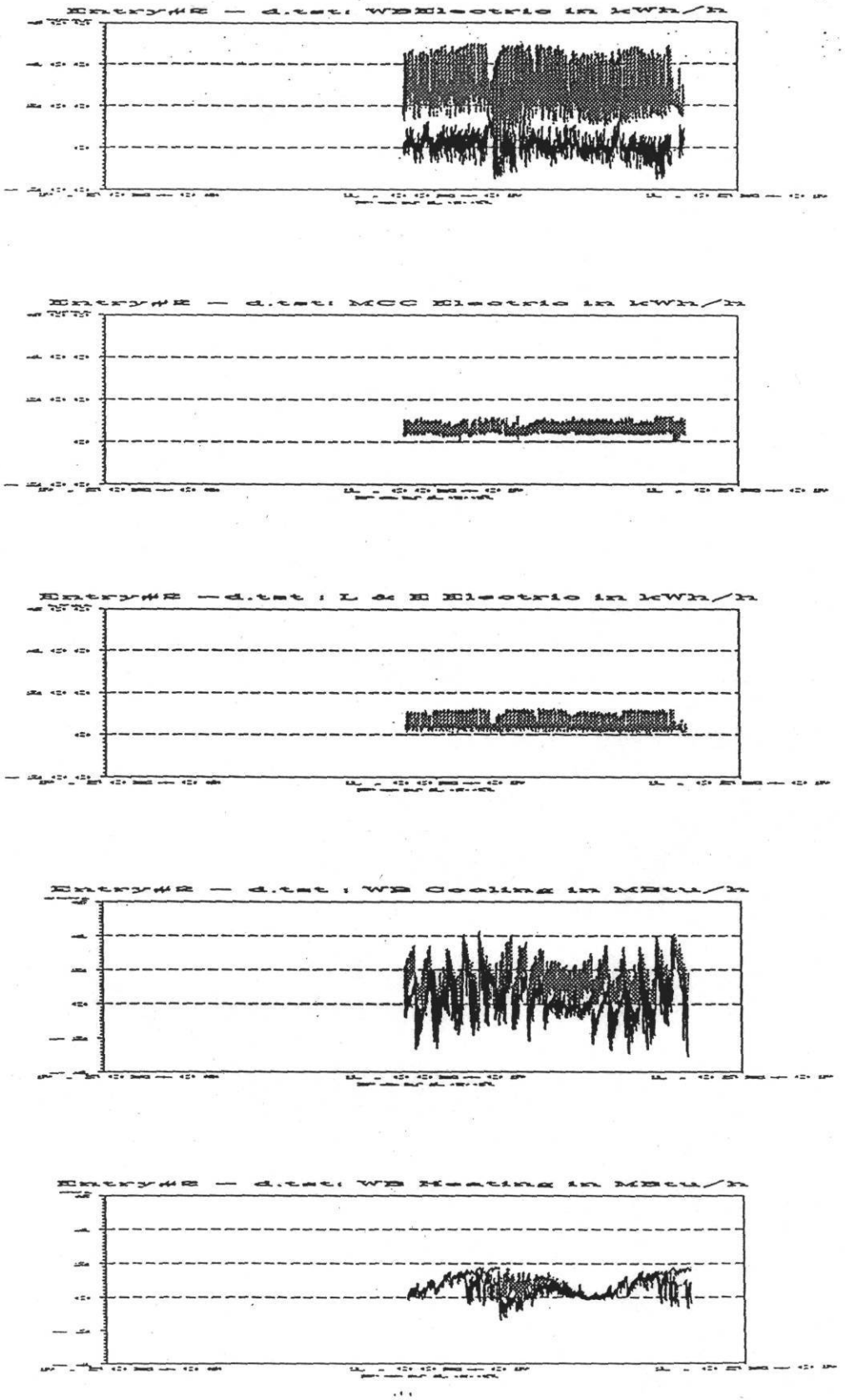


Figure 2.14: Time series plots of "baseline predicted" energy use by Entry #2 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

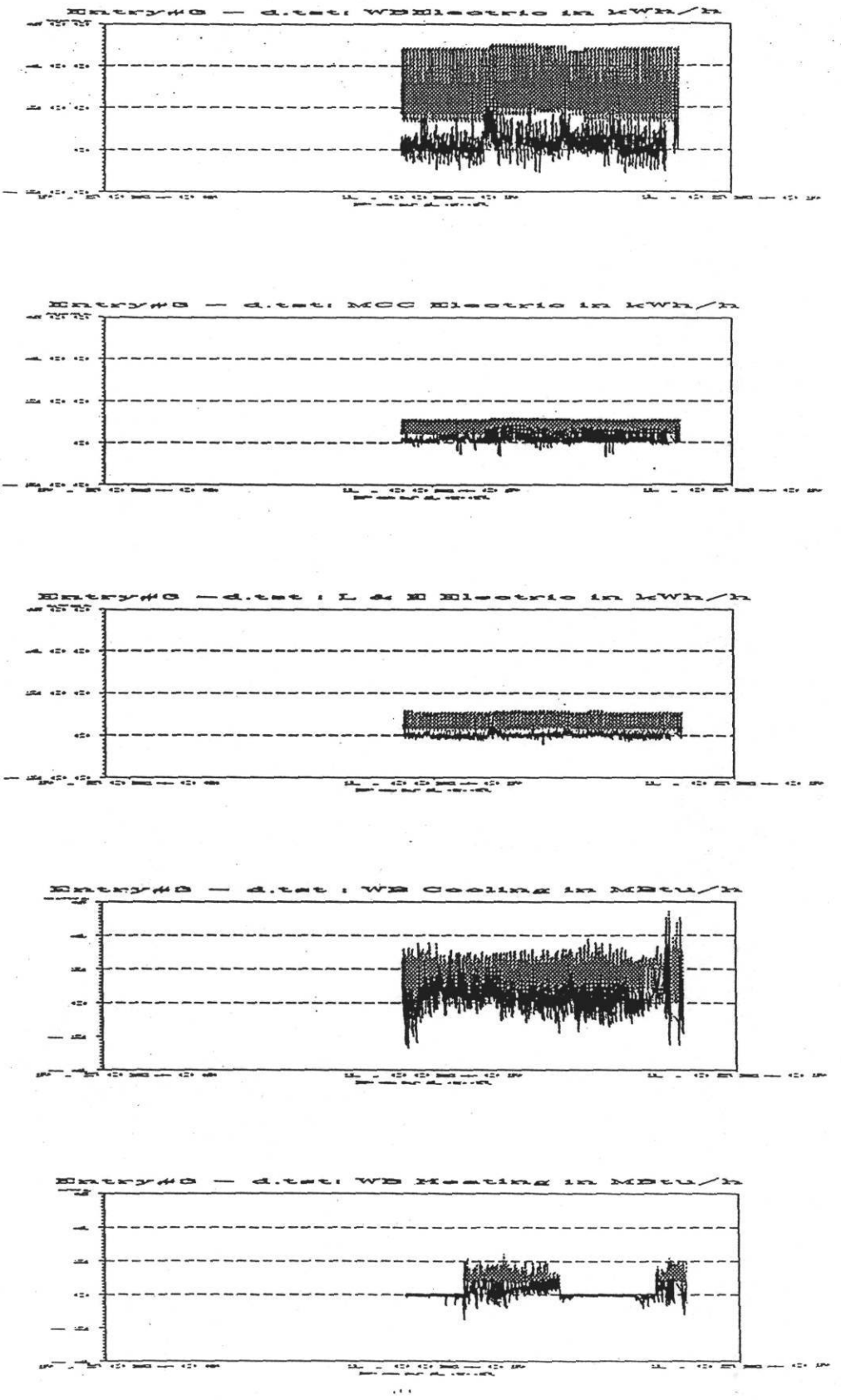


Figure 2.15: Time series plots of "baseline predicted" energy use by Entry #3 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

