NBSIR 80-1994

# Household Appliance Usage Data

Center for Consumer Product Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

Department of Energy
Washington, DC 20585

NBSIR 80-1994

# HOUSEHOLD APPLIANCE USAGE DATA

Alan D. Davies
Rudolph V. Kelly
Alvin C. Lewis
Colonel D. Lovett
Theodore J. Wang

Center for Consumer Product Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

February 1980

Final Report
Issued March 1980

Prepared for
The Department of Energy
Washington, DC 20545

# HOUSEHOLD APPLIANCE USAGE DATA

Alan D. Davies
Rudolph V. Kelly
Colonel D. Lovett
Theodore J. Wang

The Energy Policy and Conservation Act (EPCA) requires the development of test procedures for the measurement of the energy efficiencies and the computation of Estimated Annual Operating Costs (EAOC's) of consumer products covered by the EPCA. These products are refrigerators, refrigerator-freezers, dishwashers, clothes dryers, water heaters, room air conditioners, home heating equipment, television sets, kitchen ranges and ovens, clothes washers, humidifiers, dehumidifiers, central air conditioners and furnaces.

Each test procedure contains one or more factors that are determined by the consumer's usage conditions and include such items as uses per year, outdoor and indoor environment, household operating practices and ground water temperature. This report is a compilation of the sources and background for the consumer usage factors contained in the current test procedures. Uncertainties in these factors are discussed, and for selected base cases, the corresponding uncertainties in EAOC's are computed.

The purpose of the report is to provide perspective in selecting usage factors for future study and refinement. The items found to be most in need of refinement were factors bearing on temperature and humidity control and on water heating, both on national and regional bases.

Key words: Appliances; conservation; costs; energy; EPCA; residential; usage.

## I. Introduction

The Energy Policy and Convervation Act, December 22, 1975, or EPCA (PL 94-163) calls for the preparation of standard test procedures by which Estimated Annual Operating Costs (EAOC's) may be calculated for 13 major types of household consumer products. Each test procedure includes one or more factors that affect the EAOC's for that product type and that are determined by consumer choices or usage conditions, as opposed to product features determined by the manufacturer or unit costs of energy determined by other parties. These usage factors include such items as uses per year, climate parameters determined by the consumer's area of residence, indoor temperature and humidity control practices and the like. The product types and the corresponding appendices in this report are:

1. Refrigerators and Refrigerator-Freezers (Appendix A)
2. Freezers (Appendix B)
3. Dishwashers (Appendix C)
4. Clothes Dryers (Appendix D)
5. Water Heaters (Appendix E)
6. Room Air Conditioners (Appendix F)
7. Home Heating Equipment (Appendix G)
8. Television (Appendix H)
9. Kitchen Ranges and Ovens (Appendix I)
10. Clothes Washers (Appendix J)
11. Humidifiers (Appendix K), Dehumidifiers (Appendix L)
12. Central Air Conditioners (Appendix M)
13. Furnaces (Appendix N)

Appendix O contains some usage factor data related to income level and Appendix P combines the references and a bibliography.

This report is a minor revision of a 1978 report prepared by the National Bureau of Standards (NBS) for the Department of Energy (DOE) and is presented in this form to permit wider accessibility to industry and others. It covers usage factors and energy costs employed in the final test procedures in effect as of mid-August 1978. Test procedures and related materials are published in the Federal Register and are available from DOE. DOE has since issued proposed and final test procedures for central air conditioners, including heat pumps [184, 186] and revised representative average unit costs of energy [185].* 1977 energy costs are used in this report.

The DOE assignment to NBS was to:

> "Assemble and review usage data for the various covered products and recommend, where appropriate, changes to the usage factors defined by the DOE test procedures.... This task includes analysis of regional usage factors for products 6, 7, 11, 12 and heat pumps."

The work was done in support of DOE's continuing responsibility to review and improve the test procedures, of which consumer usage factors are integral parts. Objectives were to present a collected record of the background, sources, strengths and weaknesses of the factors then in use and to contribute to planning for test procedure improvements. The emphasis was on bringing out the effects of uncertainties in usage factors on uncertainties in the associated EAOC's.

The structure of the Estimated Annual Operating Cost (EAOC) calculation in the test procedure requires a statement of "the energy which is likely to be consumed annually in representative use of a consumer product" (Energy Policy and Conservation Act, Sec. 321(a)(7)). The function of such statements is to provide a standardized basis for comparing competing products and does not imply that all, or even most consumers, will experience the stated energy usage.

## II. Technical Approach

The general procedure followed for each product type was to:

1. Review the existing final test procedure for factors and considerations affecting the EAOC that are dependent on how the consumer uses the product. These factors are somewhat arbitrarily called primary or secondary usage factors, depending on their role in the prescribed EAOC calculation and on their general importance.

---

*1979 values include 4.97¢ per kWh, 36.7¢ per therm (100 000 Btu) of natural gas, 62.0¢ per gallon of number 2 heating oil and 54.5¢ per gallon of propane. 1977 values [83] include 3.8¢ per kWh and 20.7¢ per therm of natural gas.

2. Describe the background and source for the factor currently appearing in the test procedure, and where possible estimate the uncertainty in the numerical value of the factor.

3. Present data from other sources that either directly or indirectly might have provided a basis for estimating the factor.

4. Estimate the impact of the factor uncertainty on the EAOC.

Base case assumptions and EAOC's were used solely as aids in studying relative effects of usage factor uncertainties and should not be considered "typical" or national average values. Only one or two base cases were evaluated for each product type even though each type includes many variations that could be examined. No weighting by annual production or by existing inventory was attempted.

## III. Discussion

Usage factor values are much easier to criticize than to generate and defend. The general approach has been to use the value judged to be the best available at the time a commitment was required. Usage factors are subject to review and change in the same way as other parts of test procedures.

The ideal factor would be a national (or regional) average value among all potential buyers of a given product for the lifetime of the product after purchase. The corresponding factor for products already in use is not necessarily the same for several reasons. Estimating future usage practices presents obvious risks. Future buyers may differ from past buyers in objectives for the product, method of operating the home, family size, region of the country or other characteristics bearing on the factor.

The usage factors in the test procedures come from several sources, each with its own strengths and weaknesses. The broad categories of source are field survey data, analysis, and professional judgment or assumption. Some factor estimates involve a combination of these categories to arrive at their basic values. These preliminary values are reviewed for reasonableness and consistency with other factors and assumptions. Frequently some dimensional conversions, adjustments and rounding are needed to meet the needs of the test procedure.

Field Survey Data:

Field measurement survey data were the preferred basis for factor estimation. Most data of this kind were gathered by industry, professional consultants and other nongovernmental groups prior to the existence of EPCA or its test procedures. In only a few cases are these data provided even in the same terms or dimensions as needed in the test procedures, and without exception some major inferences or assumptions are necessary to obtain the needed factor. In many cases the alternative was to have no data at all. Date or period of the survey, method of sample selection, sample size, method of measurement, data on statistical distributions, weather, relevant house characteristics, household size, conversion to the general population and method of data reduction are usually missing. Many field surveys deal with energy input to a product, whereas the usage factors in the test procedures are in terms of output service to the consumer. Input and output are related by product efficiency, making the usage factor accuracy dependent on both the test method for measuring efficiency and the efficiencies of the particular products in the survey at the time of the survey. Data of this kind are also uniformly missing. Surveys covering less than a whole year may miss seasonal effects. Some factors are based on four-person households, whereas average household sizes were 3.38 in 1960 and 2.94 in 1976 [155]. Average household sizes for purchasers may be different from those of current owners of products, may vary by product and probably differ from overall national averages. Surveys based on questionnaires are suspect for many reasons. Responses are often subjective, require recall over extended periods and sometimes even depend on reactions to the interviewer and the phrasing and sequence of the questions. Weather and economic conditions during the period of a survey may not be representative and may bias the results.

Analytical Estimates:

Several important usage factors are based mainly on analytical procedures combined with official weather data, and professional estimates, recommendations or assumptions for other factors needed in the analysis. Considerable judgment is also exercised in selecting the degree of detail for the analyses. Where weighted averages are required, the available data may be inadequate to isolate buyers or current owners from the general population or may be given in groupings that are incompatible with the factor being examined. (For example, populations and sales are usually based on states or groups of states whereas weather data do not follow regional boundaries of this kind.) The major strength of analytical methods is that the analyst can insure equality of treatment within the boundaries of the data and assumptions.

Judgments and Assumptions:

These bases for a usage factor are the least satisfactory of all and are a last resort. They are reserved for those factors known to have minor effects on the EAOC or for cases where a better estimate is impractical to obtain because of time, cost or other constraints. For example, furnace and air conditioner sizing factors are not really known from systematic field studies. Such determinations would require considerable time-consuming field work. (Sizing factors are ratios of actual equipment capacity to the actual design requirements.)

## IV. Results

The principal results are given in Table 1. The numbering system for the product types follows the sequence given in the EPCA. The appendices are in the same order. The nominal EAOC's are those used in the appendices and are solely for analytical convenience. They are not necessarily typical, nor are all fuel types, output capacities or combinations of features treated. For example, only one configuration of clothes washer water temperature controls is treated.

The usage factors (UF's) are identified and the values used in the test procedures or assumed to apply to field use are given. The error propagation factors were derived from analyses of the EAOC formulas and relationships defined within the test procedures. In some cases it was necessary to further specify the characteristics of the base case model in order to evaluate an error propagation factor. These factors can be considered as partial derivatives of a percentage change in EAOC with respect to a percentage change in the usage factor, evaluated under base case conditions.

Data were available in some cases to permit the estimation of the standard deviations of the samples and the sample means of the field survey data. In most cases these standard deviations refer to metered input data, not to outputs to the consumer. Efficiencies of the individual units involved and other data on operating conditions would

Table 1. Effects of Usage Factor (UF) Uncertainties on Estimated Annual Operating Cost, EAOC

Error Propagation Factor = ($\Delta$EAOC/EAOC) (UF/$\Delta$UF) unless stated otherwise.
NA = not found or estimated.
Estimated $\Delta$UF = one standard deviation unless stated otherwise.
See appendices for descriptions of entries.

Estimated $\Delta$UF's are derived from survey statistics.
Assumed $\Delta$UF's are used simply as a basis to indicate sensitivity.
$\Delta$EAOC = nominal EAOC x Error Propagation Factor x $\Delta$UF or computed directly. A positive $\Delta$UF leads to a positive $\Delta$EAOC except as noted.

| Product Type | Usage Factor, UF | Test Procedure UF Value | Nominal EAOC, $/yr | x Error Propagation Factor | x Estimated (E) or Assumed (A) $\Delta$UF | = $\Delta$EAOC | Remarks |
|---|---|---|---|---|---|---|---|
| 1. Refrigerators, | Test result correction | 1.0 | $ 22 | 1.0 | 0.030 (E) | $0.67 | |
| Refrigerator/Freezers | factor | 1.0 | $ 78 | 1.0 | 0.0042 (E) | $0.33 | |
| 2. Freezers | Test result correction | | | | | | |
| Upright | factor | 0.85 | $ 57 | 1.0 | 0.006 (E) | $0.33 | |
| Chest | | 0.7 | $ 39 | 1.0 | 0.020 (E) | $0.78 | |
| 3. Dishwashers | Loads per year | 416 | $ 24 | 1.0 | 4.16 loads per yr | $0.24 | Normal cycle only |
| | | | $ 22 | | | $0.22 | 50 percent use of truncated cycle. |
| | Truncated cycle use | 50 percent | $ 23 | NA | 1 percent (A) | $0.03 | |
| 4. Clothes Dryers | Loads per year | 416 | $ 41 | 1.0 | 25 per yr (E) | $2.48 | |
| | Load size | 7 lb | | NA | 1 lb per load (A) | $5.20 | |
| | Initial moisture content | 70 percent | | NA | 10 percent (A) | $6.24 | |
| | Ending moisture content | 4 percent | | NA | 2 percent (A) | $2.29 | |
| | Field use factor | 1.18 | | 1.0 | 0.1 (A) | $3.49 | |
| 5. Water Heaters | Gallons used | 64.3 per day | $ 87 | NA | 1 gal per day (A) | $0.83 | gas water heater assumed. |
| | Output temperature | 145 F | | NA | 1°F (A) | $0.94 | |
| | Input temperature | 55 F | | NA | 1°F (A) | -$0.59 | |
| | Room temperature | 55 F | | NA | 15°F (A) | -$5.25 | If changed to 70 F. |

Table 1. Effects of Usage Factor (UF) Uncertainties on Estimated Annual Operating Cost, EAOC (continued)

| Product Type | Usage Factor, UF | Test Procedure UF Value | Nominal EAOC, $/yr | x Error Propagation Factor | x Estimated (E) or Assumed (A) ΔUF | = ΔEAOC | Remarks |
|---|---|---|---|---|---|---|---|
| 6. Room Air Conditioners | Annual compressor hours | 750 | $ 48 | 1.0 | 7.5 hrs/yr (A) | $0.48 | |
| 7. Home Heating Equipment | | | | | | | |
| Unvented (Electric only) | Maximum rating | 1 hr | $0.08/hr | 1.0 | 0% (E) | 0 | Supplemental, 2000 W |
| | Heating load hours | 2080 hr/yr | $100 | 1.0 | 8 per year (E) | $0.38 | Primary, 2000 W |
| | Design heating requirement adjustment factor | 0.77 | $100 | one percent per percent of C | 0.0077 (A) | $1.00 | |
| | Sizing factor | 1.2 | $100 | NA | NA | NA | No effect for existing EAOC's. Major variable for absolute EAOC's. |
| Vented | See Furnaces (product type 13) for usage factor treatment. | | | | | | |
| 8. Television: | | | | | | | |
| Monochrome | Viewing hrs/yr | 2200 | $ 5 | 1.0 | 5% (E) | $0.23/yr | |
| Color | | | $ 17 | | | $0.84/yr | |
| 9. Kitchen Ranges & Ovens | | | | | | | |
| Electric | | | | | | | |
| Conventional Range | Cooking energy output, kWh/year | 324.83 | $ 27.36(1) | 1.0 | 0.048 (E) | $1.31/yr | (1) Cooking component only. Add self-cleaning component for total. |
| Conventional Cooking Top | " | 277.74 | | | | | |
| Conventional Oven | " | 47.09 | (1) | (2) | | | |
| Microwave Oven | " | 34.2 | $ 3.34 | 1.0 | 0.073 (E) | $0.24/yr | (2) Not calculated because method of trade-off among combined components is not established. |
| Microwave/ Conventional Range, K (oven) = 0.82, L (cooking top) = 0.85 | " | 319.8 | $ 26.21(1) (2) | 1.0 | 0.048 (E) | $1.26/yr | |
| Gas | Cooking energy output, Btu/year | 1 108 000 | $ 20.43 | 0.53 | 0.048 (A) | $0.52/yr | 46.3 therms/yr for pilot lights. |
| Oven Self-cleaning: | | | | | | | |
| Electric | Cycles per year | 11 | $ 1.34 | 1.0 | one cycle (A) | $0.12/yr | |
| Gas | Cycles per year | 7 | $ 0.41 | 1.0 | one cycle (A) | $0.07/yr | |

Table 1. Effects of Usage Factor (UF) Uncertainties on Estimated Annual Operating Cost, EAOC (continued)

| Product Type | Usage Factor, UF | Test Procedure UF Value | Nominal EAOC, $/yr | x Error Propagation Factor | x Estimated (E) or Assumed (A) ΔUF | = ΔEAOC | Remarks |
|---|---|---|---|---|---|---|---|
| 10. Clothes Washers | Loads per year | 416 | $ 62 | 1.0 | 10 cycles per year (E) | $1.31 | |
| | Fill factor, fraction of full loads | 0.72 | | NA | 0.07 (A) | $2.08 | |
| | Temperature use factor | See text | | NA | See App. I | $7.66 | |
| | Suds saver | | | NA | 0.02 (A) | $1.12 | |
| 11. Humidifiers<br>Room | Operating hours per year | 700 | $ 9 | 1.0 | 300 hours per year, bias (E) | $3.86 | Indoor conditions: 70 F, 30 percent relative humidity, 0.75 air changes per hour. |
| Central | Operating hours per year | 700 | $ 9 | 1.0 | 100 hours per year, bias (E) | $1.29 | |
| Dehumidifiers | Operating hours per year | 1300 | $ 20 | 1.0 | 13 hours per year (A) | $0.21 | Indoor conditions: 75 F, 55 percent relative humidity, properly mixed to demand. |
| 12. Central Air Conditioners | Annual compressor hours<br>Indoor temperature | 1000<br>78 F | $200 | 1.0 | 10 hours (1%) (A)<br>1°F (A) | $2.00<br>-$6.00 | |

Table 1. Effects of Usage Factor (UF) Uncertainties on Estimated Annual Operating Cost, EAOC (continued)

| Product Type | Usage Factor, UF | Test Procedure UF Value | Nominal EAOC, $/yr | x Error Propagation Factor | x Estimated (E) or Assumed (A) ΔUF | = ΔEAOC | Remarks |
|---|---|---|---|---|---|---|---|
| 13. Furnaces (and Vented Heaters) | Heating Load Hours, HLH | 2080 per yr | $307 | 0.94 | 8 per year (E) | $1.11 | |
| | Oversizing Factor, SF | 1.7 | $307 | NA | NA | NA | Minor variable for relative EAOC's. Major variable for absolute EAOC's. |
| | Design temperature difference | 60 F | $307 | 0.0157 per °F | 1°F (A) | -$4.81 | 65 F - 5 F = 60 F |
| | Adjustment Factor, C | 0.77 | $307 | 0.0072 per percent of C | 0.0077 (A) | $2.22 | One percent of C |
| | Indoor temperature | 70 F | $307 | NA | 1°F (A) | $9.99 | |
| | Pilot light hours | 8760 per yr | $ 18.13 | 1.0 | exact | 0 | |
| | Heating season average outdoor temperature | 42 F | NA | NA | NA | NA | |
| | Wasted pilot light energy | 4600 hrs | $ 9.52 | 1.0 | 100 hrs (A) | $0.21 | Assuming pilot light consumption = 1000 Btu per hour, $0.207 per therm. |

be needed in order to properly estimate standard deviations of outputs. In the absence of such information, standard deviations from the best available sources are assumed to apply to outputs.

Some entries in the ΔUF column are labeled (E), meaning that they were estimated from available data and calculated. Most of the E entries are standard deviations, but some indicate systematic differences between results from field data and values used in the test procedures. Two examples are the operating hours for room and central humidifiers. Other entries are labeled (A) to designate differences that were assumed for the purpose of indicating the sensitivity of EAOC to errors in these factors. The values that were assumed do not imply any knowledge by NBS of the real magnitude of uncertainties in these factors.

The ΔEAOC column contains estimates of the effects on EAOC of the information provided in the other columns. This column is the main output of the study and is intended to provide perspective in the selection of usage factors for more intense investigation. Each is subject to the assumptions and uncertainties described in the appendices and should be used with suitable restraint. Several of them could be in error by a factor of two or more and still not qualify for early attention.

## APPENDIX A. REFRIGERATORS, REFRIGERATOR-FREEZERS

1. References: 68, 74, 87, 123, 143

2. Test Procedures: Final [87] September 14, 1977
Proposed [74] April 27, 1977

3. Primary Usage Factor: 365 cycles per year
Field energy consumption per cycle = 1.00 x test energy consumption per cycle.
One cycle = 24 hours of operation.

3.1 Value:

The use of a dimensionless correction factor of 1.00 is implied in the test procedure. Estimated consumer energy use per cycle equals correction factor times energy use per cycle measured in test.

3.2 Basis

In the interests of economy and simplicity in testing, the laboratory test procedure is designed to avoid the need for door openings and food loadings. This is done using an elevated ambient temperature and leaving the door closed throughout the test. Then a correction factor is used to convert the laboratory test results to an estimated energy consumption rate under consumer use conditions. Use of the correction factor bypasses the need to consider individually the variety of consumer usage factors that may affect energy usage.

3.2.1 Description of Basis

Data comparing energy usage in laboratory tests with field metering results were obtained from several sources and aggregating 512 refrigerator-freezer units in all. Based on these data, the average correction factor for refrigerator-freezers was 1.02 and the average test energy consumption rate was 5.62 kWh per day. For refrigerators, based on 13 units, the average correction factor was 0.88 and the average energy consumption rate was 1.61 kWh per day. These correction factors were both rounded to 1.00 for test procedure purposes. The choice of the 365 cycles per year is based upon continuous operation of the unit.

3.2.2 Estimate of Uncertainty

The average per cycle energy consumption correction factor was obtained by dividing the average energy consumption value of actual home use by the consumption value of the laboratory test for each unit. This average ratio for refrigerator-freezers was 1.02 with a standard deviation the sample ratios of 0.0946 and a standard deviation of the sample mean ratio of 0.0042. For refrigerators the average ratio was 0.88 with a standard deviation of the sample ratios of 0.109 and a standard deviation of the mean sample ratio of 0.030.

3.3 Parallel Estimates

Additional field usage data were found, but did not include matching laboratory test data.

Midwest Research Institute (MRI) [123] metered 106 homes with refrigerator-freezers during August 1976 through July 1977. A summary of MRI's results follows:

| | Defrost Method | | | |
|---|---|---|---|---|
| | Frost Free | Automatic | Manual | Average |
| Daily Consumption, kWh | 6.070 | 4.234 | 3.478 | 4.56 |
| Number Metered | 68 | 16 | 22 | 106 |

The comparable result from the field tests mentioned earlier was 5.74 kWh per day. Other annual energy consumption estimates for refrigerators and refrigerator-freezers are given in the following table.

Unit Energy Consumption by Refrigerators and Refrigerator-Freezers, in kWh per Year.

| | [123] EEI[1] | [123] Merchandising Week[2] | [143] PG&E[3] | [123] 1976 Census[4] |
|---|---|---|---|---|
| Refrigerator | | | | |
| Regular | 728 | | | |
| Frostless | 1217 | | | |
| Refrigerator-Freezers | | 1228 | | |
| 10 to 15 $ft^3$ | | | | 700 |
| 16 to 18 $ft^3$ frostless | | | | 1795 |
| 20+ $ft^3$ frostless | | | 2700 | 1895 |
| 14 $ft^3$ | | | | |
| 14 $ft^3$ frostless | | | | |
| 12 $ft^3$ | | | 1000 | |
| 12 $ft^3$ frostless | | | 1600 | |
| 16 $ft^3$ | | | 1450 | |
| 16 $ft^3$ frostless | | | 2150 | |
| 20 $ft^3$ | | | 1950 | |

[1]Appliance energy use table, 1976 REA Handbook, data source: Electrical Energy Association, 90 Park Avenue, New York, New York 10015 (about 60 appliances listed with annual kilowatt-hour data). [Edison Electric Institute (EEI) succeeded the Electric Energy Association (EEA).]

