# First Year Load Impact Study of

# Southern California Gas Company's

# 1996 Direct Assistance Program

**CPUC Study Identification Number 713**

**Project Manager**

**Barbara Cronin**
**Southern California Gas Company**

**Prepared by**

**Kenneth Parris**
**Business Economic Analysis and Research**

**Engineering Analysis Provided by**

**Robert Mowris**
**Energy Consultant**

1998

**SUMMARY TABLE:** **Completed Load Impact Study (February 1996)**
**Southern California Gas Company**

(In fulfillment of Table 6 of the Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs)

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**Study Title:**

First Year Load Impact Study of Southern California Gas Company's 1994 Direct Assistance Program

**Study ID:** 713

**Program/Program Year:**

Direct Assistance Program (DAP), Program Year 1996

**Program Description:**

SoCalGas' 1996 DAP provided subsidies for installation of energy conservation measures, energy education and repair or replacement of space heating equipment to low income customers.

**1. Table 6—Protocols for Reporting of Results of Impact Measurement Studies Used to Support an Earning Claim**

**1.A Average Participant Group and Average Comparison Group Usage (therms)**

| | Unit type | Total | Space Heater | Water Heater |
|---|---|---|---|---|
| A. Pre-installation usage | Single Family | 503 | 262 | 192 |
| | Multi Family | 266 | 173 | 140 |
| B. Post installation usage | Single Family | 475 | 247 | 178 |
| | Multi Family | 244 | 165 | 128 |

Notes: There is no comparison group; the program had separate goals for single family and multi-family dwelling units; multi-family end-use estimates sum to more than the total use estimate due to the end use saturations being significantly less than 1.0.

2. **Average net and gross end use load impacts (therms) for the 1996 program year.**

| | Unit type | Total | Space Heater | Water Heater |
|---|---|---|---|---|
| A&B Average load impacts | Single Family | 28.2 | 14.5 | 13.6 |
| | Multi Family | 22.0 | 9.6 | 12.4 |
| C. Post installation usage | Single Family | 5.6% | 5.5% | 7.5% |
| | Multi Family | 8.3% | 5.6% | 8.9% |
| D. Realization Rates | Single Family | NA | NA | NA |
| | Multi Family | NA | NA | NA |

Notes: There is no comparison group; the program had separate goals for single family and multi family dwelling units; realization rates are presented in Tables S1 and S2 below at the measure level (the program had measure specific en-ante estimates, rather than end-use specific estimates).

3. **Net to Gross Ratio:** 1.0
   Impacts in Section 2 above are both net and gross impacts since it is believed that program participants would not have taken action in absence of the program

4. **Designated Unit Intermediate Data**
   Mean values of intermediate data (both pre and post installation) are shown in Appendix C of the report.

5. **Precision of Load Impact Estimates**
   The precision of the measure-specific load impact estimates at the 90% and 80% confidence levels are shown in the fifth column of Tables S1 and S2. Confidence intervals were not calculated at the end-use level since the focus of program efforts was at the measure level.

6. **Measure Count Data**
   Measure count data for program participants are shown in the sixth column of Tables S1 and S2.

7. **Market Segment Data**

**Table 4**
**1996 Program Participation by Weather Zone**

| Weather Zone | Participants | Sample Frame | Survey Respondents |
|---|---|---|---|
| Mountain | 0.2% | 0.2% | 0.3% |
| Lower Desert | 3.7% | 2.0% | 1.7% |
| Coastal | 8.1% | 7.8% | 7.9% |
| High Desert | 9.0% | 10.0% | 10.5% |
| Inland Valleys | 41.3% | 40.1% | 43.0% |
| Coastal Valleys | 37.8% | 39.9% | 36.6% |
| Total Customers | 18,075 | 1956 | 868 |

First Year Load Impact Study of Southern California Gas Company's 1996 Direct Assistance Program, Study ID 713, filed March 2, 1998.

**Table S1**
**Single Family Therm Savings -**
**Measure Impacts, Measure Counts and Program Impacts**

| Measure | Ex-Ante Measure Impact | Ex-Post Measure Impact | Ex-Post % of Ex-Ante | Confidence[a] Intervals (90%,80%) | Ex-Post Measure Count | Ex-Post Program Impact |
|---|---|---|---|---|---|---|
| **Weatherization** | | | | | | |
| Ceiling Insulation | 38.0 | 21.1 | 55.5 | 4.2, 3.3 | 3,104 | 65,494 |
| Weatherstripping/Caulking | 9.0 | 3.3 | 36.5 | .6, .4 | 11,316 | 37,343 |
| Building Envelope Repairs | 19.0 | 5.0 | 26.3 | .9, .7 | 10,530 | 52,650 |
| Switch/Outlet Gaskets | 12.0 | .9 | 7.5 | .2, .1 | 10,132 | 9,119 |
| Evaporative Cooler Cover | 18.0 | 2.8 | 15.6 | .9, .7 | 180 | 504 |
| Exhaust Vent Damper | 4.0 | 1.9 | 47.5 | .4, .3 | 278 | 528 |
| Register Sealing | 2 | .4 | 20.0 | .1, .1 | 129 | 52 |
| Low Flow Showerhead | 12.0 | 9.0 | 75.0 | 8.8, 3.0 | 10,039 | 90,351 |
| Water Heater Blanket | 5.0 | 7.2 | 144.0 | 3.1, 2.4 | 3,374 | 24,293 |
| Faucet Aerator | 3.0 | 3.6 | 120.0 | 1.5, 1.2 | 10,748 | 38,693 |
| Pipe Insulation | 5.0 | 2.6 | 52 | 1.0, .8 | 857 | 2,228 |
| **Furnace Repair and Replacement** | | | | | | |
| Space Heating Replacement | 75[b] | 6.8 | - | 11.7, 9.1 | 1,134 | 7,711 |
| Space Heating Repair | | -23.9 | - | 20.1, 15.7 | 311 | -7,433 |
| **All Measures** | - | 28.13 | | | 11,429 [b] | 321,533 |

[a] Values are ± therm savings that define the 90% and 80% confidence intervals respectively.
[b] Ex-Ante Furnace Repair and Replacement values are only available for the combined program, i.e., repair and replacement activities for the given measure type.

[c] Estimated number of single family participants.
First Year Load Impact Study of Southern California Gas Company's 1996 Direct Assistance Program, Study ID 713, filed March 2, 1998.

**Table S2**
**Multifamily Therm Savings-**
**Measure Impacts, Measure Counts and Program Impacts**

| Measure | Ex-Ante Measure Impact | Ex-Post Measure Impact | Ex-Post % of Ex-Ante | Confidence[a] Intervals (90%,80%) | Ex-Post Measure Count | Ex-Post Program Impact |
|---|---|---|---|---|---|---|
| **Weatherization** | | | | | | |
| Ceiling Insulation | 24.0 | 14.9 | 62.1 | 2.8, 2.2 | 2,292 | 34,151 |
| Weatherstripping/Caulking | 7.0 | 2.4 | 34.3 | .4, .3 | 10,001 | 24,002 |
| Building Envelope Repairs | 13.0 | 3.6 | 27.7 | .6, .5 | 8,620 | 31,032 |
| Switch/Outlet Gaskets | 8.0 | .7 | 8.8 | .1, .1 | 9,040 | 6,328 |
| Evaporative Cooler Cover | 18.0 | 2,2 | 12.2 | 1.2, 1.0 | 314 | 691 |
| Exhaust Vent Damper | 4 | 1.4 | 35.0 | .4, .3 | 437 | 612 |
| Register Sealing | 2 | .4 | 20.0 | .1, .1 | 377 | 151 |
| Low Flow Showerhead | 12 | 8.4 | 70 | 3.5, 2.7 | 8,533 | 71,677 |
| Water Heater Blanket | 8.0 | 6.8 | 85.0 | 2.9, 2.2 | 2,776 | 18,877 |
| Faucet Aerator | 3.0 | 3.4 | 113 | 1.4, 1.1 | 9,404 | 31,974 |
| Pipe Insulation | 5 | 2.6 | 52 | 1.1, .8 | 990 | 2,574 |
| **All Measures** | - | 22.0 | | | 10,078[b] [a] | 222,069 |

[a] Values are ± therm savings that define the 90% and 80% confidence intervals respectively.
[b] Estimated number of multi-family participants.
[B] Estimated number of multi-family participants.
First Year Load Impact Study of Southern California Gas Company's 1996 Direct Assistance Program, Study ID 713, filed March 2, 1998.

## Table 7—Documentation Protocols for Data Quality and Processing

### A. Overview Information

1. **Study Title:** First Year Load Impact Study of Southern California Gas Company's 1996 Direct Assistance Program
   **Study I.D.:** 713

2. **Program/program year:** Direct Assistance Program (DAP), Program Year 1994

   Program Description: SoCalGas' 1996 DAP subsidies for installation of energy conservation measures, energy education, and repair and/or replacement of space heating equipment, to low income customers.

3. **End uses/measures:**

   **End uses:** space heating, water heating,

   **Measures:** ceiling insulation, weatherstripping/caulking, building envelope repairs, switch/outlet gaskets, evaporative cooler covers, register sealing, exhaust vent dampers, low flow showerheads, water heater blankets, pipe insulation furnace repair or replacement.

4. **Methods and models used:** Conditional demand model; specification discussed on pages 20 - 37 of the report.

5. **Participant and comparison group definitions:** Participants included SoCalGas' qualified low income customers residing in single family and multi family dwellings who received one or more program measures. There was no comparison group since none was required by the Protocols.

6. Analysis sample size: The analysis included program participants. An average of 35 months of consumption data was available for each participant included in the sample.

### B. DATA BASE MANAGEMENT

1. **Flow chart illustrating the relationships between data elements:** Included on page 11 of the report.

2. **Identify the specific data sources:** See pages 9 - 15 of the report.

3. **Diagram and describe the data attrition process:** A diagram of the process is included on page 11 of the report. Discussion of the attrition process is included in pages 15 - 18 of the report.

4. **Describe the internal/organizational data quality checks:** See pages 15 19 of the report.

5. **Provide a summary of the data collected:** Not all of the survey responses were used in the analysis. For data file contact Barbara Cronin of SoCalGas.

### C. SAMPLING

1. **Sampling procedures and protocols:** See pages 13 - 19 of the report

2. **Survey information:** See Appendix A and pages 13 - 15 of the report.

3. **Statistical descriptions:** See Appendices B, C and D of the report.

## D. DATA SCREENING AND ANALYSIS

1. **Described procedures used for the treatment of outliers:** See pages 15 - 19 of the report.

2. **Describe what was done to control for the effects of background:** Changes in household seize were incorporated when appropriate as were weather effects.

3. **Describe procedures, including those identified in Table C-12:** See page 11 and associated discussion that follows page 11 of the report.

4. **Regression statistics:** See pages 23 - 31 of the report as well as the SAS output in Appendix D.

5. **Specification:**

   See Section IV, Conditional Demand Model Development (pages 20 - 37) and Section V, Furnace Usage Estimates and Therm Savings Impacts (pages 37 - 40).

   During the initial state of the assessment "change" model specifications were considered. It quickly became clear that the use of a change model would make it extremely difficult to isolate end-use and measure specific usage. Since DAP staff required end use estimates of gas use from the study, an early decision was made to forego the further use of change model specifications in favor of "level" model specifications. The initial work employing the change model specifications was not considered sufficiently developed to warrant inclusion in the formal report.

   The specification and estimation of the level models was straightforward. Initial estimates employed models very similar to the OLS model outline in the report. The initial models contained fewer variables. For example, the variable added to account for the impact of senior citizens in the household was not included initially. This variable was added later to improve upon initial specification. Their inclusion improved the explanatory power of the subsequent models, but had little impact on the therm savings estimates. The correction for serial correlation and heteroscedasticity (which are outlined in the report) had a much greater impact on therm savings estimates than the various alternative specification of the "level" model. The alternative specifications of the OLS level model are not included in the formal report. It was believed that their inclusion would have added little value.

6. **Error in measuring variables:**

   It was not believed that measurement error presented a significant problem for this analysis. Potential problems with key survey variables (e.g., square footage, persons per household) were checked for and raw survey data were adjusted if necessary (see Section 2 of the report.

7. **Autocorrelation:** See page 29 - 30 of the report.

8. **Heteroscedasticity:** See page 30 - 31 of the report.

9. **Collinearity:** Collinearity was not believed to be a significant problem with the chosen model specification.

10. **Influential data points:** Outliers were not believed to be a problem given the size and distribution of the variables in the analytic dataset.

11. **Missing data:** See pages 18 - 19 of the report.

12. **Precision:** Standard errors were calculated using the t-values provided in Tables 8 and 9.

## E. DATA INTERPRETATION AND APPLICATION

1. **For all program participants and at the end use level....:** Net impacts are equivalent to participant gross impacts.

2. **Describe the process, choices made, and rational for ....:** There was no comparison group, since it was not required by the Protocols. It is believed that participants would not have taken the actions without the program, hence the net to gross ratio is 1.0.

February 1998

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# List of Tables and Figures

## Summary

First year load impacts for southern California Gas Company's 1996 residential Direct Assistance program (DAP) are presented below. The DAP provided assistance to low income customer groups throughout SoCalGas' service territory. The assistance consisted of subsidies for installation of energy efficiency measures, energy education, and repair and/or replacement of space heating equipment.

The impacts are provided in three tables. Table 1 summarizes results for all participants combined. While program efforts are delineated by single family homeowners, multifamily residents, and mobile homeowners, Table 1 provides an overview of total program results and results by each measure across all households. Table 2 provides results for single family participants, while Table 3 provides results for multifamily participants. Mobile home participants and participants in master metered units were not separately analyzed. They do not represent a large part of overall program efforts.

Ex-ante measure impacts are also included in Tables 2 and 3. Ex-ante measure impacts were taken from the 1995 updated DAP advice letter filing, Advice No. 2447, dated September 29, 1996, except for ex-ante impact for switch outlet gaskets which was taken from DAP's 1994 Advice letter filing, Advice No. 2267 dated February 1, 1994.

Actual 1996 measure counts and implied program savings by measure are calculated using the ex-ante measure savings. Using the ex-post measure counts as weights, the ex-post program savings are approximately 37% of the ex-ante savings for single family and 34% of the ex-ante savings for multifamily. When the Furnace Repair and Replacement program impacts are removed, the ex-post program impacts for single family rise to 45% for the ex-ante estimates. The Furnace Repair and Replacement program participants tended to show increased therm usage, all else equal (space heating replacement being the exception). This is not surprising given they had non-operational or malfunctioning furnaces.

Annual first year therm savings from 1996 program efforts averaged 26 therms per participating household. Single family participants saved an average of 28 therms, while multifamily participants averaged savings of 22 therms annually. These are considered to be net savings. A net-to-gross assessment was not conducted for the 1996 Direct Assistance Program. Given the income constraints on this customer group, the recorded actions likely would not have occurred without SoCalGas' program efforts.

It is possible that positive spillover impact could have occurred in both the low income and non-low income residential customer groups, but the effort required to estimate such impacts was believed to be too expensive relative to the potential benefits of having an estimate of the spillover impacts.

Therm values defining the 90% and 80% confidence levels for each single family and multifamily measure are provided in Tables 2 and 3 and in the detailed unit savings tables in the section entitled Appliance Usage Estimates and Therm Savings Impacts (Tables 11, 12, and 13).

**Table 1**
**All Participants Therm Savings[a] -**
**Measure Impacts, Measure Counts and Program Impacts**

| Measure | Ex-Post Measure Impact | Ex-Post Measure Count[b] | Ex-Post Program Impact |
|---|---|---|---|
| **Weatherization** | | | |
| Ceiling Insulation | 18.9 | 5,396 | 101,984 |
| Weatherstripping/Caulking | 3.0 | 21,317 | 63,951 |
| Building Envelope Repairs | 4.5 | 19,150 | 86,175 |
| Switch/Outlet Gaskets | 0.8 | 19,172 | 15,338 |
| Evaporative Cooler Cover | 2.6 | 494 | 1,284 |
| Exhaust Vent Damper | 1.7 | 949 | 1,613 |
| Register Sealing | .4 | 506 | 202 |
| Low Flow Showerhead | 8.8 | 18,572 | 163,434 |
| Water Heater Blanket | 7.0 | 6,150 | 43,050 |
| Faucet Aerator | 3.5 | 20,152 | 70,532 |
| Pipe Insulation | 2.6 | 1,846 | 4,800 |
| **Furnace Repair and Replacement** | | | |
| Space Heating Replacement | 6.8 | 1,134 | 7,711 |
| 7,711 Space Heating Repair | -23.9 | 311 | -7,433 |
| **All Measures** | 25.7 | 21,507[c] | 552,641 |

[a] There are no ex-ante measure impacts for all participants. Ex-ante estimates are provided below for single family and multifamily participants.
[b] Measure counts include multi-metered participants and mobile home participants.
[c] Estimated number of participants.

**Table 2**
**Single Family Therm Savings -**
**Measure Impacts, Measure Counts and Program Impacts**

| Measure | Ex-Ante Measure Impact | Ex-Post Measure Impact | Ex-Post % of Ex-Ante | Confidence Intervals (90%,80%) | Ex-Post Measure Count | Ex-Post Program Impact |
|---|---|---|---|---|---|---|
| **Weatherization** | | | | | | |
| Ceiling Insulation | 38.0 | 21.1 | 55.5 | 4.2, 3.3 | 3,104 | 65,494 |
| Weatherstripping/Caulking | 9.0 | 3.3 | 36.7 | .6, .4 | 11,316 | 37,343 |
| Building Envelope Repairs | 19.0 | 5.0 | 26.3 | .9, .7 | 10,530 | 52,650 |
| Switch/Outlet Gaskets | 12.0 | .9 | 7.5 | .2, .1 | 10,132 | 9,119 |
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| Exhaust Vent Damper | 4.0 | 1.9 | 47.5 | .4, .3 | 278 | 528 |
| Register Sealing | 2 | .4 | 20.0 | .1, .1 | 129 | 52 |
| Low Flow Showerhead | 12.0 | 9.0 | 75.0 | 3.8, 3.0 | 10,039 | 90,351 |
| Water Heater Blanket | 5.0 | 7.2 | 144.0 | 3.1, 2.4 | 3,374 | 24,293 |
| Faucet Aerator | 3.0 | 3.6 | 120.0 | 1.5, 1.2 | 10,748 | 38,693 |
| Pipe Insulation | 5.0 | 2.6 | 52 | 1.0, .8 | 857 | 2,228 |
| **Furnace Repair and Replacement** | | | | | | |
| Space Heating Replacement | 75[a] | 6.8 | - | 11.7, 9.1 | 1,134 | 7,711 |
| Space Heating Repair | | -23.9 | - | 20.1, 15.7 | 311 | -7,433 |
| **All Measures** | - | 28.13 | | | 11,429[b] | 321,533 |

[a] Ex-Ante Furnace Repair and Replacement values are only available for the combined program, i.e., repair and replacement activities for the given measure type.
[b] Estimated number of single family participants.