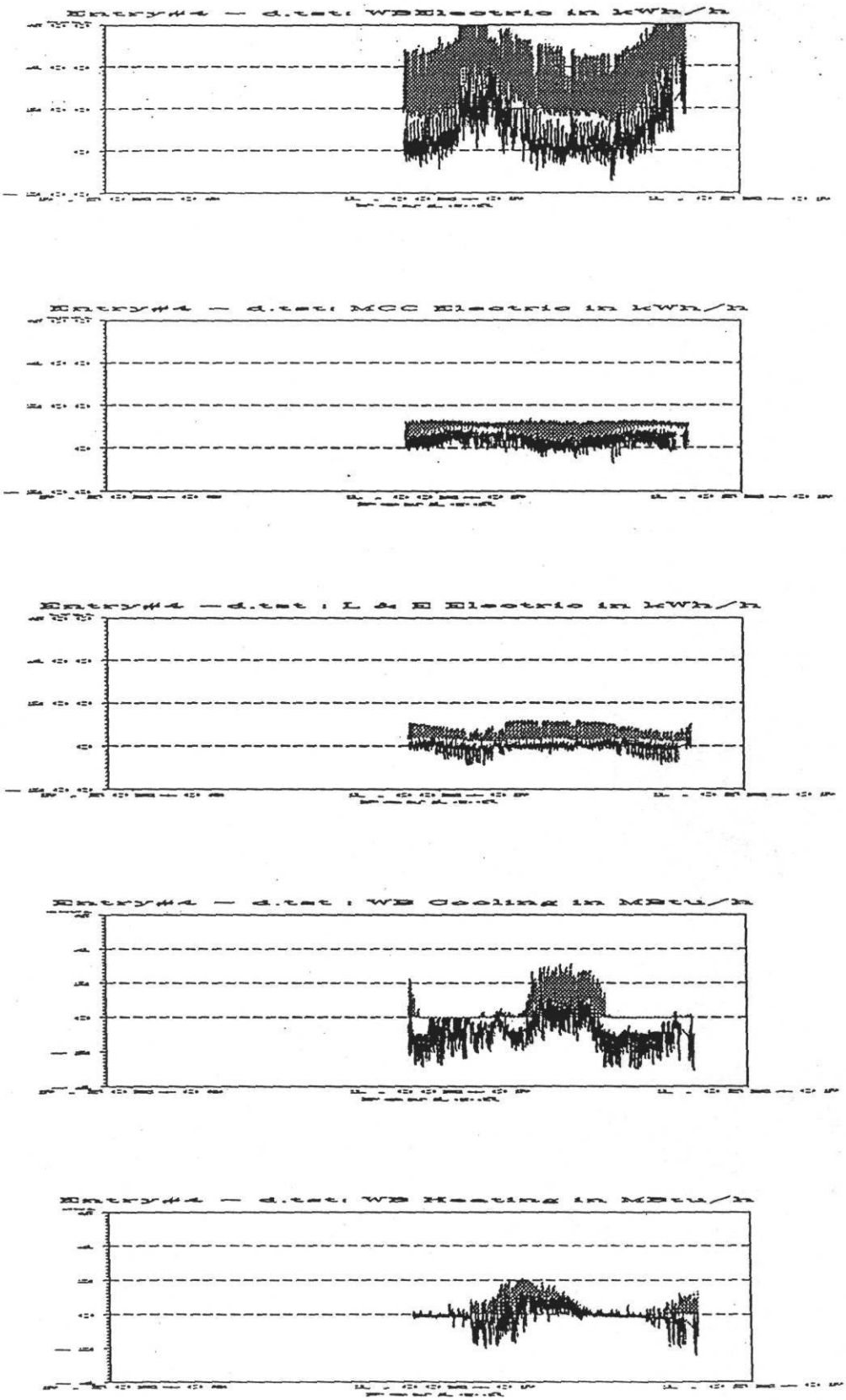


Figure 2.16: Time series plots of "baseline predicted" energy use by Entry #4 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