[2]Tabbing Appliance Energy, Merchandising Week, 3, 1973.

[3]Pacific Gas and Electric Company (Marketing Research + Service Department, Load Research Studies and Estimates).

[4]Statistical Abstract of the United States, 1976, p. 552.

[5]Edison Electric Institute (EEI) [68] also provided annual energy consumption rates for refrigerator-freezers of 1500 kWh per year for a 12.5 cu. ft. manual defrost unit and 2250 kWh per year for a 17.5 cu. ft. automatic defrost unit.

4. Secondary Usage Factor

None.

5. Impact Assessment of Uncertainties

Base case assumptions and the corresponding impact assessments are contained in the following table:

| | Refrigerators | Refrigerator-Freezers |
|---|---|---|
| (A) Energy consumption rate, kWh per test cycle | 1.61 | 5.62 |
| (B) Energy cost, $ per kWh | 0.038 | 0.038 |
| (C) EAOC, $ per year | 22 (22.33) | 78 (77.95) |
| (D) Correction factor standard deviation of the mean | 0.030 | 0.0042 |
| (E) ΔEAOC, $ per year | $0.67 per year | $0.33 per year |

(C) = 365 x (A) x (B)
(E) = (C) x (D)

6. Comments

Further expenditures to refine these correction factors do not appear warranted.

## APPENDIX B. HOUSEHOLD FREEZERS

1. References: 74, 87, 123

2. Test Procedures: Final [87] September 14, 1977;
   Proposed [74] April 27, 1977

3. Primary Usage Factor: 365 cycles per year; Adjustment factors, $C_u$ and $C_c$, for upright and chest freezers are used to estimate field energy use per cycle, $E_F$, given energy consumption per cycle during test, $E_T$,

$$E_F = C_u \text{ (or } C_c) \times E_T.$$

### 3.1 Value:

Dimensionless correction factors are $C_c = 0.7$ for chest freezers and $C_u = 0.85$ for upright freezers.

### 3.2 Basis

In the interests of economy and simplicity in testing, the laboratory test procedure is designed to avoid the need for door openings and food loadings. This is done using an elevated ambient temperature and leaving the door closed throughout the test. Then a correction factor is used to convert the laboratory test result to an estimated energy consumption rate under consumer use conditions. Use of the correction factor bypasses the need to consider individually the variety of consumer usage factors that may effect energy usage.

#### 3.2.1 Description of Basis

Data comparing energy usage in laboratory tests with field metering results were obtained from several sources and aggregating 181 upright freezers and 63 chest freezers. The test procedure determines energy use for a "cycle" of 24 hours. Since estimated annual operating costs are required, the energy use for one cycle is multiplied by 365 to convert to annual energy use.

There are few details available on how or when the field surveys were conducted; limited information and dates indicate that most of the data were collected in 1974 by

AHAM members. The sizes of the upright freezers ranged from 11.6 cu. ft. to 21.1 cu. ft. and the average test energy consumption was 4.71 kWh per day. The sizes of the chest freezers ranged from 8.3 cu. ft. to 26 cu. ft. The average test energy consumption rate for chest freezers was 4.0 kWh per day. The majority of the units tested were manual defrost. After rounding the correction factors became 0.85 for upright freezers and 0.70 for chest freezers.

### 3.2.2 Estimate of Uncertainty

The energy consumption correction factors were obtained by dividing the energy consumption value of actual home use by the consumption value of the laboratory test for each unit. This average ratio for upright freezers equals 0.85 with a standard deviation of the sample equal to .075 and a standard deviation of the mean equal to .006. For chest freezers the average ratio equals 0.70 with a standard deviation of the sample equal to .156 and a standard deviation of the mean equal to 0.020.

## 3.3 Parallel Estimates

No usage data comparable to the ones currently used were located. This is mainly because any field usage data that are found do not have matching laboratory test data. Midwest Research Institute (MRI) [123] metered 60 homes with freezers during August 1976 through July 1977. A summary of the average daily consumption by model type and defrost method is as follows:

| | Defrost Method | | | |
|---|---|---|---|---|
| Model Type | Frost-Free | Automatic | Manual | Average |
| Upright | | | | |
| Daily consumption, kWh | 6.504 | 2.860 | 3.522 | 4.159 |
| Number metered | 9 | 4 | 25 | 38 |
| Chest | | | | |
| Daily consumption, kWh | | 4.133 | 2.931 | 3.095 |
| Number metered | | 3 | 19 | 22 |

This compares with 4.025 kilowatt hours for upright freezers and 2.764 for chest freezers as measured in the field by AHAM members.

Other sources that provided annual consumption (kWh) [123] for freezers are:

| | EEI[1] | Merchandising Week[2] | 1976 Census[3] |
|---|---|---|---|
| Freezers | | 1480 | |
| 15 to 20 $ft^3$ | 1195 | | 1320 |
| 15 to 21 $ft^3$ frostless | 1761 | | 1985 |

As can be seen, data from various sources are presented in such a diverse manner that useful comparison is impractical.

[1]Appliance energy use table, 1976 REA Handbook, data source: Electrical Energy Association, 90 Park Avenue, New York, New York 10015 (about 60 appliances listed with annual kilowatt-hour data). [Edison Electric Institute (EEI) succeeded the Electrical Energy Association (EEA).]

[2]Tabbing Appliance Energy, <u>Merchandising Week</u>, 3, 1973.

[3]Statistical Abstract of the United States, 1976, p. 552.

4. Secondary Usage Factor

None

5. Impact Assessment of Uncertainties

The correction factors, $C_c$ and $C_u$, express the consumer-dependent variables for chest and upright freezers. Uncertainties in these parameters lead directly to uncertainties in the EAOC's, as indicated in the following table, where

$E_T$ = Energy consumption per test cycle, kWh.

$$\text{EAOC(\$ per yr)} = E_T \times \begin{Bmatrix} C_c \\ C_u \end{Bmatrix} \times 365 \text{ cycles per yr} \times \$0.038 \text{ per kWh.}$$

$C_c$ = correction factor for chest freezers, dimensionless.

$C_u$ = Correction factor for upright freezers, dimensionless.

$S(\bar{X})$ = Standard deviation of the sample mean correction factor.

$\Delta$EAOC = uncertainty in EAOC due to $S(\overline{X})$.

| Freezer Type | Chest | Upright |
|---|---|---|
| $E_T$, kWh per day | 4.0 | 4.71 |
| Correction factor | $C_c$ = 0.70 | $C_u$ = 0.85 |
| EAOC, $ per year | 39 (38.94) | 56 (55.53) |
| $S(\overline{X})$, dimensionless | 0.02 | 0.006 |
| $\Delta$EAOC, $ per year | 0.78 | 0.33 |

6. Comments

Further expenditures to refine these correction factors do not appear warranted.

# APPENDIX C. DISHWASHERS

1. References: 11, 13, 68, 73, 84, 112, 123, 144, 145, 163

2. Test Procedures: Final [84] August 8, 1977
   Proposed [73] March 22, 1977

3. Primary Usage Factor

3.1 Value: 416 loads per year.

3.2 Basis

The 416 loads per year are based on a survey that was conducted by Procter and Gamble in 1974 [11].

3.2.1 Description of Basis

No details were provided by Procter and Gamble on the number of times dishwashers are used per week.

3.2.2 Estimate of Uncertainty

AHAM [13] reported results of a survey involving 852 families showing 9 percent washing more than once a day, 56 percent once a day, 24 percent every other day and 11 percent less often. Assigning loads per week respectively at 10, 7, 5.5 and 2, the mean value is 5.88 loads per week, standard deviation of the sample is 2.29 loads per week and the standard deviation of the sample mean is 0.078. It is assumed that the Procter and Gamble survey for 1974 reported in [11] had a similar degree of statistical quality. Therefore, the standard deviation of the sample mean will be approximated at 0.08 loads per week.

3.3 Parallel Estimates

Procter and Gamble reported an average of seven loads per week from a 1972 survey [144, 145] and also eight loads per week [144].

Midwest Research Institute (MRI) metered 29 homes with dishwashers during August 1976 through July 1977 which indicated the annual energy usage for dishwashers was 149 kilowatt hours [123]. Other sources that give the annual energy consumption usage rate of 363 kilowatt hours are Electrical Energy Association, Statistical Abstract of the

United States--1976, and Merchandising Week, December 3, 1973 [68, 123]. It should be noted that these values represent the amount of energy to operate the dishwasher. The energy for heating the water that is used is not included.

An average of 6.8 loads per week was reported [112] from a 1975 survey of 2000 households. Data in [11] from a 1968-70 survey indicate an average of 8.1 loads per week for normal capacity units and 7.4 loads per week for large capacity units.

4. Secondary Usage Factor

Some dishwashers have features or controls that can be used to modify the normal cycle by (1) eliminating the water heating feature during the wash portion of the cycle, (2) eliminating one or more water changes, and (3) eliminating the power-dry feature after the last rinse operation. These features are designed to reduce the energy consumption of the dishwashers. There are not available at this time sufficient consumer usage data on the first two features to permit assessment of their effects on energy consumption. However, it is assumed that a switch that disables the power-dry feature (truncated cycle) is used 50 percent of the time [73]. This is based on a survey conducted by the Kitchen Aid Division of Hobart Corporation. Kitchen Aid conducted a consumer usage survey which indicated that 39 percent of the participants used the switch disabling the power-dry feature all of the time and 29 percent used this switch part of the time.

5. Impact Assessment of Uncertainties

Estimated Annual Operating Costs (EAOC's) for this product consist of two main components--the electricity or gas costs for heating the hot water and the electricity costs for operating the product's motors and dish drying heater. Some dishwashers have controls that permit the heated drying cycle to be omitted. It is estimated that users will choose to omit the drying cycle (i.e., use a truncated cycle) approximately 50 percent of the time where this feature is available, and will save approximately 0.26 kWh of the electric operating energy consumption each time that this feature is exercised [163].

The following base case will be assumed for the purposes of this analysis.

- Gas water heater with 0.75 recovery efficiency, 90 F water temperature rise; gas cost at $0.207 per therm (100 000 Btu).

- Fifteen gallons of hot water consumed per cycle.

- Annual usage is 416 cycles per year.

- Electric energy consumption is 0.674 kWh per normal cycle [163], at $0.038 per kWh.

- Electric energy consumption by the dish-drying heater is 0.26 kWh per cycle.

The resulting EAOC components and totals are:

| | Water Heating | + Product Operation | = Total |
|---|---|---|---|
| Normal cycle only | $12.91 per year | + $10.65 per year | = $23.56 per year |
| With truncation option | $12.91 per year | + $ 8.60 per year | = $21.51 per year |

These EAOC's would be reported as $24 and $22 per year, respectively.

An uncertainty in the usage rate of 0.08 cycles per week translates into 4.16 cycles per year, which is one percent of the basic usage rate of 416 cycles per year. The corresponding ΔEAOC's are $0.24 and $0.22 per year respectively for models with the normal cycle only and with the truncated cycle available.

Increasing the usage factor for the truncated cycle from 50 percent to 51 percent would result in a saving of $0.03 per year.

6. Comment

No further usage investigations are suggested for this product except for monitoring of long-term trend data provided by industry.

# APPENDIX D. CLOTHES DRYERS

1. References: 13, 20, 74, 87, 144, 155, 164, 165

2. Test Procedures: Final [87] September 14, 1977
   Proposed [74] April 27, 1977

3. Primary Usage Factor

3.1 Value: 416 loads per year.

3.2 Basis

The primary usage factor for clothes dryers was selected to be equivalent to the eight loads per week for clothes washers.

3.2.1 Description of Basis

A frequency of use of 7.95 loads per week for clothes washers was reported by AHAM [13] and was rounded to 8 loads per week (416 loads per year) for use in the clothes washer test procedure. This survey from October 1973 to September 1974 included 8567 families. The assumption was made that there is a dryer load for each washer load, and 416 loads per year was selected as the usage factor for clothes dryers. The same reference [13] includes data from a clothes dryer survey of 6564 families, with an average usage of 7.1 loads per week. Family sizes were not reported.

Additional data have become available from AHAM dryer energy field test which was conducted during 1977 [20]. The reported usage frequency was 8.15 cycles per week based on a survey of 20 families with an average family size of 4.8 persons per family. (The average household size in March 1976 is estimated at 2.94 persons [155].)

3.2.2 Estimate of Uncertainty

Analysis of the statistical information of the data in reference 13 leads to the following estimates of standard deviation in loads per year: sample:250, sample mean:25.

3.3 Parallel Usage Factors

A survey by the Oklahoma Gas and Electric Company [164] yielded an average usage rate of 520 loads per year. This survey was based on 33,000 loads run in 64 dryers. The average family size of the 64 participating families was 4.8. This survey was conducted during March 1970 through April 1971.

An average of 7.1 loads per week was reported in reference 13 from a 6564 family survey conducted over the period of October 1973 through September 1974.

An average of seven loads per week was reported by Procter and Gamble [144] from a survey of three panels of approximately 500 homemakers each.

Market Facts, Inc., conducted a questionnaire survey during the period of September 1-19, 1977 [165]. There were 346 respondents to a question on the frequency of clothes dryer use. An average of 290 loads per year was estimated from these data.

4. Secondary Usage Factors

- Field Use Factor, FU = 1.18

This factor is a multiplier specified in a test procedure [87] formula for computing dryer energy consumption by consumers given consumptions measured in the tests. An average energy consumption of 2.5 kWh per cycle for electric dryers was calculated from Oklahoma Gas and Electric data [164]. The average energy consumption for 1972 production, as measured by the AHAM test procedure then in effect was estimated at 1.923 kWh per cycle [87]. This 1.923 kWh per cycle was increased to 2.12 kWh per cycle to account for a change from the AHAM to the DOE test procedures in the amount of drying to be done, 2.5 ÷ 2.12 = 1.18 = FU.

Data in hand will not support an estimate in the uncertainty in this factor.

- Load Size, standard size dryer: 7 pounds.
  compact dryer: 3 pounds.

Dryer load sizes refer to the weight of fabrics in a bone-dry condition. Weights of water in the fabrics are expressed as percentages of dry weight.

A 5.8 pound average load was reported by AHAM in reference 11 for clothes washers. This survey, believed to be sponsored by Procter and Gamble in 1968 to 1970, was based on 2558 loads in normal capacity washers and 1638 loads in large capacity washers. This 5.8 pound load was adjusted upward to 7 pounds to correspond with the AHAM standard test load and the trend to larger dryers. No field data are available to support the 3 pound load for compact dryers. The three pound load conforms to industry practices.

In a recent letter [20], AHAM reported an average load size of 6.5 pounds from a survey of 20 families. The average family size was 4.8 persons and the average usage was 8.15 cycles per week.

No field data are available to support estimates of uncertainty for these load sizes.

- Load Composition: test clothes containing 50 percent cotton and 50 percent polyester fibers.

No field data were provided to support the proposition that most families dry synthetic clothes separately from cotton clothes. Procter and Gamble reported in reference 144 the results of a 1972 survey on fabric types as 60 percent plain cotton, 20 percent cotton/synthetic blends and 20 percent synthetics. General Electric Company [87] estimated that in an average washer load the ratio of natural fiber to synthetic fiber was approximately one.

No field data are available to support an estimate of uncertainty for load composition.

- Moisture Content: 70 percent of fabric weight at start ($W_w$), 4 percent of fabric weight at the end ($W_d$).

NBS recommended that the test procedure be based on the removal of an amount of water equal to 66 percent of the fabric weight (70 percent at the start to 4 percent at the end) instead of the 60 percent water removal specification contained in the AHAM test procedure HLD-2EC. Industry concurred.

There are no field data available supporting either these limits or estimates of uncertainty in them.

5. Impact Assessment of Uncertainties

An electric dryer is selected for impact analyses. The formula for Estimated Annual Operating Cost, EAOC, [87] is given as:

$$EAOC = 416 \text{ cycles per year} \times E_{ce} \text{ kWh per cycle} \times \$0.038 \text{ per kWh}$$

$$= 416 \times \frac{66}{W_w - W_d} \times \text{test energy per cycle, } E \times FU \times \$0.038$$

Inserting nominal values, the base case EAOC is

$$EAOC = 416 \times \frac{66}{(70-4)} \times 2.21 \times 1.18 \times 0.038 = \$41.22 \text{ per year,}$$

which would be reported as $41 per year.

- Loads per Year

Using the estimated uncertainty of 25 loads per year from section 3.2.2,

$$\Delta EAOC \text{ (loads per year)} = 25 \times 2.21 \times 1.18 \times 0.038 = \$2.48 \text{ per yr.}$$

- Load Size

NBS has determined that dryer efficiency in terms of pounds of water removed per kWh decreases as the load size decreases, from approximately 2.09 pounds of water per kWh for a seven pound load to approximately 2.05 pounds of water per kWh for a six pound load. Assuming a change in average load size from seven to six pounds,

$$\Delta EAOC \text{ (load size)} = 416 \times 0.038 \times 1.18 \times 0.66 \times \left(\frac{6}{2.05} - \frac{7}{2.09}\right)$$
$$= -\$5.20 \text{ per year.}$$

- Initial Water Content

If the initial water content was 80 percent of the load dry weight instead of 70 percent, an additional 0.7 pounds of water would have to be removed per load (7 x (0.80-0.70) = 0.7). Estimating the water removal efficient at 7 x (0.70-0.04) pounds per load/2.21 kWh per load = 2.09 pounds of water per kWh, this change in initial water content would lead to a

$$\Delta EAOC \text{ (initial water content)} = 416 \times \frac{0.7}{2.09} \times 1.18 \times 0.038 = \$6.24 \text{ per year.}$$

• Ending Moisture Retention

Though the moisture removal efficiencies near the end of a drying cycle are not known, it is estimated that these efficiencies will be only slightly reduced by a change in moisture retention from four percent to two percent. A change from 2.09 to 2.04 pounds per kWh will be assumed for such a change. On this basis,

$$\Delta \text{EAOC (moisture retention)} = 416 \times 1.19 \times 0.038 \times 7 \times \left(\frac{0.68}{2.04} - \frac{0.66}{2.09}\right)$$
$$= \$2.29 \text{ per year.}$$

• Field Use Factor

Assume a change in the field use factor, FU, from 1.18 to 1.08. This would lead to a

$\Delta$EAOC (FU) = 416 loads per year x 2.21 kWh per load x \$0.038 per kWh x (1.08-1.18) = -\$3.49 per year.

• Load Composition

Further study is needed to estimate the effect of changing the shares of cotton and synthetic fibers on the energy consumption of clothes dryers and on the load compositions currently occurring in the field. Therefore, no estimate of the effect of this variable on EAOC is made.

6. Comments

The empirical bases for loads per year, field use factor, load size and water removal are not strong. Perhaps loads per year and load size could usefully be combined into pounds per year for the purposes of estimating EAOC. A combined input energy metering and clothes weighing survey is suggested in which care is taken to obtain a statistically representative sample of household sizes. An estimate of initial water content might be obtainable from manufacturer tests of clothes washers.

# APPENDIX E. WATER HEATERS

1. References: 3, 57, 62, 74, 96, 123, 133, 143, 166, 167, 168, 183

2. Test Procedures: Final Amendment [183] October 19, 1978
   Proposed Amendment [62] April 3, 1978
   Final [57] October 4, 1977
   Proposed [74] April 27, 1977

3. Primary Usage Factor:

3.1 Value:

National average hot water usage = 64.3 gallons per day, 365 days per year with nominal tank temperature 145 F, input water temperature 55 F, and ambient air temperature 55 F [57].

3.2 Basis:

Hot water usage estimates were not obtained from direct measurements of water use, but instead were derived [166] from input energy metering data and general service efficiency factors.

The average hot water use in gallons was computed as

$$\frac{\text{average energy consumed in heating water}}{\text{energy required per gallon heated}}$$

$$= \frac{(\text{average total energy consumed}) \times (\text{average service efficiency})}{\text{energy required per gallon heated}}$$

3.2.1 Description of Basis

The energy consumed was treated independently for gas and for electric water heaters. The average gas energy of 378 therms per year was taken as the average of the average annual energy consumptions reported for regional usage by five gas utility companies. The average gas heater service efficiency of 47 percent was taken as the average of results of laboratory studies on one gas heater tested by the Institute of Gas Technology and on two gas heaters tested by the Houston Lighting and Power Company. The average annual energy consumption for the electric heaters of 6012 kWh per year was taken as the average of the average annual regional energy consumptions reported by 13 electric utility companies. The average service efficiency for the electric heater of 75 percent was taken as the average of results of (a) laboratory tests conducted on one heater by the Institute of Gas Technology and on three heaters by the Houston Lighting and Power Company, and (b) field tests on 54 metered units by Detroit Edison over two weeks in the summer and two weeks in the winter.

In each separate case--gas and electric--reported results were combined into unweighted averages without regard to sampling methods or representativeness of the localities, of the heater manufacture or size, or of specific operating conditions. The data collected in the field were those offered voluntarily by the utility companies and varied widely in format, in detail, and in estimated reliability. In most instances the thermostat setting was unknown; and no information was provided on whether the water heaters were usually located outside the house, in unheated cellars, or inside the heated or air-conditioned volumes of housing units. Most of the data were for individual houses, but some were for apartments.

The annual median water surface temperature (as reported by the U.S. Geological Survey) was taken to be the annual average tank water-input temperature for the specific location involved.

3.2.2 Estimate of Uncertainty

No direct data are available to support an estimate of uncertainty in national average hot water usage.

The magnitude of systematic errors cannot be reasonably estimated because of the diversity of the reported observations. Also, sampling errors and biases cannot be computed because of lack of evidence of a probability sample. Several sources expressed concern that the value of 64.3 gallons per day as a national average is too high. At least one source expressed concern that the value was too low.