**Table 3**
**Multifamily Therm Savings-**
**Measure Impacts, Measure Counts and Program Impacts**

| Measure | Ex-Ante Measure Impact | Ex-Post Measure Impact | Ex-Post % of Ex-Ante | Confidence Intervals (90%,80%) | Ex-Post Measure Count | Ex-Post Program Impact |
|---|---|---|---|---|---|---|
| **Weatherization** | | | | | | |
| Ceiling Insulation | 24.0 | 14.9 | 62.1 | 2.8, 2.2 | 2,292 | 34,151 |
| Weatherstripping/Caulking | 7.0 | 2.4 | 34.3 | .4, .3 | 10,001 | 24,002 |
| Building Envelope Repairs | 13.0 | 3.6 | 27.7 | .6, .5 | 8,620 | 31,032 |
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| Exhaust Vent Damper | 4 | 1.4 | 35.0 | .4, .3 | 437 | 612 |
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| Low Flow Showerhead | 12 | 8.4 | 70 | 3.5, 2.7 | 8,533 | 71,677 |
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| Faucet Aerator | 3.0 | 3.4 | 113 | 1.4, 1.1 | 9,404 | 31,974 |
| Pipe Insulation | 5 | 2.6 | 52 | 1.1, .8 | 990 | 2,574 |
| **All Measures** | - | 22.0 | | | 10,078[a] | 222,069 |

[a] Estimated number of multi-family participants.

## Introduction

The 1996 Direct Assistance Program (DAP) provided a wide range of assistance to low income customer groups throughout SoCalGas' service territory. The assistance consisted, primarily, of full subsidies for installation of energy efficiency measures, energy education, and repair and/or replacement of space heating equipment, when necessary.

It is very important to note that the program also served an equity objective in assisting customers who were highly unlikely or unable to participate in other residential conservation programs because of income constraints. This program allowed income eligible customers to receive the benefits of energy conservation without the hardship of making cash investments.

Additional program benefits included the operation of the Direct Assistance Training Center. The Center provided "hands on" training to students from disadvantaged areas in outreach assessment, appliance identification, basic home weatherization, advanced weatherization (home repair), and mobile home weatherization.

SoCalGas used a variety of community-based organizations (CBO) and local contractors for locating and recruiting households who qualified for program participation, i.e., households whose annual income is less than the Low Income Weatherization income limits established by the California Public Utilities Commission. Staff from these community-based organizations were trained by SoCalGas in the installation of ceiling insulation and other conservation measures.

There were two major energy programs run under the DAP in 1996: 1) the Weatherization Program, and 2) the Furnace Repair and Replacement Program (FRRP). The Weatherization Program focused on the installation of conservation measures in single family, multifamily, and mobile homes. Conservation measures were aimed at reducing space heating and water heating energy use. The space heating-related measures included: ceiling insulation, weatherstripping, caulking, switch and outlet gaskets, evaporative cooler covers, exhaust vent dampers, register sealings, and building envelope repairs (the repair of windows, walls, and doors to reduce air infiltration). The water heating-related measures included: low-flow showerheads, water heater blankets, faucet aerators, and pipe insulation.

The Furnace Repair and Replacement Program repaired or replaced inoperative or potentially hazardous furnaces, for income-eligible customers in owner-occupied homes. This program has been particularly helpful for senior citizens and disabled customers. Typical furnace repairs consisted of the repair or replacement of control units, pilots, and thermostats. Repair of forced air furnaces also included repair or replacement of the fan motor, limit switch, and delay switch. Furnaces were replaced when they had cracked or rusted fire boxes that created a significant fire or carbon monoxide risk; when repair parts were unavailable; or when replacement was less costly than repair.

This report summarizes the results of a statistical analysis aimed at estimating the first year load impacts of the aforementioned elements of the 1996 Direct Assistance Program. The focus of this effort is on the energy use impacts of the DAP, rather than job creation, skill enhancement, public safety, and public health benefits generated through DAP efforts. This report does not include results from an audit pilot program conducted during 1996 which provided modified measures to approximately 220 low income customers.

The objective of this study was to: 1) estimate the load impacts attributable to the DAP Furnace Repair and Replacement Program efforts, for gas space heating equipment; and 2) estimate the impact of weatherization and other DAP conservation measures on space heating and water heating therm usage.

These objectives were accomplished using conditional demand analysis (CDA), a statistical technique that disaggregates monthly them consumption data into appliance-specific average usage. The technique uses individual customer recorded monthly therm usage both before and after installation of conservation measures (and/or repair or replacement of a furnace) to estimate changes in energy usage. Customer-specific demographic information and regional weather data are also directly employed in the estimation process.

The data employed in the analysis, and its development, are outlined herein in the section entitled Analytic Data Set Development. The estimation of the CDA model is described in the section entitled Conditional Demand Model Development and load impacts are included in the section entitled Usage Estimates and Therm Savings Impacts. Appendices include the participant survey instrument, the engineering report assigning weighting factors, summary statistics for variables included in the CDA model, and the SAS System output for the CDA model.

## Analytic Data Set Development

This section describes the development of the data used in the analysis of the 1996 DAP usage impacts. The required analytic data set was created from the integration of four separate data sets: the 1996 program participant file, SoCalGas' monthly customer billing file, the heating degree day file, and the 1996 Direct Assistance Program Participants Survey file. The relationship of these datasets with respect to the development of the analytic data set is shown set is shown in Figure 1. A brief description of each data set follows.

### *Program Participation Records*

SoCalGas has historically maintained two DAP transaction databases, one for Weatherization Program participants and one for Appliance Repair and Replacement Program participants. These on-line databases are used to track program transaction activities from eligible customer identification, through verification of eligibility, measure and equipment installation, installation verification, contractor request for reimbursement, and check issuance to the contractor. The files contain information pertaining to each stage of DAP delivery. The core systems were developed during the late 1980's, but have been modified as the DAP has changed through time. the systems are routinely internally audited and have been reviewed by the California Public Utilities Commission (CPUC).

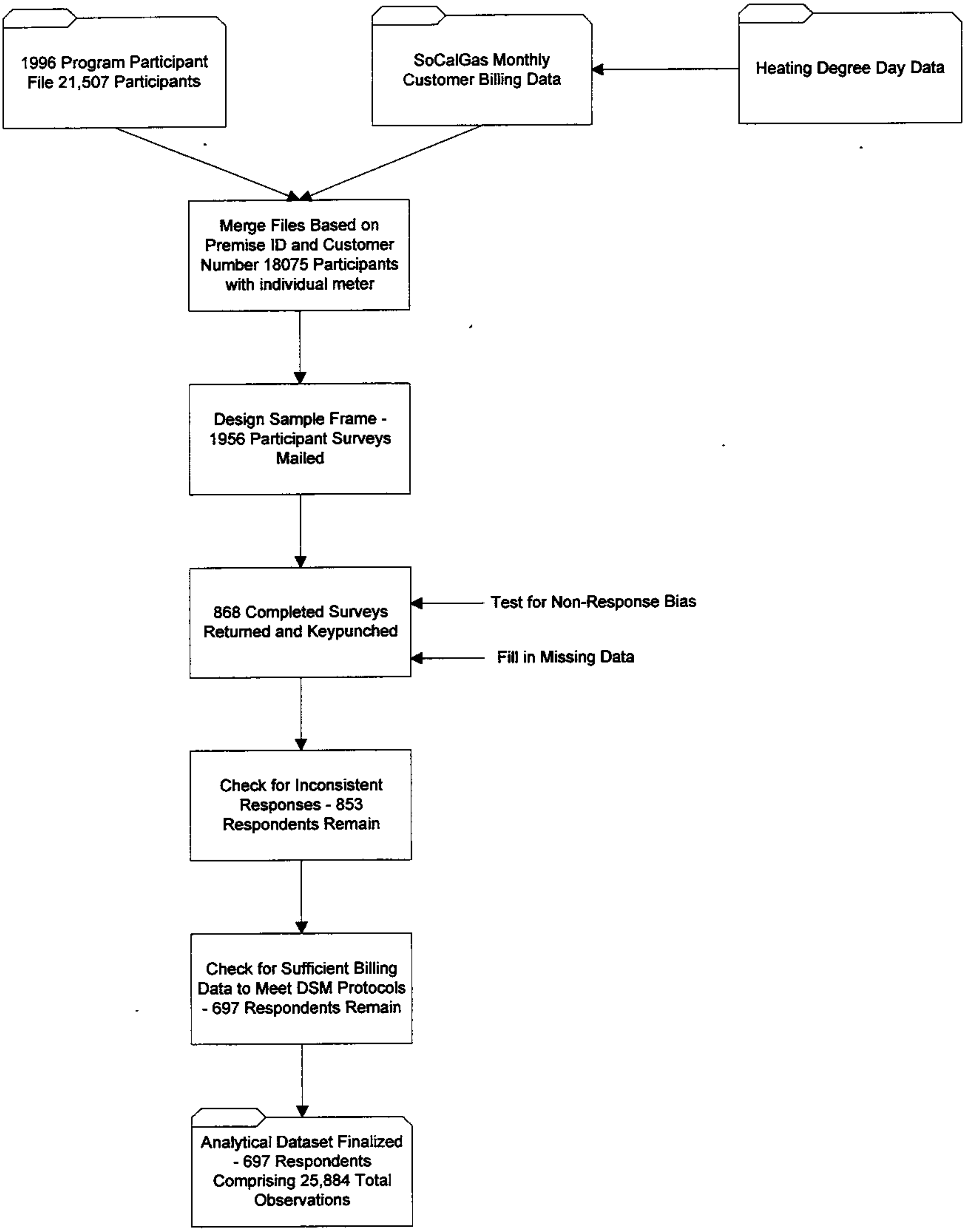
The Program participation files contain data vital to the estimation of load impacts. Specifically:

- Program the customer participated in (Weatherization and/or FRRP)
- Appliances replaced
- Appliances repaired
- Conservation measures undertaken

- Date each repair, replacement, and measure was implemented
- Premise and customer identification number (used to match billing records to the customer)
- Address (used to assign weather data and used in the participant survey implementation)

Figure 1

Analytic Data Set Development



The premise and customer identification numbers are appended to the participation files as customers are submitted for qualification to the program. The customer name, address, and account number from the customer bill are used to identify the premise and customer identification numbers. The participation process does not continue if an accurate identification of the customer on the SoCalGas customer information system cannot be made.

### *Billing Data*

Gas consumption data was obtained from the customer billing files maintained by SoCalGas. The customer billing file contains monthly therm usage for each SoCalGas customer. The correct billing data for each program participant was obtained by matching the premise and customer identification numbers on the DAP participation files with those on the customer billing file. This matching process is superior to matching upon account number because account numbers change as customers move. A 100% match rate was achieved.

Key participant-specific information obtained from the customer billing files included:

- monthly therm consumption for each 1996 DAP participant from January, 1995 through November, 1997
- meter read dates
- monthly billing days

### *Weather Data*

Weather variables were created to account for the effect of weather on space heating energy use and on water heating energy use. For space heating a set of climate area and billing cycle-specific "heating degree days" variables with a 65 degree Fahrenheit base was created. Daily temperatures were employed to create daily heating degree variables over the billing data time frame. These daily values were aggregated into monthly values for each combination of six SoCalGas weather zones and each possible billing cycle. An identical process was undertaken using normalized weather (a file of thirty year average weather data maintained by SoCalGas for its service territory and climatic subregions). This process allowed household-specific weather to be employed in the estimation process.

Water heating energy use is partially dependent upon the difference between desired hot water temperature and inlet water temperature. Average daily air temperature was used as a surrogate for inlet water temperature. A similar process to that described above for heating degree days was undertaken with average daily temperature. Household-specific average monthly temperatures were created using actual temperatures and using thirty-year averages.

The heating degree day and average temperature weather variables (both actual and 30 year normalized) were merged with the DAP participant and billing data using address and billing cycle information. The "actual" variables were used for estimation of savings, while the "normalized" variables were used for simulation of the model and calculation of program impacts.

***Program Participants Survey***

In August 1997, a mail survey of 1996 DAP participants was conducted. The *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs as adopted by CPUC D. 93-05-063* (Protocols), did not require that a comparison group of non-participants be included in the DAP evaluation. The aim of the survey was to obtain household characteristics, appliance utilization and demographic data needed to estimate a conditional demand model.

The first step in the survey process was to determine an appropriate sample frame. The DAP participants were divided into the following six strata. The strata were chosen based upon the primary program participation categories. Target sample sizes were estimated for each stratum to achieve a minimum 10% precision at the 90% confidence level (based on consumption):

| | |
|---|---|
| Single family Weatherization Program, attic and groundwork | 63 |
| Single family weatherization Program, groundwork only | 66 |
| Multiple family Weatherization Program, attic and groundwork | 100 |
| Multiple family Weatherization Program, groundwork only | 144 |
| Furnace Repair and Replacement Program, some repair | 56 |
| Furnace Repair and Replacement Program, replacement only | 60 |

Combination Spanish and English version surveys were mailed to 1956 participants. The English version survey instrument is provided in Appendix A. A total of 869 surveys were returned, slightly higher than a 42% response rate. The target sample size for each stratum was met with the exception of the multifamily weatherization, groundwork only stratum. The 141 completed surveys for that stratum still provided a 10% precision at a 90% confidence interval (the level required by the Protocols).

Table 4 provides the distribution of participants, sample frame, and survey respondents by climate zone. The distribution is quite consistent for each category.

**Table 4**
**1996 Program Participation by Weather Zone**

| Weather Zone | Participants | Sample Frame | Survey Respondents |
|---|---|---|---|
| Mountain | 0.2% | 0.2% | 0.3% |
| Lower Desert | 3.7% | 2.0% | 1.7% |
| Coastal | 8.1% | 7.8% | 7.9% |
| High Desert | 9.0% | 10.0% | 10.5% |
| Inland Valleys | 41.3% | 40.1% | 43.0% |
| Coastal Valleys | 37.8% | 39.9% | 36.6% |
| Total Customers | 18,075 | 1956 | 868 |

The returned surveys were double keypunched and linked with customer identifiers from the program participation files that allowed the survey results to be merged with the participation records, billing data, and weather data described above.

### Testing For Sample Nonresponse Bias

After the completed surveys were returned and a database of respondents was created, nonresponse bias tests were performed to make certain that the weights attached to survey respondents accurately represent the 1996 participant population. The nonresponse bias tests were performed by comparing average 1996 usage respondent usage to average 1996 usage of the non-respondents for each of the six strata. Annual average usage values were created by calculating average use per day and scaling by 365.

Using the average annual usage values and standard deviations, t-ratios were generated and the null hypothesis that no significant difference existed between respondent and non-respondent average use was tested. The null hypothesis was rejected when the test statistic value was greater than 1.96. Table 5 below shows the results of the nonresponse bias tests for the six strata.

**Table 5**
**Initial Nonresponse Bias Test Results**

| | | Non-Respondents | | | Respondents | | | |
|---|---|---|---|---|---|---|---|---|
| **Strata** | **Sample** | **n** | **Mean** | **Std** | **n** | **Mean** | **Std** | **t-Test** |
| **Weatherization** | | | | | | | | |
| **Attic & Groundwork Single Family** | 252 | 128 | 457 | 218 | 124 | 442 | 217 | .55 |
| **Groundwork Only Single Family** | 264 | 132 | 429 | 215 | 132 | 459 | 216 | -1.10 |
| **Attic & Groundwork Multifamily** | 400 | 259 | 281 | 174 | 141 | 279 | 163 | .15 |
| **Groundwork Only Multifamily** | 576 | 374 | 237 | 165 | 202 | 220 | 153 | 1.24 |
| **Furnace Repair and Replacement** | | | | | | | | |
| **Repair** | 224 | 86 | 605 | 314 | 138 | 500 | 199 | 2.77 |
| **Replace** | 240 | 109 | 514 | 222 | 131 | 472 | 218 | 1.49 |

The fact that the t-test numbers for one of the two Furnace Repair and Replacement (FRRP) strata are greater than 1.96 suggests that nonresponse bias exists. The bias was corrected by substratifying the stratum based on annual therm usage and reweighting the sample. The FRRP repair stratum respondents were divided into two substrata based on annual consumption level. The FRRP repair group consumption level breakpoint was 850 therms. The results of the nonresponse bias tests after substratifying the FRRP repair stratum appear in Table 6.

**Table 6**
**Nonresponse Bias Test Results After Substratification**

| ARRP | | Non-Respondents | | | Respondents | | | |
|---|---|---|---|---|---|---|---|---|
| Strata | Sample | n | Mean | Std | n | Mean | Std | t-Test |
| Repair <= 850 therms | 198 | 68 | 474 | 173 | 130 | 470 | 159 | .15 |
| Repair > 850 therms | 26 | 18 | 1099 | 216 | 8 | 987 | 135 | -1.60 |

### Inconsistency and Consumption History Screens

The participant survey was double-keyed to ensure accurate transcription of survey responses. In addition, the survey results were reviewed for obvious anomalies. Particular attention was paid to variables that were known to be important in the subsequent statistical assessment.

For example, the square footage variable is very important in the determination of gas space heating use. For this reason household floor space, number of bedrooms and number of residents variables were compared in order to remove respondents with very inconsistent responses to combinations of these variables. Three inconsistency screens were developed involving floor space and number of bedrooms and floor space and the number of residents. The description of the screening criteria and number of respondents follow:

1. Less than 600 square feet of floor space and six or more bedrooms--0 respondent deleted
2. More than 2000 square feet of floor space and two or fewer bedrooms—1 respondent deleted
3. Less than 600 feet of floor space and seven or more residents--15 respondents deleted

A total of 16 respondents were removed from the analysis because of the above mentioned inconsistencies, leaving 852 respondents (see Table 7 and Figure 1).

The Protocols require a minimum of twelve months of pre installation consumption history and nine months of post installation period consumption history for inclusion in the conditional demand analysis. Billing history information was collected from January, 1995 through November, 1997. A total of 155 survey respondents were dropped because the Protocol consumption history requirements were not achieved.

Table 7 shows the initial distribution of survey respondents by strata.