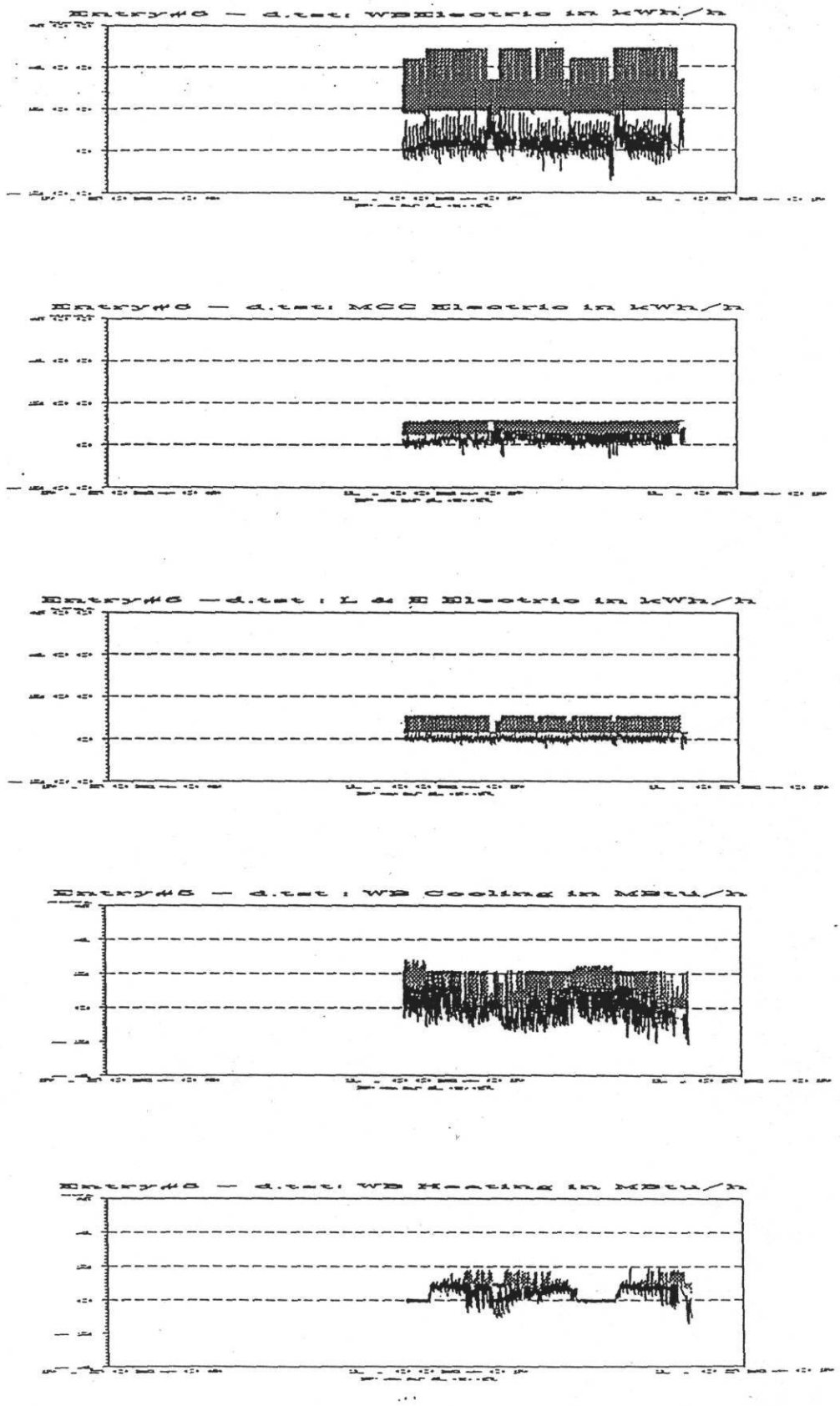


Figure 2.17: Time series plots of "baseline predicted" energy use by Entry #5 and energy savings in BUS building for the period of Jul.14,1991 to Dec.31,1992 for (a) Whole-Building Electricity, (b) Motor Control Center Electricity, (c) Light and Equipment Electricity, (d) Whole-Building Cooling, and (e) Whole-Building Heating channels.

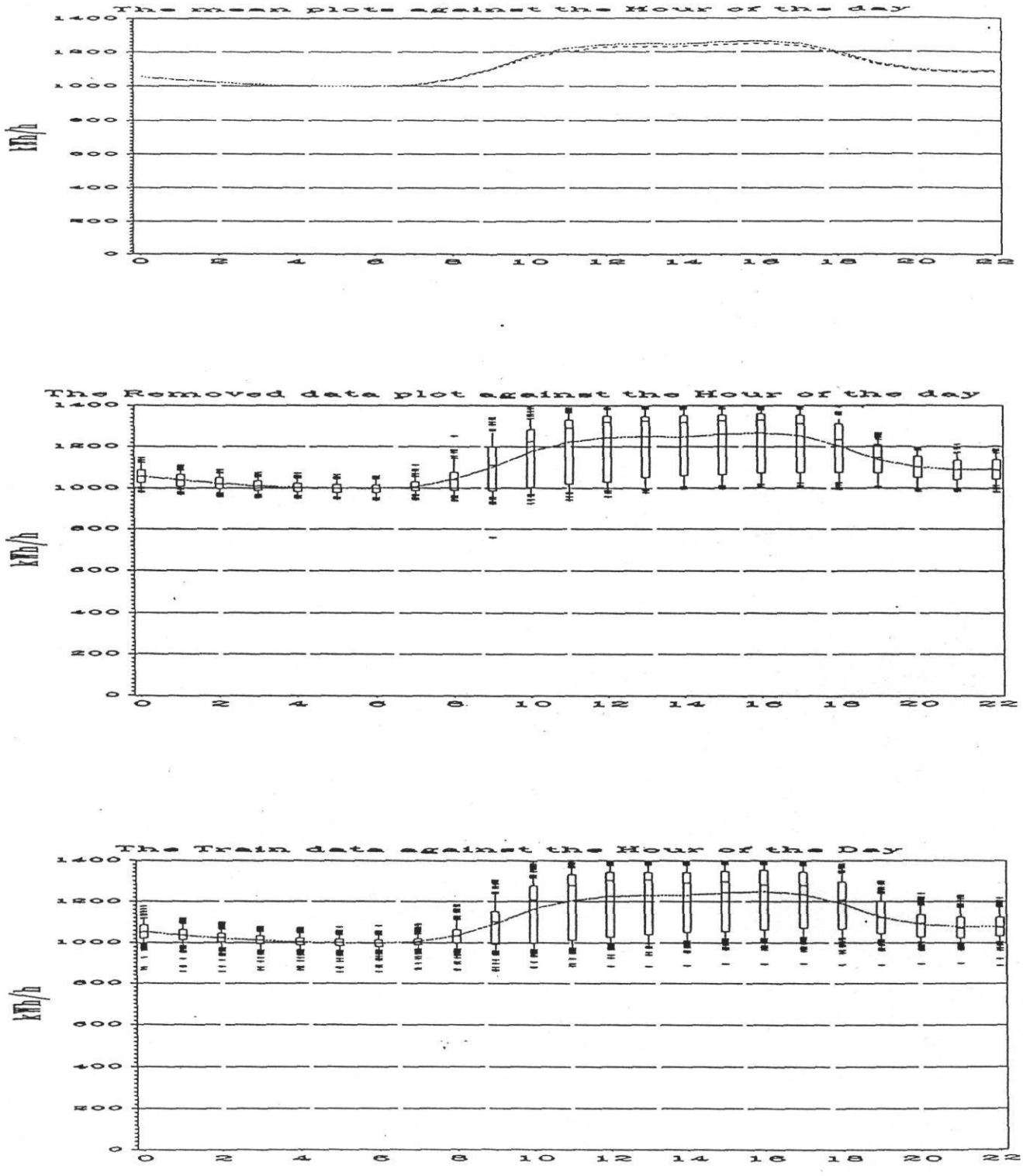


Figure 3.1: The box and whisker mean (BWM) plots of WBE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) removed data and (c) Train data.