The formal mathematical relationship,

$$\text{Average daily water use} = \frac{\underset{\text{consumed}}{(\text{average daily energy})} \times \underset{\text{efficiency}}{(\text{average service})}}{750}$$

is in error on the high side (i.e., gives too large a value of average water use) because it includes an additional average of cross-product terms of energy and service efficiency. The magnitude of the cross-product contribution is unknown.

3.3 Parallel Estimates

The average annual energy consumption from which the flow data were computed--6017 kWh for electric water heaters and 378 therms for gas heaters--may be compared with related estimates from other sources given below.

| Source | Annual Energy Consumption Electric (kWh) | Gas (Therms) |
|---|---|---|
| Edison Electric Institute [123,167] | 4219 | 144 |
| San Diego Gas & Electric [167] | 4308 | 147 |
| Pacific Gas & Electric [143,167] | 4811 | 164.2 |
| Hittman Associates [167] | 4400 | 150 |
| Federal Power Commission [167] | 4280 | 146.1 |
| Rand Corporation [167] | 4400 | 260 |
| A. D. Little [168] | | 192 |
| Efficient Electricity Use Handbook Smith, Editor, Pergamon Press [150] | 3876 | 300 |
| ORNL [156] | 4500 | |
| Midwest Research Institute [123] | 4046 | |
| Merchandizing Week [123] | 4515 | |
| Potomac Electric Power [123] | 5400 | |
| University of Illinois [123,133] | 4233 | 95.5 |
| East Ohio Gas Company [133] | 8253 | 446 |
| Zinder [133] | 5220 | 292 |
| AGA [133] | | 288 |
| Ohio Power [133] | 4880 | |

Dates are not known for the above data, but they are believed to be about 1970-1975 in general. A trend in gas energy consumed by water heaters per year is shown by reports [3] from the American Gas Association which indicate for 1971, 316 therms; and for 1975, 325 therms.

The only known published data on directly metered, household water consumption is that of the Twin Rivers, New Jersey study [96], indicating an average of 64.7 gal per day. Six electric water heaters and six gas heaters were metered with recordings at hourly intervals. The electric water heaters were 82 gallon capacity; the gas heaters were 40 gallon capacity. Water-flow readings were recorded directly onto magnetic tape. Although observations were made over a longer period, the recordings were transcribed and reported for an interval of only 41 days during November and December of 1976.

A draft report by A. D. Little [168] gives a value of 71.4 gal per day, with no indicated derivation for this figure. Mutch [167] cites Richard Quinn [M.Sc. Thesis, University of Tennessee, Knoxville, August 1972] as indicating 50.0 gal per day.

4. Secondary Usage Factors

4.1 a. Water supply temperature: 55 F [57].

b. Tank thermostat setting: 145 F [57].

c. Room ambient temperature: 55 F [57].

5. Impact Assessment of Uncertainties

A gas water heater will be used as the base case in assessing the impact of uncertainties in the consumer usage factors. The general approach for each usage factor will be to take the partial derivative of the Estimated Annual Operating Cost, EAOC, formula prescribed in reference 57 with respect to each usage factor taken in turn, and then to evaluate the resulting EAOC based on a selected increment in the factor. The EAOC formula for a gas water heater is

$$\text{EAOC} = 365 \text{ days per year} \times C_f \times \frac{\$0.207 \text{ per therm}}{100\ 000 \text{ Btu per therm}}$$

where

$C_f$ = average Btu per day of fuel consumed,

$$= C_{wh} + C_{us} \times \left(24\ \frac{\text{hours}}{\text{day}} - \frac{C_{wh}}{P}\right) - J_h - J_c.$$

Since $J_h$ and $J_c$ are not functions of the usage factors to be examined, they will disappear from all partial derivatives and therefore will be dropped from further consideration.

$$C_{wh} = \frac{k \times U \times (T_o - T_i)}{E_r}$$

where

$k$ = 8.25 Btu per gallon °F

$U$ = 64.3 gallons per day.

$T_o$ = 145°F = outlet water temperature

$T_i$ = 55°F = inlet water temperature

$E_r$ = 0.65 = assumed recovery efficiency.

$$C_{us} = \underline{S} \times k \times V \times (T_o - T_r),$$

where

$S$ = 0.05 per hour = assumed fraction of hourly heat loss

$k$ is defined above

$V$ = 50 gallons = assumed tank capacity

$T_o$ is defined above.

$T_r$ = 55°F = room temperature specified in [57]

$P$ = 50 000 Btu per hour = assumed fuel input rate.

Omitting the credits for $J_h$ and $J_c$,

$$EAOC = 365 \times \frac{0.207}{100\ 000} \times k \times \left(\frac{U \times (T_o - T_i)}{E_r} + S \times V \times (T_o - T_r) \times \left(24 - \frac{k \times U \times (T_o - T_i)}{P \times E_r}\right)\right)$$

$$= 365 \times \frac{.207}{100\ 000} \times 8.25 \times \left(\frac{64.3 \times 90}{0.65} + 0.05 \times 50 \times 90 \times \left(24 - \frac{8.25 \times 64.3 \times 90}{50\ 000 \times 0.65}\right)\right)$$

= \$87.09 per year which would be reported as \$87 per year.

Collecting terms that are not functions of usage factors,

$$EAOC = 0.0062333 \times \left(\frac{U \times (T_o - T_i)}{0.65} + (T_o - T_r) \times (60 - 0.0006346 \times U \times (T_o - T_i))\right)$$

- Daily water usage: $\Delta U$ = 1 gallon per day (gpd)

$$\frac{\Delta(EAOC)}{\Delta U} = 0.0062333 \times \left(\frac{90}{0.65} + 90 \times (-0.0006346 \times 90)\right) = \$0.83 \text{ per gpd per year.}$$

• Outlet temperature: $\Delta T_o = 1°F$

$$\frac{\Delta(EAOC)}{\Delta T_o} = 0.0062333 \times (\frac{64.3}{0.65} + 60 - 0.0006346 \times 64.3 \times 90 - 90 \times 0.0006346 \times 64.3)$$

= \$0.94 per °F per year.

• Inlet temperature: $\Delta T_i = 1°F$

$$\frac{\Delta(EAOC)}{\Delta T_i} = 0.0062333 \times (\frac{-64.3}{0.65} + 90 \times 0.0006346 \times 64.3)$$

= -\$0.59 per °F per year.

• Ambient room temperature: $\Delta T_r = 1°F$

$$\frac{\Delta(EAOC)}{\Delta T_r} = 0.006233 \times (-1) \times (60 - 0.0006346 \times 64.3 \times 90)$$

= -\$0.35 per °F per year.

If the room temperature is assumed to be 70 F instead of 55 F, the change in EAOC would be approximately 15 x -\$0.35 = \$5.25 per year.

6. Comments

The nominal EAOC for gas water heaters is 378 therms per year x \$0.207 per therm = \$78.25 per year, and for electric water heaters is 6017 kWh per year x \$0.038 per kWh = \$228.64 per year. The empirical bases for U, $T_o$ , $T_i$ and $T_r$ are very marginal. In view of the importance of water heaters to the energy program, independent field verification of each of these usage factors is recommended. It is suspected that a value for $T_r$ nearer to 70°F than to 55°F will be found, for example.

# APPENDIX F. ROOM AIR CONDITIONERS

1. References: 56, 72, 78, 102, 142, 169, 170

2. Test Procedures: Final [78] June 1, 1977
   Proposed [72] July 27, 1976

3. Primary Usage Factor

3.1 Value: 750 hours of compressor operation per year.

3.2 Basis

Room Air-Conditioning Lifetime Cost Considerations: Annual Operating Hours and Efficiencies by David A. Pilati of Oak Ridge National Laboratory [142] is a report in which the annual compressor operating hours for ten cities are estimated. This work was extended to get the 750 hours.

3.2.1 Description of Basis

The present usage factor is not based on field measurements of operating hours. An analytical approach was used to calculate the estimated national average hours of use for room air conditioners. The National Bureau of Standards [102], using the Oak Ridge Report [142] as a starting point, computed the average hours of air conditioner operation for 138 Standard Metropolitan Statistical Areas (SMSA's). From this work the estimated national average of 730 hours of compressor operating time was computed and rounded up to the 750 value.

The methodology that was used is described below.

A. In [142] the author estimated the annual compressor operating hours for ten cities using selected weather years. He also modified the National Bureau of Standards' Load Determination (NBSLD) computer program to calculate compressor operating hours while also accounting for the ability of natural ventilation to provide cooling. The assumptions were that the house was air conditioned at 78°F when required and the windows are opened if the outdoor conditions can maintain the inside temperature between 75°F and 78°F. Compressor hours for the ten cities were averaged using census data and market saturation data [170] as weighting factors to produce Result (A).

B. Using the same population and market saturation data [170] average air conditioning demand hours was calculated yielding Result (B). Demand hours, for there analysis, are defined as the larger of two numbers: hours of dry bulb temperature above 80°F, or wet bulb temperature above 67°F. The required data were obtained from the Engineering Weather Data Manual AFM88-8 [56], which contains average data for a period of ten years or more for the given locations.

C. A ratio was determined by dividing (A) by (B). This ratio, when multiplied by 100, becomes the percent of time that the room air conditioner compressor is operating per demand hour.

D. The annual national average air conditioning demand hours, weighted for population and market saturation was calculated using the following data:

1. Air conditioning demand hours were obtained from the Engineering Weather Data Manual AFM88-8 [56].

2. Census data for 138 Standard Metropolitan Statistical Areas (SMSA's), representing 65 percent of the total national population, were used for the population weights.

3. The room air conditioner market saturation data, grouped into nine geographic regions, were obtained from the February 24, 1975, issue of Merchandising Week [170].

E. Weighted annual national average compressor operating hours were then estimated using the ratio obtained in (C) and the population and market saturation data described above.

3.2.2 Estimate of Uncertainty

The empirical data that are available are not adequate to support an estimate of uncertainty in the national average hours of compressor operation. If such data are collected, additional auxiliary information should also be obtained so that relationships to long-term national or regional conditions may be established. Thermostat settings, local weather data and information permitting the estimation of air conditioner oversizing or undersizing are among the items needed.

### 3.3 Parallel Estimates

AHAM [169] obtained field data on compressor operating hours per year from 11 locations in order to check calculation method against field test data. There are no details of how the tests were conducted. The results are summarized in Table C-1.

Table C-1. Measured Compressor Operating Hours for Room Air Conditioners

| City | Samples N | Measured Hours |
|---|---|---|
| Syracuse | 2 | 51 |
| Grand Rapids | 2 | 210 |
| NYC 1975 | 57 | 297 |
| NYC 1974 | 114 | 299 |
| Newark | 4 | 320 |
| Dayton | 2 | 203 |
| Chicago | 33 | 666 |
| Moline | 2 | 837 |
| St. Louis | 29 | 781 |
| Louisville | 2 | 565 |
| Evansville | 5 | 1066 |
| San Antonio | 2 | 679 |

## 4. Secondary Usage Factors

### 4.1 Automatic Fan Operation

The automatic fan cycle is designed to reduce the energy consumption of air conditioners by shutting off the fan when the thermostat turns off the compressor. In [142], Pilati estimates that the automatic fan operation has a potential energy savings of 10 percent. A similar estimate has been determined from data [169] covering 171 room air conditioners field tested in the New York City area in 1974 and 1975. The options of continuous fan operation or automatic cutoff are available on many units so that a user may select the most satisfactory operating mode.

### 4.2 Regional Usage

The same analytical approach used in calculating the estimated national average hours were used to calculate an average for each of nine census regions. As can be seen in Table C-2 the estimated hours of use differ considerably from region to region.

Table C-2. Estimated Hours of Use for Nine Census Regions

| Census Regions | Hours of Use |
| --- | --- |
| 1. West South Central (AR, LA, OK, TX) | 1414 |
| 2. South Atlantic (DE, MD, DC, VA, WV, NC, SC, GA, FL) | 1162 |
| 3. East South Central (KY, TN, AL, MS) | 1106 |
| 4. West North Central (MN, IA, MO, ND, SD, NB, KS) | 654 |
| 5. Middle Atlantic (NY, NJ, PA) | 541 |
| 6. East North Central (OH, IN, IL, MI, WI) | 482 |
| 7. Mountain (AZ, WY, MT, ID, UT, CO, MN, NV) | 414 |
| 8. New England (ME, NE, VT, MA, RI, CT) | 402 |
| 9. Pacific (CA, OR, WA, HI, AK) | 264 |

## 4.3 Ventilation Practice of Householders

Few data are available on ventilation use patterns of householders; however, it is assumed that users of room air conditioners, unlike consumers who cool with central air conditioners, are more inclined to open windows when the outdoor wind speed and temperature are adequate to maintain a comfortable indoor temperatures. Ventilation can make a substantial difference in the cooling required by air conditioners, thus affecting hours of use.

5. Impact Assessment of Uncertainties

The expected annual operating cost for room air conditioners is given by EAOC = electrical input power in kilowatts x average use cycle of 750 hours x price of electricity in $/kWh. The average power input required by a room air conditioner produced in 1972 was 1700 watts. Using this as a basis, at an electricity cost rate of 3.8¢/kWh, the average annual cost of operation for a room air conditioner would be $48. A one percent error in the annual usage factor would lead to a $0.48 change in the EAOC.

6. Comments

The 750 hours per year usage factor is based entirely on analyses and assumptions, and however reasonable they may be, field surveys for some of the input parameters are advisable. Consumer practices regarding ventilation, temperature objectives and shutoff periods might be obtainable at reasonable cost. Extension of the regional analyses to cover latent as well as sensible heat removal requirements is suggested.

# APPENDIX G. UNVENTED HOME HEATING EQUIPMENT

1. References: 64, 75, 86

2. Test Procedures: Final [64] May 10, 1978
   Final [86] August 31, 1977
   Proposed [75] May 11, 1977

3. Primary Usage Factors

3.1 Usage Factor Values:

One hour of operation at maximum capacity for supplemental heaters.
Heating load hours, HLH = 2080 hours per year for primary heaters.
Adjustment factor, C = 0.77, for design heating requirement, DHR, dimensionless.

3.2 Basis

Electric heaters constitute the only class of unvented heating equipment covered by the test procedure. Operating costs for supplemental heaters are on the basis of cost per hour since no rational basis exists for estimating average annual usage of this type of product.

See Appendix N for a discussion of the basis for HLH and C, including a description of the basis and estimates of uncertainty.

3.3 Parallel Estimates

See Appendix N.

4. Secondary Usage Estimates

A sizing factor, SF, equal to 1.2 was adopted by DOE for primary heaters based on testimony on proposed test procedures. This factor, which is dimensionless, is the ratio of the maximum heating capacity of the heater to the design heating requirement, DHR. This factor is based on information presented by those commenting on the proposed test procedure as being representative of residential applications.

No method has been developed for estimating the uncertainty of this value of SF.

5. Impact Assessment of Uncertainties

The heating efficiency of electric heaters is assumed to be 1.0. Therefore, the impact of any uncertainties in the usage factor of one hour is zero.

6. Comments

No further action is suggested for supplemental heaters. Any improvements made in the factors for HLH for furnaces and vented heaters can be applied directly for primary heaters.

# APPENDIX H. TELEVISION RECEIVERS

1. References: 66, 68, 74, 77, 83, 87, 123, 126, 134, 136, 143, 150, 156

2. Test Procedures: Final [87] September 14, 1977
   Proposed [77] May 24, 1977
   Proposed [74] April 27, 1977

3. Primary Usage Factor

3.1 Value: 2200 hours per year of viewing time, 6560 hours per year of standby or off time [87].

3.2 Basis

Television 1976 by the A. C. Nielsen Company [136] is a marketing brochure reporting television audience characteristics in the U.S. as of September 1975. Nielsen ratings, based on a sample of 1200 households in the nation, are used in the selection of television programs and the determination of advertising revenues.

3.2.1 Description of Basis

The key statement in the brochure is that "Daily TV usage averaged six hours, eight minutes per home during 1975." On the basis of 365 days per year, the annual usage per home would be 2239 hours, which was rounded down to 2200 hours per year. Quoting again from the brochure, "In September 1975 69.6 million of the nation's households had at least one television set. This represents a near saturation level of approximately 97% of all U.S. households. Thirty million TV homes (43%) have two or more sets, and 51.2 million (74%) have at least one color receiver." If all homes having two or more sets had exactly two sets, there would be an average of 1.43 sets per household, while an assumption of one and a half sets per household would make an allowance for the cases of three or more sets per household. This leads to a minimum average annual usage of 1500 hours per set. The actual average would be between 1500 and 2200 hours per year, since more than one set could be on at a time. No objection was raised by the public or industry to the use of 2200 hours per year as the usage factor per set, notwithstanding the fact that the 2200 hours is on a household basis. (Nielsen monitors all sets in a household. [136], confirmed by telephone, November 15, 1978.) Nielsen estimates 1.63 sets per household, and that hours per household have been stable since 1975. [Telephone contact, November 15, 1978.]

Nielsen also provided data for November 1975 [136] on viewing time (hours:minutes) per week for the total U.S. (45:07); color (47:22), monochrome (38:50) and household size: one and two persons (37:26), three and four persons (50:36), and five and above (56:46). Average time per person for this period (November 1975) was (27:09).

### 3.2.2 Estimate of Uncertainty

An absolute maximum standard deviation for the estimate of the mean viewing time per year for the 1200 member sample is approximately 110 hours per year, or 5 percent of the mean value. This may be derived by assuming that the average "on" time of 6 hours out of 24 hours per day resulted from one quarter of the sets being on all the time and three-quarters never turned on. Any departure from this extreme assumption will lead to a smaller standard deviation of the mean.

## 3.3 Comparable Estimates

Whereas no independent estimates of operating hours per year were located, several sources contain estimates of annual energy consumption and some provide annual operating cost estimates. Both types of estimates may loosely be considered comparable to operating hours per year, given a willingness to make assumptions about hourly energy use or hourly operating cost. The recurrence in the following table of figures that are identical or within reasonable roundoff range indicates that the number of original sources is quite small. Background on the development of these estimates was not found.

Estimates of annual energy consumption or operating cost for television.

| Ref. No. | Source/ Author | Year | Dimensions, per year | Color Tube | Color Solid State | Monochrome Tube | Monochrome Solid State |
|---|---|---|---|---|---|---|---|
| | A. D. Little | 1974 | $10^6$ Btu | -----------1.5----------- | | | |
| | AHAM | 1974 | $10^6$ Btu | ---1.7---- | | ---1.2----- | |
| 68 | EEI | | kWh | 528 | 320 | 220 | 100 |
| | AHAM | 1974 | kWh | ---498---- | | ---352----- | |
| 123 | EEA | | kWh | 660 | 440 | 350 | 120 |
| 66 | Derven, Nichols | | kWh | 660 | 444 | 348 | 120 |
| 143 | PG&E | | kWh | 600 | 350 | 350 | 120 |
| 156 | ORNL | 1970 | kWh/HH | -----------417----------- | | | |
| 156 | ORNL | 1980 | kWh/HH | -----------440----------- | | | |
| 156 | ORNL | 1990 | kWh/HH | -----------470----------- | | | |
| 156 | ORNL | 1970 | kWh/unit | ---500----- | | ---350----- | |
| 134 | Newman, Day | 1969 | kWh/unit | ---502----- | | ---362----- | |
| 150 | Smith | 1970 | kWh/unit | ---456----- | | ---360----- | |
| 150 | Smith | | kWh/unit | -----------417----------- | | | |
| 123 | Merch. Week | | kWh | ---502----- | | ---362----- | |
| 123 | PEPCO | | kWh | ---450----- | | ---345----- | |
| 123 | CACEQ | | kWh | ---540----- | | ---400----- | |
| 120 | Murphy | | $ | 34.56 | 23.04 | 9.12 | 6.33 |
| 87 | DOE | 1977 | kWh | 2200 x 0.13 = 286 | | 2200 x 0.04 = 88 | |

4. Secondary Usage Factors

Switches Controlling Standby Power:

Some receivers have a quick-warmup capability that uses power to keep filaments warm while the set is not in use. In some cases, switches are provided to turn off this standby power and thus save energy. Industry suggested that an energy-saving credit be given where such switches are provided. Although no data were found indicating consumer usage of such a feature, DOE assigned a credit of 50 percent [87] of any standby power use if such a switch is provided. Standby power loads vary widely with the particular design, with a one to ten Watt range covering the great bulk of the cases.

Home Entertainment Center Operating Costs:

The energy consumption involved in playing video games and in other non-television uses was considered negligible at the weighted average level of overall receiver sales [87]. Therefore, this feature is not included in the test procedures or estimates of annual operating costs. Video recorders are not considered parts of television sets. It is assumed that set operation for recording is covered in the operating time and that playback time does not have a significant effect on overall average operating time.

5. Impact Assessment of Uncertainties

Practically all receivers now being built are solid state. Using the Electric Energy Association (EEA) annual consumption estimates [123] as the most widely accepted, the bases of these calculations will be 440 kWh per year for color receivers and 120 kWh per year for monochrome receivers. The cost of electric energy currently specified by DOE [83] is $0.038 per kWh, yielding Estimated Annual Operating Costs (EAOC's) of $16.72 for color sets and $4.56 for monochrome sets. If the DOE power levels of 130 W for color sets and 40 W for monochrome sets [87] are used together with 1500 operating hours per year, the EAOC's would be $7.41 per year for color sets and $2.28 per year for monochrome sets.

Using the results of Section 3.2.2, and assuming that EAOC errors arise solely from errors in the annual operating hours, it may be seen that maximum errors at one standard deviation of the error in the sample mean are limited to 5 percent, or $0.84 per year for color and $0.23 per year for monochrome receivers.

A 10W standby circuit operating for the full 6560 standby hours per year would consume 65.6 kWh per year at a cost of $2.49 per year, this being on the high side of the expected range. The 50 percent credit for a defeat switch for standby power would yield a saving less than $1.25 per year.

6. Comments

No further action is suggested for this product.