**Table 7**
**Survey Respondents**

| Strata | Initial Respondents | Remaining Respondents After Floor Space Screens | Respondents With Sufficient Data |
|---|---|---|---|
| **Weatherization** | | | |
| **Attic & Groundwork - Single Family** | 124 | 120 | 101 |
| **Groundwork Only - Single Family** | 132 | 128 | 105 |
| **Attic & Groundwork - Multifamily** | 141 | 141 | 102 |
| **Groundwork - Multifamily** | 202 | 198 | 140 |
| **Appliance Repair and Replacement** | | | |
| **Repair < 850 therms** | 130 | 129 | 125 |
| **Repair > 850 therms** | 8 | 8 | 8 |
| **Replacement** | 131 | 128 | 116 |
| **Total** | 868 | 852 | 697 |

The Protocols state that the sample employed in the calculation of program impacts should yield consumption estimates meeting a 90% confidence interval with 10% precision criterion. The multifamily groundwork sample falls slightly below the target number for the 90/10 sample design. The remaining strata each meet the 90/10 target.

### Estimation of Missing Values

While 868 surveys were returned, respondents sometimes failed to answer certain key questions. Missing values were not significant enough to warrant recontacting the respondents; but there was an attempt to fill in missing values for the following key survey variables: floor space, number of residents, water heater temperature, number of clothes drying loads, space heating fuel, water heating fuel, and cooking fuel.

Regression equations were estimated to fill missing floor space and number of residents. The floor space equation depended upon the number of bedrooms, dwelling type, and home ownership. Approximately 24% of the respondents had missing floor space values that were provided using this approach. The number of residents equation depended upon dwelling type, presence of senior citizens, and number of bedrooms. Just under 3% of the respondents were supplied with values using this approach. Water heater temperature was filled by assigning the average temperature level from homes that answered the water heater temperature question by strata. One third of the respondents were assigned water heater temperature values using the average for their stratum.

For the number of clothes drying loads missing values were filled by number of residents for households that answered those questions. Nearly 5% of respondents were assigned clothes drying loads using the average value of respondents in the same stratum who answered the question.

Space heating, cooking and water heating missing fuel types were filled by using the baseline allowance code appearing in the Gas Company's customer billing system. This is a preferred approach to using mean values from the survey since the baseline allowance codes are determined through on-site inspection by SoCalGas field staff. Ten percent of the space heating fuel types, 22% of the water heating fuel types, and 12% of the cooking fuel types were assigned using this approach.

The estimation of missing values was the last step in the separation of the final analytic data set used in the conditional demand analysis described next.

## Conditional Demand Model Development

The objectives of the monthly energy use model developed from the merged survey and billing record data base (i.e., the analytic data set) were to:

1. Measure the impact that weatherization measures have on space heating consumption,
2. Measure the impact of conservation measures on water heating consumption, and
3. Measure the usage impacts attributed to the repair and replacement of space heating appliances/equipment.

Equipment usage impacts and conservation savings are provided in Tables 1, 2 and 3 within the Summary section of this report. They are also included in Tables 11, 12 and 13 within Appliance Usage Estimates and Therm Savings Impacts, following this section. Space heating equipment usage and related weatherization savings are estimated under normal weather conditions as required by the Protocols.

A detailed presentation of the DAP monthly energy use and load impact equation is provided in this section. An overview of the estimation technique and data sources employed is described first, then the overall energy demand equation is presented. Finally, the appliance-specific equation results are presented with an interpretation of the coefficients.

### *Estimation Technique*

The estimation technique used in this study is conditional demand analysis. The conditional demand technique provides a method of distributing total household natural gas consumption among the gas-using appliances present in the home. In addition, the technique allows estimation of changes in major appliance use due to the installation of conservation measures and/or the repair or replacement of major appliances.

Conditional demand analysis was used in lieu of other approaches for two reasons. First, the approach had been successfully employed to assess the 1993 and 1994 DAP. A comparison of 1996 and 1994 results was of interest to SoCalGas. Second, other approaches either did not provide the detailed results CDA would afford (i.e., result at an end-use basis for various types of program participants) or would have demanded information that was unavailable (e.g., reasonably accurate energy use priors for individual end-uses across many types of customers).

A change in consumption model, where the change in usage is modeled as a function of the change in weather, as well as changes in conservation from the previous year, was also considered in the early stages of this study. Robust, end-use specific usage estimates could not be derived, so the approach was discarded.

Although several versions of the CDA were estimated only the final version (based on goodness of fit and reasonable annual usage estimate values) is presented in the report. The other versions focused on attempting to measure rebound effects and energy education influences. Due to multi-collinearity problems and inconsistent survey responses (e.g. practice energy education by taking short showers while stating that they enjoy longer showers) the rebound effect terms were dropped from the final model.

The conditional demand technique is based on the proposition that the natural gas use of each household is the sum of the natural gas used by each of the appliances in the household. In mathematical terms, natural gas use is expressed as:

Use = gsh*GSH+gwh*GWH+grg*GCK+gdy*GDY+gp*PHSPA

where:

| | |
|---|---|
| Use | is household consumption |
| gsh | is gas space heating use |
| GSH | is a gas space heat indicator variable |
| gwh | is gas water heating use |

| | |
|---|---|
| GWH | is a gas water heating indicator variable |
| grg | is gas range use |
| GCK | is a gas range indicator variable |
| gdy | is gas dryer use |
| GDY | is a gas dryer indicator variable |
| gp | is gas pool/spa heating use |
| PHSPA | is a pool/spa heating indicator variable |

The indicator variables take the value of 1 if the appliance is present in the household and 0 if the household does not own or operate the appliance. Most DAP participant households had gas space heating and water heating - the indicator variable for these appliances was 1 for most households. Few of the DAP participant households had pools or spas--the indicator variable was most often 0 (but when a natural gas pool or spa heater is present it has a large impact on household gas consumption).

For each of the above mentioned appliances a usage equation is created. The usage equation relates the expected use of a particular appliance to key factors that will influence its monthly use. For example, the number and age composition of residents will affect water heater use, square footage of the residence and weather conditions will affect space heating use, and conservation measures, as well as the presence of replaced or repaired equipment, will affect the monthly consumption of specific appliances.

Information for every factor is required for each DAP participant household. The data elements integrated to estimate the appliance equations include:

1) survey data on household appliance ownership, household characteristics, and the condition of the existing appliances,

2) program participant information regarding the date conservation measures were installed, ad the measures installed,

3) monthly consumption, meter read date and billing days from company billing records, and,

4) weather data (in heating degree days) in the temperature zone in which each household is located and for the time period covered by each energy bill.

The sources for these data elements were outlined in the section, Analytical Data Set. The discussion that follows details the process of using that data to estimate conditional demand models of appliance energy use.

### *Estimation Process and Regression Results*

A three stage estimation process was employed to obtain a regression model from which reasonable appliance usage estimates and therm savings impacts could be determined. In addition to employing a sound, established theoretical framework, reasonable estimates, from an econometric standpoint, are estimates of regression coefficients that are unbiased and consistent. An unbiased estimate fairly represents the true value of what it is estimating; drawing repeated samples of the same number of program participants and recalculating water heater blanket savings would yield, on average, an unbiased estimate. Consistency refers to sampling distribution. As the sample size grows, a consistent estimator is one in which the sample distribution becomes more tightly concentrated around the true value of what is being estimated, rather than concentrating around another value.

Traditional econometric theory clearly defines how the properties (e.g., unbiasedness and consistency) of estimated regression coefficients and their estimated standard errors depend on the error structure of the model employed. If the regression error terms are serially correlated (i.e., the value of residuals follow a pattern determined by the value of preceding residuals) or heteroskedastic (i.e., the magnitude of residual values are related to the value of some other variable), the estimated coefficients can be unbiased and consistent, but the standard errors of the coefficients are inconsistent. If the standard errors are inconsistent, hypothesis tests conducted with them may be inaccurate. Of more direct importance to this study, the 90% and 80% confidence intervals developed around the usage and savings estimates would be inaccurate.

The error structure of a model based on a pooled cross-section and time-series data set is likely to be cross-sectionally heteroskedastic and time-wise autoregressive. A CDA model requires a pooled cross-section and time-series data set. Consequently, a CDA model should be tested for serial correlation and heteroskedasticity. Corrections for the presence of serial correlation and/or heteroskedasticity in the error structure should be undertaken, when evidence of these two problems is discovered.

Both of these problems were discovered during the estimation of the conditional demand model for the 1996 DAP. This prompted the use of a three-stage process to develop acceptable estimates of appliance usage of conservation savings. The first stage involved the development of the basic model, its estimation using ordinary least squares, and testing for serial correlation. The second stage involved correcting the first stage results for the presence of serial correlation and testing for heteroskedasticity. The third stage involved correction of the second stage results for the presence of heteroskedasticity. The summary appliance usage and conservation impacts provided in this report employ the third stage model results.

### First Stage - Ordinary Least Squares

This stage involved the estimation of a regression equation using ordinary least squares. The initial assumption was that the error terms were not serially correlated, nor heteroskedastic.

The Direct Assistance Program equation was estimated using January, 1995 through November, 1997 billing year data. All households had at least one year of consumption history prior to the installation of conservation and at least nine months of post conservation installation consumption history, as required by the Protocols. The regression equation was weighted to adjust for varying lengths of consumption history present. The weight equaled the inverse of the ratio of monthly observations for all households.

Appendix C contains definitions of the model variables as well as summary statistics (mean, standard deviation, minimum and maximum) for the untransformed variables of the first stage. Appendix D contains the SAS System regression results for all three stages.

The first stage equation yielded an adjusted R-squared value of .80 which is typical for an analysis that restricts the intercept to zero and calculates the R-square assuming no intercept was included in the model. The estimated model coefficients and their t values are displayed in Tables 8 and 9. Estimated coefficients from all three stages are included in these tables. The results are what was generally anticipated during the formulation of the original specification. Interpretation of individual coefficients is discussed below in the Appliance-Equipment Specific Gas Use Estimation section.

**TABLE 8**
**Conditional Demand Model Parameter Estimates**
**Space Heating**

| Space Heating Variables | Ordinary Least Squares | | Correction for Serial Correlation | | Correction for Heteroskedasticity | |
|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| **Space Heating (GSH)** | | | | | | |
| GSH*(SHNW=0) | 13.492206 | 37.13 | 14.514831 | 27.45 | 8.031182 | 27.0 |
| GSH*(SHNW=)*SUMMER | -2.675415 | -8.41 | -.973782 | -.503 | -1.015214 | -6.42 |
| GSH*(SHNW=0)*SQFT*HDD*TIME | -.000000102 | .08 | -.00000047 | -.51 | -.00000062 | -.64 |
| GSH*(SHNW=0)*SQFT*HDD*EDH*DPOST | .000013814 | 4.91 | .000009891 | 3.90 | .000004619 | 1.69 |
| GSH*SQFT*HDD*QUAL*NON_SH | .000101 | 35.33 | .000095 | 37.38 | .000095293 | 33.26 |
| GSH*(SHNW=0)*SOFT*HDD*QUAL*RSH*PRE | .000109 | 25.65 | .000098956 | 25.34 | .000096063 | 19.79 |
| GSH*SQFT*HDD*QUAL*RSH*POST | .000106 | 18.81 | .000097091 | 19.54 | .00091763 | 15.03 |
| GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*PRE | .000110 | 16.22 | .0001 | 15.93 | .00094802 | 11.79 |
| GSH*SQFT*HDD*QUAL*FSH*POST | .000143 | 16.34 | .000119 | 14.93 | .000109 | 11.07 |
| GSH*SQFT*HDD*NQUAL | .000122 | 38.31 | .000111 | 39.93 | .000109 | 11.07 |
| GSH*SQFT*HDD*MULTI | -.00005936 | -18.65 | -.000045499 | -15.30 | -.000033272 | -11.37 |
| GSH*SQFT*HDD*WTHR | .000058 | -7.40 | -.000044919 | -5.82 | -.000053146 | -6.21 |
| GSH*SQFT*HDD*OLD | .000038847 | 18.77 | .000049859 | 25.41 | .000046841 | 22.45 |
| GSH*SQFT*HDD*PORTHT | -.000021129 | -9.11 | -.000017689 | -7.17 | -.000016070 | -5.70 |
| | | | | | | |

**TABLE 9**
**Conditional Demand Model Parameter Estimates**
**Water Heating, Cooking, Clothes Drying, and Pool/Spa Heating**

| Water Heat, Cooking, Clothes Drying, and Pool/Spa Heating Variables | Ordinary Least Squares | | Correction for Serial Correlation | | Correction for Heteroskedasticity | |
|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| **Water Heat (GWH)** | | | | | | |
| GWH*DT*TIME*LOG(NUMINHH) | -.006061 | -2.57 | -.004509 | -1.56 | -.004178 | -1.78 |
| GWH*DT*LOG(NUMINHH)*DPOST *EDW | -.016302 | -3.53 | -.033220 | -5.29 | -.001312 | -.28 |
| GWH*DT*LOG(NUMINHH) | .145633 | 28.29 | .165061 | 20.04 | .215639 | 37.03 |
| GWH*DT*CONS*LOG(NUMINHH) | .08112 | 2.53 | .052911 | 1.23 | -.125260 | -3.92 |
| GWH*DT*OLD*LOG(NUMINHH) | .025217 | 5.64 | -.005384 | -.76 | .006653 | 1.19 |
| GWH*DT*MULTI*LOG(NUMINHH) | .-03689 | -9.06 | -.042211 | -6.26 | -.061238 | -13.84 |
| | | | | | | |
| **Cooking (GCK)** | | | | | | |
| GCK*LOG(NUMINHH) | 1.654087 | 7.45 | .434052 | 1.07 | 1.951097 | 7.42 |
| GCK*HDD*(DPOST=0)*(OVENHT) | .039966 | 10.11 | .025262 | 6.42 | .026489 | 6.41 |
| GCK*HDD*DPOST=1)*(OVENHT1) | | | | | | |
| | | | | | | |
| **Clothes Dryer (GDY)** | | | | | | |
| GDY*DRYL | .497459 | 24.50 | .735534 | 18.52 | .680638 | 20.89 |
| | | | | | | |
| **Pool/Spa Heating (PHSPA)** | | | | | | |
| PHSPA | 36.498930 | 25.22 | 45.485291 | 17.29 | 27.766310 | 13.45 |
| PHSPA*CDD | .003288 | 8.72 | .003854 | 11.23 | .005904 | 16.50 |
| | | | | | | |

where:

| **Variable** | **Definition** |
|---|---|
| OVENHT | use range to space heat prior to weatherization indicator |
| OVENHT1 | use range to space heat after weatherization indicator |
| CONS | sum of water heater conservation saving impact |
| DRYL | number of clothes drying loads |
| DT | difference between tank water and air temperature |
| GCK | gas range indicator |

| | |
|---|---|
| GDY | gas dryer indicator |
| GSH | gas space heating indicator |
| GWH | gas water heating indicator |
| HDD | number of heating degree days (base 65) |
| CDD | number of cooling degree days (base 70) |
| MULTI | multiple family residence indicator |
| NON_SH | space heater not replaced/repaired indicator |
| NQUAL | households not qualifying for appliance replacement |
| NUMINHH | number of people in the home |
| OLD | persons over 65 in the home indicator |
| POST | post space heater installation |
| DPOST | post weatherization installation period indicator |
| PRE | pre space heater installation period indicator |
| QUAL | households that qualify for appliance replacement |
| EDH | indicator for space heating education practice |
| EDW | indicator for water heating education practice |
| RSH | space heater replaced indicator |
| SHNW | space heat not working indicator |
| SQFT | square footage of the home |
| SUMMER | summer season indicator |
| TIME | time taking value of 1 in 1995 and 3 in 1997 |
| WHNW | water heater not working indicator |
| WTHR | sum of weatherization measures saving impact |
| PORTHT | electric portable heater |

A Durbin Watson statistic was calculated to assess whether serial correlation was present. The Durbin Watson statistic was .427 indicating the presence of serial correlation. Respondent-specific rho values were also calculated. These are shown on page 7 of Appendix D. The average rho value for the dataset is .743.

There also appeared to be significant heteroskedasticity present, based upon a review of the plot of residuals versus monthly therm use (page 4 of Appendix D). Evidence of serial correlation and heteroskedasticity led to the second stage estimation where a serial correlation correction was conducted.

**Second Stage - Correction for Serial Correlation**

The second stage was actually begun with the estimation of the respondent specific rho values discussed above. The predicted values from the initial conditional energy demand equation were used to estimate the level of correlation in the error term over time for each respondent (i.e., household). This was done by fitting an autoregressive model of order one, an AR(1) model, for each respondent.

The AR(1) model can be described as follows:

$$e_{i,t} = rho_i * e_{i,t-1} + N_{i,t}$$

where:

$e_{i,t}$ is the regression error term from the first stage for the $i^{th}$ respondent in month t

$N_{i,t}$ is a "white noise" error term for the $i^{th}$ respondent in month t

Estimates of $rho_i$, $P_i$, are obtained by regressing residuals from the first stage OLS model on the residuals values lagged one period. This is done separately for each respondent.

The estimated $P_i$ values are used to transform the dependent variable and all the regressors. It is important to remember that each regressor in Tables 8 and 9 has a time (t) and a household (i) subscript attached to it. These subscripts were left out of the table for presentation purposes. For example, the last variable in Table 8, GSH*SQFT*HDD*PORTHT, should be interpreted as $(GSH*SQFT*HDD*PORTHT)_{i,t}$. The transformation involves replacing the value of $(GSH*SQFT*HDD*PORTHT)_{i,t}$ with the value of $(GSH*SQFT*HDD*PORTHT)_{i,t}$ - Pi* $(GSH*SQFT*HDD*)_{i,t-1}$.

Next the energy demand equation was re-estimated using the transformed variables to correct for the correlation in the error term. This correction generates more consistent regression parameter estimates. The parameter estimates from this second stage are also summarized in Tables 8 and 9. The detailed results are contained in Appendix D beginning on page 9. The adjusted R-squared is .66. With very few exceptions, coefficients retained the same signs and magnitudes.

**Third Stage - Correction for Heteroskedasticity**

The third stage begins with a supplementary regression that serves two ends, it tests for the presence of heteroskedasticity and provides weights that can be used to correct for the heteroskedasticity that does exist. The supplementary regression takes the residuals computed from the second stage regression and estimates their squared value across households as a function of the number of appliances present in each home, season of the year, and which Direct Assistance Program segment the household belongs. The coefficients and t-values are provided below in Table 10. Note that the coefficient of STOCKTERM has a significant t-value. This implies that heteroskedasticity is present, i.e. the variance of the error term is influenced by the magnitude of monthly consumption.