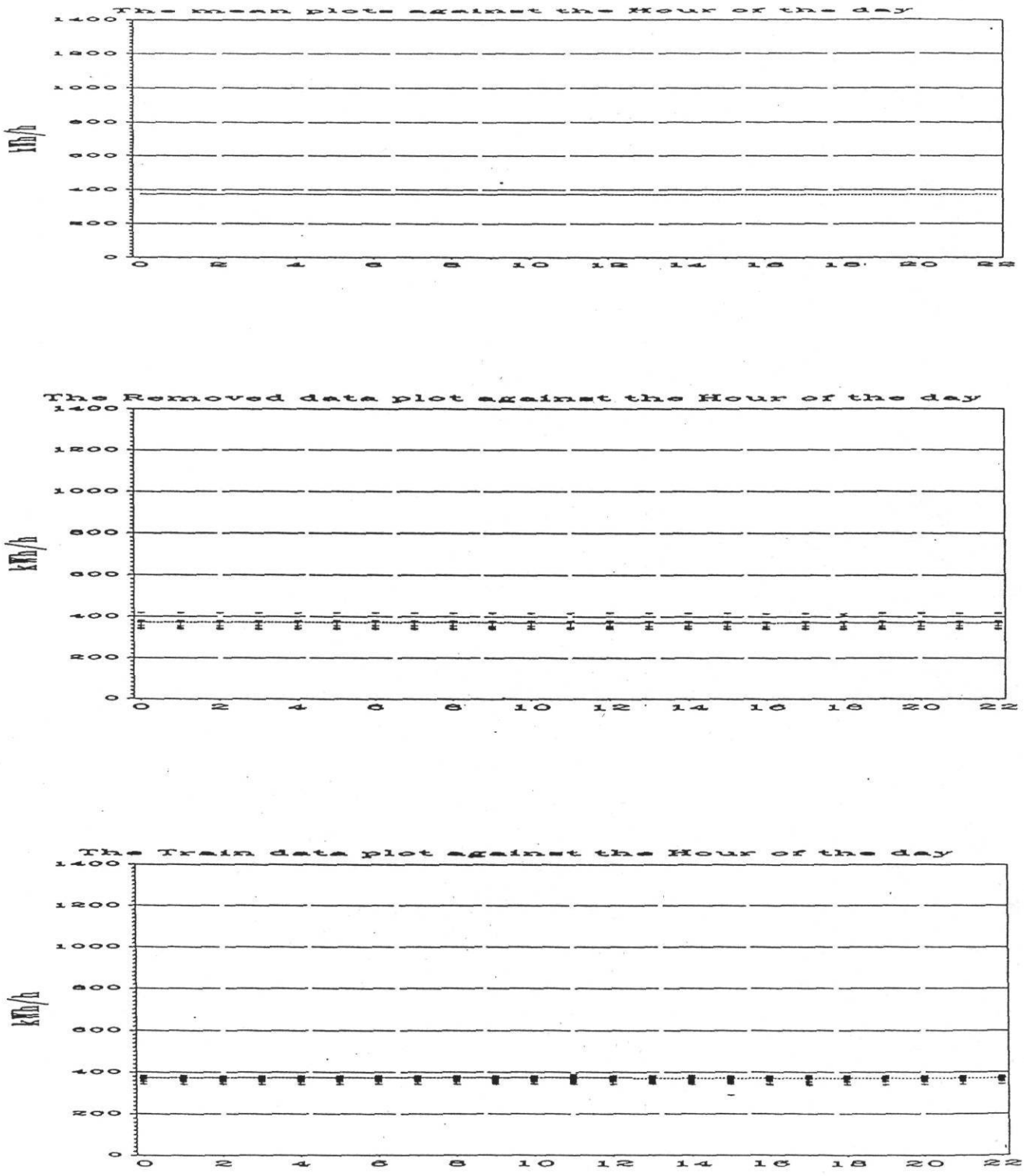


Figure 3.2: The box and whisker mean (BWM) plots of MCC energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) removed data and (c) Train data.

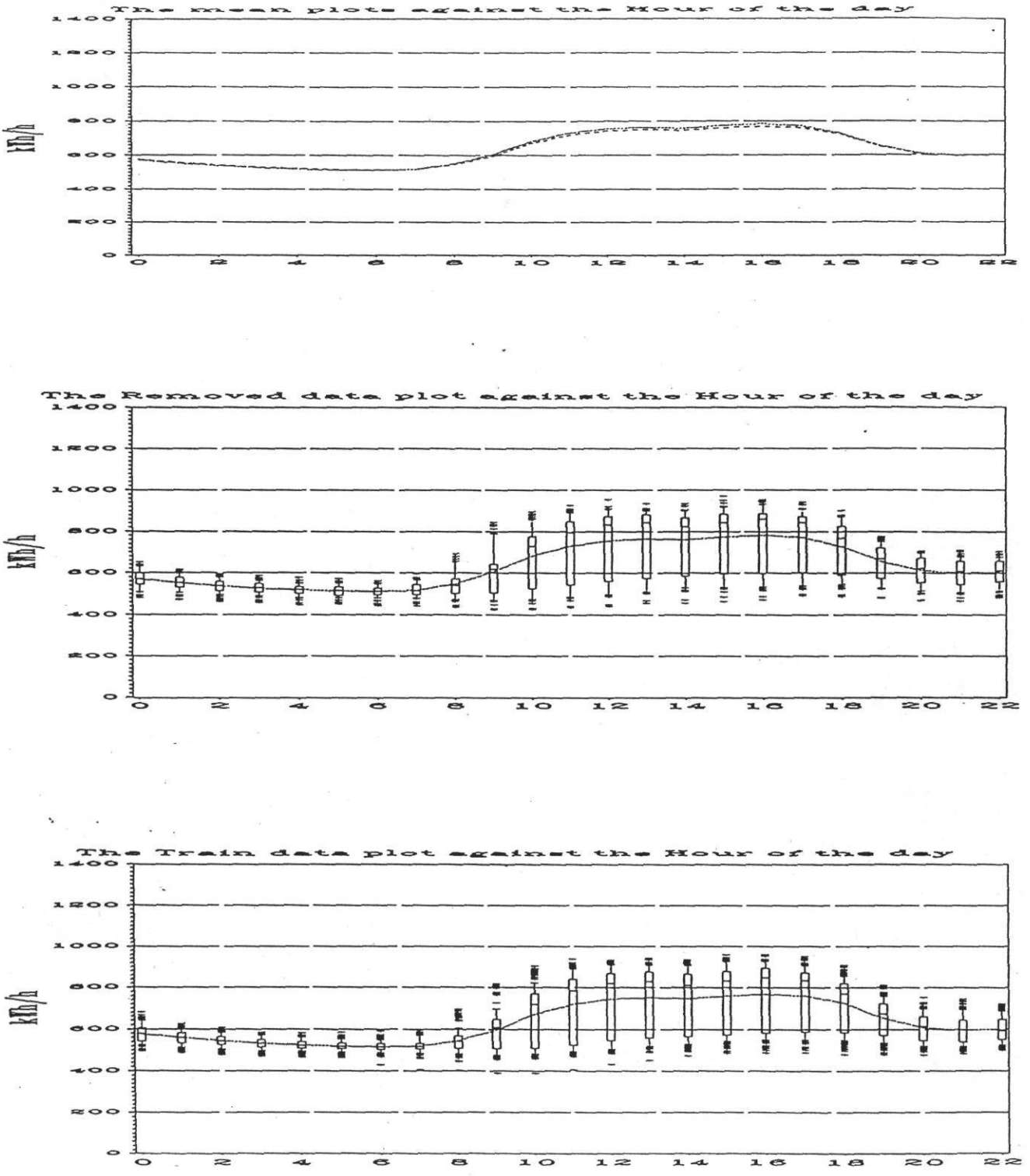


Figure 3.3: The box and whisker mean (BWM) plots of LEQ energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) removed data and (c) Train data.