# APPENDIX I. KITCHEN RANGES AND OVENS

1. References: 7, 14, 17, 28, 29, 55, 60, 61, 64, 69, 82, 108, 109, 123, 133, 134, 143, 150, 156, 157, 171, 172, 173, 174, 175

2. Test Procedures: Final [64] May 10, 1978
   Corrections to Proposed Test Procedure [61] February 14, 1978
   Proposed [60] December 30, 1977
   Proposed [82] June 16, 1977

3. Primary Usage Factors:

3.1 Values:

Annual useful cooking energy outputs by product type [64]:

Conventional electric oven: 47.09 kWh
Gas oven: 160 700 Btu
Electric cooking top: 277.7 kWh
Gas cooking top: 947 500 Btu
Conventional range: 1 108 000 Btu
Microwave oven: 34.2 kWh
Microwave/conventional electric range: 308.9 kWh
Microwave/conventional gas range: 1 054 000 Btu

K = 0.82 = Estimated fraction of usage for a conventional oven due to microwave oven usage [64].

L = 0.85 = Estimated fraction of usage for a conventional cooking top due to microwave oven usage [64].

3.2 Basis:

The annual useful cooking energy outputs given above are not directly measured field survey results. They were calculated from a combination of field metering of energy inputs [7, 17, 23, 171, 172], efficiency measurements using industry test procedures [14, 108, 109, 173] and adjustments to translate results from industry test procedures [14, 64] to results from procedures prescribed by DOE. Considerable judgment was exercised in reconciling data from various sources to identify field data that would be "typical" for test procedure purposes.

The term "useful cooking energy output" refers to the heat absorbed by the standardized aluminum block or water load during the test procedure. The term "energy into the food" or its equivalent is used in some technical discussions to mean the useful cooking energy output, but is not rigorously the same. In actual cooking, some heat goes into the cooking utensils and the efficiency of the thermal coupling into utensils varies widely depending on the shape of the utensil bottom and burner coverage, both of which affect the energy reaching the food.

3.2.1 Description of Basis

DOE, NBS, AHAM (Association of Home Appliance Manufacturers) and GAMA (Gas Appliance Manufacturers Association) coordinated in the development of the primary usage factors. AHAM provided the field data [7, 17] on which the factors are based, as described below. The results were developed in terms of kWh, which apply directly to electric products. In the interests of maintaining comparability, the useful cooking outputs for gas products are the same as for the corresponding electric products, using a conversion factor of 3412 Btu per kWh.

Average Energy Consumption

The values given in the proposed test procedures for the annual useful energy output of kitchen ranges and their components are based on AHAM field tests. These tests covered 12 months and included 80 electric range installations for families varying in size from two to eight members. Of these 80 installations, 24 had microwave ovens in addition to a conventional range.

Based on AHAM data for a family size of four, the following values for average energy consumption [7] were reported:

| | |
|---|---|
| Surface units (cooking top) | 380 kWh/year |
| Conventional oven | 376 kWh/year |
| Microwave oven | 88 kWh/year |

The values given above include energy consumption for self-cleaning ovens and for clocks, whereas in the proposed test procedures both the self-cleaning and clock energy are calculated separately.

In the absence of field data on the average energy consumption of clocks and self-cleaning operations these energy values have been estimated as follows:

Self-cleaning energy. Laboratory measurements at NBS indicated that an electric oven requires about 3.2 kWh per cleaning cycle. AHAM has estimated that electric self-cleaning ovens are cleaned an average of 11 times per year. Hence, the average annual energy consumption for self-cleaning would be 11 x 3.2, or 35.2 kWh per year. Since 55 of the 80 electric ranges in the AHAM field test program were self-cleaning models the average energy consumption among all 80 ranges would be 55/80 x 35.7 = 24.2 kWh per year, to be subtracted from the overall average oven consumption of 376 kWh/year.

Clock energy. Laboratory measurements at NBS indicated that the most common range clocks use about 2.7 watts, or 2.7 x 8.76 = 23.7 kWh per year. It is not known whether or not this clock consumption would have been fully registered on the watt-hour meters used in the AHAM field tests. It has been observed in NBS laboratories that clock consumption alone will register on some watt-hour meters but not on others, or that the registration may be erratic. It is recommended therefore that only half of the computed consumption, or 11.8 kWh per year, be deducted from the annual consumption to account for average clock consumption as measured by the watt-hour meters.

In these test procedures the clock consumption is added to the oven cooking energy consumption to determine total oven energy consumption and also an oven energy factor. Although only 50 percent of the estimated clock consumption has been applied as a correction to the field test data on oven consumption, the full clock consumption is used in the test procedures for determining total consumptions and energy factors.

Applying the two corrections as estimated above to the value given by AHAM for energy consumption of a conventional oven, the net input energy for oven cooking becomes 376 - (24.2 + 11.8) = 340 kWh/year.

Average Efficiency

The average efficiencies of the ovens and cooking tops used in the AHAM field test were reported as follows:

| | |
|---|---|
| Surface units (cooking top) | 0.7309 [172] |
| Conventional oven | 0.1413 [14] |
| Microwave oven | 0.3885 [14] |

The value of 0.1413 for conventional ovens was determined by a test procedure proposed by AHAM which differs from the present oven test procedure [64]. From laboratory tests of representative ranges using both test procedures, NBS estimates that the average efficiency of the ovens used in the AHAM field program would be approximately 2 percent lower using the present procedure than that reported by AHAM. Hence, the average conventional oven efficiency was corrected to 0.1413 x 0.98 = 0.1385.

Annual Useful Cooking Energy Outputs

The values used in the test procedure [64] for annual useful cooking energy outputs are derived from data provided by AHAM. Average annual energy consumptions for families of four are given in reference 7, and component efficiencies are given in references 14 and 172. The energy consumption and efficiency values for ovens were amended as noted above. Useful cooking energy outputs were computed on the basis of Input x Efficiency = Output for cooking tops, conventional ovens and microwave ovens (MWO's). These results in kWh per year were rounded and used individually and in combinations for electric cooking equipment. Output requirements for gas equipment were computed using 3412 Btu per kWh and rounded. Results of this process are given below.

| Component | Input, kWh per year | Electric Unit Efficiency | Output, kWh per year | Output (Gas) Btu per year |
|---|---|---|---|---|
| Cooking top | 380 | 0.7309 | 277.7 | 947 500 |
| Conventional oven | 340 | 0.1385 | 47.09 | 160 700 |
| Conventional range | 720 | | 324.8 | 1 108 000 |
| MWO | 88 | 0.3885 | 34.2 | ---- |

AHAM observed that the average cooking energy consumption for MWO owners was less than for non-owners and requested that this difference be reflected in the test procedures for ranges that structurally combine conventional cooking tops and ovens and microwave ovens. (Common cavity conventional and microwave ovens are not treated by the test procedure.) The method for handling this issue is the introduction of two coefficients, K = 0.82 for conventional ovens and L = 0.85 for cooking tops, that multiply the input energies determined by the basic test procedures.

The values for the usage factors K and L were derived primarily from the data [28] provided by the General Electric Company (G.E.) at the February 16, 1978 test procedure hearing. G.E. presented three sets of data applicable to establishing usage factors:

(a) Energy consumption for a U.S. Department of Agriculture week's menu for a family of four cooked with and without a microwave oven. The energy measurements were normalized to the bases of 720 kWh annual cooking input energy without microwave, and 88 kWh/yr microwave oven consumption.

(b) The same as above except using the AHAM menu.

(c) Field survey data for six families before and after the addition of a microwave oven. The "before" data covered a period of two years and the "after" data was for nine months following a three-month period to allow for adjustment and learning to use the new appliances.

Since the G.E. field data yielded an average microwave oven energy consumption of 77.9 kWh per year rather than 88 kWh per year, the data were normalized by NBS to 88 kWh/yr consumption as shown in the following table.

Normalization of G.E. Data
(All values in kWh per year energy inputs except K and L)

| Component | (A) Without MWO | (B) With MWO | (C) (B)-(A) | (D) (1) | (E) (2) | (F) (3) |
|---|---|---|---|---|---|---|
| Cooking top | 399.5 | 346.3 | -53.2 | -60.1 | 339.4 | 0.850=L(GE) |
| Oven | 321.3 | 277.0 | -44.3 | -50.0 | 271.3 | 0.844=K(GE) |
| MWO | -- | 77.9 | 77.9 | 88.0 | 88.0 | |
| Total | 720.8 | 701.2 | -19.6 | -22.1 | 698.7 | |

(1) (D) = (C) x 88/77.9.
(2) (E) = (A) + (D).
(3) (F) = (E)/(A).

K = 1/4 x (2xK(GE) + K (USDA menu) + K (AHAM menu)) = 0.82.
L = 1/4 x (2xL(GE) + L (USDA menu) + L (AHAM menu)) = 0.85.

NBS gave double weight to the G.E. data and single weights to the USDA and AHAM menu results.

A summary of the three sets of data: cooking USDA menu, cooking AHAM menu, and G.E. field data, all normalized for 88 kWh per year for the microwave oven is shown below.

| | K, Oven Usage Factor | L, Top Usage Factor | Reduction In Energy Input, % | Reduction In Energy Output, % |
|---|---|---|---|---|
| USDA Menu | 0.764 | 0.886 | 4.9 | 2.6 |
| AHAM Menu | 0.842 | 0.834 | 4.0 | 6.0 |
| G.E. Field Survey | 0.844 | 0.850 | 3.1 | 5.0 |

Considering that the choice of foods to be cooked in the microwave oven for the two different menus was somewhat arbitrary, these three sets of data are in fairly good agreement. For comparison it may be noted that the usage factors (K = 0.812 and L = 0.663) recommended by AHAM at the 2/16/78 [28] public hearing on proposed test procedures would result in a reduction in energy input of 13.7 percent and a reduction in output of 21.0 percent. Data presented by Litton would give a reduction in input of 14.7 percent and a reduction in output of 12.0 percent.

The usage factors given in the test procedure were calculated by averaging the USDA and AHAM menu values of K and L, and in turn average these results with the G.E. field survey values. The resultant values, K = .823 and L = .855, were then rounded down to two significant digits.

The basis for the constants in the efficiency equations is as follows. All cooking efficiency equations are derived from the definition of cooking efficiency, total useful cooking energy output divided by total energy input required for cooking.

The general formula used for computing efficiencies for combined products is

$$Eff_T = \frac{O_T}{\sum_{i=1}^{i=n} O_i/Eff_i}$$

where

$Eff_T$ = efficiency of a combination of cooking components.

$Eff_i$ = efficiency of the ith cooking component, i = 1 through n components.

$O_T$ = the total useful energy output for that class of appliance.

$O_i$ = the useful energy output for the ith component, i = 1 through n.

It can be seen that the coefficient of each term in the denominator is the ratio of the useful energy output of that component to the total useful energy output of the complete appliance. ---

The following have been used in computing these ratios:

| | Useful Energy Output (kWh) w/o Microwave | With Microwave |
|---|---|---|
| Conventional oven | 47.09 | 38.61* |
| Cooking top | 277.7 | 236.05** |
| Microwave oven | --- | 34.19 |

*47.09 x 0.82 = 38.61

**277.7 x 0.85 = 236.05

The derivation of the various constants used in the efficiency equation is shown below:

| Section | Combination | Useful Output | Fraction of Total Output |
|---|---|---|---|
| 4.3.2 | Conventional oven | 47.09 | 0.1450 |
| | Cooking top | 277.7 | 0.8550 |
| | Total | 324.8 | |
| | Conventional oven | 38.61 | 0.1250 |
| 4.5.2 | Cooking top | 236.05 | 0.7643 |
| (4.5.2.1)* | Microwave oven | 34.19 | 0.1107 |
| | Total | 308.85 | |
| | Conventional oven | 38.61 | 0.5304 |
| (4.5.2.2)* | Microwave oven | 34.19 | 0.4696 |
| | Total | 72.80 | |
| | Cooking top | 236.05 | 0.8735 |
| (4.5.2.3)* | Microwave oven | 34.19 | 0.1265 |
| | Total | 270.24 | |

*If other combinations of microwave oven with conventional oven or cooking top are included.

### 3.2.2 Estimates of Uncertainty:

No direct field data on annual useful cooking energy outputs are available. These outputs were derived for test procedure purposes by multiplying the average input energy measured in the field by the average efficiency of the particular type of cooking device. Limited data are in hand on energy consumption, but the corresponding data on individual device efficiencies are not available. The available energy consumption data were examined for families of four to derive estimates of the coefficients of variation for the population and for the estimate of the population mean. (Coefficient of variation, V, is the standard deviation divided by the mean for the sample variable being examined.) The results of the calculation are:

Table I-1. Energy Consumption Sample Statistics* [14]

| Electric Cooking Device | Sample Size | Coefficient of Variation of the Population | Coefficient of Variation of the Population Mean | Mean, kWh per year |
|---|---|---|---|---|
| Conventional Ovens; | | | | |
| Microwave oven (MWO): | | | | |
| Non-owners | 67 | 0.401 | 0.049 | 391 |
| MWO owners | 10 | 0.446 | 0.141 | 264 |
| Conventional Cooking Tops: | | | | |
| MWO non-owners | 67 | 0.508 | 0.062 | 353 |
| MWO owners | 10 | 0.358 | 0.113 | 240 |
| Conventional Ranges (Cooking Tops and Ovens): | | | | |
| MWO non-owners | 67 | 0.391 | 0.048 | 734 |
| MWO owners | 10 | 0.357 | 0.113 | 503 |
| MWO's | 10 | 0.232 | 0.073 | 93.1 |

*These results apply to families of four and were derived from detailed metering results for two quarter-year periods. The average values do not replace those reported by AHAM for whole-year metering results. It is not known whether clock or self-cleaning energies have been subtracted.

Microwave/conventional ranges: Coefficient of variation of the population mean is deduced for the GE sample of six cases to the coefficient of variation for the population of the range energy consumption of MWO owners: $0.358/\sqrt{6} = 0.146$.

### 3.3 Parallel Estimates:

There are no field data that report useful cooking energy outputs in the terms specified in the DOE test procedure, nor as specified in the longer-established industry test procedures. Energy inputs have been measured and reported by several investigators in various surveys from the 1950's to the present. Details such as sample size, equipment features, demographic data and standard deviation or its equivalent are missing in practically every case. Where cooking efficiencies are provided, the background information is similarly unavailable. Cooking energy outputs are derived by taking products of averages.

Energy inputs to ranges have been decreasing during the past 30 years. Probable causes cited for this trend include decreasing household size, greater tendencies to eat away from home, more prepreparation of foods cooked at home and increasing use of special-purpose cooking devices.

The Edison Electric Institute, EEI, or its predecessor the Electric Energy Association, EEA, has provided the most frequently cited information on the energy consumption for electric ranges: 1250 kWh per year in 1950, 1225 kWh per year in 1959 and 1175 kWh per year in 1969 for ranges without a self-cleaning feature [150, 156], and 1205 kWh per year [123] in 1969 for ranges with self-cleaning. EEI has recently completed another study of energy use by household appliances [69] and gives 700 kWh per year for ranges without self-cleaning ovens and 730 with self-cleaning ovens, based on a sample of 257 ranges. High and low consumption were 835 and 663 kWh per year. Consumption by microwave ovens is given as 190 kWh per year by EEI both before and after the recent study.

W. Blumst [29] reported the following field metering data for electric ranges.

| Survey Period | kWh per Year | Survey Area | Remarks |
|---|---|---|---|
| 1945-51 | 1231 | PA, MI, NY | |
| 1955-60 | 1037 | IL, TX, MI | |
| 1964-66 | 994 | OH, MD | |
| 1972-73 | 740 | AZ, UT, Northern CA | 96 residences |

Other annual energy consumption figures for electric ranges are:

| Ref. | Average kWh/yr | Period | Source | Remarks |
|---|---|---|---|---|
| 157 | 1500 | -- | East Ohio Gas | |
| 157 | 1606 | -- | U.S. Dept. of Agriculture | |
| 157 | 1176 | -- | Ohio Edison | Derived from monthly rate estimate. |
| 174 | (338) | 1972 | Ernst & Ernst | (Electric Oven) |
| 174 | (371) | 1972 | Ernst & Ernst | (Electric cooking top) |
| 174 | 721 | 1972 | Ernst & Ernst | Electric range |
| 55 | (208) | -- | Litton | (Cooking top)<br>Metering test of nine |
| 55 | (258) | -- | Litton | (Oven)<br>Litton microwave over/ under ranges. |
| 55 | (108) | -- | Litton | (Microwave oven) |
| 55 | 574 | -- | Litton | Combined annual consumption |
| 123 | 782 | 1976-7 | MRI | 56 ranges metered |
| 123 | (553) | 1976-7 | MRI | 13 built-in cooking tops metered |
| 123 | (401) | 1976-7 | MRI | 11 built-in ovens metered |

MRI suggests a rule of thumb formula for daily kWh, D, of D = 1.4 + 0.2 x number of residents.

| | | | | |
|---|---|---|---|---|
| 123 | 2071 | 1973 | Merchandising Week | |
| 123 | 1550 | -- | Citizens Advisory Committee on Environmental Quality | |
| 123 | 1210 | -- | University of Illinois | |

| | | | | |
|---|---|---|---|---|
| 133 | 980 | -- | Living Difference Project | |
| 133 | 1606 | -- | USDA-TB1073 | (Cited in Living Difference brochure) |
| 133 | 1452 | -- | Zinder | " |
| 133 | 840 | -- | Ohio Power | " |
| 143 | 750/775 | 1975 | Pacific Gas & Electric | Single family dwellings, without/with self-cleaning ovens. |
| 143 | 600/620 | 1975 | Pacific Gas & Electric | Multi-family dwellings, without/with self-cleaning ovens. |

Ref. 173 Source: AHAM; results of field metering test, families of four, kWh/yr.

Non-owners of microwave ovens, 20 cases

| Cooking Device | Low | Median | High |
|---|---|---|---|
| Cooking tops | 88 | 352 | 928 |
| Ovens | 96 | 344 | 875 |
| Cooking tops + ovens | 299 | 696 | 1702 |

Owners of microwave ovens, 9 cases

| Cooking Device | Low | Median | High |
|---|---|---|---|
| Cooking tops | 85 | 232 | 503 |
| Ovens | 142 | 300 | 875 |
| Cooking tops + ovens | 286 | 532 | 968 |
| Microwave ovens | 56.4 | 84 | 141.1 |
| Total combination | 381 | 616 | 1027 |

Gas Range Energy Consumption, Therms per Year.
(1 therm = 100 000 Btu.)

| Ref. | Average Therms/yr | Year | Source | Remarks | |
|---|---|---|---|---|---|
| 109 | (41.4) | 1972 | GAMA | (oven) | Computed adjustments to earlier values |
| 109 | (38.3) | 1972 | GAMA | (cooking top) | to achieve correlation with electric ranges. |
| 109 | 79.7 | 1972 | GAMA | | |
| 157 | 99 | — | East Ohio Gas | | |
| 108 | (49.8) | 1972 | GAMA | (oven) | These estimates include estimated annual |
| 108 | (48.9) | 1972 | GAMA | (cooking top) | consumptions by pilot lights of 20.2 therms |
| 108 | 98.7 | 1972 | GAMA | | for ovens, 26.1 therms for cooking tops and 46.3 therms for ranges. |
| 143 | 108/90 | 1975 | Pacific Gas & Electric | Single/multi-family dwellings | |
| 134 | 100 | 1960 | American Energy Consumer | | |
| 134 | 106 | 1966 | American Energy Consumer | | |
| 134 | 105 | 1971 | American Energy Consumer | | |
| 133 | 77.1 | — | Living Difference Project | | |
| 133 | 109.1 | — | USDA-TB1073 | | |
| 133 | 103.2 | — | Zinder | | |
| 133 | 105 | 1971 | AGA Survey | | |

The K and L factors were examined in a contract study [175] sponsored jointly by NBS and DOE. The data came from food cooking and eating diaries submitted by a nationally representative sample of 96 MWO owners and a demographically matched sample of 96 non-owners. The survey year was 1975. The relevant findings revealed no important difference between owners and non-owners with respect to the kinds and amounts of food eaten at home and that MWO owners prepared about nine percent of their foods in MWO's. Given equal displacements by MWO's, this result would lead to K=L=0.91. An additional survey was conducted to estimate the relative displacement by MWO's of tasks that would otherwise be done with ovens and countertops. The results indicated a 12 percent (L = 0.88) displacement from cooking tops and a six percent displacement from ovens (K = 0.94). The similarity between owners and non-owners regarding food kinds and amounts calls into question the lower cooking energy output requirement assigned in the test procedure to microwave/conventional ranges.

4. Secondary Usage Factors:

The remaining usage factor is the number of oven cleanings per year. Energy consumption allowances in the test procedure [64] for oven cleanings are based on seven cleanings per year for gas ovens and 11 per year for electric ovens. These specifications are based on very limited industry data and DOE will review these specifications when more complete field data become available. NBS provided an estimate of 3.2 kWh as the energy consumption per cleaning of an electric oven. (See Section 3.2.1.) Based on the test of one unit and the application of engineering judgment NBS estimates the energy consumption for self-cleaning of a gas oven to be approximately one-third of a therm per cycle.

5. Impact Assessment of Uncertainties

Assuming energy consumption of 720 kWh per year for electric ranges, 98.7 therms per year for gas ranges with pilots and 88 kWh per year for MWO's, the estimated annual operating costs, EAOC, not counting oven cleaning or clocks, become $27.36, $20.43 and $3.34, respectively. Using the K = 0.82 and L = 0.85 values in the test procedure and base value consumptions for electric ovens and cooking tops of 340 and 380 kWh per year, the EAOC of a microwave/conventional range, again omitting oven cleaning and clocks, would be 689.8 kWh per year x $0.038 per kWh = $26.21 per year.

Estimates of uncertainty in the average efficiencies of the various components are unavailable. Using the coefficients of variation of the population means for energy consumption in Table I-1, the errors in EAOC at the one standard deviation level would be approximately:

| Cooking Device | $\Delta$EAOC | Remarks |
|---|---|---|
| Electric Range | $1.31 per year | 0.048 x $27.36 = $1.31 |
| Gas Range | $0.52 per year | 0.048 x (98.7 - 46.3) x $0.207 = $0.52 |
| MWO | $0.24 per year | 0.073 x $3.34 = $0.24 |
| Microwave/ Conventional Electric Range | $1.26 per year | 0.048 x $26.21 = $1.26 |

Self-cleaning of electric ovens is estimated at 35.2 kWh per year for 11 cleanings per year, or about $1.34 per year. The effect on EAOC of an error of one cleaning per year would be approximately $0.12 per year.

Self-cleaning of gas ovens is estimated at 2.3 therms per year for seven cleanings per year, or about $0.48 per year. The effect on EAOC of one cleaning per year would be approximately $0.07 per year.