**Table 10**
**Estimated Functional Form of Heteroskedasticity**

| Variable | Description | Coefficient | t-value |
|---|---|---|---|
| INTERCEPT | regression intercept | 48.349 | 4.25 |
| MF | multifamily indicator | -75.842 | -6.06 |
| WINTER | Dec.-Mar. indicator | 133.841 | 8.79 |
| SPRING | Apr.-June, Nov. indicator | 82.975 | 5.69 |
| WINTER*MF *STOCKTERM | Winter indicator interacted with multifamily | -.00032 | -1.64 |
| SPRING*MF *STOCKTERM | Spring indicator interacted with multifamily | -.000204 | 1.04 |
| STOCKTERM | Expected monthly usage based upon respondent-specific appliance holdings and estimated use per appliance from second stage results | .300164 | 6.97 |
| STOCKTERM*MF | Stock term interacted with multi participation | -.124057 | -1.35 |
| WINTER*STOCKTERM | | .060075 | .97 |
| SPRING*STOCKTERM | | -.332414 | -5.44 |

**Notes:** Indicators are binary variables..

The correction for heteroskedasticity involves transforming the dependent and independent variables from the second stage regression using the square root of the predicted values from the supplementary regression. Assume $vhat_{i,t}$ is the square root of the predicted value. Use the previous example variable from Table 9, $(GSH*SQFT*HDD*PORTHT)_{i,t}$, after the second stage transformation. The estimated value of the error term from this third equation was then used to weight the second stage equation, i.e. $(GSH*SQFT*HDD*PORTHT)_{i,t}*vhat_{i,t}$.

The conditional demand model was then re-estimated using the transformed value of the dependent and independent variables. The regression coefficients estimated in this third stage have both consistent and unbiased estimates of the error term. They are shown in Tables 8 and 9, as well as in Appendix D.

While there is some loss of observations using this procedure more than 25,000 monthly observations were incorporated in the third stage regression model. The adjusted R-squared value from the third stage regression is .64. The parameter estimates from this third stage model were used to calculate program impacts.

### *Appliance/Equipment Specific Gas Use Estimation*

The space heating (gsh) water heating (gwh), cooking (grg), clothes drying (gdy), and pool/spa heating (gp) demand equations for both segments are explained in the remainder of this section.

### Gas Space Heating

The actual space heating load is based on customer behavior and the principles of thermodynamics. Therm usage depends upon the efficiency of the heating system, the thermal integrity of the home, the area to be heated, and the desired household indoor temperature. Due to the qualifications of the Direct Assistance Program, four categories of space heating customers are modeled. The categories are:

a) single family homeowners that **did not** need their space heater replace/repaired,

b) single family homeowners that **needed** their space heater **repaired,**

c) single family homeowners that **needed** their space heater **replaced,** and

d) single family renters and multiple family residents

It is expected that the efficiency of the heating system for those customers who had the space heating system replaced or repaired was worse than the other two categories space heater efficiency prior to repairing the heater or installing the new space heater. Both the survey data and the program participation file provided information concerning whether the existing space heater was inoperative prior to replacement or repair. If the heater was inoperative, the space heating terms were set equal to zero during the months the participant claimed the space heater was not working.

The presence of weatherization measures (attic insulation, caulking/weatherstripping, building envelope repairs, switch outlet gaskets, register seal, exhaust vent damper, and evaporative cooler cover) improves the thermal integrity of the home. The program measure file, along with the participant survey, provided information concerning weatherization measures. The dates of measure installation provided a tool to develop pre and post weatherization indicators. It was assumed that customers who claimed weatherization measures existed in the survey, but had no program measure installation information for a particular item, already had the weatherization item present in the home. A term equaling the sum of expected savings (25 percent for attic insulation, 4 percent for caulking/weatherstripping 6 percent for building envelope repairs, .6 percent for register sealing, 2.5 percent for exhaust vent damper, and 3 percent for evaporative cooler covers) from the weatherization items was entered into the equation for each space heating group. These estimates were developed as a results of a detailed engineering analysis (see Appendix B).

The desired indoor temperature in the home is thought to be dependent on the age characteristics of the people in the home. Specifically, it was assumed that households with at least one member over 65 years have higher indoor temperature requirements than other household age formations.

A time trend term incrementing one each year is included to account for the general economic conditions facing low income households (this was suggested by past reviewers). Note that for the non-qualifying group, differences between single family and multiple family dwellings are taken into account with a multiple family interaction.

The space heating usage model takes the form described below (the coefficient and t-values are provided in Table 8).

| | | |
|---|---|---|
| gsh | = | 8.031182 * GSH*(SHNW=0) |
| (t2) | - | 1.015214 * GSH*(SHNW=0)*SUMMER |
| (t3) | - | .00000062 * GSH*(SHNW=0)*SQFT*HDD*TIME |
| (t4) | + | .000004619 * GSH*(SHNW=0)*SQFT*HDD*EDH*DPOST |
| (t5) | + | .000095293 * GSH*SQFT*HDD*QUAL*NON_SH |
| (t6) | + | .000096063 * GSH*(SHNW=0)*SQFT*HDD*QUAL*RSH*PRE |
| (t7) | + | .000091763 * GSH*SQFT*HDD*QUAL*RSH*POST |
| (t8) | + | .000094802 * GSH*(SHNW=0)*SQFT*HDD*QUAL*FSH*PRE |
| (t9) | + | .000109 * GSH*SQFT*HDD*QUAL*FSH*POST |
| (t10) | + | .000102 * GSH*SQFT*HDD*NQUAL |
| (t11) | - | .00003327 * GSH*SQFT*HDD*NQUAL*MULTI |
| (t12) | - | .00053146 * GSH*SQFT*HDD*WTHR |
| (t13) | + | .000046841 * GSH*SQFT*HDD*OLD |
| (t14) | - | .00001607 * GSH *SQFT*HDD*PORTHT |

where the variables are defined following Table 9.

The first two terms capture the space heating non-weather sensitive loads. The coefficients have the expected signs with the summer term t2 capturing the customers who turn off pilot lights during the summer. Term t3 captures the effect of time on space heating use. The time trend (t3) has a negative coefficient suggesting that space heating use declines as the years go by.

Term t4 measures the impact of practicing space heating education on space heating use. Surprisingly, the term has a positive but insignificant coefficient suggesting an overall zero impact on space heating use.

Term t5 captures the use per degree day foot for the single family homeowners who did not need the space heating equipment replaced/repaired. The ratio of t12 to t5 measures the proportion of expected weatherization savings that were achieved by this group and the value is .558.

Terms t6 and t7 measure the space heating use for those participants who received a new space heater. The post period use per degree day foot (t7) is nearly 5 percent lower than the pre-installation period (t6) value. The weatherization measure impact (t12) is 58 percent the size of the post period usage value.

Terms t8 and t9 evaluate the space heating use for those participants who had the space heater repaired. The post period use per degree day foot (t9) is nearly 15 percent higher than the pre-installation period (t8) value. The weatherization measure impact (t12) is nearly 50 percent the size of the post period usage value.

Terms t10 and t11 measure the space heating use for those participants who were not single family homeowners. The multiple family resident use per degree day foot (t11) is more than 30 percent less than the single family renter (t10) value. The weatherization measure impact (t12) is more than 52 percent the size of the single family usage value.

The impact of installing weatherization measures is captured in term t12. The ratio of savings to base usage for the various groups was denoted above. Finally, the presence of seniors (t13) increases gas use, and households with portable electric heaters (t14) use less space heating energy than other households.

**Gas Water Heating**

Gas water heating use depends on the temperature of the incoming water, the number of people in the home, and the efficiency of the water heater tank. The average air temperature during the month is used to approximate the temperature of the incoming water. The survey respondents were asked the water heater temperature setting of the water heater as well as the number of people in the home. The log of the people plus 1 was used to model the impact household size has on water heating use.

Four conservation measures impact water heating use. The low flow showerhead and faucet aerator impact the volume of water used while pipe insulation and the blanket influence the implied efficiency of the heater tank. A term equaling the sum of expected savings (taken from the engineering analysis in Appendix B and equal to 7.5% for the low flow showerhead, 3 percent for faucet aerator, 2.25 percent for pipe insulation's and 6 percent for heater blanket) from the conservation measures was entered into the water heating equation. The water heating usage model takes the form (t-values reported in Table 9):

| | | |
|---|---|---|
| gwh | = | -.004178 * GWH*DT*TIME*LOG(NUMINHH+1) |
| (t2) | + | -.001312 * GWH*DT*EDW*LOG(NUMINHH+1)*DPOST |
| (t3) | + | .215639 * GWH*DT*LOG(NUMINHH+1) |
| (t4) | - | .125260 * GWH*LOG(NUMINHH+1)*CONS |
| (t5) | + | .006653 * GWH*DT*OLD*LOG(NUMINHH+1) |
| (t6) | - | .061238 * GWH*DT*MULTI*LOG(NUMINHH+1) |

where the variables are defined following Table 9.

The first water heating term captures the impact time has on water heating use. The negative coefficient indicates as the years go by decreased water heating use is experienced. Term t2 measures the impact of water heat education on water heating use. The negative coefficient implies decrease in use when education was practiced, but the t-ratio is insufficient.

Term t3 measures water heating use per person per degree of temperature difference. The value of t3 is positive and implies usage decreases as temperature rises.

Water heating conservation impacts are captured in term t4. The value of t4 suggests that nearly 60 percent of the expected water heating savings are achieved after conservation is installed. Terms t5 and t6 capture the impacts of seniors and multiple family households have on water heating use. The value of t5 (senior-citizen impact) is positive while the value of t6 (living in multiple family homes) is negative.

### Gas Cooking

Gas cooking usage is assumed to be dependent upon the number of people in the home. In addition, customers who claimed they use cooking equipment for space heating was modeled.

The gas cooking usage model takes the form (t-values reported in Table 9):

| | | |
|---|---|---|
| grg | = | 1.951097 * GCK*LOG(NUMINHH+1) |
| (t2) | + | .026489 * GCK*OVENHT*HDD*(DPOST=0 |
| (t3) | + | .020353 * GCK*OVENHT1*HDD*DPOST* |

where the variables are defined following Table 9.

Note that the use per degree day diminishes after weatherization for those households that use cooking equipment for space heating.

**Gas Clothes Dryer**

Dryer use is expressed as a function of the number of clothes drying loads done in the home. The estimated clothes dryer equation is expressed as follows:

gdy = .680638 * GDY * DRYL

where GDY is the gas dryer indicator and DRYL is the number of clothes drying loads. As expected the clothes drying usage increases as the number of drying loads rise.

**Gas Pool/Spa Heat**

The pool/spa heat use is expressed as an indicator variable and a cooling degree day term. The estimated pool heating equation is expressed as follows:

gp = 27.7663 * PHSPA

t2 + .005904 * PHSPA*CDD

where PHSPA is the gas pool/spa heating indicator. The estimated coefficients indicates that pool heating use increases as the temperature rises.

## Usage Estimates and Therm Savings Impacts

This section of the report presents the annual furnace usage estimates as well as the saving impacts from weatherization measures, conservation measures, repaired and replaced furnaces. The space and water heating usage estimates are based on average monthly weather conditions over the past 30 years in the Gas Company's weather zones weighted for program participation.

The remainder of the section is organized as follows. First the method used to estimate furnace usage and associated savings are discussed. Second, the usage and conservation savings estimates are presented.

### *Method of Calculating Furnace Therm Use*

The energy use model regression coefficients displayed in Tables 8 and 9 are employed to predict monthly consumption under normal weather condition values (both heating degree days and average temperature). Households participating in the furnace replacement program had annual furnace energy use values calculated for the following scenarios:

a) no weatherization/conservation measures installed and furnace was working prior to repair/replacement
b) furnace was repaired/replaced
c) all weatherization/conservation measures were installed

Customers participating in the weatherization and conservation program had annual furnace energy use values estimated for the two scenarios described below.

a) no weatherization/conservation measures were installed
b) all weatherization/conservation measures were installed

Monthly weather conditions, as well as other household characteristics taken from the survey, are held constant throughout all the scenarios for all survey households. This approach permits the differences in furnace usage among the scenarios to truly reflect the therm savings attributed to the measure or repaired/new furnace. Simulation results are presented in the next section.

### *Furnace Usage and Weatherization Measure Savings Estimates*

Furnace specific annual energy use values are provided below. Values for households participating in the furnace replacement program are given first, followed by the weatherization and conservation measure group usage estimates. The space heating savings values are somewhat lower than the 1994 values although the water heating savings are modestly higher than the 1994 estimates.

Table 11 displays the annual space heating energy use estimates for replaced and repaired furnaces along with therm usage that define the 90% and 80% confidence intervals respectively. The replacement numbers indicate that the space heating post-installation period usage values are statistically different from the pre-installation period values. Space heating use declined after the furnace was replaced. The furnace repaired numbers show usage increases after furnace is repaired.

**Table 11**

**Furnace Replacement and Repair Therm Usage/Savings**

| End Use | Pre Installation | Post Installation | Therm Savings |
|---|---|---|---|
| Space Heating Replacement | 274.9 | 268.1<br>(11.7, 9.1) | 6.8 |
| Space Heating Repair | 286.4 | 310.3<br>(20.1, 15.7) | -23.9 |

**Notes:**

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm usage after participation are the ± therm usage that define the 90% and 80% confidence intervals respectively.

Table 12 lists the weatherization and conservation results with the 90 percent and 80 percent therm confidence band in parenthesis. All the space heating weatherization saving values are statistically different than zero. Ceiling insulation savings are greatest in the repair and replace groups and least in the multiple family direct assistance group.

**Table 12**
**Space Heating Measures Therm Savings**

| Class | Ceiling Insulation | Weather-stripping/ Caulking | Building Envelope Repairs | Switch/ Outlet Gasket | Evap. Cooler Cover | Exhaust Vent Damper | Register Seal |
|---|---|---|---|---|---|---|---|
| ARRP Replace | 21.2<br>(4.1, 3.2) | 3.3<br>(.1, .5) | 5<br>(.7, .6) | .9<br>(.1, .1) | 3<br>(.9, .7) | 2<br>(.2, .2) | 5<br>(.1, .1) |
| ARRP Repair | 22.6<br>(4.9, 3.4) | 3.6<br>(.7, .5) | 5.5<br>(.9, .7) | 1<br>(.2, .2) | 3.2<br>(1, .8) | 2.1<br>(.3, .3) | 0 |
| Weatherization Single Family | 21<br>(4.2, 3.3) | 3.6<br>(.6, .4) | 5<br>(.9, .7) | .9<br>(.2, .1) | 2.8<br>(.9, .7) | 1.9<br>(.4, .3) | .4<br>.1, .1) |
| Weatherization Multifamily | 14.9<br>(2.8, 2.2) | 2.4<br>(.4, .3) | 3.6<br>(.6, .5) | .7<br>(.1, .1) | 2.2<br>(1.2, 1.0) | 1.4<br>(.4, .3) | .4<br>(.1, .1) |

**Notes:**

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm savings after participation are the ± therm savings that define the 90% and 80% confidence intervals respectively.

Table 13 provides unit therm savings for water heating measures. As with space heating, all the water heating conservation therm savings are statistically different than zero. The low flow shower heads have the largest therm savings from water heating conservation.

**Table 13**
**Water Heating Measures Therm Savings**

| Class | Low Flow Showerhead | Water Heater Blanket | Faucet Aerator | Pipe Insulation |
|---|---|---|---|---|
| Weatherization Single Family | 9<br>(3.8, 3.0) | 7.2<br>(3.1, 2.4) | 3.6<br>(1.5, 1.2) | 2.6<br>(1.0, .8) |
| Weatherization Multifamily | 8.4<br>(3.5, 2.7) | 6.8<br>(2.9, 2.2) | 3.4<br>(1.4, 1.1) | 2.6<br>(1.1, .8) |

**Notes:**

a) After correcting for serial correlation and heteroskedasticity

b) The parenthetical values below each mean annual therm savings after participation are the ± therm savings that define the 90% and 80% confidence intervals respectively.

# APPENDIX A

# SURVEY OF 1996 DIRECT ASSISTANCE PROGRAM PARTICIPANTS

**The Gas Company™**

## *Survey of 1996 Direct Assistance Program Participants*

Dear Direct Assistance Program Participant:

**We need your help.** Your household has been selected to be part of a survey conducted for The Gas Company. In 1996 your household, or former occupant of this residence, participated in The Gas Company's Direct Assistance Program. We would now like to ask you about your gas appliances and how you use them.

The information that you provide us with will be used in a study required by the California Public Utilities Commission. In addition, it will help us plan for future energy needs and ensure that you and other customers continue to receive dependable quality service. **All of your answers will be kept confidential.**

We have enclosed $1.00 as our way of saying thank you for your cooperation. If you have any questions or problems with this survey, please call the Direct Assistance Program Hotline from 8:00 a.m. to 5:00 p.m. Monday through Friday.

(800) 331-7593

Thank you for your time and cooperation.

(POR FAVOR, VOLTEE LA HOJA PARA VERSION EN ESPAÑOL)

## *Survey of 1996 Direct Assistance Program Participants*

1. What kind of building is your residence?

   - ❑ Single Family Home
   - ❑ House on a lot behind the main house
   - ❑ Duplex/Triplex
   - ❑ Apartment Building
   - ❑ Mobile Home
   - ❑ Townhouse/Condominium

2. Does your home have more than one floor?

   ❑ Yes ❑ No

3. Do you own or rent your home?

   ❑ Own ❑ Rent

4. A) How many people, including babies, live in your home?

   ______ Total number of residents

   B) Did the number of people living in your home increase or decrease at any time during the last 3 years?

   ❑ Yes ❑ No

   If yes, how many times? _____________

   If increased first time, by how many? _______
   If decreased first time, by how many? _______

   Approximately when did it change?
   _________ Month, _______ Year

   If increased second time, by how many? ______
   If decreased second time, by how many? ______

   Approximately when did it change?
   _________ Month, _______ Year

If increased third time, by how many? ________
If decreased third time, by how many? ________

Approximately when did it change?
_________ Month, ________ Year

5. Are there any children <u>under the age of 3 years</u> living in your home?

☐ Yes ☐ No

6. Are there any persons <u>over the age of 65 years</u> living in your home?

☐ Yes ☐ No

7. A) How many square feet of living space are in your home (excluding garages, basements and porches)?

___________ Total square feet

If not certain, please choose from the square feet scale below:

☐ Less than 600 ☐ 1251 - 1500
☐ 600 - 800 ☐ 1501 - 2000
☐ 801 - 1000 ☐ 2001 - 2500
☐ 1001 - 1250 ☐ Over 2500

B) Has the square footage changed during the last three (3) years?