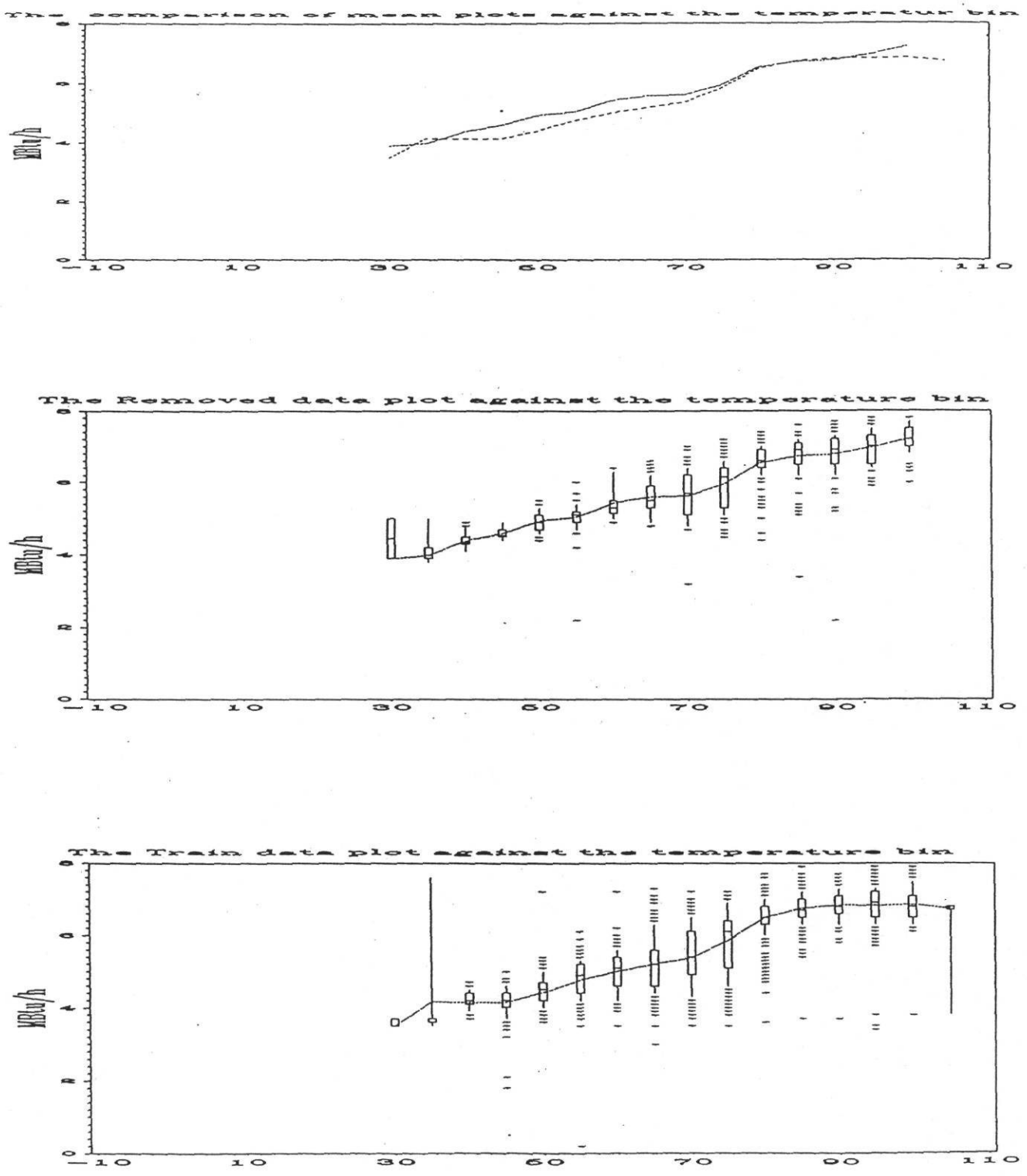


Figure 3.4: The box and whisker mean (BWM) plots of CWE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.

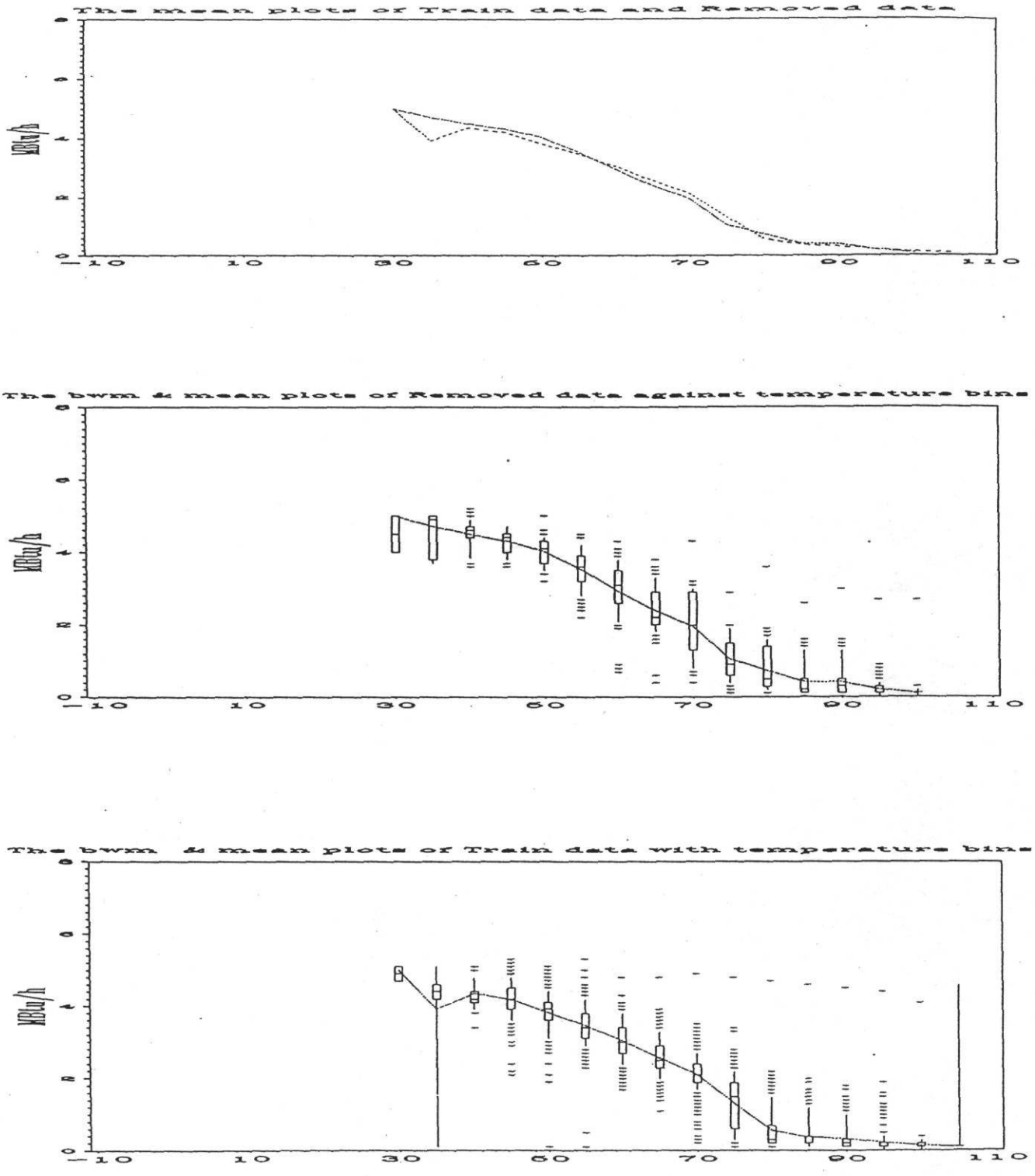


Figure 3.5: The box and whisker mean (BWM) plots of HWE energy use data in ZEC to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, (b) removed data and (c) Train data.