Effects of errors in outputs for components in combined systems are not estimated since methods for handling task displacements to other components have not been established.

6. Comments

a. There appears to be no good way to directly measure useful cooking energy output in the field, forcing recourse to metering energy inputs and multiplying these results by component efficiencies determined by a test procedure. Therefore, such a metering program is suggested, to be done by a party that is independent of the manufacturers and coupled with efficiency determinations using the DOE test procedures. Care should be taken in selecting a representative sample of subjects, since it is suspected that the average household sizes would be significantly smaller that the four-person families forming the basis for the current usage factors.

b. Since the objective is to determine useful cooking energy, in fairness to microwave ovens it may be appropriate to assign to the pots and pans part of the heat absorbed by the aluminum blocks used for testing conventional ovens and cooking tops.

c. Obtain sufficient data on clock energy consumption and meter responses so that home metering results may be suitably corrected.

d. Review the logical basis for the K and L factors to insure comparability for a prospective purchaser of cooking energy outputs among competing products.

e. Accept any new data from industry on the frequencies of oven cleaning, but do not incur any new costs for such information. The effects on the EAOC are not expected to be large in any case.

# APPENDIX J. CLOTHES WASHERS

1. References: 11, 12, 13, 68, 76, 83, 88, 90, 112, 123, 144, 150

2. Test Procedures: Final [88] September 28, 1977
   Proposed [76] May 17, 1977

3. Primary Usage Factors:

3.1 Value: 416 loads per year.

3.2 Basis:—Eight loads per week [11, 144], 7.95 loads per week [13]; 8 loads per week x 52 weeks per year = 416 loads per year.

3.2.1 Description of Basis

Procter and Gamble (P&G) [144] recommended eight loads per week as the appropriate clothes washer usage rate for a 1972 base year, based on data from a nationally representative panel. AHAM [11] attributes to a 1971 survey by P&G an average of eight loads per week, or 416 loads per year. AHAM [11] provided statistical information from a 1968-70 P&G interview survey of 401 owners of normal capacity and 276 owners of large capacity clothes washers. The average loads per week were 8.1 for normal capacity units and 7.4 for large capacity washers, for a weighted average of 7.8 loads per week. See Table J-1. AHAM [13] provided additional updated survey data from a sample of 3567 families with a mean average rate of 7.95 loads per week. Eight loads per week were selected as a convenient value for test procedure purposes.

Table J-1 [11]
Number of Loads Washed in Week

| | Normal Capacity | Large Capacity |
|---|---|---|
| Base - Total Interviews | 401 | 276 |
| Number of Loads Washed | | |
| 1 | 2% | 2% |
| 2 | 3 | 3 |
| 3 | 5 | 7 |
| 4 | 7 | 9 |
| 5 | 18 | 19 |
| 6 | 7 | 7 |
| 7 | 10 | 10 |
| 8 | 9 | 9 |
| 9 | 9 | 11 |
| 10 | 5 | 5 |
| 11 | 4 | 3 |
| 12 | 4 | 4 |
| 13 | 5 | 3 |
| 14 | 3 | 1 |
| 15 or more | 9 | 7 |
| Average | 8.1 | 7.4 |
| Median | 7 | 7 |

3.2.2 Estimates of Uncertainty:

Frequency distributions in terms of percent of sample versus loads per week were provided [11, 13] by AHAM. Standard deviations of the samples and sample means computed from these data follow:

| Reference | Clothes Washer Category | Sample Size | Standard Deviation (loads per week) Sample | Sample Mean | Mean, Loads per Week |
|---|---|---|---|---|---|
| 11 | Normal | 401 | 3.9 | 0.19 | 8.1 |
| 11 | Large | 276 | 3.6 | 0.22 | 7.4 |
| 11 | Combined | 677 | 3.9 | 0.15 | 7.8 |
| 13 | All | 8567 | 4.6 | 0.05 | 7.95 |

A standard deviation of the mean of 0.2 loads per week would translate to 52 weeks per year x 0.2 loads per week = 10.4 loads per year, which will be simplified to an uncertainty of ten loads per year out of 416 loads per year.

3.3 Parallel Estimates

Figure J-1 contains results of an August 1959 survey published by the Florida Power and Light Company [90].

A 1975 survey pretest by Marketing Research Corporation of America [112] yielded an average of 6.8 loads per week.

Several sources provided estimates of the electric energy consumed by clothes washers. These values evidently do not account for heating the water.

| Reference | Consumption, kWh per year | Remarks |
|---|---|---|
| 68 | 103 | Edison Electric Institute |
| 123 | 100 | Citizens Advisory Committee on Environmental Quality |
| 123 | 90 | Merchandising Week |
| 123 | 88 | Midwest Research Institute (8/76-7/77) |
| 123 | 65 | Potomac Electric Power Company |
| 123 | 98 | University of Illinois |
| 150 | 45 | 1950 T.T. Woodson |
| 150 | 60 | 1960 |
| 150 | 363 | 1970 |

4. Secondary Usage Factors:

Fill Level

A Usage Fill Factor means the fraction of the loads in which the designated water fill level is selected. The following values are used in the test procedure [88].

$F_{max}$ = 0.72 = Usage Fill Factor, maximum.

$F_{min}$ = 0.28 = Usage Fill Factor, minimum.

These are weighted averages from a survey conducted between 1968 and 1970 [11], based on the following data:

Figure J-1

# DOMESTIC ELECTRIC WATER HEATER RESIDENTIAL SURVEY
## FLORIDA POWER & LIGHT CO. - FLORIDA POWER CORP. - TAMPA ELECTRIC CO.
## AUGUST 1959

| | Florida Power & Light Co. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Northern Region | Eastern Division | Western Division | Southeast Division | Miami Area | FP&L System | Florida Power Corp. | Tampa Electric Co. | Grand Total | Percent |
| Number in Family | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 1 - 3 | 109 | 50 | 47 | 66 | 358 | 630 | 79 | 53 | 762 | 48.6 |
| 4 and over | 88 | 59 | 53 | 57 | 430 | 687 | 46 | 74 | 807 | 51.4 |
| Type of Residence | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 1 - 1-1/2 Baths With | | | | | | | | | | |
| 2 Bedrooms | 98 | 31 | 49 | 17 | 147 | 342 | 82 | 31 | 455 | 29.0 |
| 3 Bedrooms and Over | 63 | 39 | 21 | 15 | 166 | 304 | 20 | 44 | 368 | 23.5 |
| 2 - 2-1/2 Baths With | | | | | | | | | | |
| 2 Bedrooms | 8 | 4 | 6 | 25 | 57 | 100 | 12 | 6 | 118 | 7.53 |
| 3 Bedrooms and Over | 26 | 35 | 24 | 65 | 402 | 552 | 6 | 40 | 600 | 38.25 |
| 3 - 3-1/2 Baths With | | | | | | | | | | |
| 3 Bedrooms | 1 | 0 | 0 | 0 | 11 | 12 | 1 | 2 | 15 | .9 |
| 4 Bedrooms and Over | 1 | 0 | 0 | 1 | 5 | 7 | 2 | 4 | 13 | .82 |

## ELECTRIC WATER HEATERS

| | Northern Region | Eastern Division | Western Division | Southeast Division | Miami Area | FP&L System | Florida Power Corp. | Tampa Electric Co. | Grand Total | Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| Age of Installation | 197 | 109 | 100 | 123 | 786 | 1317 | 125 | 127 | 1569 | 100.0% |
| 0 - 2 Years | 91 | 67 | 36 | 95 | 306 | 595 | 52 | 10 | 657 | 41.9 |
| 3 - 5 Years | 54 | 17 | 40 | 27 | 361 | 499 | 34 | 14 | 547 | 34.9 |
| Over 5 Years | 52 | 25 | 24 | 1 | 121 | 223 | 39 | 103 | 365 | 23.2 |
| Watts Input | 197 | 109 | 100 | 123 | 786 | 1317 | 125 | 127 | 1569 | 100.0% |
| Up to 1500 Watts | 101 | 102 | 67 | 90 | 551 | 911 | 97 | 107 | 1115 | 71.0 |
| Over 1500 Watts | 96 | 7 | 33 | 33 | 237 | 406 | 26 | 20 | 454 | 29.0 |
| Temperature of Water | 197 | 109 | 100 | 123 | 786 | 1317 | 125 | 127 | 1569 | 100.0% |
| 130° or Less | 18 | 29 | 17 | 21 | 263 | 348 | 11 | 16 | 375 | 23.9 |
| 131 - 140° | 90 | 53 | 30 | 37 | 310 | 520 | 30 | 26 | 578 | 36.8 |
| 141 - 150° | 68 | 25 | 35 | 47 | 193 | 368 | 52 | 33 | 453 | 28.9 |
| Over 150° | 21 | 2 | 16 | 18 | 22 | 81 | 32 | 50 | 163 | 10.4 |
| Where Installed | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| Closet | 14 | 12 | 4 | 8 | 26 | 64 | 7 | 6 | 77 | 4.9 |
| Kitchen | 53 | 0 | 35 | 0 | 86 | 174 | 22 | 55 | [illegible] | [illegible] |
| Bath | 3 | 0 | 3 | 1 | 2 | 9 | 1 | 3 | 13 | 0.8 |
| Utility Room | 104 | 71 | 56 | 106 | 478 | 817 | 45 | 21 | 883 | 56.3 |
| Other | 23 | 26 | 2 | 6 | 246 | 303 | 50 | 36 | 391 | 24.9 |
| Distance to Bath | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 1 - 20 Feet | 137 | 76 | 60 | 56 | 300 | 629 | 84 | 75 | 788 | 50.2 |
| 21 - 30 Feet | 46 | 14 | 30 | 45 | 254 | 389 | 26 | 36 | 453 | 28.9 |
| Over 30 Feet | 14 | 19 | 10 | 22 | 234 | 299 | 15 | 14 | 328 | 20.9 |

## CLOTHES WASHERS

| | Northern Region | Eastern Division | Western Division | Southeast Division | Miami Area | FP&L System | Florida Power Corp. | Tampa Electric Co. | Grand Total | Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Clothes Washer | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| Automatic | 154 | 86 | 93 | 104 | 698 | 1135 | 99 | 101 | 1335 | 85.1 |
| Conventional | 27 | 14 | 3 | 4 | 44 | 92 | 10 | 12 | 114 | 7.3 |
| No Clothes Washer | 16 | 9 | 4 | 15 | 46 | 90 | 16 | 14 | 120 | 7.6 |
| Loads per Week | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 1 - 5 | 75 | 38 | 29 | 40 | 321 | 503 | 61 | 43 | 607 | 38.7 |
| 6 - 10 | 76 | 51 | 49 | 45 | 316 | 537 | 35 | 49 | 621 | 39.6 |
| Over 10 | 30 | 11 | 16 | 23 | 105 | 187 | 13 | 21 | 221 | 14.1 |
| No Clothes Washer | 16 | 9 | 4 | 15 | 46 | 90 | 16 | 14 | 120 | 7.6 |
| Number of Loads per Day | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 2 or Less | 113 | 61 | 55 | 73 | 438 | 740 | 86 | 68 | 894 | 57.0 |
| Over 2 | 68 | 39 | 41 | 35 | 304 | 487 | 23 | 45 | 555 | 35.4 |
| No Clothes Washer | 16 | 9 | 4 | 15 | 46 | 90 | 16 | 14 | 120 | 7.6 |
| Days Washing per Week | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| 2 or Less | 70 | 36 | 17 | 26 | 257 | 406 | 43 | 41 | 490 | 31.2 |
| 3 - 4 Days | 44 | 30 | 33 | 40 | 208 | 355 | 34 | 27 | 416 | 26.5 |
| 5 - 7 Days | 66 | 33 | 47 | 42 | 278 | 466 | 32 | 45 | 543 | 34.7 |
| No Clothes Washer | 17 | 10 | 3 | 15 | 45 | 90 | 16 | 14 | 120 | 7.6 |
| Washed In (Total Loads) | 1242 | 666 | 732 | 795 | 5066 | 8501 | 616 | 785 | 9902 | 100.0% |
| Hot Water | 613 | 329 | 320 | 390 | 2101 | 3753 | 377 | 323 | 4453 | 45.0 |
| Warm Water | 597 | 321 | 355 | 405 | 2753 | 4431 | 239 | 450 | 5120 | 51.7 |
| Cold Water | 32 | 16 | 57 | 0 | 212 | 317 | 0 | 12 | 329 | 3.3 |
| Rinsed In (Total Loads) | 1242 | 666 | 732 | 795 | 5066 | 8501 | 616 | 785 | 9902 | 100.0% |
| Hot Water | 98 | 88 | 39 | 0 | 683 | 706 | 24 | 26 | 756 | 7.7 |
| Warm Water | 617 | 281 | 493 | 565 | 3200 | 5158 | 462 | 525 | 6145 | 62.0 |
| Cold Water | 527 | 297 | 200 | 230 | 1183 | 2657 | 130 | 234 | 3001 | 30.3 |
| Use Detergents | 197 | 109 | 100 | 121 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| Yes | 175 | 98 | 91 | 109 | 688 | 1161 | 91 | 116 | 1368 | 87.2 |
| No | 4 | 3 | 3 | 1 | 12 | 23 | 4 | 1 | 28 | 1.8 |
| No Comment | 18 | 8 | 6 | 13 | 88 | 133 | 30 | 10 | 173 | 11.0 |
| New Fabrics & Detergents | 197 | 109 | 100 | 123 | 788 | 1317 | 125 | 127 | 1569 | 100.0% |
| Wash in Cooler Water - Yes | 102 | 62 | 45 | 14 | 336 | 579 | 57 | 66 | 702 | 44.7 |
| " " " " - No | 70 | 32 | 43 | 79 | 128 | 352 | 29 | 17 | 618 | 39.4 |
| No Comment | 25 | 15 | 12 | 10 | 124 | 186 | 39 | 24 | 249 | 15.9 |

| | Washer Capacity | | |
|---|---|---|---|
| | Normal | Large | Composite |
| Total loads | 3231 | 2047 | 5278 |
| Maximum fill, percent | 79 | 60 | 72 |
| Partial fill, percent | 21 | 40 | 28 |

No field data are available on which to base an estimate of uncertainty for $F_{max}$ or $F_{min}$. An uncertainty of 0.07 (approximately ten percent of $F_{max}$) will be used for analysis purposes.

Suds Saver Use Factor

Some clothes washers permit the saving and re-use of the wash water. Since the wash water is continually losing heat, it is assumed that the suds saver will save energy only when the first load uses a hot wash cycle and the second load uses a warm wash cycle in a multiple load session. Since the actual frequency of multiple load sessions is unknown, it is assumed that 50 percent of the annual hot wash loads occur in two-load sessions.

The use factors appearing in the test procedure [88] for clothes washers equipped with suds savers are:

$X = 0.86$ = frequency of use without suds saver.

$X = 0.14$ = frequency of use of suds-saver feature.

Based on the 1975 temperature use factors provided in HLW-2EC [12], NBS determined that consumers would use a hot wash 28 percent of the time. This would result in 116 "hot" wash loads a year (116 = 0.28 x 416) based on the representative average use cycle of 416 cycles per year. After assigning 50 percent frequency of use factor to these figures, NBS has estimated that the consumers would use the suds-saver feature, if available, for 58 loads per year, or 14 percent ($0.14 = \frac{58}{416}$) of the annual loads. Data on wash water reuse obtained by interviewing 677 families [11] are given below.

| | Normal Capacity | Large Capacity | Composite |
|---|---|---|---|
| Total Interviews | 401 | 276 | 677 |
| Used fresh water for all loads, percent | 84 | 91 | 87 |
| Reused water for some loads | 16 | 9 | 13 |

Since no field data are available on which to base an estimate the uncertainty in these factors, an uncertainty of 0.02, will be assumed for analysis purposes.

Temperature Use Factors

The following temperature use factors, TUF's,* were developed from a 1975 industry survey, published in AHAM HLW-2EC [12] and excerpted from the test procedure [88].

5. APPLICABLE TEMPERATURE USE FACTORS FOR DETERMINING HOT WATER USAGE FOR VARIOUS WASH/RINSE TEMPERATURE SELECTIONS FOR ALL AUTOMATIC CLOTHES WASHERS

5.1 *Five temperature selection* ($n=5$).

| Wash/rinse temperature setting: | *Temperature use factor (TUF)* |
|---|---|
| Hot/warm | 0.18 |
| Hot/cold | .12 |
| Warm/warm | .30 |
| Warm/cold | .25 |
| Cold/cold | .15 |

5.2 *Four temperature selection* ($n=4$).

| Wash/rinse temperature setting—alternate I: | *Temperature use factor (TUF)* |
|---|---|
| Hot/warm | 0.18 |
| Hot/cold | .12 |
| Warm/cold | .55 |
| Cold/cold | .15 |
| Alternate II: | |
| Hot/warm | 0.18 |
| Hot/cold | .12 |
| Warm/warm | .30 |
| Warm/cold | .40 |
| Alternate III: | |
| Hot/cold | 0.12 |
| Warm/warm | .18 |
| Warm/cold | .55 |
| Cold/cold | .15 |

5.3 *Three temperature selection* ($n=3$).

| Wash/rinse temperature setting: | *Temperature use factor (TUF)* |
|---|---|
| Alternate I: | |
| Hot/warm | 0.30 |
| Warm/cold | .55 |
| Cold/cold | .15 |
| Alternate II: | |
| Hot/cold | 0.30 |
| Warm/cold | .55 |
| Cold/cold | .15 |
| Alternate III: | |
| Hot/cold | 0.30 |
| Warm/warm | .55 |
| Cold/cold | .15 |

6. APPLICABLE TEMPERATURE USE FACTORS FOR DETERMINING HOT WATER USAGE FOR VARIOUS WASH/RINSE TEMPERATURE SETTINGS FOR ALL SEMI-AUTOMATIC CLOTHES WASHERS

6.1 *Six temperature settings* ($n=6$).

| Wash/rinse temperature setting: | *Temperature use factor (TUF)* |
|---|---|
| Hot/hot | 0.15 |
| Hot/warm | .09 |
| Hot/cold | .06 |
| Warm/warm | .42 |
| Warm/cold | .13 |
| Cold/cold | .15 |

*TUF = fraction of loads in which the indicated wash/rinse temperature setting was used.

Results from 1971 and 1975 surveys [12] are given below.

### APPLICABLE USE FACTORS FOR DETERMINING HOT WATER USAGE FOR VARIOUS WASH/RINSE TEMPERATURE SELECTIONS

**I. Five Temperature Selection**

| Wash/Rinse Temperature Setting | 1971 Survey Use Factor | 1975 Survey Use Factor |
|---|---|---|
| Hot/Warm | .25 | .18 |
| Hot/Cold | .15 | .12 |
| Warm/Warm | .30 | .30 |
| Warm/Cold | .20 | .25 |
| Cold/Cold | .10 | .15 |

**II. Four Temperature Selection**

| Wash/Rinse Temperature Setting | 1971 Survey Use Factor | 1975 Survey Use Factor |
|---|---|---|
| **A. Alternate I** | | |
| Hot/Warm | .25 | .18 |
| Hot/Cold | .15 | .12 |
| Warm/Cold | .50 | .55 |
| Cold/Cold | .10 | .15 |
| **B. Alternate II** | | |
| Hot/Warm | .25 | .18 |
| Hot/Cold | .15 | .12 |
| Warm/Warm | .30 | .30 |
| Warm/Cold | .30 | .40 |
| **C. Alternate III** | | |
| Hot/Cold | .15 | .12 |
| Warm/Warm | .30 | .18 |
| Warm/Cold | .45 | .55 |
| Cold/Cold | .10 | .15 |

**III. Three Temperature Selection**

| Wash/Rinse Temperature Setting | 1971 Survey Use Factor | 1975 Survey Use Factor |
|---|---|---|
| **A. Alternate I** | | |
| Hot/Warm | .40 | .30 |
| Warm/Cold | .50 | .55 |
| Cold/Cold | .10 | .15 |
| **B. Alternate II** | | |
| Hot/Cold | .40 | .30 |
| Warm/Cold | .50 | .55 |
| Cold/Cold | .10 | .15 |
| **C. Alternate III** | | |
| Hot/Cold | .40 | .30 |
| Warm/Warm | .50 | .55 |
| Cold/Cold | .10 | .15 |

IV. Other

If other wash/rinse temperature combinations, or user selections are other than those shown, they can be incorporated into this appendix.

No data are available on which to base estimates of uncertainty for these factors. An adjusted case will be specified in Section 5 for analysis purposes.

5. Impact Assessments of Uncertainty

The effects of uncertainties in the various usage factors on the Estimated Annual Operating Cost, EAOC, by selecting a base case and then varying each usage factor in turn.

Base Case:

- Cycles per year = 416.
- Electric energy per cycle for motor and controls = 0.22 kWh.
- Electric hot water is used with a temperature rise of 90 F. The resulting energy cost per gallon is

  8.33 pounds per gallon x 90 F/3412 Btu per kWh = 0.22 kWh per gallon.

- Electricity cost = $0.038 per kWh [83].
- Fill Factor, maximum = $F_{max}$ = 0.72 = 1-$F_{min}$.
- Minimum fill, $V_{min}$ = 0.5 x maximum fill, $V_{max}$.
- Suds Saver Use Factor = $X_2$ = 0.14 = 1-$X_1$.
- Temperature Use Factors: Four temperature selection, Alternate II: (H = Hot, W = Warm, C = Cold).

| Temperature Settings | Hot Water, gal per cycle, $V_i$ | Temperature Use Factors, $TUF_i$ Base Case | Adjusted Case |
|---|---|---|---|
| H/W | 32.3 | 0.18 | 0.10 |
| H/C | 21.0 | 0.12 | 0.10 |
| W/W | 22.6 | 0.30 | 0.20 |
| W/C | 11.3 | 0.40 | 0.60 |

- Fresh make-up hot water for suds return cycle = $S_H$ = 2 gal.
- The washer is time-filled.