☐ Yes ☐ No

If YES, approximately, when did it change?
_________ Month, ______ Year

8. How many bedrooms are in your home?
____ Total number of bedrooms

9. Which of the following appliances are in your home and are used by <u>your household members only?</u> For those appliances that you use in your home, please check the fuel it uses to operate.

| | **Present** (Used by household members use only) | | **Fuel Type** | | |
|---|---|---|---|---|---|
| | **Yes** | **No** | **Gas** | **Electric** | **Don't know** |
| Forced Air Furnace | ❑ | ❑ | ❑ | ❑ | ❑ |
| Wall Furnace | ❑ | ❑ | ❑ | ❑ | ❑ |
| Central Air Conditioner | ❑ | ❑ | ❑ | ❑ | ❑ |
| Window/Wall Air Conditioner | ❑ | ❑ | | | |
| Water Heater | ❑ | ❑ | ❑ | ❑ | ❑ |
| Oven | ❑ | ❑ | ❑ | ❑ | ❑ |
| Cooktop | ❑ | ❑ | ❑ | ❑ | ❑ |
| Range | ❑ | ❑ | ❑ | ❑ | ❑ |
| Clothes Dryer | ❑ | ❑ | ❑ | ❑ | ❑ |
| Pool or Spa Heater | ❑ | ❑ | ❑ | ❑ | ❑ |
| Dishwasher | ❑ | ❑ | | | |
| Clothes Washer | ❑ | ❑ | | | |

10. What is the temperature setting of your water heater? (in degrees Fahrenheit °F)

❑ Low (under 120 °F)

❑ Medium (121° - 130 °F)

❑ High (over 130 °F)

❑ Use water from central water heater which serves apartment building

❑ Don't know

11. Please estimate the total weekly number for each of the following activities in your home. Include all household members.

_____ Total number of showers or baths per week

_____ Total number of hot water or warm water clothes washer loads per week

_____ Total number of clothes dryer loads per week

_____ Total number of dishwasher loads per week

_____ Total number of times dishes are washed at sink per week

12. Which, if any, of the following energy-saving measures are present in your home?

| Measure | Yes | No | Don't Know |
|---|---|---|---|
| Attic/Ceiling insulation | ❒ | ❒ | ❒ |
| Caulking/weatherstripping around doors and windows | ❒ | ❒ | ❒ |
| Water heater blanket/wrap | ❒ | ❒ | ❒ |
| Low flow showerhead | ❒ | ❒ | ❒ |

13. Do you use a portable electric space heater in your home?

❒ Yes ❒ No

14. Did you ever use your oven or stove to heat your home prior to receiving services from The Gas Company?

❒ Yes ❒ No

15. Have you used your oven or stove to heat your home since receiving services from The Gas Company?

    ☐ Yes ☐ No

16. Do you use a thermostat to adjust your furnace?

    ☐ Yes ☐ No

    (If yes, please complete questions 17 through 20)

17. What temperature do you keep your furnace thermostat set at?

    _____°F

    If not certain, please choose one of the temperature ranges shown below:

    ☐ 65 °F to ☐ 68 °F
    ☐ 69 °F to ☐ 72 °F
    ☐ 73 °F to ☐ 76 °F
    ☐ Above 76 °F

18. Do you turn off your thermostat at night?

    ☐ Yes ☐ No

19. Do you turn off your thermostat when no one is home?

    ☐ Yes ☐ No

20. If you reduce your thermostat setting at night, what do you set it at?

    _____oF

21. Since receiving services from The Gas Company are you:

| | | |
|---|---|---|
| Setting your furnace thermostat higher? | ☐ Yes | ☐ No |
| Enjoying longer showers? | ☐ Yes | ☐ No |

22. Do you have any hot water leaks in your home?

☐ Yes ☐ No

23. How many months have you had leak(s)?

_______ months

24. Do you practice energy conservation as a result of the Energy Education provided by The Gas Company?

☐ Yes ☐ No

25. **If yes,** please indicate which energy conservation practices you are still using

**Space heating**

| | |
|---|---|
| Set back thermostat at night or when no one is home | ☐ |
| Wear warmer clothing during the winter months | ☐ |
| Keep the furnace clean and replace filters | ☐ |
| Do not block heating outlets with furniture | ☐ |

**Water heating**

| | |
|---|---|
| Take short showers rather than baths | ☐ |
| Keep the water heater set at 120 °F | ☐ |
| Repair leaky faucets, showers | ☐ |
| Use cold or warm water whenever possible | ☐ |

## *Survey of 1996 Direct Assistance Program Participants*

*This last section of questions deals with the* ***Appliance Repair or Replacement Program (ARRP)*** *sponsored by The Gas Company. This program is offered only to single family homeowners.*

1. Did you participate in the Appliance Repair or Replacement Program (ARRP) in 1996?

   ❐ Yes ❐ No

   **IF NO, STOP!** Thank you very much for helping The Gas Company with this survey.

2. A) Did you have your **furnace** replaced or repaired in 1996 under ARRP?

   ❐ Yes ❐ No ❐ Don't know

   B) If yes, was the **furnace** working before it was replaced or repaired?

   ❐ Yes ❐ No

   C) If the **furnace** was not working, how long had it not been working?

   _____ Approximate number of months

***Thank you very much for helping The Gas Company with this survey.***

# APPENDIX B

# ASSIGNMENT OF WEIGHTING FACTORS FOR DIRECT ASSISTANCE PROGRAM MEASURES

## Weighting Factors

DOE-2 simulations were used to develop the weighting factors for weather-sensitive space heating measures, and engineering algorithms were used to develop weighting factors for water heating measures. The weighting factors represent relative therm savings for each measure, and are used to develop the coefficients in the regression model. **Table 1** shows the weighting factors used for single- and multi-family measures.[1]

### Table 1. Weighting Factors by Measure

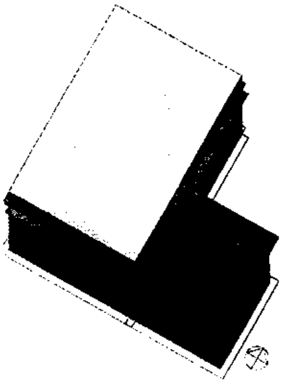
| **Space Heating Measure** | **Weighting Factor %** |
|---|---|
| Attic Insulation | 25.0 |
| Weatherstripping/Caulking | 4.0 |
| Building Envelope Repair | 6.0 |
| Switch/Outlet Gasket | 1.2 |
| Evaporative Cooler Cover | 3.5 |
| Exhaust Vent Damper | 2.4 |
| Register Sealing | 1.2 |
| **Water Heating Measure** | **Weighting Factor %** |
| Low-Flow Showerhead | 7.5 |
| Water Heater Blanket | 6.0 |
| Faucet Aerator | 3.0 |
| Pipe Insulation | 2.3 |

## Building Simulation Analysis

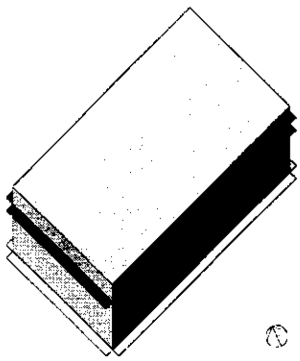
Two building prototypes were used in the DOE-2 simulations. These included a single-family detached prototype and a multi-family apartment as shown in **Figure 1**. Modeling assumptions for each prototype are provided below.

[1] Relative therm savings for single- and multi-family measures were close enough to justify using a single set of weighting factors for both building types.

**Figure 1. Single- and Multi-Family DOE-2 Prototypes**



1-Story Single-Family Residence
with attached garage



1-Story Multi-family Apartment
with adiabatic common walls

- ***Single-Family Detached Prototype.*** The single-family prototype is a one-story building with 1,060 square feet of conditioned floor area, a slab foundation, and a natural gas forced-air furnace. The base case has no insulation in the walls and R-4 ceiling insulation in the roof. Peak lighting intensity is 0.4 W/sf and the peak internal loads are 1.6 Btu/hr-ft$^2$. Windows are single pane metal frame with U-value of 1.1 Btu/hr-ft$^2$-F and a shading coefficient of 1.0. The window-to-floor area ratio is 0.16 and floor to ceiling height is 8 feet. Peak occupancy level is 4 persons. The Sherman-Grimsrud infiltration method was used to model infiltration and the base case leakage area to floor area ratio is 0.001.[2] The baseline heating setpoint is 70 F, with a setback to 65 F from 9 AM to 3 PM and a setback to 65 F from 10 PM to 6 AM. The ex-post thermostat setpoint from 6 PM to 9 PM was raised from 70 F to 71 F in order to model a slight "rebound" effect. All other ex-post thermostat setpoints and setbacks remained the same as the baseline. No air conditioning is modeled for the DAP participants.
- ***Multi-Family Apartment.*** The multi-family prototype is a one floor apartment with two adiabatic walls (i.e., common walls), and a natural gas forced-air furnace. The base case has no insulation in the walls and R-4 ceiling insulation in the roof. Peak lighting intensity is 0.3 W/sf and the peak internal loads are 1.9 Btu/hr-ft$^2$. Windows are single pane metal frame with U-value of 1.1 Btu/hr-ft$^2$-F and a shading coefficient of 1.0. The window-to-floor area ratio is 0.16 and floor to ceiling height is 8 feet. Peak occupancy level is 2 persons per unit. The Sherman-Grimsrud infiltration method was used to model infiltration and the base case leakage area to floor area ratio is 0.0007. Leakage area for the multi-family prototype is lower than the single-family prototype due to having two adiabatic walls and, therefore, less shell area to contribute to overall leakage area. The baseline heating setpoint is 70 F,

[2] A leakage ratio of 0.001 is typical for a "loose" or leaky older residence, see page 2.86, *DOE-2 Supplement*, Version 2.1E, Lawrence Berkeley Laboratory, Berkeley, CA 94720, 1993.

with a setback to 65 F from 9 AM to 3 PM and a setback to 65 F from 10 PM to 6 AM. The ex-post thermostat setpoint from 6 AM to 9 AM was raised from 70 F to 71 F in order to model a slight "rebound" effect. All other ex-post thermostat setpoints and setbacks remained the same as the baseline. No air conditioning is modeled for the DAP participants.

### *Calibrating DOE-2*

The DOE-2 simulations were calibrated using average utility billing data[3] and Typical Meteorological Year (TMY) weather data for Los Angeles. Prototypes were modeled both with and without the space heating measures in order to develop the weighting factors. TMY weather data are based on historical weather data from 1952 to 1975 and are constructed from individual months rather than entire years.[4, 5] TMY weather data for the simulations were obtained from the California Energy Commission[6] and are based on weather data from the National Climatic Data Center[7] in North Carolina.

### *Space Heating Measures*

DOE-2 space heating simulation results and unadjusted weighting factors are shown in **Table 2**. Baseline unit energy consumption (UEC) for the single-family prototype is 236 therms and baseline UEC for the multi-family prototype is 140 therms. These baseline values are calibrated to average UECs for single and multi-family residences.[8] DOE-2 results for each measure are used to develop a set of unadjusted weighting factors. The unadjusted weighting factor for attic insulation is set at 25 percent. Unadjusted weighting factors for the other measures are calculated as the ratio of measure savings to attic insulation savings. Adjustments are made to the measure-specific weighting factors after the regression

[3] *Integration of Billing and Metering Data*, prepared for the California Demand Side Management Advisory Committee: The Subcommittee on Modeling Standards for End Use Consumption and Load Impact Models, prepared by Pacific Consulting Services, 1320 Solano Avenue, Suite 203, Albany, CA 94706, December 1994.

[4] Standard TMY weather data is constructed by reviewing individual months of weather data from each weather station over a 23 year period. A typical month for each of the 12 calendar months from the long term period of record is chosen and used to form the TMY. The basis of the selection for a typical month consists of 13 daily indices calculated from the hourly values of dry bulb and wet bulb temperature, wind velocity, and solar radiation. Month/year combinations that have statistics "close" to the long term statistics are candidates for typical months. Final selection of a typical month includes consideration of persistence of the weather patterns.

[5] *Does It Matter Which Weather Data You Use in Energy Simulations?*, Y. Joe Huang, Drury Crawley, 1996 ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, 1001 Connecticut Avenue, S.W., Suite 801, Washington, DC 20036, September 1996.

[6] *California Thermal Climate Zones*, Bruce Maeda, California Energy Commission, 1516 Ninth Street, Sacramento, CA 95814, 1992.

[7] TMY (Typical Meteorological Year), TRY (Test Reference Year), and other weather data is available from the National Climatic Data Center, 151 Patton Avenue, #120, Asheville, NC 28801.

[8] The average DAP single family UEC is 235 therms and average DAP multi-family UEC is 140 therms (personal communication with Ken Parris, Business Economic Analysis and Research, 6639 San Miguel Avenue, Lemon Grove, CA 91945, July 8, 1997)

coefficients are calculated from the billing data.[9] DOE-2 simulation results for single and multi-family prototypes are almost identical (refer to **Table 2**). Therefore, one set of "adjusted" weighting factors is used to calculate the regression coefficients for both building prototypes. These weighting factors are shown in **Table 1**.

## Table 2. DOE-2 Simulation Results and Unadjusted Weighting Factors

| | Single Family | | | Multi-Family | | |
|---|---|---|---|---|---|---|
| **Space Heating Measure** | **Space Heating** Therms | **Measure Savings** Therms | **Weighting Factor** % | **Space Heating** Therms | **Measure Savings** Therms | **Weighting Factor** % |
| Baseline | 236 | - | - | 140 | - | - |
| Attic Insulation | 205 | 31 | 25.0 | 116 | 24 | 25.0 |
| Weatherstripping/Caulking | 231 | 5 | 4.0 | 136 | 4 | 4.1 |
| Building Envelope Repair | 231 | 8 | 6.5 | 134 | 6 | 6.3 |
| Switch/Outlet Gasket | 234 | 2 | 1.6 | 138 | 2 | 2.1 |
| Evaporative Cooler Cover | 231 | 5 | 4.0 | 136 | 4 | 4.2 |
| Exhaust Vent Damper | 233 | 3 | 2.4 | 138 | 2 | 2.1 |
| Register Sealing | 235 | 1 | 0.8 | 139 | 1 | 1.0 |

**<u>Attic Insulation</u>**

DAP attic insulation options are based on the "existing" level of insulation found in the residence. A sample of eighty-one 1994 DAP participants showed average pre-insulation levels of R-4 and average post-insulation levels of R-19. Using these R-values in the DOE-2 models yielded estimated therm savings of 34 therms for single family residences and 24 therms for multi-family residences. The unadjusted weighting factor for attic insulation is set at 25 percent. All other weighting factors for space heating measures are referenced to this value using the ratio of measure savings to attic insulation savings. The relative values, and not the magnitude of the values, are important in terms of estimating the regression model coefficients.

[9] Adjustments are based on the t-ratio values and confidence intervals. T-ratios must be greater than 2 and the confidence interval for each measure must not pass through zero (K. Parris, Business Economic Analysis and Research, 6639 San Miguel Avenue, Lemon Grove, CA 91945).

**Weatherstripping/Caulking**

Weatherstripping/caulking was modeled in DOE-2 by assuming a 7.2 percent reduction in overall leakage area[10] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 5 therms. Therefore, based on the attic insulation reference of 25 percent, the adjusted weighting factor for weatherstripping/caulking is 4 percent.

**Building Envelope Repair (BER)**

BER was modeled in DOE-2 by assuming a 12 percent reduction in overall leakage area[11] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 8 therms. Therefore, the adjusted weighting factor for BER is 6 percent.

**Switch/Outlet Gasket Covers (Gaskets)**

Gaskets were modeled in DOE-2 by assuming a 3 percent reduction in overall leakage area[12] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 2 therms. Therefore, the adjusted weighting factor for gaskets is 1.2 percent.

**Evaporative Cooler Cover**

Evaporative Cooler Covers were modeled in DOE-2 by assuming a 7.2 percent reduction in overall leakage area[13] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 5 therms. Therefore, the adjusted weighting factor for evaporative cooler covers is 3.5 percent.

**Exhaust Vent Damper (Dampers)**

Dampers were modeled in DOE-2 by assuming a 4 percent reduction in overall leakage area[14] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 3 therms. Therefore, the adjusted weighting factor for dampers is 2.4 percent.

**Register Sealing**

Register sealing was modeled in DOE-2 by assuming a 1.5 percent reduction in overall leakage area[15] (FRAC-LEAK-AREA). The DOE-2 results show expected annual savings of 1 therm. Therefore, the adjusted weighting factor for register sealing is 1.2 percent.

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[10] *Component Leakage Area in Residential Buildings*, C. Reinhold, R. Sonderegger, Lawrence Berkeley Laboratory, LBL-16221, Berkeley, CA 94720, 1983.

[11] Ibid.

[12] Ibid.

[13] Assumes evaporative cooler cover reduces effective leakage area by 72 $cm^2$ (11 $in^2$).

[14] Ibid.

[15] Ibid.

### *Water Heating Measures*

Water heating measures are modeled using engineering algorithms. Modeling assumptions for each measure are discussed below. The average water heating UEC for DAP single-family residences is 200 therms and the average UEC for DAP multi-family residences is 160 therms.[16] Estimates of natural gas water heater energy consumption by end use or standby loss are shown in **Table 3.**[17] These values are used to develop estimates of therm savings and weighting factors for the DAP water heating measures.

**Table 3. Natural Gas Water Heater Energy Consumption by End Use**

| End Use or Standby Loss | Relative Energy Consumption % |
|---|---|
| Shower | 23.0 |
| Tub | 7.0 |
| Sink | 7.0 |
| Clotheswasher | 16.0 |
| Dishwasher | 8.0 |
| Pilot Loss | 13.0 |
| Distribution Loss | 13.0 |
| Tank Loss | 13.0 |

**Low-Flow Showerhead**

Showering accounts for 23% of total water heating energy use (see **Table 3**). Energy savings are calculated as a percentage savings based on assumed pre- and post-retrofit flow rates. A standard non-conserving showerhead has a typical rated flow rate of 3.5-6 gallons per minute (at 80 psi water pressure). Low-flow showerheads use 2.4 gal/min (at 80 psi). Low-flow showerheads can reduce shower energy use by 33 percent and save approximately 10-15 therms annually. Therefore, the weighting factor for low-flow showerheads is 7.5 percent.

[16] Personal communication with Ken Parris, Business Economic Analysis and Research, 6639 San Miguel Avenue, Lemon Grove, CA 91945, June 16, 1997.