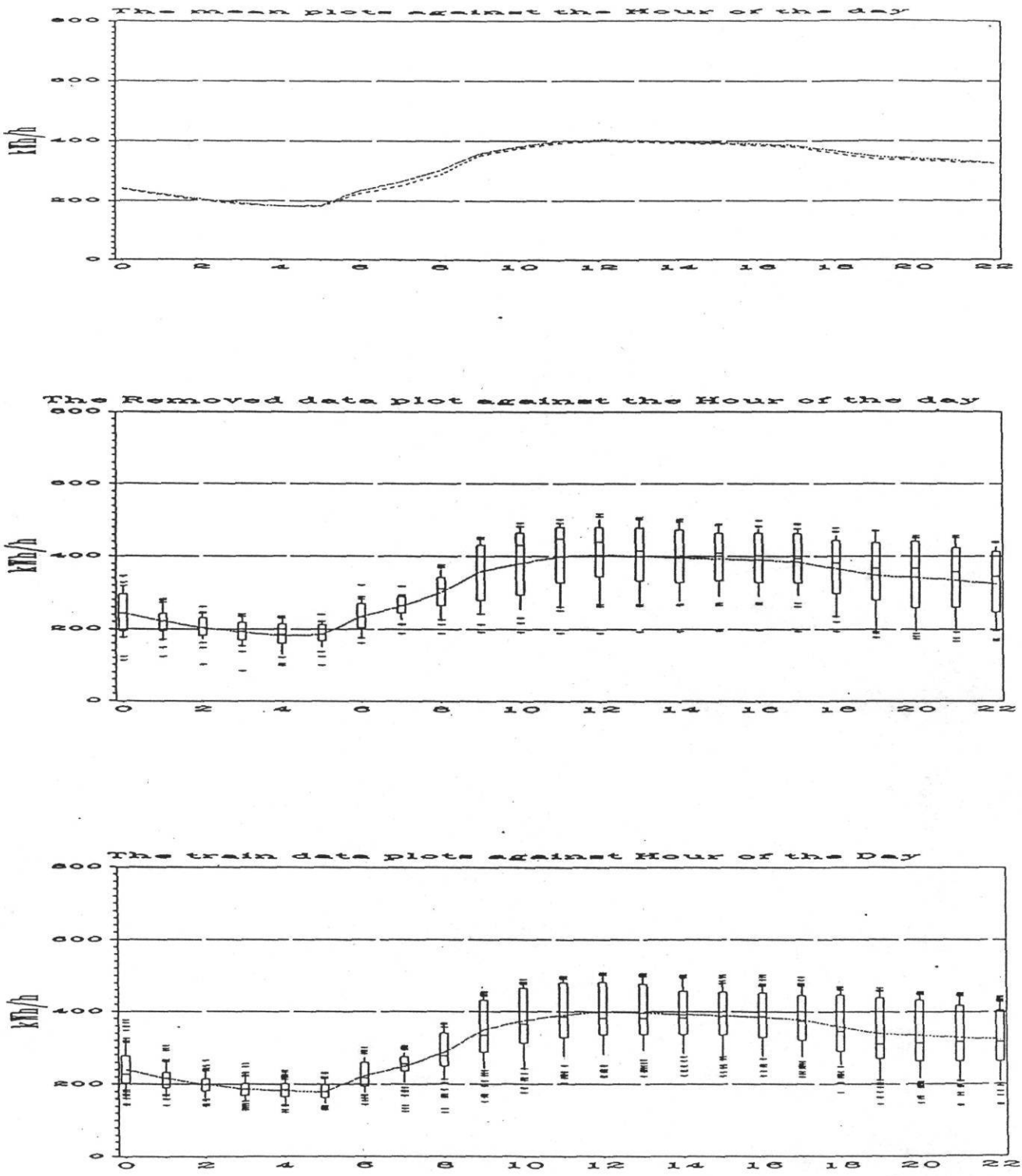


Figure 4.1: The box and whisker mean (BWM) plots of WBE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.