Using the base case assumptions given above and the formulas in the test procedure [88], the following weighted value formula for hot water volume, V, may be derived:

$$V = \frac{1+F_{max}}{2} \times (x_1 \times \sum_{i=1}^{n} V_i \times TUF_i + (1-X_1)(TUF_w \times S_H)).$$

Inserting values for the base case,

$$\sum_{i=1}^{4} V_i \times TUF_i = (32.3 \times 0.18) + (21.0 \times 0.12) + (22.6 \times 0.30)$$
$$+ (11.3 \times 0.40) = 19.63 \text{ gal of hot water per cycle.}$$

$$V = \frac{1+0.72}{2} \times [(0.86 \times 19.63) + (0.14 \times 0.70 \times 2)]$$

$$= 14.69 \text{ gal per cycle.}$$

$$\text{EAOC (base case)} = 416 \times [(14.69 \times 0.22 + 0.22)] \times 0.038$$

$$= \$54.57 \text{ per year,}$$

which would be reported as $55 per year.

Cycles per Year

An estimated uncertainty of ten cycles per year is assumed. The corresponding uncertainty in EAOC is

$$\Delta\text{EAOC} = \$54.57 \times 10 \div 416 = \$1.31.$$

Fill Level

An estimated uncertainty in $F_{max}$ of 0.07 is assumed, leading to an adjusted value of 0.79 for $F_{max}$. Accordingly,

$$V(\text{adjusted}) = V(\text{base}) \times \frac{1+0.79}{1+0.72} = 14.69 \times \frac{1.79}{1.72}$$

$$= 15.29 \text{ gal per cycle.}$$

The corresponding EAOC is

$$\text{EAOC(adjusted)} = 416 \times 0.038 \times 0.22 \times (15.29 + 1)$$

$$= \$56.65 \text{ per year, and}$$

$\Delta EAOC = \$56.65 - 54.57 = \$2.08$ per year.

Suds Saver

An estimated uncertainty in $X_i$ of -0.02 is assumed, meaning that the use of the suds saver would apply to 16 percent, rather than 14 percent of the cycles.

$$V(\text{adjusted}) = \frac{1.72}{2} \times [(0.84 \times 19.63) + (0.16 \times 0.70 \times 2)]$$

$$= 14.37 \text{ gallons of hot water per cycle,}$$

$$EAOC(\text{adjusted}) = 416 \times 0.22 \times 0.038 \times (14.37 + 1)$$

$$= \$53.45 \text{ per year,}$$

and $\Delta EAOC = \$53.45 - 54.57 = -\$1.12$ per year.

Temperature Use Factors

The adjusted values that are assumed are shown in the section defining the base case. A substantial shift towards the use of a warm/cold cycle is assumed. In this case,

$$\sum_{i=1}^{4} V_i \times TUF_i = (32.3 \times 0.10) + (21.0 \times 0.10) + (22.6 \times 0.20)$$

$$+ (11.3 \times 0.60) = 16.63 \text{ gal per cycle,}$$

$$V = \frac{1.72}{2} \times [(0.86 \times 16.63) + (0.14 \times 0.8 \times 2)]$$

$$= 12.49 \text{ gallons per cycle, and}$$

$$EAOC(\text{adjusted}) = 416 \times 0.22 \times 0.038 \times (12.49 + 1)$$

$$= \$46.91 \text{ per year.}$$

$\Delta EAOC = \$46.91 - 54.57 = -\$7.66$ per year.

6. Comments

All of the uncertainties in the usage factors are essentially assumed. Therefore, the first action suggested for this product type is to solicit from industry (mainly Procter and Gamble) better values for these uncertainties. Given such data, it is suspected that monitoring of future industry findings will suffice.

# APPENDIX K. HUMIDIFIERS

1. References: 43, 50, 51, 58, 64, 79, 176

2. Test Procedures: Final [58] October 18, 1977
   Proposed [79] June 1, 1977

3. Primary Use Factor

3.1 Value

National average annual use cycle, for both room and central humidifiers, are 700 hours for units with humidistats and 1600 hours for units without humidistats [58].

3.2 Basis

An analytical approach [43] was employed, using a bin-method calculation to determine operating hours within separate geographic areas of several weather-reporting stations across the U.S. Humidifiers were assumed to be matched to the load in each case and set to maintain 30 percent relative humidity at 70 F temperature. The house air-infiltration rate was taken to be 0.75 air changes per hour. (It had been independently determined [50] that humidification is not required at any time for Hawaii, the Canal Zone, Puerto Rico, the Virgin Islands, or Guam.).

When both types are operating under humidistat control, the actual usage cycle for central humidifiers differs from that for room humidifiers because central units are confined in their operation to periods when the furnace is on, whereas room units operate independently and, accordingly, may operate at any time whenever humidity is required [58]. Thus, the procedure differs in the usage calculations for the two types.

3.2.1 Description of Basis

Central Humidifiers [43]:

The major steps in the analysis of humidistat controlled central humidifiers were

1. For each specific regional location, determine the furnace duty factor, DFF, for each temperature bin.

2. Correspondingly, determine the duty factor, DFH, for a humidifier of assumed size.

3. Identify the temperature bin for which the ratio of DFH/DFF is a maximum and adjust the size of the humidifier to make DFH = DFF for that bin. Holding the new humidifier size fixed, adjust the DFH's for the other bins in the same proportion needed to achieve the DFH = DFF equality described above.

4. Using these duty factors as weighting factors and the observed hours for each bin, compute humidifier annual operating hours, HHRS. Byproduct calculations also included annual furnace hours, FHRS, humidifier capacity, CAP, in gallons per day and humidification gallons per year, GAL.

5. Using year-round housing units as reported in the 1970 census as weighting factors, calculate weighted average values at the national level for HHRS, FHRS, CAP and GAL. Recent sales statistics for central humidifiers would have been preferred for doing these weighting calculations, but no such statistics were located.

6. Adjust the derived value for HHRS for factors and considerations not explicitly included in the analytical model, and round the result to whole hundred hours.

The analysis results are summarized in Table K-1.

For the case of central humidifiers without humidistats it is recognized that any such unit will normally operate whenever the furnace is on. The average annual furnace hours derived from Table K-1 is approximately 1600 hours per year.

Room Humidifiers [43]:

The main steps in the analytical development of usage data for humidistat-controlled room humidifiers are outlined below.

1. Select system design objectives: indoor temperature and relative humidity, and design capacity level for humidification.

Table K-1. Analysis Results for Humidistat Controlled Central Humidifiers

| Case # | Station | State | Cap. GAL/DAY | GAL/YR | FHRS | HHRS |
|---|---|---|---|---|---|---|
| 1 | Portland | ME | 9.1 | 312 | 1910.2 | 823.1 |
| 2 | Burlington | VT | 10.3 | 496 | 1856.0 | 1155.8 |
| 3 | L.G. Hanscom Fld. | MA | 8.9 | 295 | 1814.1 | 797.7 |
| 4 | Mitchell AFB | NY | 7.7 | 236 | 1695.7 | 734.4 |
| 5 | Niagara Falls | NY | 7.8 | 284 | 1976.7 | 872.9 |
| 6 | McGuire AFB | NJ | 7.3 | 238 | 1769.4 | 782.7 |
| 7 | Wilkes-Barre | PA | 8.9 | 298 | 1747.4 | 806.3 |
| 8 | Wright-Pat. AFB | OH | 7.7 | 222 | 1558.4 | 694.6 |
| 9 | Indianapolis | IN | 8.2 | 246 | 1595.6 | 721.7 |
| 10 | O'Hare IAP | IL | 9.2 | 347 | 1677.7 | 901.5 |
| 11 | Battle Creek | MI | 7.7 | 283 | 1891.3 | 876.9 |
| 12 | Green Bay | WI | 10.0 | 411 | 1865.0 | 987.4 |
| 13 | Minneapolis | MN | 10.4 | 484 | 1788.5 | 1121.2 |
| 14 | Des Moines | IA | 9.6 | 384 | 1604.5 | 961.0 |
| 15 | Kansas City | MO | 8.2 | 252 | 1434.3 | 742.5 |
| 16 | Grand Forks | ND | 12.1 | 649 | 1906.5 | 1289.9 |
| 17 | Sioux Falls | SD | 10.6 | 515 | 1714.6 | 1161.3 |
| 18 | Grand Island | NE | 9.3 | 373 | 1656.9 | 962.1 |
| 19 | Offutt AFB | NE | 9.2 | 376 | 1628.3 | 976.5 |
| 20 | Dodge City | KS | 7.8 | 240 | 1545.8 | 735.6 |
| 21 | Wilmington | DE | 7.0 | 208 | 1739.5 | 713.4 |
| 22 | Andrews AFB | DC | 7.6 | 206 | 1600.8 | 652.3 |
| 23 | Langley AFB | VA | 5.8 | 102 | 1463.1 | 423.7 |
| 24 | Elkins | WV | 8.3 | 236 | 1687.6 | 680.4 |
| 25 | Greensboro | NC | 6.2 | 135 | 1459.2 | 521.0 |
| 26 | Charleston | SC | 4.8 | 37 | 1070.7 | 185.0 |
| 27 | Augusta | GA | 5.7 | 38 | 1105.7 | 162.4 |
| 28 | Dobbins AFB | GA | 6.2 | 77 | 1323.0 | 301.7 |
| 29 | Jacksonville | FL | 4.7 | 14 | 733.7 | 70.4 |
| 30 | Louisville | KY | 7.6 | 155 | 1418.7 | 492.3 |
| 31 | Memphis NAS | TN | 6.1 | 92 | 1315.0 | 360.5 |
| 32 | Maxwell AFB | AL | 5.5 | 47 | 1075.7 | 206.3 |
| 33 | Jackson | MS | 5.9 | 34 | 1084.6 | 138.9 |
| 34 | Little Rock | AR | 6.1 | 83 | 1181.6 | 329.7 |
| 35 | New Orleans | LA | 4.0 | 12 | 832.4 | 74.7 |
| 36 | Tulsa | OK | 6.8 | 149 | 1322.5 | 526.4 |
| 37 | Carswell AFB | TX | 5.9 | 83 | 1062.5 | 341.0 |
| 38 | Malmstrom AFB | MT | 10.8 | 480 | 1626.4 | 1064.0 |
| 39 | Boise | ID | 7.6 | 230 | 1888.7 | 728.9 |
| 40 | Cheyenne | WY | 65.4 | 702 | 1977.3 | 257.7 |
| 41 | Lowry AFB | CO | 8.4 | 451 | 1771.8 | 1289.0 |
| 42 | Albuquerque | NM | 10.8 | 408 | 1546.2 | 903.1 |
| 43 | Davis-Monthan AFB | AZ | 3.5 | 85 | 1005.7 | 536.4 |
| 44 | Everett | WA | 6.0 | 33 | 2341.0 | 133.2 |
| 45 | Los Angeles | CA | 3.5 | 1 | 1057.2 | 5.9 |
| 46 | Elmendorf AFB | AK | 10.6 | 674 | 2309.5 | 1531.7 |
| 47 | Portland | OR | 6.0 | 25 | 2039.7 | 99.2 |
| 48 | Wendover AFB | UT | 27.3 | 467 | 1708.3 | 411.3 |
| 49 | Stead AFB | NV | 58.1 | 628 | 1979.8 | 259.3 |
| 50 | Schilling AFB | KS | 7.8 | 275 | 1552.1 | 845.0 |
| 51 | Seymour-Johnson AFB | NC | 5.8 | 89 | 1236.8 | 367.0 |
| 52 | Shaw AFB | SC | 5.7 | 80 | 1186.0 | 338.6 |
| 53 | Vandenberg AFB | CA | 1.2 | 1 | 2141.4 | 10.9 |

2. Select the geographical locations to be studied.

3. Determine for each location the statistical distribution of the outdoor humidity ratio (density of water vapor vs. density of dry air) in terms of potential demand hours per year.

4. Determine the design level difference in humidity ratio between outdoor conditions and the balance point for each location. (The balance point is that humidity ratio at which no contribution is required from the humidifier.)

5. Calculate the equivalent full-load operating hours, using the weighting factors for each humidity ratio difference associated with the design level.

6. Calculate national averages for demand hours and for operating hours weighted by year-around housing units for the state.

7. Apply adjustments to the national averages for factors not treated in the analysis, and round the results to whole hundred hours.

For the case of room humidifiers without humidistats, it is arbitrarily established that annual operating hours are the same as those for central humidifiers without humidistats, namely, 1600 hours.

Table K-2 shows the results of calculations of local and of national average usage hours under different rates of house air infiltration for humidistat-controlled room humidifiers. Although in present houses the infiltration rate is about one air change per hour [176], an average value of 0.75 air change per hour is assumed in anticipation of energy-conserving home improvements, such as increased installations of storm windows. On the basis of 0.75 air change per hour, the annual operation for a humidistat-controlled room humidifier is computed to be 1000 hours. Similarly, for a humidistat-controlled central humidifier the annual operation is computed to be 600 hours. A compromise, common, usage figure of 700 hours for each type is selected for purposes of performance comparisons among humidifiers of the two types.

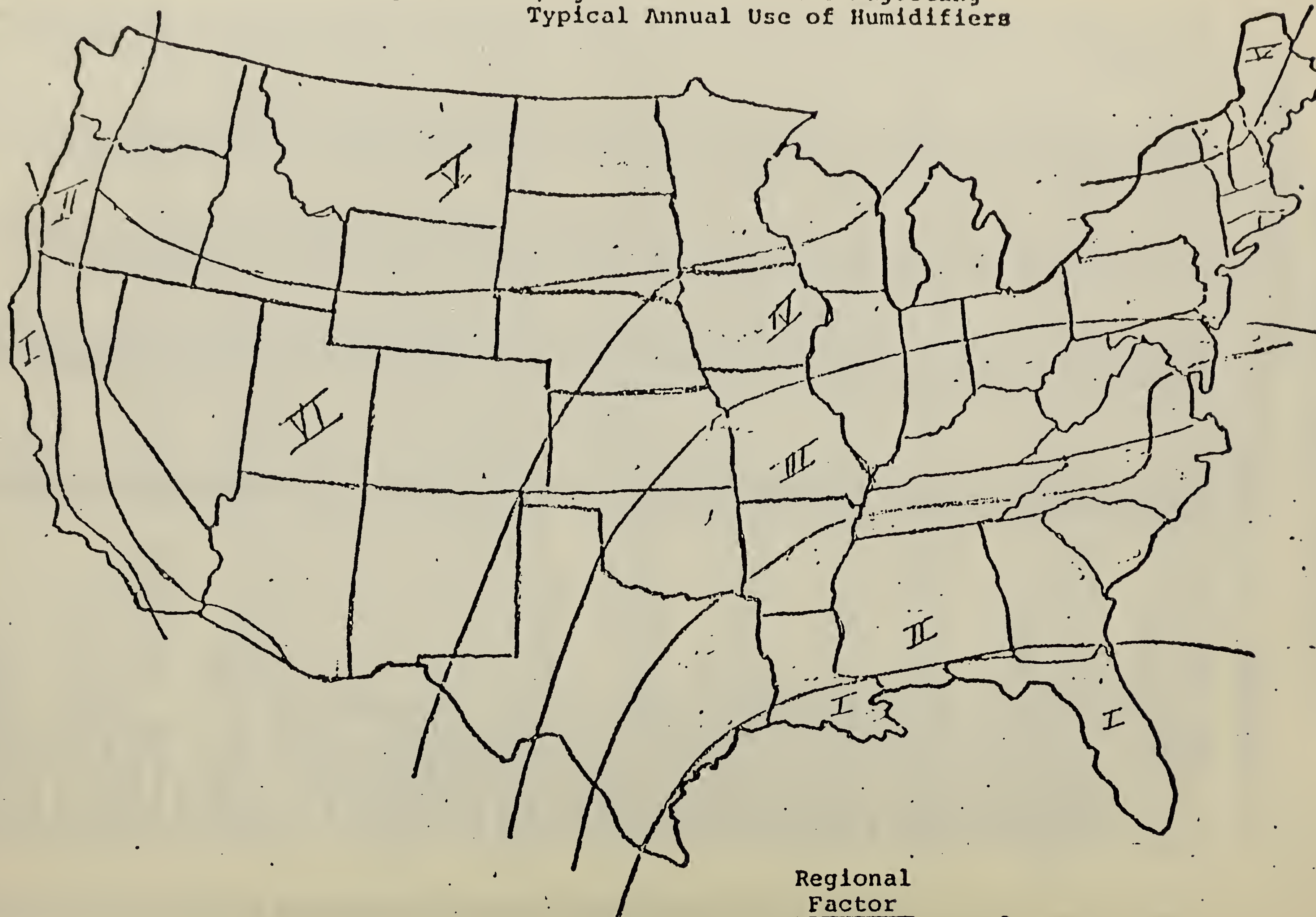
The data in Table K-2 were used to generate the humidification zone map, Figure K-1. The national average

Table K-2. Room Humidifier Operating Hours
for Different Air-Infiltration Rates

| | Station | State | Air Changes Per Hour 1.5 | 1.0 | 0.75 | 0.5 |
|---|---|---|---|---|---|---|
| 1 | Portland | ME | 1806 | 1631 | 1531 | 1199 |
| 2 | Burlington | VT | 2362 | 2197 | 2097 | 1767 |
| 3 | L. G. Hanscom. Fld. | MA | 1810 | 1622 | 1510 | 1162 |
| 4 | Mitchell AFB | NY | 1607 | 1423 | 1306 | 1017 |
| 5 | Niagara Falls | NY | 1660 | 1499 | 1404 | 1090 |
| 6 | McGuire AFB | NJ | 1769 | 1598 | 1492 | 786 |
| 7 | Wilkes-Barre | PA | 1596 | 1411 | 1305 | 957 |
| 8 | Wright-Pat. AFB | OH | 1293 | 1124 | 1027 | 725 |
| 9 | Indianapolis | IN | 1372 | 1207 | 1113 | 797 |
| 10 | O'Hare AP | IL | 1711 | 1533 | 1431 | 1078 |
| 11 | Battle Creek | MI | 1677 | 1489 | 1379 | 1019 |
| 12 | Green Bay | WI | 2285 | 2114 | 2012 | 1646 |
| 13 | Minneapolis | MN | 2369 | 2206 | 2109 | 1784 |
| 14 | Des Moines | IA | 1876 | 1712 | 1616 | 1294 |
| 15 | Kansas City | MO | 1293 | 1105 | 999 | 700 |
| 16 | Grand Forks | ND | 3002 | 2866 | 2784 | 2504 |
| 17 | Sioux Falls | SD | 2400 | 2230 | 2130 | 1793 |
| 18 | Grand Island | NE | 1962 | 1769 | 1656 | 1299 |
| 19 | Offutt AFB | NE | 1842 | 1676 | 1579 | 1269 |
| 20 | Dodge City | KS | 1703 | 1496 | 1375 | 959 |
| 21 | Schilling AFB | KS | 1428 | 1260 | 1163 | 864 |
| 22 | Wilmington | DE | 1473 | 1294 | 1183 | 862 |
| 23 | Andrews AFB | DC | 1546 | 1366 | 1253 | 970 |
| 24 | Langley AFB | VA | 798 | 679 | 610 | 411 |
| 25 | Elkins | WV | 1425 | 1254 | 1155 | 835 |
| 26 | Greensboro | NC | 1089 | 930 | 829 | 565 |
| 27 | Seymour-Johnson AFB | NC | 700 | 591 | 525 | 347 |
| 28 | Charleston | SC | 649 | 347 | 296 | 167 |
| 29 | Shaw AFB | SC | 543 | 444 | 385 | 245 |
| 30 | Augusta | GA | 473 | 389 | 349 | 207 |
| 31 | Dobbins AFB | GA | 817 | 689 | 610 | 403 |
| 32 | Jacksonville | FL | 194 | 172 | 166 | 53 |
| 33 | Louisville | KY | 1301 | 1131 | 1026 | 475 |
| 34 | Memphis NAS | TN | 781 | 675 | 613 | 432 |
| 35 | Maxwell AFB | AL | 437 | 357 | 309 | 195 |
| 36 | Jackson | MS | 433 | 354 | 308 | 185 |
| 37 | Little Rock | AR | 686 | 568 | 496 | 306 |
| 38 | New Orleans | LA | 132 | 108 | 96 | 31 |
| 39 | Tulsa | OK | 1104 | 951 | 858 | 396 |
| 40 | Carswell AFB | TX | 553 | 452 | 390 | 233 |
| 41 | Malmstrom AFB | MT | 2698 | 2462 | 2324 | 1799 |
| 42 | Boise | ID | 2057 | 1741 | 1546 | 1036 |
| 43 | Cheyenne | WY | 3413 | 3229 | 3103 | 2620 |
| 44 | Lowry AFB | CO | 2686 | 2473 | 2340 | 1814 |
| 45 | Albuquerque | NM | 3341 | 3095 | 2945 | 2309 |
| 46 | Davis-Monthan AFB | AZ | 2076 | 1724 | 1481 | 923 |
| 47 | Stead AFB | NV | 3604 | 3208 | 2962 | 2112 |
| 48 | Everett | WA | 788 | 384 | 296 | 121 |
| 49 | Los Angeles | CA | 50 | 6 | 4 | 1 |
| 50 | Vandenberg AFB | CA | 187 | 26 | 19 | 5 |
| Housing unit weighted | | national average | 1241 | 1083 | 999 | 722 |

Residence: 1500 sq ft x 8 ft ceilings
Internal moisture release: 0.7 lb/hr

Figure K-1. Regional Factors for Adjusting Typical Annual Use of Humidifiers




| | Regional Factor |
|---|---|
| I | 0.1 |
| II | 0.5 |
| III | 1.0 |
| IV | 1.5 |

operating hours apply to zone III. Approximate operating hours for the other zones are found by multiplying zone III hours by the appropriate regional factor. Alaska should be included in zone VI.

3.2.2 Estimate of Uncertainty

Weather data employed in the analysis [51] are from hourly observations over periods of several years, so that statistical errors in the average values of temperature and humidity at the various stations are believed to be insignificant for practical purposes. The major concerns for possible uncertainty in the computed average usage value lie in assumptions on the nature and measure of individual requirements for comfort in the home for which no general field survey data were located.

3.3 Parallel Estimates

No reliable survey data bearing on a national average usage cycle are known.

4. Secondary Usage Factors

Humidity control objective: 30 percent relative humidity at 70 F.