[17] These values are averages taken from the following studies: *Water Conservation in California*, Bulletin 198-84, California Department of Water Resources, Sacramento, CA, July 1984. *Supply Curves of Conserved Energy: A Tool for Least-Cost Energy Analysis,* A. Meier, T. Usibelli, Proceedings of Energy Technology Conference, Government Institutes Inc., Rockville, MD, pp. 1264-1265, March 1986. *Residential Hot Water Use Patterns*, D. Stevenson, Canadian Electrical Association, Report #111U268, Montreal, July 1983. *Water Heater Innovations*, Progressive Builder, Howard Geller, pp. 24-26, September 1985.

All other weighting factors for water heating measures are referenced to this value using the ratio of measure savings to low-flow showerhead savings.

**Water Heater Blanket**

Most gas water heaters sold in the United States prior to 1986 have 2" of imperfectly distributed R-4 fiberglass insulation on the sides and part of the top. Water heater blankets can only insulate part of the sides and the top edge of the tank. Energy losses from an older gas water heater represent about 13 percent of the total energy use (see **Table 3**). Adding a water heater blanket will reduce tank losses by about 40 percent and save about 8-12 therms annually.[18] Therefore, the weighting factor for water heater blankets is 6 percent.

**Faucet Aerator**

Approximately 7% of total water heating energy use passes through kitchen and bathroom sinks (see **Table 3**). Faucet aerators can reduce water heating energy use by about 2 percent[19] and save about 4-6 therms annually. Therefore, the weighting factor for faucet aerators is 3 percent.

**Pipe Insulation**

Pipe Insulation is modeled in a similar way to heat traps, since both do approximately the same thing in terms of reducing heat losses from the water heater inlet and outlet pipes.[20] Like heat traps, pipe insulation will typically improve the water heater energy factor[21] by 0.02 and save approximately 3.7-4.6 therms annually. Other empirical studies of energy savings from pipe insulation show similar levels of savings.[22, 23, 24] Therefore the average weighting factor for pipe insulation is 2.3 percent.

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18 Heat traps are installed on the cold-water inlet and hot-water outlet of water heaters. They typically improve the water heater energy factor by 0.02 (Gas Appliance Manufacturers Association).

19 Ibid.

20 Heat traps are installed on the inlet/outlet and typically improve the energy factor by 0.02 (GAMA).

21 Gas Appliance Manufacturers Association.

22 *Effects of Insulation of Heat Traps on Energy Standby Losses of Storage-Tank Water Heaters*, M. Perlman and E. Thompson, , Ontario Hydro Research Report 82-172-K, 1982.

23 *Residential Water Heating—Energy Conservation Alternatives*, M. Perlman, Ontario Hydro, 1991.

24 *Domestic Water Heating—Summary Research Findings for Conventional Systems*, J. R. Biemer, C. D. Auburg, C. W. Ek, , pp. J-3 to J-10, Conservation in Buildings: A Northwest Perspective, 19-22 May, 1985.

# APPENDIX C

# SUMMARY STATISTICS OF MODEL VARIABLES

**Appendix C**
**Summary Statistics of Model Variables**

| Variable | Definition | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| AER | aerator dummy | .380 | 485 | 0 | 1 |
| AVGT | average air temperature | 64.387 | 8.165 | 0 | 93 |
| BLANK | water heater blanket dummy | .401 | .490 | 0 | 1 |
| CAULK | caulking/weatherstripping dummy | .435 | .496 | 0 | 1 |
| CONWH | aggregate conservation measure water heater term | 5.114 | 5.571 | 0 | 31.01 |
| CONW#2 | practice water heat education*difference in tank water and airtemp*people | 18.558 | 35.578 | 0 | 184.73 |
| COOKHT | cooking equipment use for space heating before period*HDD | 4.254 | 31.084 | 0 | 584.97 |
| COOKHTA | cooking equipment use for space heating *HDD*post weatherization | 1.409 | 16898 | 0 | 515.91 |
| COOK | persons in household* cooking dummy | .719 | .521 | 0 | 2.48 |
| DRY | dryer loads per week | 3.169 | 6.205 | 0 | 97 |
| ENV | building envelope repair dummy | .472 | .499 | 0 | 1 |
| FEET_CHG | survey variable, 1 if size of home has changed*otherwise | .001 | 03 | 0 | 1 |
| GWAT | water heater*difference in tank water and air temp | 70.748 | 38.023 | 0 | 207.03 |
| GWATMF | water heater term for multifamily residents * difference in tank water and air temp*people | 19.911 | 36.571 | 0 | 20.1 |
| GWATT | water heater term time trend * difference in tank water and air temp*people | 126.643 | 101.115 | 0 | 554 |
| G_COOK | cooking dummy | .516 | .321 | 0 | 1 |
| G_DRY | dryer dummy | .376 | .484 | 0 | 1 |
| G_HEAT | gas space heating dummy | .923 | .267 | 0 | 1 |
| G_WAT | gas water heating dummy | .895 | .306 | 0 | 1 |
| HDD | heating degree days using a 65 degree base | 92.139 | 113.391 | 0 | 855 |
| HEAT0C | pilot light load dummy | .865 | 341 | 0 | 1 |
| HEAT0CS | pilot light load dummy * summer period dummy | .388 | .487 | 0 | 1 |
| HEAT1A | furnace replaced post period dummy*HDD*SQFT | 2372.91 | 25128.05 | 0 | 761563 |
| HEAT1AF | furnace repaired post period dummy*HDD*SQFT | 686.568 | 14135 | 0 | 915774 |
| HEAT1B | furnace replaced pre period dummy*HDD*SQFT | 3919.29 | 32609 | 0 | 930645 |
| HEAT1BF | furnace repaired pre period dummy*HDD*SQFT | 1096.8 | 18025 | 0 | 973045 |
| HEAT1C | furnace control group dummy*HDD*SQFT | 40259 | 102003 | 0 | 944933 |
| HEAT1Q | furnace repair/replacement non-qualifier*HDD*SQFT | 34819 | 79533 | 0 | 761267 |

**Appendix C**
**Summary Statistics of Model Variables (cont. 2)**

| Variable | Definition | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| HEAT_C | conservation terms dummy * HDD * SQFT | 46259 | 102003 | 0 | 944933 |
| HEAT1_M | multifamily dummy * HDD *SQFT | 19508 | 57288 | 0 | 684536 |
| HEAT1_O | senior citizen dummy * HDD * SQFT | 31906 | 90508 | 0 | 1003930 |
| HEAT1_P | portable heat * HDD * SQFT | 11393 | 54454 | 0 | .930645 |
| HEATT | time trend * HDD * SQFT | 143007 | 251045 | 0 | 2747321 |
| INSUL | ceiling insulation dummy | .853 | .354 | 0 | 1 |
| LOWFL | low flow showerhead dummy | .478 | .499 | 0 | 1 |
| MF | multifamily dummy | .357 | .479 | 0 | 1 |
| NUMINHH | number in household | 3.465 | 2.106 | 1 | 20 |
| NUM_CHG | dummy for change in residents within the last three years | .248 | .496 | 0 | 1 |
| PIPE1 | pipe insulation dummy | .031 | .172 | 0 | 1 |
| POOLSPA | gas pool and spa heater dummy | .013 | .115 | 0 | 1 |
| PORTHT | portable heat dummy | .136 | .343 | 0 | 1 |
| SF | single family dummy | .643 | .479 | 0 | 1 |
| SPEC1 | switch gasket dummy | .369 | .483 | 0 | 1 |
| SPEC2 | evaporative cooler cover dummy | .008 | .091 | 0 | 1 |
| SPEC3 | exhaust vent damper | .018 | .134 | 0 | 1 |
| SPEC4 | register sealing dummy | .013 | .113 | 0 | 1 |
| SQFT | square footage | 954 | 410.901 | 150 | 3200 |
| THM | monthly therm usage | 32.585 | 26.296 | 0 | 384 |
| WAT_O | water heater dummy * senior citizen dummy * temperature difference between tank and air temperatures | 19.58 | 32.32 | 0 | 158.20 |
| WH_TEM | water heater temperature | 121.017 | 6.33 | 110 | 140 |

# APPENDIX D

# 1996 DIRECT ASSISTANCE PROGRAM REGRESSION ANALYSIS RESULTS

Model: MODEL1
NOTE: Restrictions have been applied to parameter estimates.
NOTE: Restrictions on intercept. R-square is redefined.
Dependent Variable: THERMS

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 26 | 857879510.56 | 32995365.791 | 3970.779 | 0.0001 |
| Error | 25858 | 214868187.52 | 8309.5439525 | | |
| U Total | 25884 | 1072747698.1 | | | |

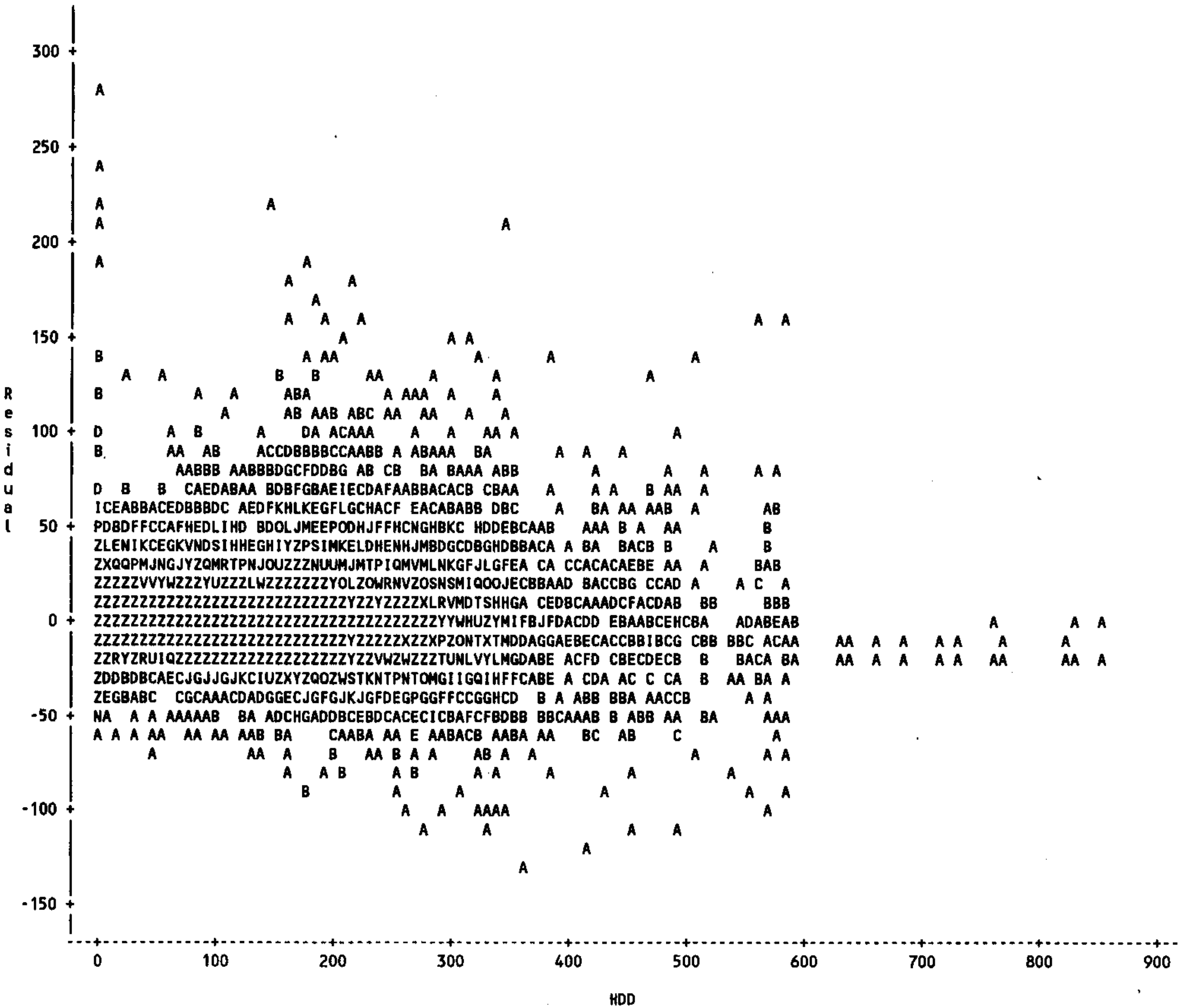
| | | | |
|---|---|---|---|
| Root MSE | 91.15670 | R-square | 0.7997 |
| Dep Mean | 32.37531 | Adj R-sq | 0.7995 |
| C.V. | 281.56239 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| INTERCEP | 1 | -1.33227E-15 | 0.00000000 | . | . |
| CONWH | 1 | 0.081120 | 0.03209527 | 2.527 | 0.0115 |
| WAT_O | 1 | 0.025217 | 0.00446797 | 5.644 | 0.0001 |
| GWAT | 1 | 0.145633 | 0.00514806 | 28.289 | 0.0001 |
| COOK | 1 | 1.654087 | 0.22207167 | 7.448 | 0.0001 |
| HEATOC | 1 | 13.492206 | 0.36334138 | 37.134 | 0.0001 |
| HEATOCS | 1 | -2.675415 | 0.31826407 | -8.406 | 0.0001 |
| HEATE | 1 | 0.000013814 | 0.00000281 | 4.913 | 0.0001 |
| CONWH2 | 1 | -0.016302 | 0.00462455 | -3.525 | 0.0004 |
| GWATMF | 1 | -0.036890 | 0.00407257 | -9.058 | 0.0001 |
| WATT | 1 | -0.006061 | 0.00236094 | -2.567 | 0.0103 |
| HEATT | 1 | -0.000000102 | 0.00000122 | -0.083 | 0.9336 |
| COOKHT | 1 | 0.039966 | 0.00395428 | 10.107 | 0.0001 |
| COOKHTA | 1 | 0.021830 | 0.00693669 | 3.147 | 0.0017 |
| HEAT1C | 1 | 0.000101 | 0.00000286 | 35.327 | 0.0001 |
| HEAT1A | 1 | 0.000106 | 0.00000566 | 18.813 | 0.0001 |
| HEAT1B | 1 | 0.000109 | 0.00000425 | 25.645 | 0.0001 |
| HEAT1Q | 1 | 0.000122 | 0.00000318 | 38.305 | 0.0001 |
| HEAT1AF | 1 | 0.000143 | 0.00000875 | 16.338 | 0.0001 |
| HEAT1BF | 1 | 0.000110 | 0.00000678 | 16.222 | 0.0001 |
| HEAT1_O | 1 | 0.000038847 | 0.00000207 | 18.772 | 0.0001 |
| HEAT1_P | 1 | -0.000021129 | 0.00000232 | -9.113 | 0.0001 |
| HEAT_C | 1 | -0.000058504 | 0.00000791 | -7.395 | 0.0001 |
| HEAT1_M | 1 | -0.000059365 | 0.00000318 | -18.645 | 0.0001 |
| DRY | 1 | 0.497459 | 0.02030389 | 24.501 | 0.0001 |
| POOLSPA | 1 | 36.498930 | 1.44743556 | 25.216 | 0.0001 |
| POOLCDD | 1 | 0.003288 | 0.00037726 | 8.717 | 0.0001 |
| RESTRICT | -1 | 472914 | 20222.506587 | 23.386 | 0.0001 |

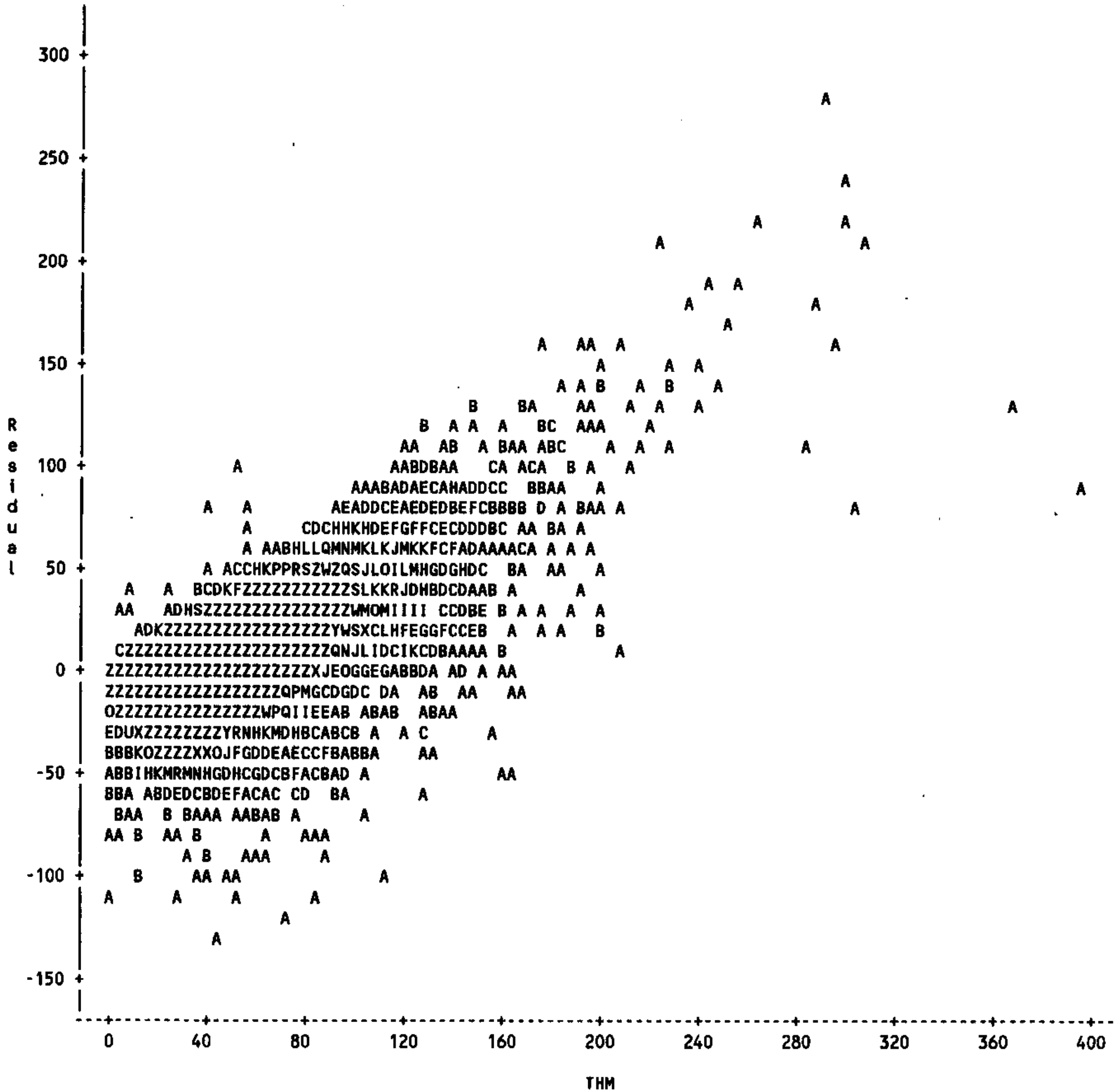
| | |
|---|---|
| Durbin-Watson D | 0.427 |
| (For Number of Obs.) | 25884 |
| 1st Order Autocorrelation | 0.786 |

Plot of RESID*HDD. Legend: A = 1 obs, B = 2 obs, etc.