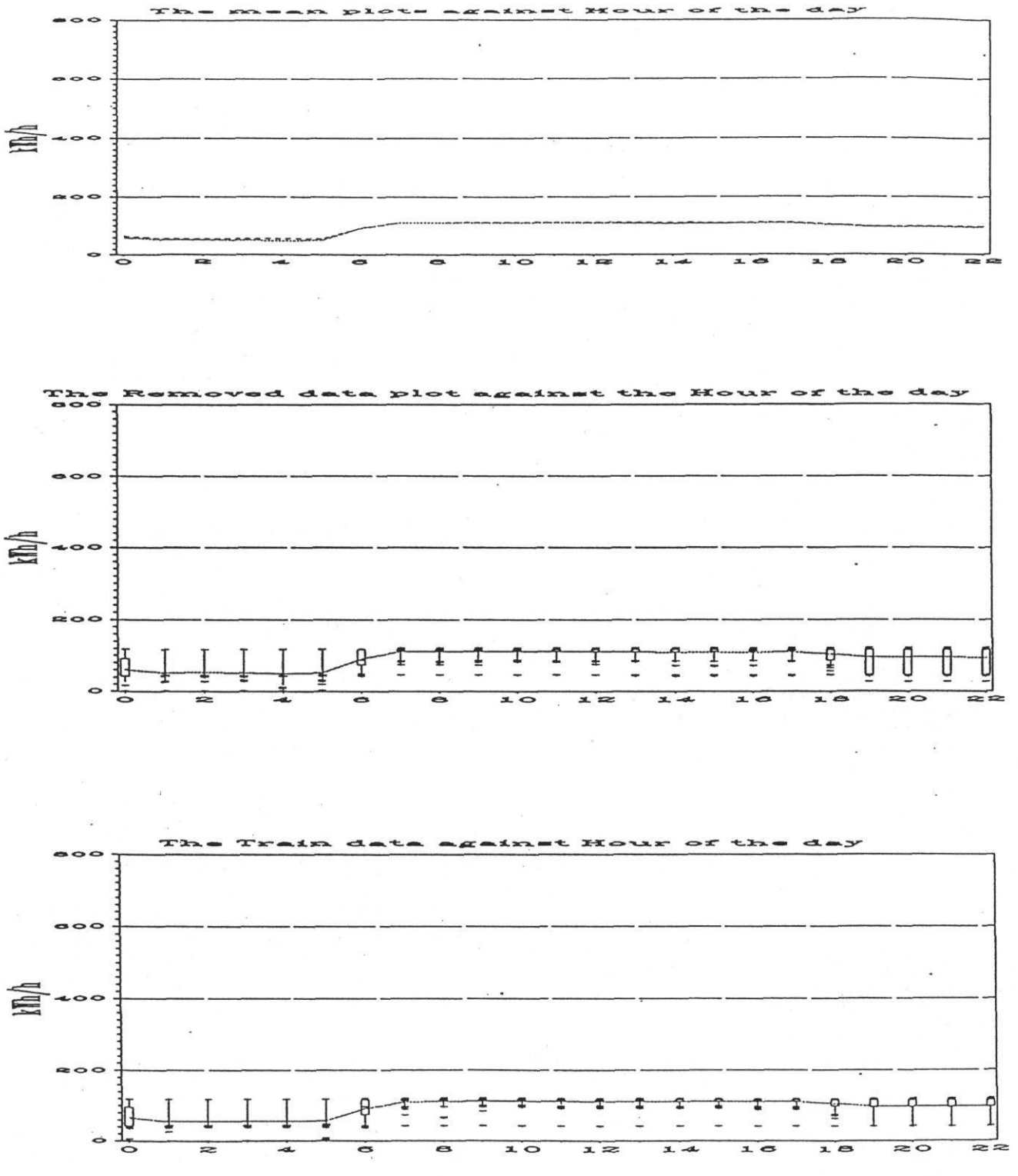


Figure 4.2: The box and whisker mean (BWM) plots of MCC energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.

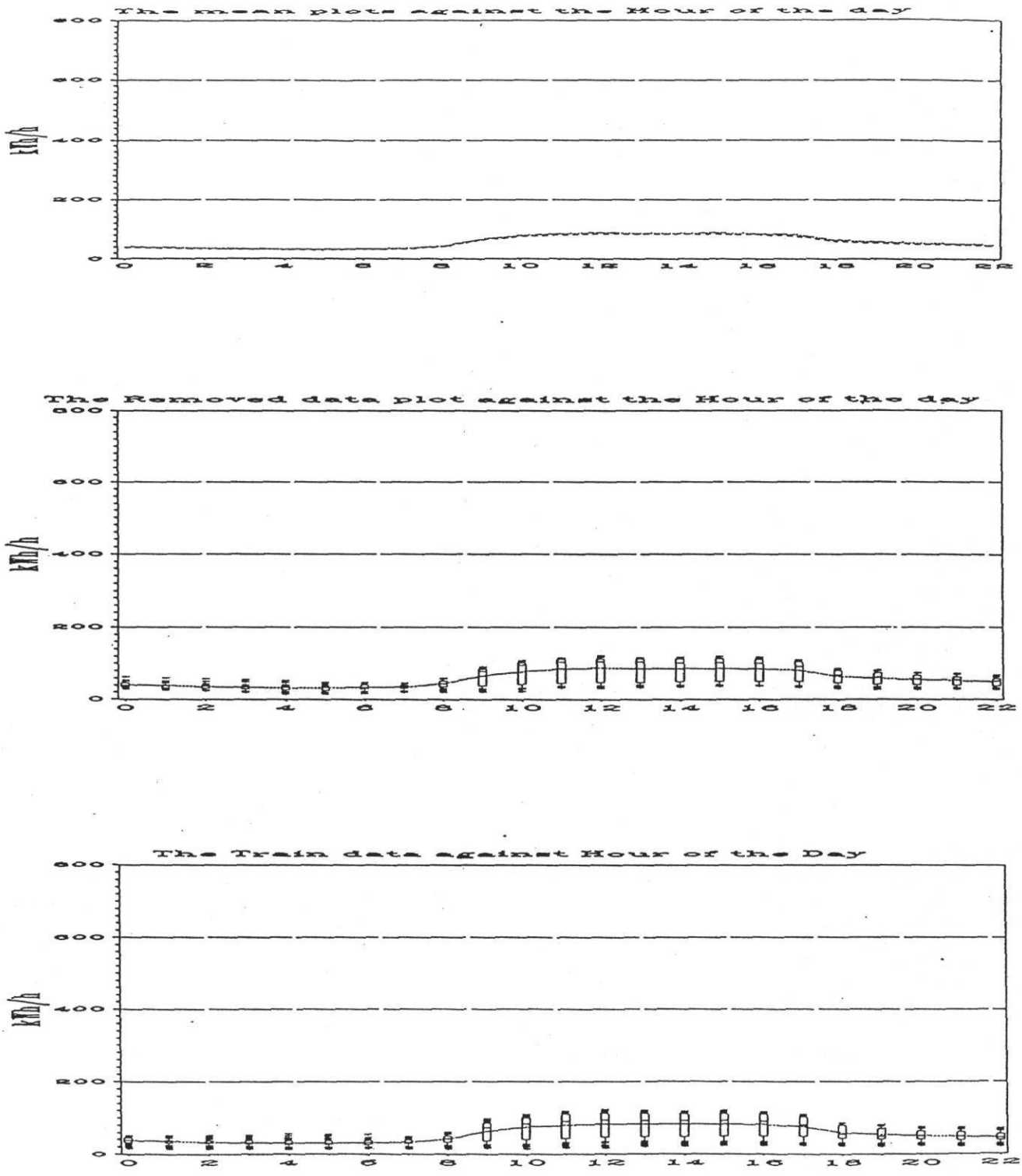


Figure 4.3: The box and whisker mean (BWM) plots of LEQ energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.