5. Impact Assessment of Uncertainties

Two cost components are recognized in the operation of a humidifier. One is the cost of the electrical energy to operate the fans and motors that move the water into an air stream. The other is the load on the home heating system to evaporate the water. Operating costs are calculated in Table K-3 below for one typical portable and one typical central unit for a day of operation at rated capacity. Electric energy costs are based on $0.38 per kWh. Evaporation costs are based on 1054 Btu per pound of water at 70 F, 8.3 pounds of water per gallon, and a gas heating system operating at 65 percent efficiency at a cost of $0.207 per therm (100 000 Btu per therm). The ratings refer to units offered in the Sears, Roebuck and Co. catalog for fall and winter 1977. These units are used as base cases in the subsequent discussion.

Table K-3. Breakdown of Operating Costs for Humidifers

| Type | Rating Gal/Day | Rating Watts | Operating Costs in Cents per Day Motor | Evaporation | Total |
|---|---|---|---|---|---|
| Portable | 12 | 110 | 10 | 22 | 32 |
| Central | 13 | 58 | 5 | 24 | 29 |

Data on the distribution of humidifiers by type and capacity were not located. The annual operating cost of both base case units is seen to be approximately 30 cents for a 24-hour day or $9 for a 700-hour year. A percentage change in the annual operating hours leads to the same percentage change in EAOC. Thus, a change to 1000 hours per year would mean a ΔEAOC of $3.86 per year and a change to 600 hours per year would mean a ΔEAOC of -$1.29 per year.

6. Comments

a. The annual operating hours of properly sized room (1000 hours per year) and central humidifiers (600 hours per year) will not be the same for reasons given earlier. Some basis should be developed that will avoid the need to force both types of humidifers to use the same usage factor.

b. Operating hours for central humidifiers were estimated before the current method for computing furnace operating hours was available [64]. A reassessment is suggested that is expected to yield fewer annual operating hours per year and compensating sizing adjustments for central humidifiers.

c. Humidifier EAOC's include the costs of heat to evaporate the water and electricity for its mechanical operation. Since the energy for mechanical operations eventually becomes heat in the house, it is suggested that this heat input be applied as a credit to the evaporating process.

d. Since the EAOC's for humidifiers are small in any case, it is suggested that any further significant expenditures on usage factors for this product type be avoided.

# APPENDIX L. DEHUMIDIFIERS

1. References: 6, 8, 50, 54, 56, 58, 79, 165, 177, 178

2. Test Procedures: Final [58] October 18, 1977
   Proposed [79] June 1, 1977

3. Primary Use Factor

3.1 Value

National average annual use cycle, 1300 hours of full-load operation, assuming indoor conditions of 55 percent relative humidity and 75 F temperature [58, 59].

3.2 Basis

Analytical computation [54] of usage hours was based upon consideration of climate data extending over at least ten years at each of 36 locations in the continental United States, weighting over nine regions for numbers of wired homes and regional market saturation. Two factors that are not tested are assumed to compensate. These are the possibility that a user might not promptly empty a full drip pan, which would decrease the operating hours, and the operating hours needed to remove moisture added by household activities in the conditioned space. Also information provided by AHAM on the distribution of dehumidifier shipments [58].

3.2.1 Description of Basis

The main steps in the analysis were:

1. Select design objectives for indoor dry bulb temperature and relative humidity (75 F, 55%) and determine the corresponding humidity ratio, W (e.g., pounds of water per pound of dry air (in the mixture)).

2. Select locations in each region of the country [56], that have high humidity levels and that are near to or representative of large populations. Thirty-six locations were chosen for analysis, with varying success in meeting all the criteria.

3. Construct a table to convert combinations of outdoor dry bulb bin and mean coincident wet bulb

temperature to the heat removal requirement per pound of dry air in the mixture needed to produce the desired indoor humidity level. (In technical terms, this is the enthalpy difference, in Btu per pound of dry air in the mixture, needed to remove the latent heat of the excess humidity.)

4. For each of the selected locations and all months of the year, determine the cumulative hours at each enthalpy level, and the total of all these demand hours.

5. Using the assumed design level criterion, determine the corresponding design enthalpy levels. A 95 percent design level was used, meaning that the indoor design humidity level could be maintained during at least 95 percent of the demand hours per year. (A different meaning of this criterion could be used. In reference 6, such criteria refer to percentages of all hours (2928) during June through September. On a 95 percent design basis, approximately 150 hours per year would be at or above the design condition.)

6. Compute the annual operating hours at each enthalpy level, assuming a weighting factor of 1.0 for the hours at or above the design enthalpy, and proportionately lower weighting factors for the demand hours at lower enthalpy levels. Add these results to obtain average annual operating hours for the location being analyzed.

7. Average these annual operating hours for all selected locations in a region to obtain regional averages.

8. Using regional market saturations and number of wired homes [177], produce an estimate of potential average operating hours at the national level.

9. Round the national average downward to allow for inattention, the possibility that a user might not empty a full container of condensate promptly. Add a like number of hours to allow for removal of a share of the moisture from internal household activities.

Analysis results are given by site in Table L-1.

Table L-1. Results by Location [50, 54]

| | Location | State | Demand Hours | Enthalpy Design Level, Btu/lb | Operating Hours |
|---|---|---|---|---|---|
| 1 | Mitchell AFB | NY | 2216 | 4 | 1620 |
| 2 | McGuire AFB | NJ | 2107 | 4 | 1582 |
| 3 | Burlington | VT | 1074 | 3 | 617 |
| 4 | Hanscom Field | MA | 1397 | 4 | 790 |
| 5 | Wilkes-Barre | PA | 1662 | 3 | 1272 |
| 6 | Andrews AFB | DC | 2500 | 5 | 1636 |
| 7 | Wilmington | DE | 2595 | 5 | 1539 |
| 8 | Langley AFB | VA | 3399 | 7 | 2122 |
| 9 | Seymour-Johnson AFB | NC | 3388 | 7 | 2112 |
| 10 | Elkins | WV | 2141 | 3 | 1359 |
| 11 | Augusta | GA | 3713 | 7 | 2578 |
| 12 | Charleston | SC | 4315 | 9 | 2369 |
| 13 | Jacksonville | FL | 5052 | 9 | 2911 |
| 14 | O'Hare Int. AP | IL | 1697 | 5 | 1021 |
| 15 | Indianapolis | IN | 2277 | 5 | 1392 |
| 16 | Battle Creek | MI | 1645 | 3 | 1043 |
| 17 | Wright-Patterson AFB | OH | 2384 | 4 | 1655 |
| 18 | Green Bay | WI | 1277 | 4 | 720 |
| 19 | Maxwell AFB | AL | 4070 | 8 | 2435 |
| 20 | Louisville | KY | 2892 | 5 | 1955 |
| 21 | Jackson | MS | 3878 | 7 | 2635 |
| 22 | Memphis NAS | TN | 3689 | 7 | 2348 |
| 23 | Little Rock | AR | 3500 | 7 | 2277 |
| 24 | New Orleans | LA | 5663 | 9 | 3586 |
| 25 | Tulsa | OK | 3380 | 6 | 2070 |
| 26 | Ellington AFB | TX | 5704 | 9 | 3425 |
| 27 | Des Moines | IA | 1971 | 5 | 1224 |
| 28 | Dodge City | KS | 1299 | 2 | 898 |
| 29 | Minneapolis | MN | 1481 | 4 | 841 |
| 30 | Kansas City | MO | 2526 | 5 | 1565 |
| 31 | Grand Island | NE | 1738 | 3 | 1230 |
| 32 | Grand Forks | ND | 754 | 3 | 328 |
| 33 | Sioux Falls | SD | 1430 | 3 | 837 |
| 34 | Walker AFB | NM | 82 | 2 | 82 |
| 35 | Los Angeles | CA | 2210 | 2 | 1838 |
| 36 | Everett | WA | 62 | 2 | 44 |
| | Elmendorf AFB | AK | 0 | | 0 |
| | Albrook AFB | CZ | 8760 | | 7403 |
| | Andersen AFB | GU | 8760 | | 6369 |
| | Pearl Harbor | HI | 8760 | | 6622 |
| | Roosevelt Roads NAVSTA | PR | 8760 | | 7032 |
| | Virgin Island (same as PR) | | 8760 | | 7032 |

### 3.2.2 Estimate of Uncertainty

Weather Bureau data employed in the analysis are from hourly observations over periods of ten years or more, so that statistical errors in the average values of temperature and humidity at the various stations are believed to be insignificant for practical purposes. The major concern for possible uncertainty in the computed average usage value lies in assumptions on the nature and measure of individual requirements for comfort in the home for which no general field survey data are available.

### 3.3 Parallel Estimates

The only other known usage estimate is 1920 hours per year obtained from an AHAM field sample [8].

Tests were conducted during the summer of 1974 in the homes of 21 employees of dehumidifier manufacturers in Ohio, Illinois, Indiana, and New Jersey. Records were kept of rated capacity of test units, watts input, hours used, and total kWh. However, no data were provided on the weather that was experienced, humidity control objectives and achievements or on equipment capacities relative to needs.

Reported running (compressor operating) hours ranged from 375 to 4048, with an average of 1920 hours, a standard deviation of 985 hours for the sample and a standard deviation of 215 hours for the sample mean. The analytical model was applied to a location in each of these states, yielding an average of about 1400 hours. The significance of the difference in the two mean values (1920 vs. 1400 hours) has not been evaluated.

## 4. Secondary Usage Factors

No field-usage data are available that might be adequate for projecting a national average of operating conditions for dehumidifiers. ASHRAE [178] assumes 55 percent relative humidity and 75 F temperature during the cooling season. In a survey conducted by Market Facts [165] 83 out of 151 respondents indicated that they used thermostat settings of at least 77 F during the cooling season. The 75 F temperature used in the analysis refers to conditions in the controlled space. Moisture removed by air conditioners is not assumed.

5. Impact Assessment of Uncertainties

The EAOC is calculated as

(usage in hours) x (energy in kWh consumed per hour of use)
x (cost in dollars per kWh of energy consumed).

The average energy consumption rate in the AHAM survey [8] was 0.43 kW, which will be used in estimating the EAOC.

EAOC = 1300 hours x 0.43 kWh/hr x $0.038 per kWh = $21.24 per year, which would be reported as $21 per year.

Inasmuch as EAOC is directly proportional to annual usage, a one percent error in usage computation induces a one percent error in EAOC. Thus, an error of 13 hours in annual usage--i.e., one percent of 1300 hours--implies an error of about 21 cents in EAOC.

6. Comments

a. A map showing a small number of dehumidifier operating hour zones may be useful. The data in Table L-1 could be used, augmented by additional points where they are needed.

b. The EAOC's for dehumidifiers are not large enough to warrant intensive work on usage factors for this product alone. However, general studies of environmental control practices in residences are recommended for the benefit of all the environmental control products.

## APPENDIX M. CENTRAL AIR CONDITIONERS

1. References: 13, 59, 65, 70, 81, 99, 150

2. Test Procedures: Final [59] November 25, 1977
Final rule correction [65] June 5, 1978
Proposed [81] June 14, 1977

3. Primary Use Factor

3.1 Value: 1000 hours of full load compressor operation per year.

3.2 Basis

The 1000 hour value was analytically derived to be consistent with the corresponding usage factor for room air conditioners of 750 hours per year.

3.2.1 Description of Basis

The basis for the primary use factor is contained in Appendix B of reference 179, reproduced here as Annex M-1. Parallel estimates are also described. The appendix is copied intact, including its own numbering for figures, tables and references. Some of the references also appear in Appendix P.

3.2.2 Estimate of Uncertainty

Uncertainty in the calculated usage cycle was not estimated because the method of calculation produced a single value for each location and did not include a basis for determining variations among consumer usage at a given location. An indication of the variation in operating hours within a geographically small locality can be obtained from survey data on room air conditioners (New York City area, 1974 and 1975 seasons) provided by AHAM [13]. For 171 observations, the mean was approximately 400 hours per year. The standard deviation of the sample was a surprisingly high 345 hours per year and the standard deviation of this sample mean was 26 hours per year.

3.3 Comparable Estimates

There are no other known estimates of operating hours per year with supporting evidence. T. T. Woodson [130] cites a "typical" energy consumption of 3600 kWh/yr with an "average" power of 3000 watts, which corresponds to about

1200 hours usage. The Edison Electric Institute [70] recommends that "the study of central air conditioners be tabled until energy-use values can be investigated further." It notes that "the range of responses [from member companies to inquiries concerning household usage] is too widespread."

4. Secondary Usage Factors

a. Thermostat setting

Market Facts for October 24, 1977, cites thermostat settings with central air conditioners as given in Table M-1.

Table M-1. Survey Data on Thermostat Settings with Central Air Conditioners

| Temperature Setting | Respondents Day | Respondents Night |
|---|---|---|
| ≤65 F | 5 | 5 |
| 66-68 | 1 | 2 |
| 69-72 | 17 | 16 |
| 73-76 | 45 | 40 |
| ≥77 | 83 | 79 |
| Off at night | -- | 14 |
| Total reported cases | 151 | 156 |
| Average* setting | 75 | 75 |

*These averages were computed by regarding the temperature of the coolest group as exactly 65 and that of the warmest as exactly 77. Also the "off at night" category was considered to be at a temperature setting of 80.

NAHB/Heimath in a report to the FEA of March 1975, indicate an average summer thermostat setting of 74 F for 20 homes in the Columbus, Ohio, area with central air conditioners.

The Honeywell results of 1670 hours [99] for a 78 F set point and 1800 hours for a 75 F set point, indicate approximately a 3 percent increase in operating hours per degree F decrease in thermostat setting in this temperature range.

b. Ventilation practice of householders

Empirical data are needed on the number of air changes per hour under different conditions and in different parts of the country. Homes with central air conditioners were assumed to be unventilated, whereas those with room air conditioners were assumed to be ventilated when outdoor air temperatures were between 75 F and 78 F.

c. Outdoor Temperatures

A statistical distribution of outdoor temperatures during the cooling season is provided for use in seasonal efficiency calculations. Neither this distribution, nor the cooling load hour data provided in reference 59, 65 and 81 enter the EAOC calculation directly.

5. Impact Assessment of Uncertainties

The expected annual operating cost is given by

$$EAOC = \frac{(\text{capacity in Btu per hr}) \times (\text{operating hrs per yr}) \times (\text{cost of electricity in \$ per kWh})}{(\text{seasonal EER in Btu per Wh}) \times (\text{1000 Wh per kWh})} .$$

The following base conditions are used for the purpose of this analysis: 1000 hours of operation, SEER = 7 Btu per Wh, capacity = 40 000 Btu per hr, and energy cost = $0.038 per kWh.

With these values the EAOC is approximately $200 per year. A one percent reduction in usage hours corresponds to a reduction in the EAOC of about $2.

A one-degree increase in indoor temperature decreases the operating hours by an estimated 3 percent, for a change in EAOC of approximately -$6 per year.

6. Comments

The comments for room air conditioners (Appendix F) also apply for central air conditioners. In addition, examination of oversizing practices is suggested.

ANNEX M-1

Central Air Conditioners and
Heat Pumps Operating in the Cooling Mode

The purpose of this memorandum is to provide a national average annual use cycle for residential central air conditioning equipment in support of the NBS test procedure proposal for this product type. The recommended usage cycle is 1000 full load compressor operating hours per year and is based on a review of analytical and field survey work by other investigators.

It is important that the meaning and limitations of this figure be conveyed to the consumer. No single value for an average annual use cycle should be expected to match the experience by an arbitrarily selected user or group of users in a given cooling season and locality. The usage value of 1000 compressor operating hours per year is reasonably close to a derivable national average. It is rounded to avoid an unwarranted impression of direct applicability to all users and situations and bears a reasonable relationship to the 750 hours per year of compressor operation being used for room air conditioners.

Three approaches were compared in developing the recommended value for annual compressor operating hours.

A. Comparison with Room Air Conditioners

It was assumed in this approach that users of room air conditioners will tend to use natural ventilation to achieve their cooling objectives when outdoor conditions permit, while users of central air conditioners will tend to avoid natural ventilation during the cooling season.

Pilati (Ref. 1) compared the effects on compressor hours of ventilation and non-ventilation strategies in a hypothetical home. He used a modified NBSLD program and a year's hour-by-hour weather data for each of ten cities. (See Table 1.) An indoor thermostat set point of 78F was assumed. These data and data from "ASHRAE Handbook of Fundamentals," American Society of Heating, Refrigerating and Air Conditioning Engineers; 1972, were then used in a multi-variable regression analysis to extend the results over the nation, and to produce the "Predictions" for the same ten cities, also given in Table 1. The ventilated (V) and unventilated (UV) results were cross-plotted by NBS in Figure 1. Separate linear regressions by NBS of the NBSLD and Predictions results yielded

(NBSLD): Hours(UV) = 291 + 1.097 x Hours(V)

(Predictions) Hours(UV) = 297 + 1.097 x Hours(V)

These two equations were then evaluated using the room air conditioner compressor operation value of 750 hours per year as Hours(V), yielding 1114 and 1120 hours per year, respectively for Hours(UV).

It is to be noted that differences of 100 hours per year among otherwise comparable cases are common in Pilati's results, reflecting effects of using different analysis methods and data bases. It is also apparent that operating hours vary widely across the nation.

B. Bin Method A

In Reference 2 Honeywell reported the results of a compressor-hours analysis for 26 cities, based on data from Reference 3. Six of these cities coincided with Pilati's selections. (See Table 1.)

Table 1. Estimated Compressor Hours Per Year[a]

| City | NBSLD[b] Adaptation Vent. | NBSLD[b] Adaptation Unvent. | Alternate[b] Prediction Vent. | Alternate[b] Prediction Unvent. | Honeywell[c] (Unvent., 78F) | Honeywell[c] (Unvent., 75F) |
|---|---|---|---|---|---|---|
| Atlanta | 983 | 1521 | 993 | 1577 | 1189 | 1452 |
| Chicago | 455 | 727 | 596 | 868 | 638 | 804 |
| Dallas | 1604 | 2003 | 1518 | 1979 | 1658 | 1901 |
| Miami | 2169 | 2901 | 2363 | 2971 | 2984 | 3480 |
| Minneapolis | 374 | 590 | 319 | 462 | 622 | 779 |
| New Orleans | 1880 | 2305 | 1663 | 2157 | 2018 | 2373 |
| New York | 393 | 755 | 357 | 765 | | |
| Phoenix | 1870 | 2122 | 1826 | 2102 | | |
| San Diego | 162 | 592 | 150 | 583 | | |
| Topeka | 627 | 932 | 713 | 1023 | | |

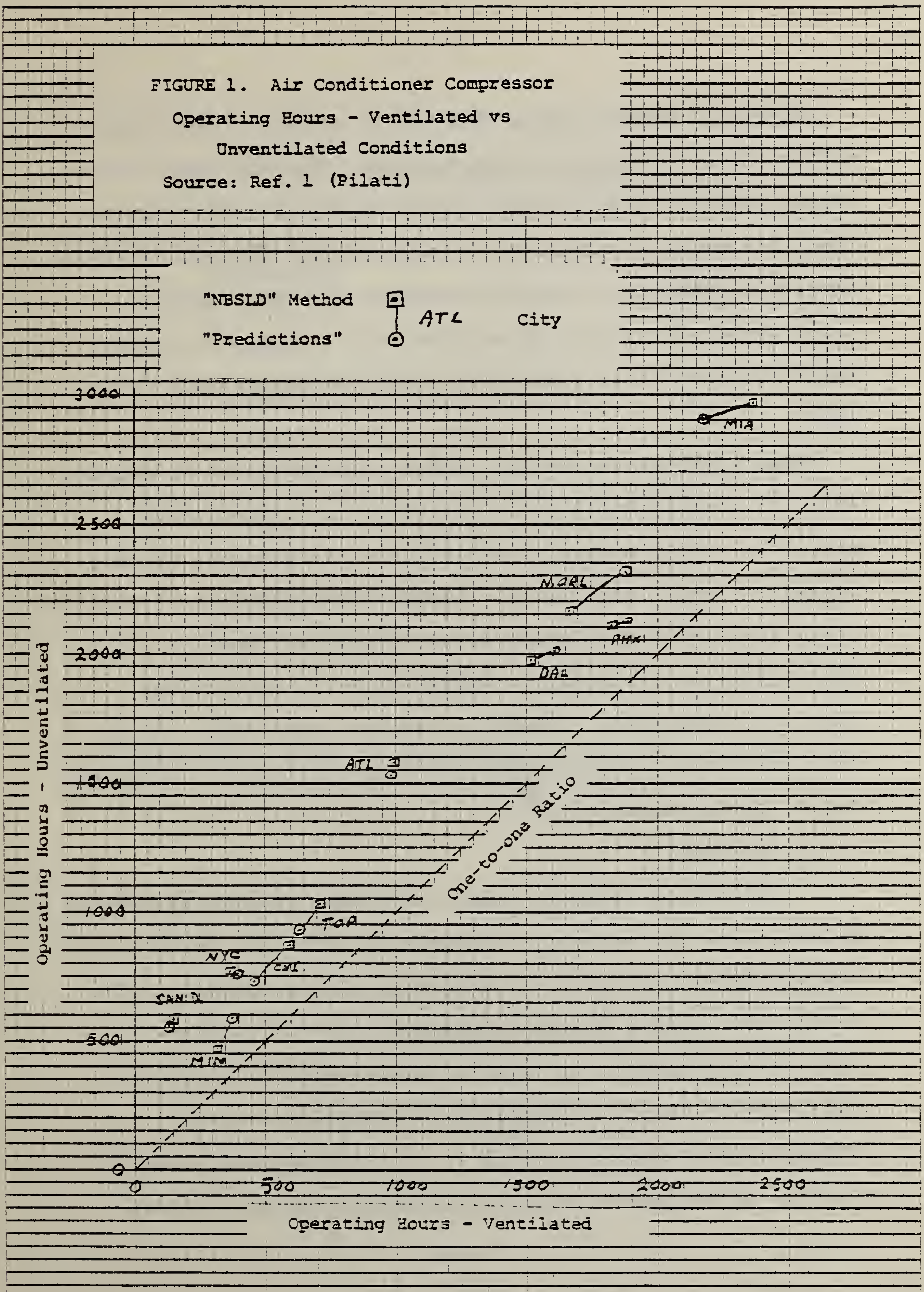
(a) All results are from computer calculations. The first five columns are based on an indoor dry bulb control temperature of 78F.

(b) Source: Reference 1.

(c) Source: Reference 2.