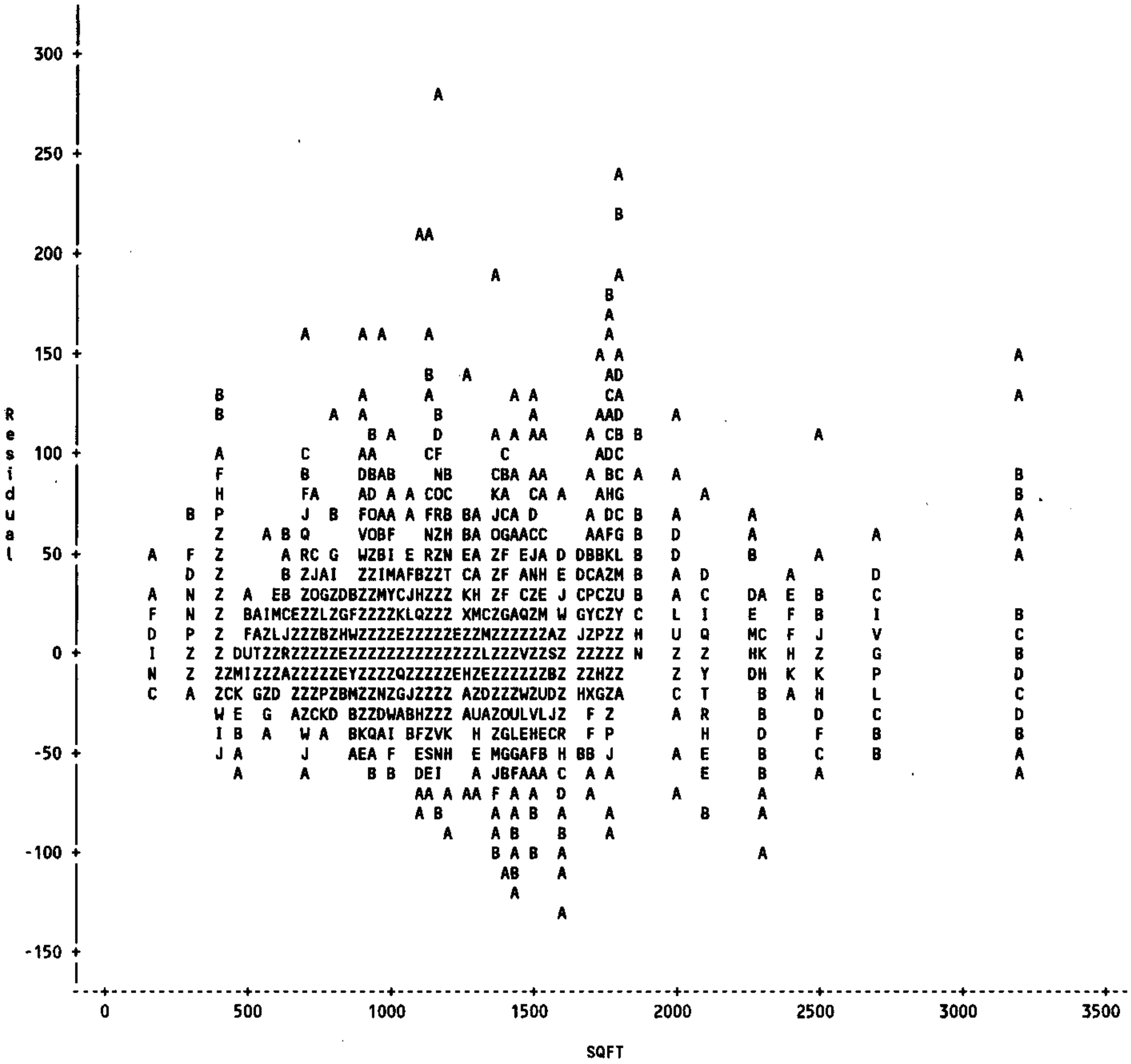

NOTE: 16784 obs hidden.

Plot of RESID*THM. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 20150 obs hidden.

Plot of RESID*SQFT. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 18602 obs hidden.

| RHO1 | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| . | 5 | 0.7 | 5 | 0.7 |
| 0 | 3 | 0.4 | 8 | 1.2 |
| 0.1 | 4 | 0.6 | 12 | 1.7 |
| 0.2 | 9 | 1.3 | 21 | 3.1 |
| 0.3 | 21 | 3.1 | 42 | 6.1 |
| 0.4 | 25 | 3.6 | 67 | 9.8 |
| 0.5 | 45 | 6.6 | 112 | 16.3 |
| 0.6 | 65 | 9.5 | 177 | 25.8 |
| 0.7 | 105 | 15.3 | 282 | 41.1 |
| 0.8 | 170 | 24.8 | 452 | 65.9 |
| 0.9 | 191 | 27.8 | 643 | 93.7 |
| 1 | 43 | 6.3 | 686 | 100.0 |

Analysis Variable : RHO

| N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| 681 | 0.7425823 | 0.1902047 | 0.0131629 | 0.9925015 |

Model: MODEL1
NOTE: Restrictions have been applied to parameter estimates.
NOTE: Restrictions on intercept. R-square is redefined.
Dependent Variable: DTHM

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 26 | 131862557.03 | 5071636.8088 | 1903.969 | 0.0001 |
| Error | 24983 | 66547675.585 | 2663.7183519 | | |
| U Total | 25009 | 198410232.61 | | | |

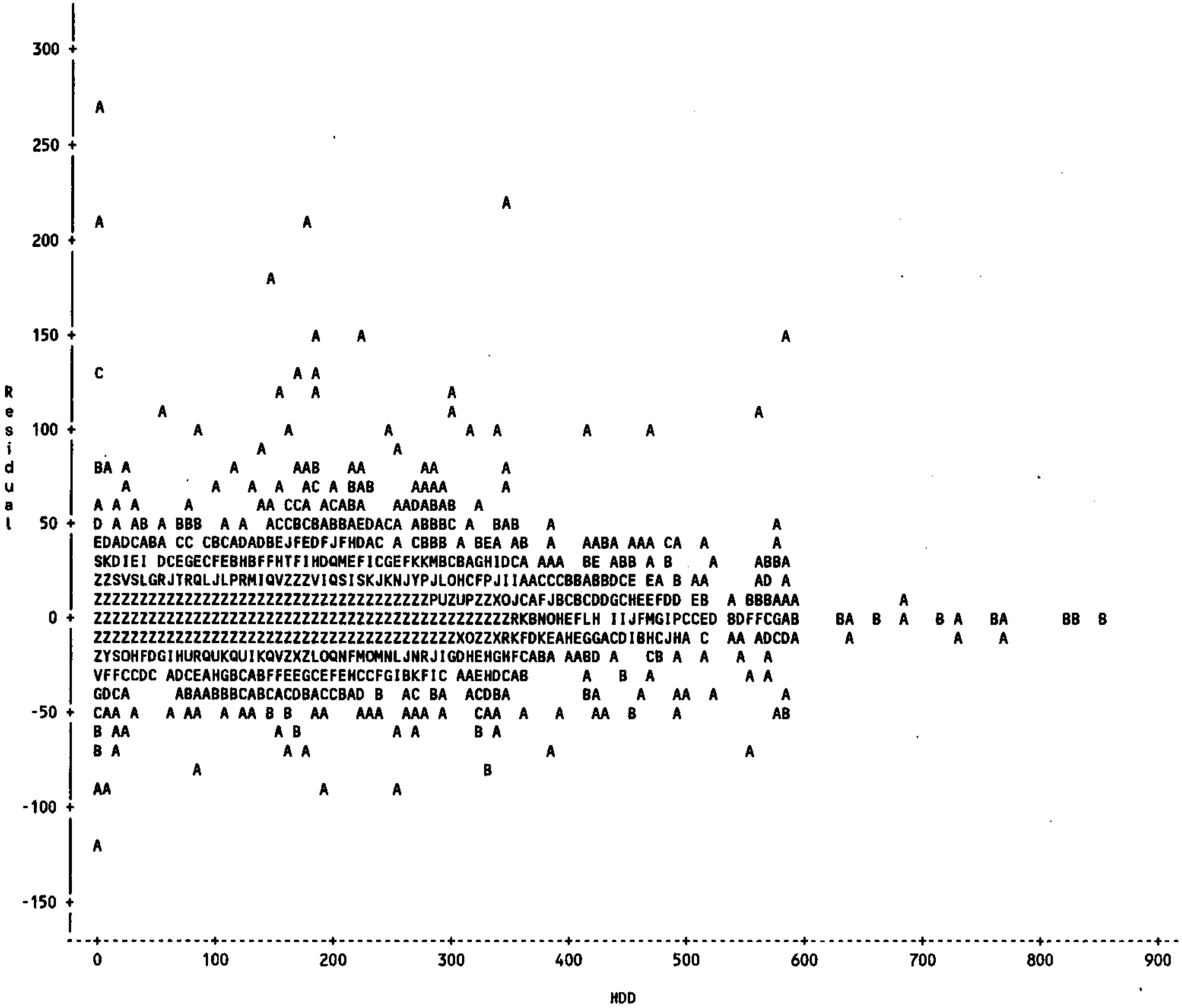
| | | | |
|---|---|---|---|
| Root MSE | 51.61122 | R-square | 0.6646 |
| Dep Mean | 8.60574 | Adj R-sq | 0.6642 |
| C.V. | 599.72995 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| INTERCEP | 1 | -8.32667E-17 | 0.00000000 | . | . |
| DWAT_O | 1 | -0.005384 | 0.00704776 | -0.764 | 0.4449 |
| DHEATE | 1 | 0.000009891 | 0.00000254 | 3.899 | 0.0001 |
| DCONWH2 | 1 | -0.033220 | 0.00628263 | -5.288 | 0.0001 |
| DHEAT1P | 1 | -0.000017689 | 0.00000247 | -7.173 | 0.0001 |
| DHEAT1O | 1 | 0.000049859 | 0.00000196 | 25.412 | 0.0001 |
| DCOOKHT | 1 | 0.025262 | 0.00393499 | 6.420 | 0.0001 |
| DCOOKHTA | 1 | 0.008920 | 0.00648055 | 1.376 | 0.1687 |
| DHEATOC | 1 | 13.514831 | 0.49240546 | 27.447 | 0.0001 |
| DHEATOCS | 1 | -0.973782 | 0.19363901 | -5.029 | 0.0001 |
| DGWATMF | 1 | -0.042211 | 0.00674200 | -6.261 | 0.0001 |
| DGWATT | 1 | -0.004509 | 0.00288683 | -1.562 | 0.1184 |
| DHEATT | 1 | -0.000000470 | 0.00000092 | -0.510 | 0.6102 |
| DHEAT1A | 1 | 0.000097091 | 0.00000497 | 19.543 | 0.0001 |
| DHEAT1B | 1 | 0.000098956 | 0.00000391 | 25.336 | 0.0001 |
| DHEAT1Q | 1 | 0.000111 | 0.00000279 | 39.931 | 0.0001 |
| DHEAT1C | 1 | 0.000095304 | 0.00000255 | 37.379 | 0.0001 |
| DHEAT1MF | 1 | -0.000045499 | 0.00000297 | -15.296 | 0.0001 |
| DHEAT_C | 1 | -0.000044919 | 0.00000772 | -5.818 | 0.0001 |
| DHEAT1AF | 1 | 0.000119 | 0.00000798 | 14.934 | 0.0001 |
| DHEAT1BF | 1 | 0.000100 | 0.00000629 | 15.928 | 0.0001 |
| DGWAT | 1 | 0.165061 | 0.00823882 | 20.035 | 0.0001 |
| DCONWH | 1 | 0.052911 | 0.04304313 | 1.229 | 0.2190 |
| DCOOK | 1 | 0.434052 | 0.40683184 | 1.067 | 0.2860 |
| DDRY | 1 | 0.735534 | 0.03970891 | 18.523 | 0.0001 |
| DPOOLSPA | 1 | 45.485291 | 2.63065821 | 17.290 | 0.0001 |
| DPOOLCDD | 1 | 0.003854 | 0.00034321 | 11.229 | 0.0001 |
| RESTRICT | -1 | 71483 | 25244.258341 | 2.832 | 0.0046 |

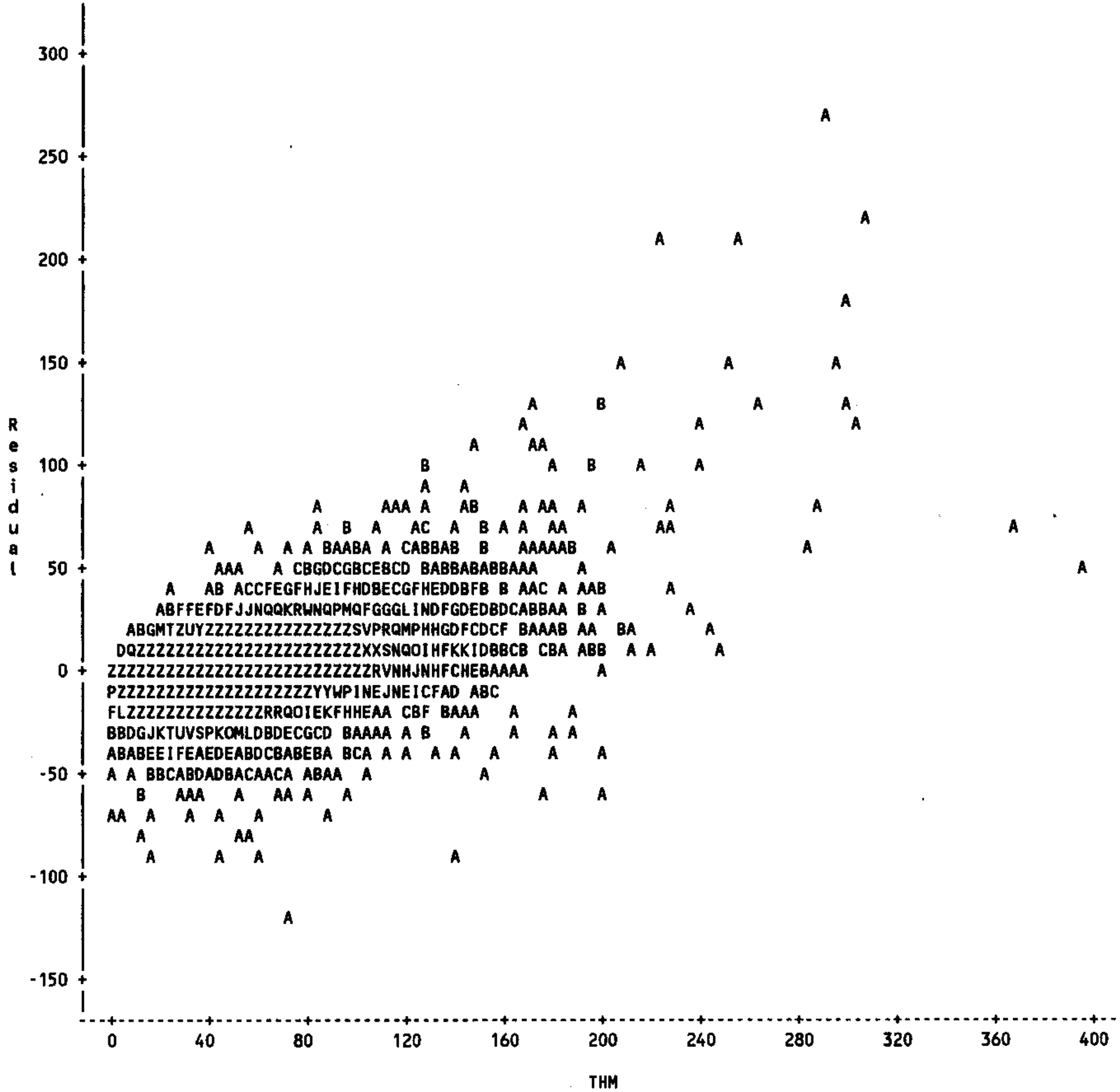
| | |
|---|---|
| Durbin-Watson D | 1.820 |
| (For Number of Obs.) | 25009 |
| 1st Order Autocorrelation | 0.090 |

Plot of RESID*HDD. Legend: A = 1 obs, B = 2 obs, etc.



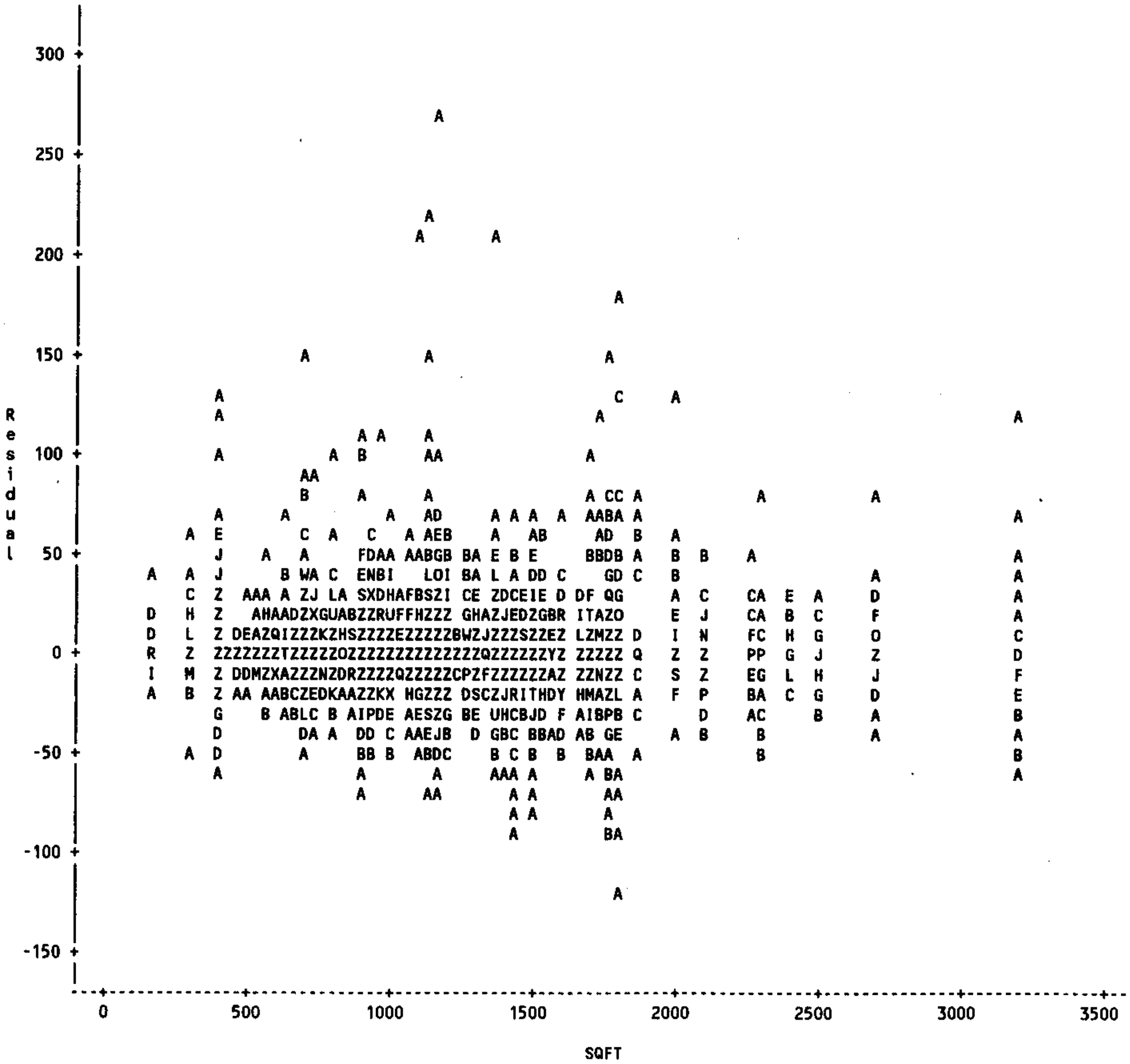

NOTE: 189 obs had missing values. 18540 obs hidden.