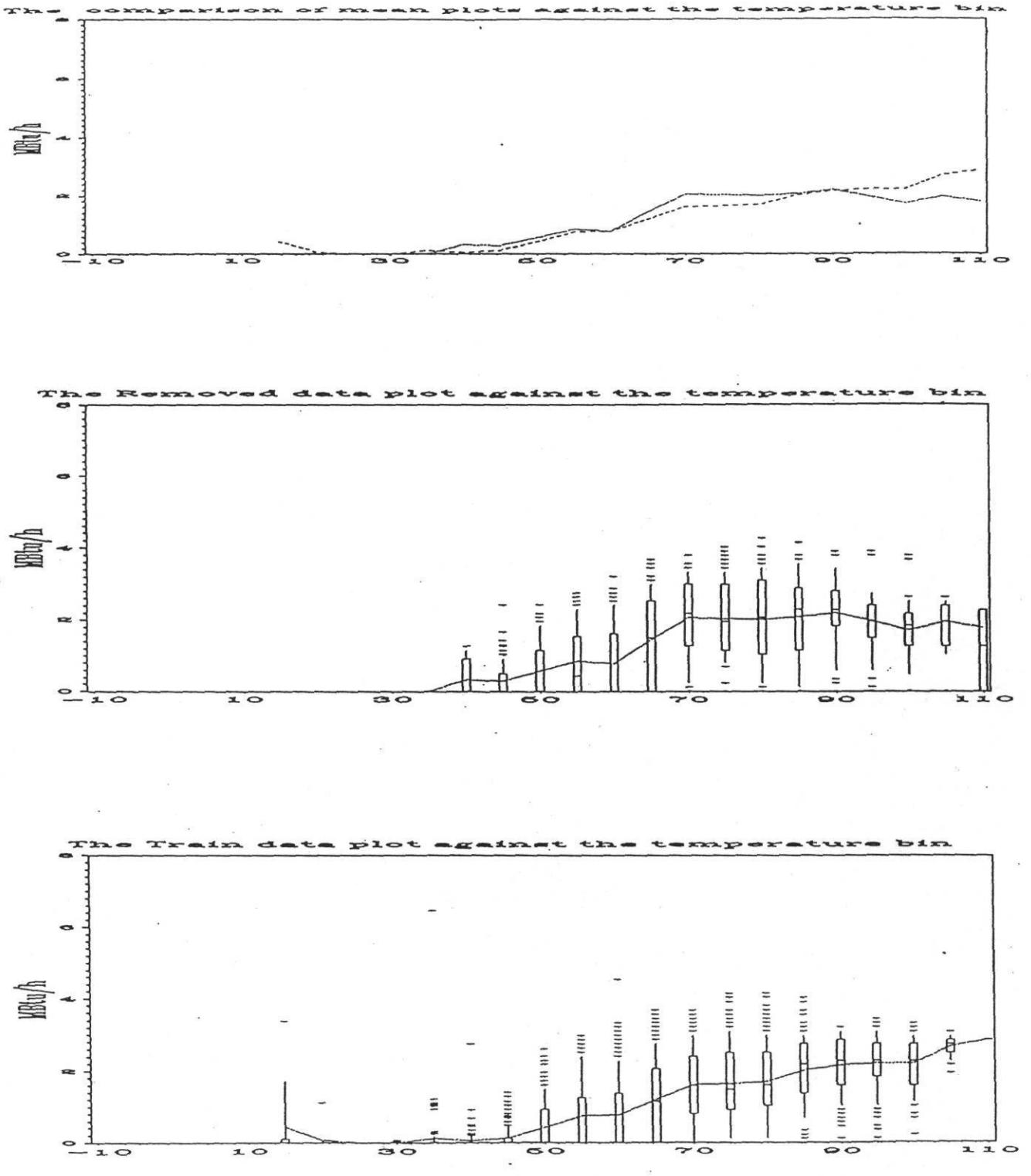


Figure 4.4: The box and whisker mean (BWM) plots of CWE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.

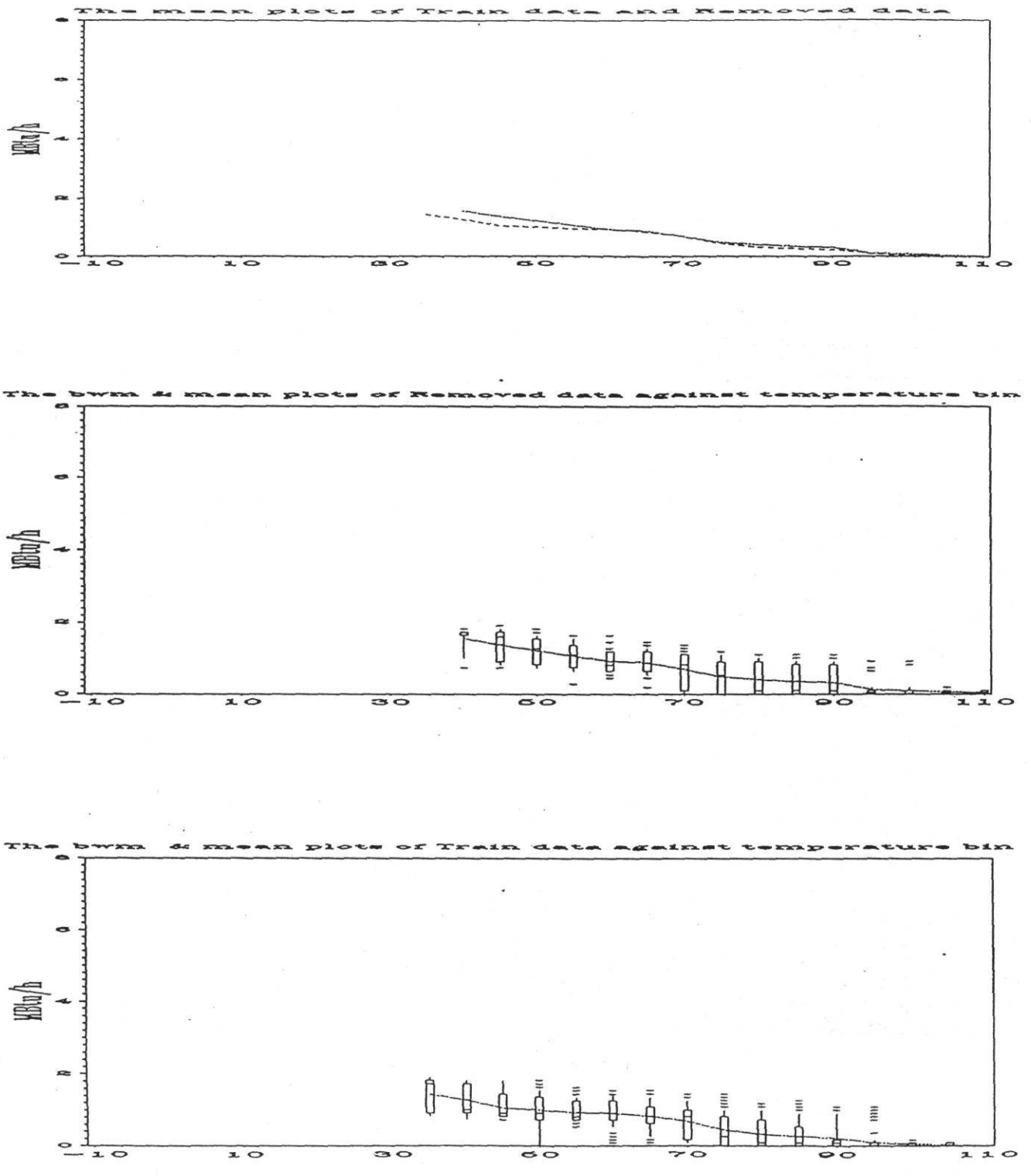


Figure 4.5: The box and whisker mean (BWM) plots of HWE energy use data in BUS building to check the predictability of the removed data from the given train data (a) mean plots of train and removed data, , (b) removed data and (c) Train data.