Plot of RESID*THM. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 189 obs had missing values. 20405 obs hidden.

Plot of RESID*SQFT. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 189 obs had missing values. 19823 obs hidden.

Model: MODEL1
Dependent Variable: RES

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 9 | 5273951187.4 | 585994576.37 | 36.164 | 0.0001 |
| Error | 24999 | 405080695891 | 16203875.991 | | |
| C Total | 25008 | 410354647078 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 4025.40383 | R-square | 0.0129 |
| Dep Mean | 111.16825 | Adj R-sq | 0.0125 |
| C.V. | 3621.00149 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| INTERCEP | 1 | 48.348597 | 11.38425541 | 4.247 | 0.0001 |
| IP | 1 | 0.300164 | 0.04308181 | 6.967 | 0.0001 |
| WIN | 1 | 133.840887 | 14.88598808 | 8.991 | 0.0001 |
| SPR | 1 | 82.974751 | 14.57215208 | 5.694 | 0.0001 |
| WINP | 1 | 0.060075 | 0.06172362 | 0.973 | 0.3304 |
| WINI | 1 | -0.000325 | 0.00019891 | -1.635 | 0.1020 |
| SPRP | 1 | -0.332414 | 0.06107335 | -5.443 | 0.0001 |
| SPRI | 1 | 0.000204 | 0.00019569 | 1.043 | 0.2970 |
| PART | 1 | -0.124057 | 0.09223871 | -1.345 | 0.1786 |
| F_PART | 1 | -75.842362 | 12.50745347 | -6.064 | 0.0001 |

Model: MODEL1
NOTE: Restrictions have been applied to parameter estimates.
NOTE: Restrictions on intercept. R-square is redefined.
Dependent Variable: DTHM

Analysis of Variance

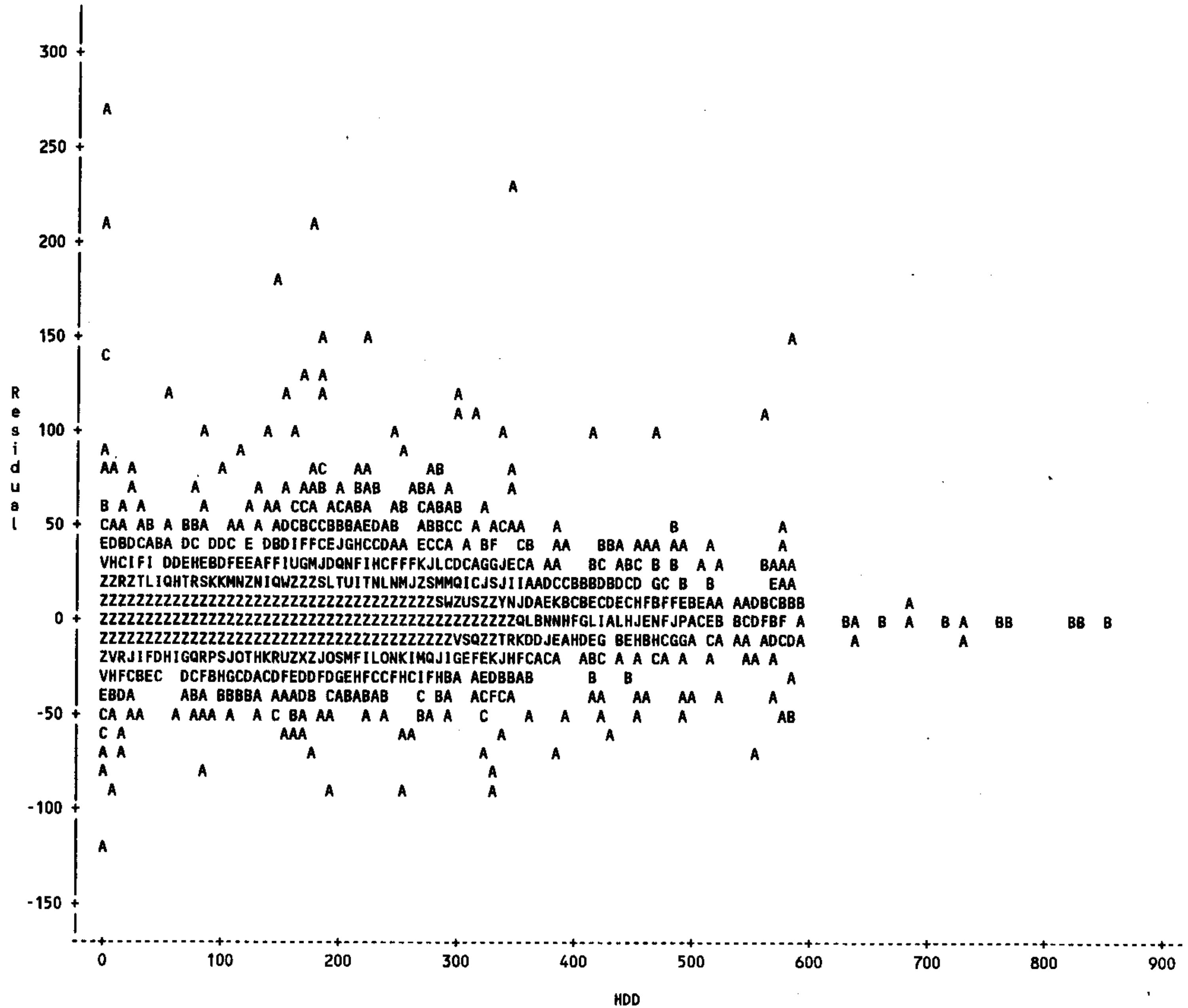
| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 26 | 962588.23124 | 37022.62428 | 1682.119 | 0.0001 |
| Error | 24983 | 549863.76462 | 22.00952 | | |
| U Total | 25009 | 1512451.9959 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 4.69143 | R-square | 0.6364 |
| Dep Mean | 5.70952 | Adj R-sq | 0.6361 |
| C.V. | 82.16859 | | |

Parameter Estimates

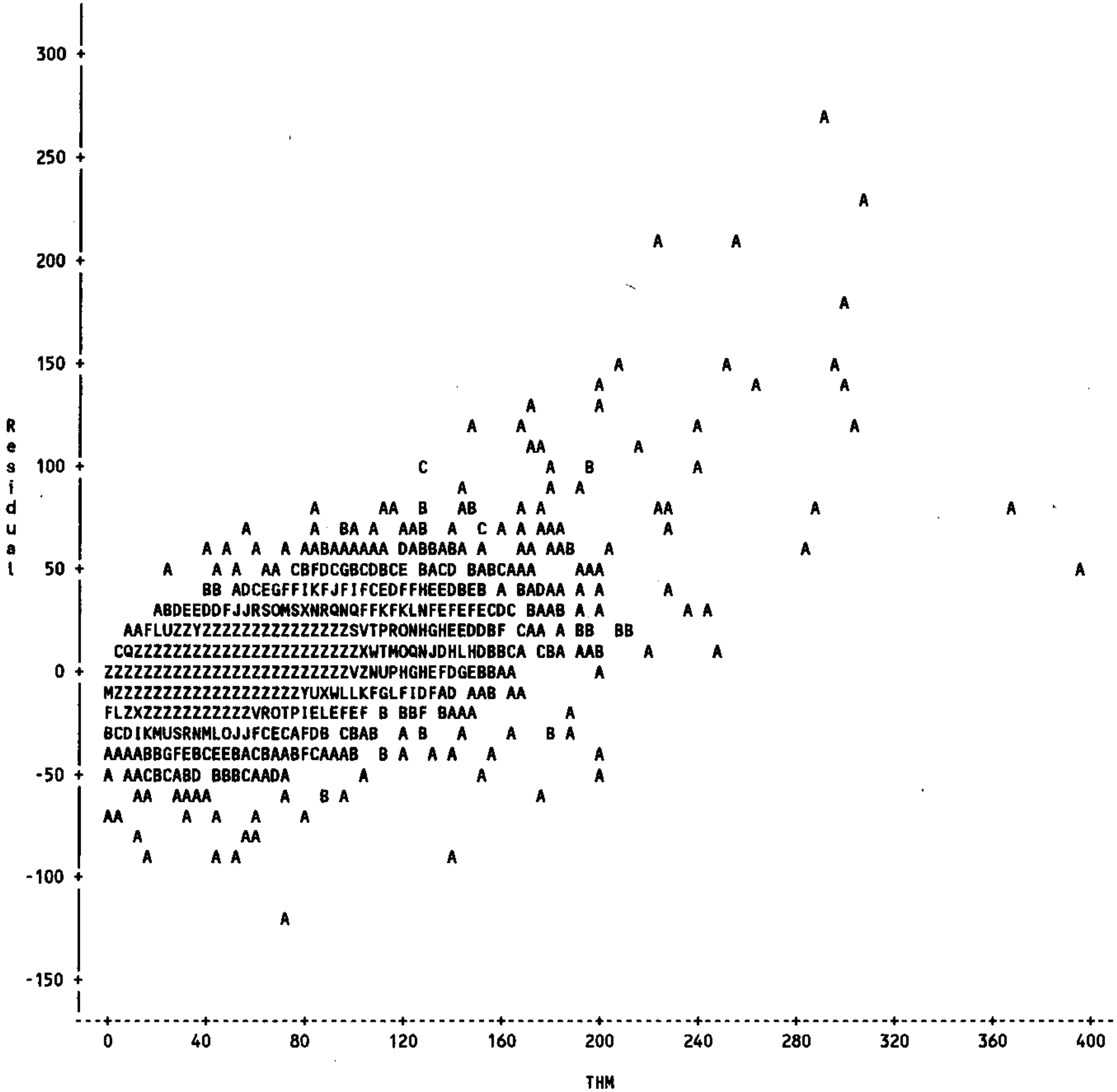
| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| INTERCEP | 1 | 9.714451E-17 | 0.00000000 | . | . |
| DWAT_O | 1 | 0.006653 | 0.00559819 | 1.188 | 0.2347 |
| DHEATE | 1 | 0.000004619 | 0.00000273 | 1.692 | 0.0907 |
| DCONWH2 | 1 | -0.001312 | 0.00469426 | -0.279 | 0.7799 |
| DHEAT1P | 1 | -0.000016070 | 0.00000282 | -5.695 | 0.0001 |
| DHEAT1O | 1 | 0.000046841 | 0.00000209 | 22.451 | 0.0001 |
| DHEATOC | 1 | 8.031182 | 0.29745718 | 26.999 | 0.0001 |
| DHEATOCS | 1 | -1.015214 | 0.15811618 | -6.421 | 0.0001 |
| DCOOKHT | 1 | 0.026489 | 0.00413003 | 6.414 | 0.0001 |
| DCOOKHTA | 1 | 0.020353 | 0.00626577 | 3.248 | 0.0012 |
| DGWATMF | 1 | -0.061238 | 0.00442499 | -13.839 | 0.0001 |
| DGWATT | 1 | -0.004178 | 0.00234349 | -1.783 | 0.0746 |
| DHEATT | 1 | -0.000000620 | 0.00000097 | -0.639 | 0.5227 |
| DHEAT1A | 1 | 0.000091763 | 0.00000608 | 15.085 | 0.0001 |
| DHEAT1B | 1 | 0.000096063 | 0.00000485 | 19.789 | 0.0001 |
| DHEAT1Q | 1 | 0.000102 | 0.00000323 | 31.665 | 0.0001 |
| DHEAT1C | 1 | 0.000095293 | 0.00000286 | 33.262 | 0.0001 |
| DHEAT1MF | 1 | -0.000033272 | 0.00000293 | -11.367 | 0.0001 |
| DHEAT_C | 1 | -0.000053146 | 0.00000856 | -6.207 | 0.0001 |
| DHEAT1AF | 1 | 0.000109 | 0.00000983 | 11.073 | 0.0001 |
| DHEAT1BF | 1 | 0.000094802 | 0.00000804 | 11.792 | 0.0001 |
| DGWAT | 1 | 0.215639 | 0.00582417 | 37.025 | 0.0001 |
| DCONWH | 1 | -0.125260 | 0.03192961 | -3.923 | 0.0001 |
| DCOOK | 1 | 1.951097 | 0.26304266 | 7.417 | 0.0001 |
| DDRY | 1 | 0.680638 | 0.03258792 | 20.886 | 0.0001 |
| DPOOLSPA | 1 | 27.766310 | 2.06504906 | 13.446 | 0.0001 |
| DPOOLCDD | 1 | 0.005904 | 0.00035780 | 16.501 | 0.0001 |
| RESTRICT | -1 | 581.848688 | 292.67858928 | 1.988 | 0.0468 |

Plot of RESID*HDD. Legend: A = 1 obs, B = 2 obs, etc.



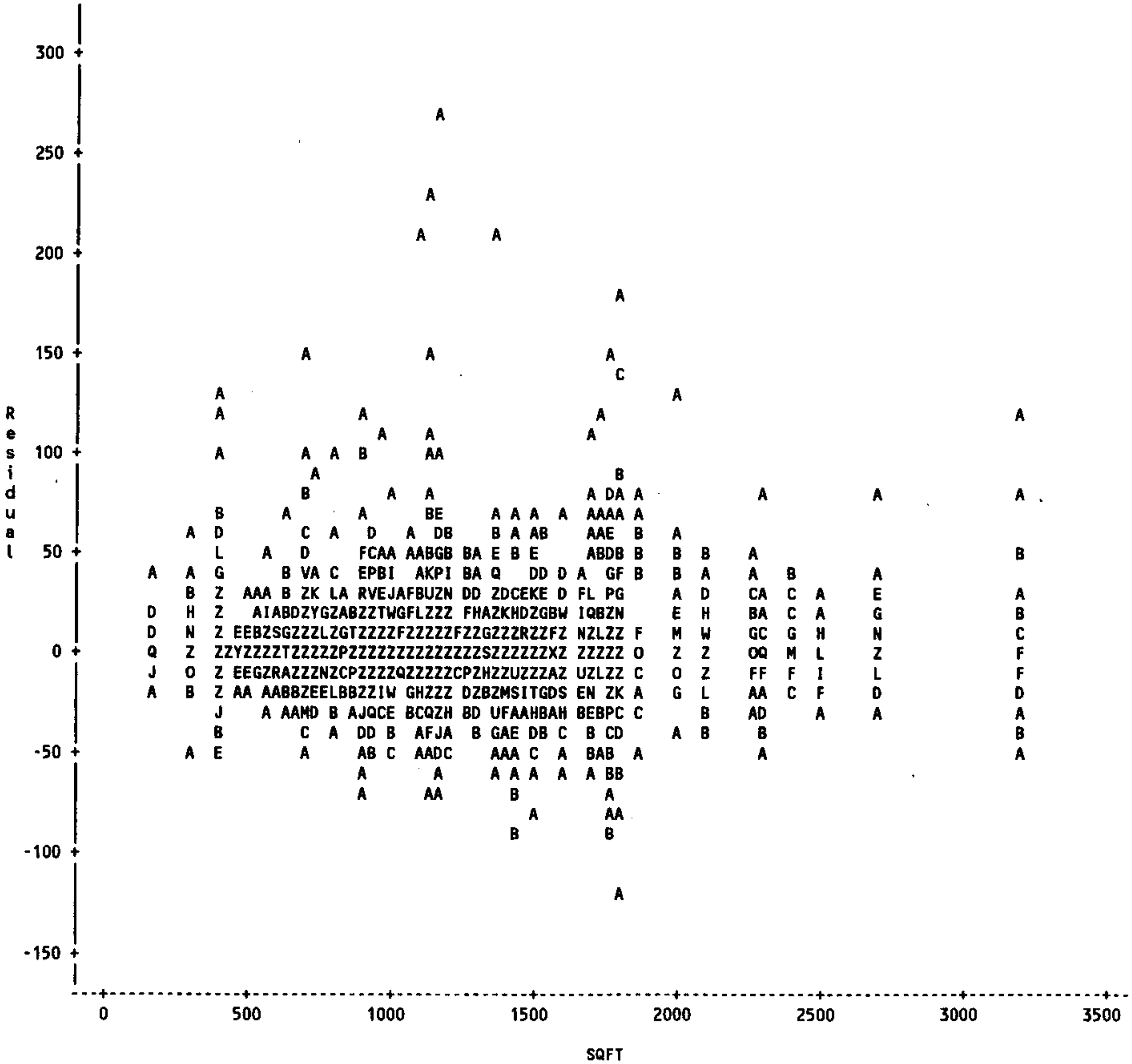

NOTE: 189 obs had missing values. 18518 obs hidden.

Plot of RESID*THM. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 189 obs had missing values. 20442 obs hidden.

Plot of RESID*SQFT. Legend: A = 1 obs, B = 2 obs, etc.




NOTE: 189 obs had missing values. 19795 obs hidden.