FIGURE 1. Air Conditioner Compressor Operating Hours - Ventilated vs Unventilated Conditions

Source: Ref. 1 (Pilati)



Reference 3 contains weather data from 205 stations at which hourly readings had been taken for at least ten years. This publication provides the mean number of hours per year for which the dry bulb temperature was observed in each of a succession of five-degree bins. Compressor operating hours for an unventilated house were estimated for three temperature control methods, including a 78F set point and a balance point (outdoor temperature above which a cooling load exists) ten degrees below the set point.

While Pilati used two analysis methods, based on the use of specific weather years and Honeywell used a third method and averaged weather data, their averaged results for the six cities in common are reasonably comparable. Averages among the six cities for Pilati's NBSLD and Predictions methods and Honeywell's bin method are 1675 hours, 1669 hours and 1518 hours, respectively. Honeywell's averaged result is about 9% below Pilati's for these cities. Honeywell's six-city average with a 75F set point is 1798 hours, giving an indication of the sensitivity of compressor hours to the thermostat set point.

C. Bin Method B

This method, examined by NBS, is also based on data from Reference 3. The results from this approach are recognized as being more approximate than from approaches A and B because of the methods of data aggregation. The average number of hours in each temperature bin were first combined by state and then weighted by the number of housing units with central air conditioners by state (from Reference 4) to develop the nationally averaged bin-hours presented in Table 2. The compressor was assumed to be off for outdoor temperatures below the balance point and to operate

Table 2. Distribution of Hours in Temperature Bins[a]

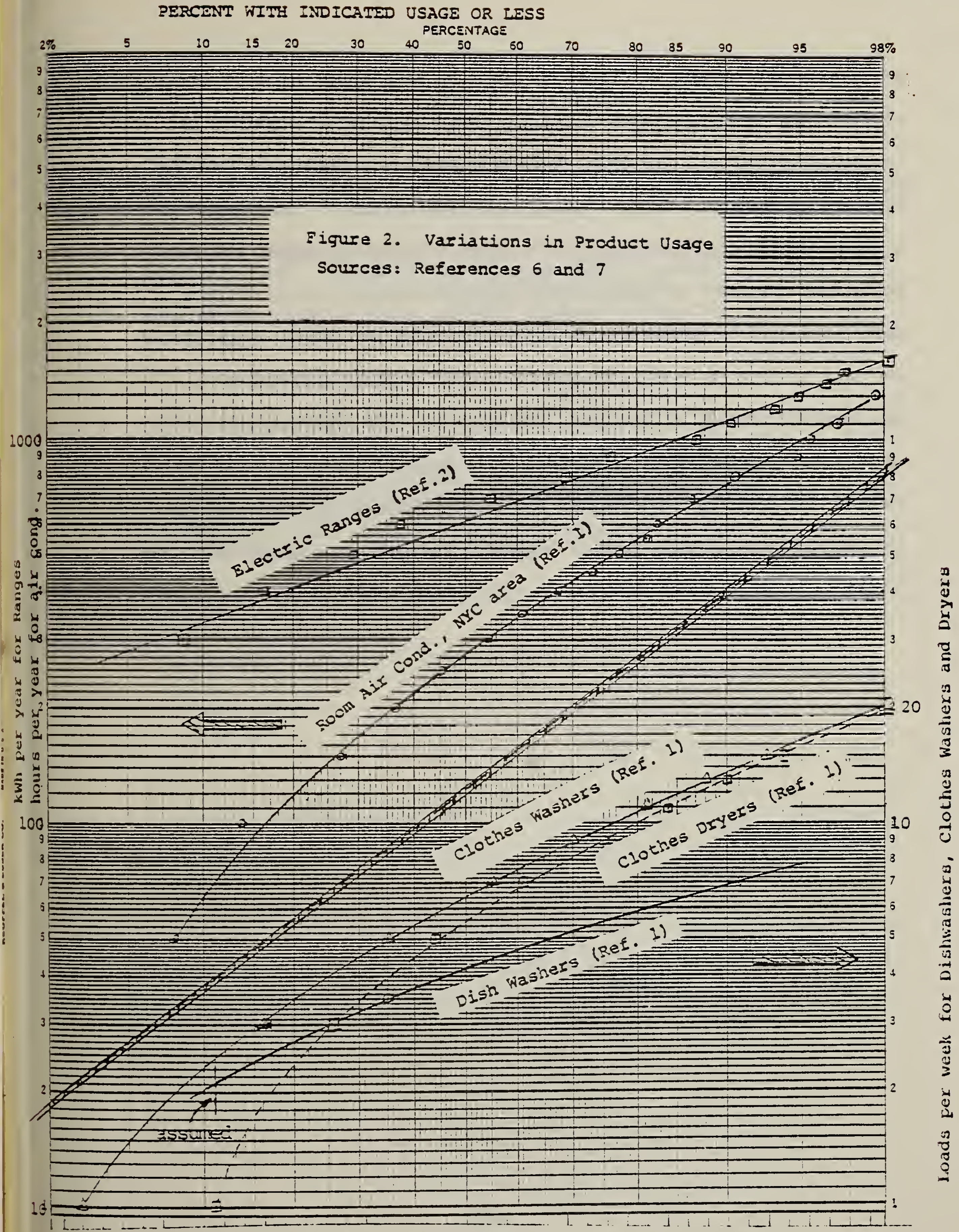
| Temperature Bin, °F | Hours per Year |
|---|---|
| 65-69 | 825 |
| 70-74 | 890 |
| 75-79 | 830 |
| 80-84 | 620 |
| 85-89 | 400 |
| 90-94 | 200 |
| 95-99 | 70 |
| 100-104 | 15 |

(a) Source of basic data on average hours per year by dry bulb temperature bin is Reference 3. Bin-hours were weighted by state with data from Reference 4 on homes with central air conditioners in 1970.

continuously for temperatures at and above a temperature determined by the design point and any system oversizing. A linear relationship with respect to outdoor temperature was used to estimate the fraction of operating time for conditions between these two temperatures. Assuming a 78F set point, a 68F balance point, a 95F design point and a ten percent oversizing factor, a value of 1238 compressor operating hours per year results. Use of a 65F balance point yields 1373 hours.

One characteristic of these bin methods is that all excursions of outdoor temperature into the cooling demand region contribute to the total compressor hours, however brief they may be or whenever they may occur during the year. However, there are some practical reasons for adjusting these theoretical results. Because of the thermal masses of walls and building contents, indoor temperatures do not respond immediately or fully to short-term outdoor temperature fluctuations. Operating hours would be reduced by any tendencies to confine system usage to the main cooling season. Also, no allowance is made in the analyses for conservation-motivated setbacks during vacations or other periods of absence. Thus, some downward adjustment of theoretical results appears warranted.

Statistical information has been provided by industry on the consumer usage patterns for several product types, including room air conditioners. The data are summarized in Figure 2 in the form of cumulative distribution plots. One particularly interesting study involved 171 homes and two cooling seasons in the New York City area. The raw data shows a usage range from less than 50 hours to over 2200 hours per year. (All but four of the 171 observations were 1300 hours or less, leading to the highest


PERCENT WITH INDICATED USAGE OR LESS
PERCENTAGE
Figure 2. Variations in Product Usage
Sources: References 6 and 7
Electric Ranges (Ref.2)
Room Air Cond., NYC area (Ref.1)
Clothes Washers (Ref. 1)
Clothes Dryers (Ref. 1)
Dish Washers (Ref. 1)
kWh per year for Ranges
hours per year for air cond.
Loads per week for Dishwashers, Clothes Washers and Dryers
assumed

percentile plot point that could be shown on this graph paper.) It is evident that no single value for usage could usefully be regarded as "representative" even for this relatively limited climate area and the two cooling seasons. Table 1 provides an indication of the effects of climate variation across the nation, which contribute further to usage variation. Weather variations from season to season also contribute uncertainties. It is therefore recommended that the annual usage factor for this product be heavily rounded to avoid an undue impression of applicability in all situations. The value of 1000 compressor hours per year is recommended, both because it is reasonably close to analytical results cited earlier and because it would provide a convenient basis for calculations if some form of regional treatment is considered in the future.

References (for Annex M-1)


1. "Room Air Conditioner Lifetime Cost Consideration: Annual Operating Hours and Efficiencies"; Pilati, David A., Oak Ridge National Laboratory; October 1975.

2. "Reducing Energy Consumption During the Cooling Season--an Analog Computer Study"; Honeywell Corporation Report 70-6245; September 1974.

3. "Engineering Weather Data, AFM88-8, Chapter 6, TM5-785, NAVFAC P-89"; Departments of the Air Force, the Army and the Navy; 15 June 1967.

4. U.S. Census of Housing; 1970 U.S. Summary HC(1)B1.

5. "Test Procedure Review--Central Air Conditioners"; National Bureau of Standards; March 1977.

6. "Statement on Room Air Conditioners (to the Federal Energy Administration)"; Association of Home Appliance Manufacturers; September 22, 1976 (also presented to Department of Commerce, July 29, 1976).

7. "Summarization of AHAM Range Energy Consumption Field Data"; 1976.

## APPENDIX N. FURNACES AND VENTED HEATERS

1. References: 5, 6, 56, 64, 85, 130, 134, 135, 178, 180, 181, 182

2. Test Procedures: Final [64] May 10, 1978
Proposed [85] August 11, 1977

3. Primary Usage Factors [64]

3.1 Values

Heating Load Hours per Year = HLH = 2080 hours per year.

Adjustment factor for changing the design heating requirement and heating hours to the actual heating load experienced by the heating system = C = 0.77.

3.2 Basis

The numerical value for HLH may be computed as follows.

$$\frac{5200 \text{ degree-days per year} \times 24 \text{ hours per day} \times SHL}{(65\ F - 5\ F) \times SHL} = \qquad (1)$$

2080 hours per year,

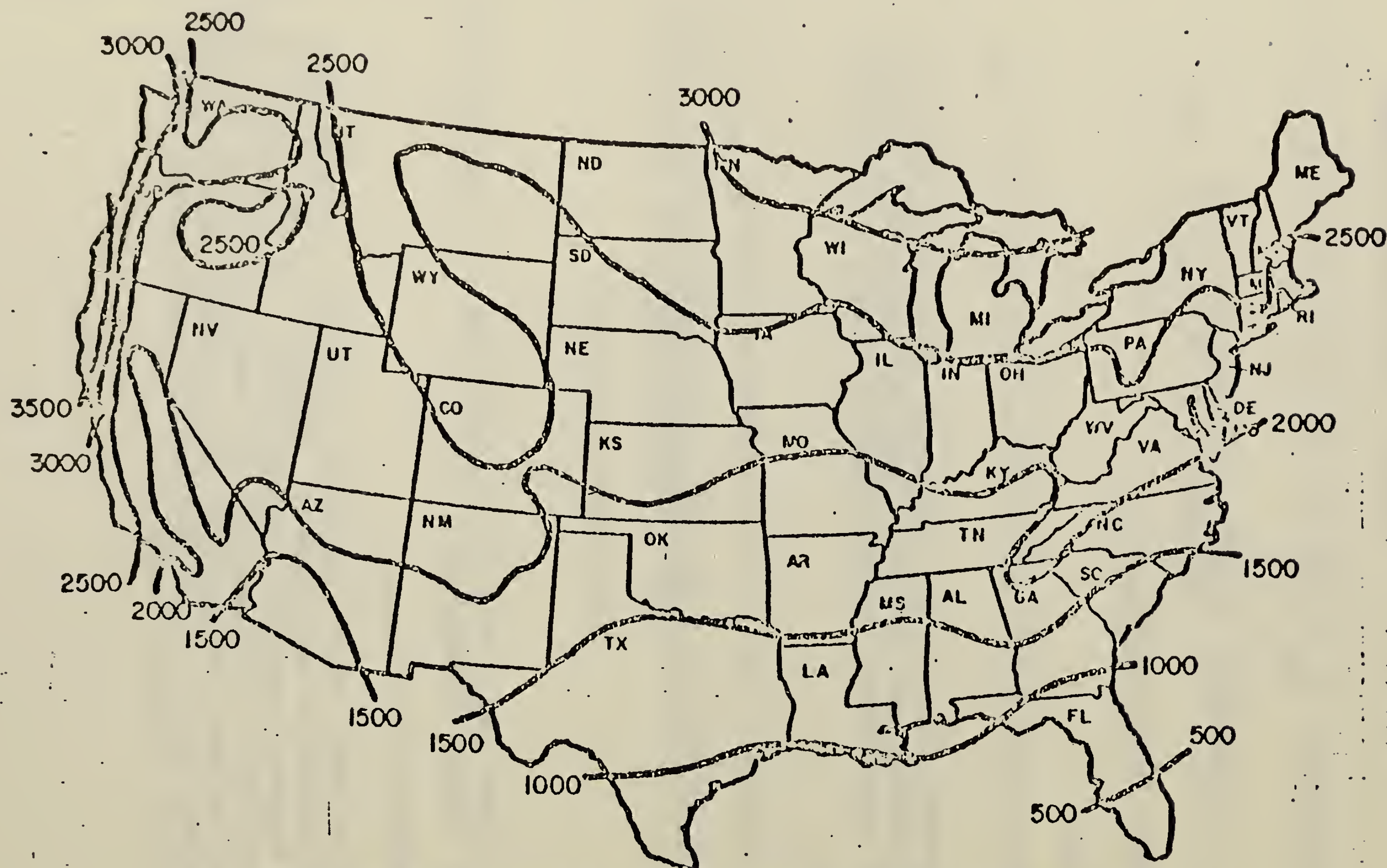
where

SHL = heat loss rate of the structure in Btu per hour per degree Fahrenheit.

3.2.1 Description of Basis

Heating loads vary from zero in Hawaii to very high values in Minnesota and Alaska. Figure N-1 [64] provides HLH values to support regional calculations. The function of the heating load hours parameter is to combine certain climate and indoor factors into a form that is concise and convenient for analytical uses, while meeting the requirement for a representative national value.

Figure N-1. Heating Load Hours (HLH) for the United States and Territories




This map is reasonably accurate for most parts of the United States but is necessarily highly generalized and consequently not too accurate in mountainous regions, particularly in the Rockies.

Alaska - 3500 HLH
Hawaii and Territories - 0 HLH

Both the 5200 degree-days and the 5 F outdoor air design temperature figures are based on weighted averages using long-term weather data from many stations in the conterminous United States (the 48 states and the District of Columbia). States were weighted by the numbers of housing units using gas or oil as the primary heating fuel, as reported in the 1970 Census. The figure of 65 F appearing in Equation 1 was introduced [182] in the early 1930's and is the traditional reference temperature for computing degree-days. It is sometimes called a balance point, or zero heat point, marking the outdoor dry bulb temperature boundary between a load and no load on the heating system. Actual indoor temperatures will be higher than the balance point due to other heat sources such as cooking, body heat, lights, etc.

The rate of conduction and infiltration heat loss by a structure is, for practical purposes, considered proportional to the difference between indoor and outdoor temperatures. The component of this loss supplied by the heating system is proportional to the difference between the balance point (65 F) and the current temperature. The number of degree-days in a day at a given location is computed by finding the arithmetic average of the high and low temperatures for the day and subtracting the result from the balance point. No heating degree-days are counted if the average is above the balance point. The total heating degree-days for a year are proportional to the annual heating load.

The (65 F - 5 F) term in the denominator of Equation 1 is a temperature difference used for system design purposes. The design temperature is not normally the extreme low temperature ever recorded at a station. Instead, engineering practice is to choose a slightly higher, but still reasonable design criterion. The 5 F figure was rounded from a weighted average (among stations) of design temperatures at the 2 1/2 percent level, meaning that on the average (at each station) 2 1/2 percent of the hours in the coldest three months of the year, or 54 hours per year [56], are expected to be colder than the design temperature. Stations with large degree-day values tend to have large design temperature differences and long heating seasons, and conversely for the warmer climates.

Thus, the numerator of Equation 1 is an estimate in Btu per year of the annual heating load of a residence as seen by a furnace. This load is proportional to the heat loss rate of the structure, SHL. The denominator is the heat loss rate in Btu per hour of the same structure under design temperature conditions, and is also proportional to SHL. SHL is used in selecting a furnace, but cancels out in the HLH calculation. HLH is an intermediate parameter in the calculations of burner operating hours, BOH, in which an experience factor, C (described next), and an oversizing factor have important roles.

Industry commentators expressed concern during the hearings [64] on the proposed test procedure that use of 65 F as a balance point is no longer representative of current home construction and heating practices and leads to serious overestimates of heating costs. DOE recognizes this fact, but noted that changing the balance point temperature would require an extensive and lengthy analysis, and determined that the current standard practice of using 65 F as the balance point would be continued until new data are available. After reviewing data, NBS recommended and DOE accepted an adjustment factor, C, of 0.77 as a multiplier for changing the design heating requirement and heating hours to the approximate actual heating load experienced by the heating system. This is the old NEMA (National Electrical Manufacturers Association) factor [178] and corresponds to the ratio of

$$\frac{18.5 \text{ hours/day}}{24 \text{ hours/day}} = 0.77$$

which is a correction factor recommended in the 1970 ASHRAE Handbook and Product Directory [180] for use in estimating annual heating requirements.

Regional heating load hours, HLH, are provided by a map in the test procedure [64] for conterminous U.S.A., 3500 hours for Alaska and zero hours for Hawaii and territories.

### 3.2.2 Estimates of Uncertainties

There are several points at which HLH could be criticized, but these are almost exclusively at the conceptual level. The data for degree-days and design temperatures at the weather stations selected to represent states come from the best available sources, e.g., [5, 6, 56, 178]. Averages for each location have been compiled over at least ten years and normally for twenty to thirty years, yielding results of good statistical quality. Averaging these results over many locations in the nation further reduces random error in the estimates of average weather conditions.

Data on outdoor design temperatures are given in standard references to the nearest whole degree. Although statistical support has not been sought for the assumption, the implication is that the design data are accurate within one-half a degree Fahrenheit for a given location. The resulting national average value was rounded more than a half a degree to produce the computationally convenient value of 5 F.

In a similar manner, general statistics on the variability of average degree-days for a location were not sought. However, there are variations from year to year and from place to place in a weather station service area. An indication of the variability may be inferred by comparing some data for the Washington, D.C., area. A value of 4626 degree-days [182] was used in the 1930's. In the Reference Section of Heating and Ventilating, March 1954 [181], the annual degree days are given at 4333 for National Airport. Subsequent averages for the Airport are 4224 per year, which was the standard for many years, and then changed in 1973 by NOAA to the current normal value of 4211. Thus, there appears to be a minor warming trend at least at National Airport. In addition, annual degree-day results at National Airport were obtained for the most recent 15 years. The average value was 4132, with a standard deviation of 391 degree-days per year for this sample and a standard deviation of the sample mean of 101 degree-days. The coefficient of variation (= standard deviation/mean) of the mean for this location is 0.024. At least 40 stations contributed to the overall average, leading to an overall coefficient of variation of approximately 0.004 for the sample mean.

Degree-day variations within the service area of a weather station can be important. Listings in [181] for 1954 for the Washington area show 4333 degree-days per year for the Airport, 4258 for the city and 4539 for Silver Hill, MD, which is 6 1/2 miles east southeast from the center of the city. Calculations (data from [56]) for Andrews AFB, which is 11 miles east southeast of the city center and has design temperatures about three degrees cooler [6] than National Airport show 4774 degree-days per year compared to 4224 [5] for National Airport. Temperatures in the Washington suburbs are often five to ten degrees below those at National Airport.

The 65 F balance point temperature was proposed [182] in the 1920's as a result of a study by a gas utility company. Several changes since that date indicate that a re-examination of that balance point would be in order. Residential construction is considerably tighter, reducing heat losses from air exfiltration. Much more insulation is being used, reducing heat losses by conduction through the walls and ceilings. There are many more heat releasing appliances in homes, reducing the additional heat requirements from furnaces. Higher fuel costs are encouraging the use of lower thermostat settings during the heating season.

DOE recognizes the general nature and effects of the factors listed above, but has deferred any change from the 65 F balance point until deeper study reveals a better alternative. In lieu of making such a change and in recognition of the tendency of unmodified test procedures to overestimate furnace energy use, an adjustment factor, C = 0.77, is introduced in the energy calculations. In effect, it reduces the estimate of the design heating requirement in the calculation of burner operating hours, BOH. The value for C of 0.77 was recommended by NBS after a review of data and accepted by DOE. No systematic basis exists for estimating the uncertainty of this factor.

3.3 Parallel Estimates

No alternative methods for estimating degree-days, the balance point temperature or the design temperature were found in the accepted literature. The current NEMA Manual for Electric Comfort Conditioning suggests the use of 15 to 17 hours per day instead of 18.5 hours per day in developing the "C" factor for electric heating systems.

The relationship of degree-days to the choice of a balance point temperature was examined analytically for 24 locations spread throughout the nation. Data on average hours per year in successive temperature bins [56] were used to compute degree-days with various balance points. The results are shown in Figure N-2 in which degree-days at 65 F were plotted against the corresponding degree-days for other balance points: 50 F, 55 F, 60 F and 65 F. The formulas in Figure N-2 are linear regressions. Plot points were omitted except for the 50 F case. A heavy horizontal line designates 5200 degree days using a 65 F base. Noting that 5200 x C = 5200 x 0.77 = 4004 degree-days, it can be seen that using an adjustment factor C = 0.77 is equivalent to changing the balance point temperature from 65 F to about 60 F for a nominal 5200 degree-day location. However, holding C fixed will lead to other equivalent balance point temperatures as degree-days are varied, as in regional studies, for example.

The effect of a change of one degree Fahrenheit in either the indoor temperatures (70 F) or the balance point temperature (65 F) at 5200 degree-days is approximately 900/5 = 180 degree-days. The corresponding effect on HLH would be approximately 72 hours per degree F.

4. Secondary Usage Factors

4.1 Factor Definitions and Quantities

- Average Furnace Sizing Factor = 1.7, dimensionless,

$$= \frac{\text{Steady-state output of furnace}}{\text{Design heating requirement of building}}$$

Furnaces are usually selected with a capacity that is considerably greater than necessary to meet the normal design heating requirement. For example, heating engineers in the Washington, D.C., area use 0 F as the design temperature rather than values of 15 F to 17 F obtained from weather data. Excess furnace capacity will also increase when retrofitting actions are taken, such as adding insulation and storm doors and windows.

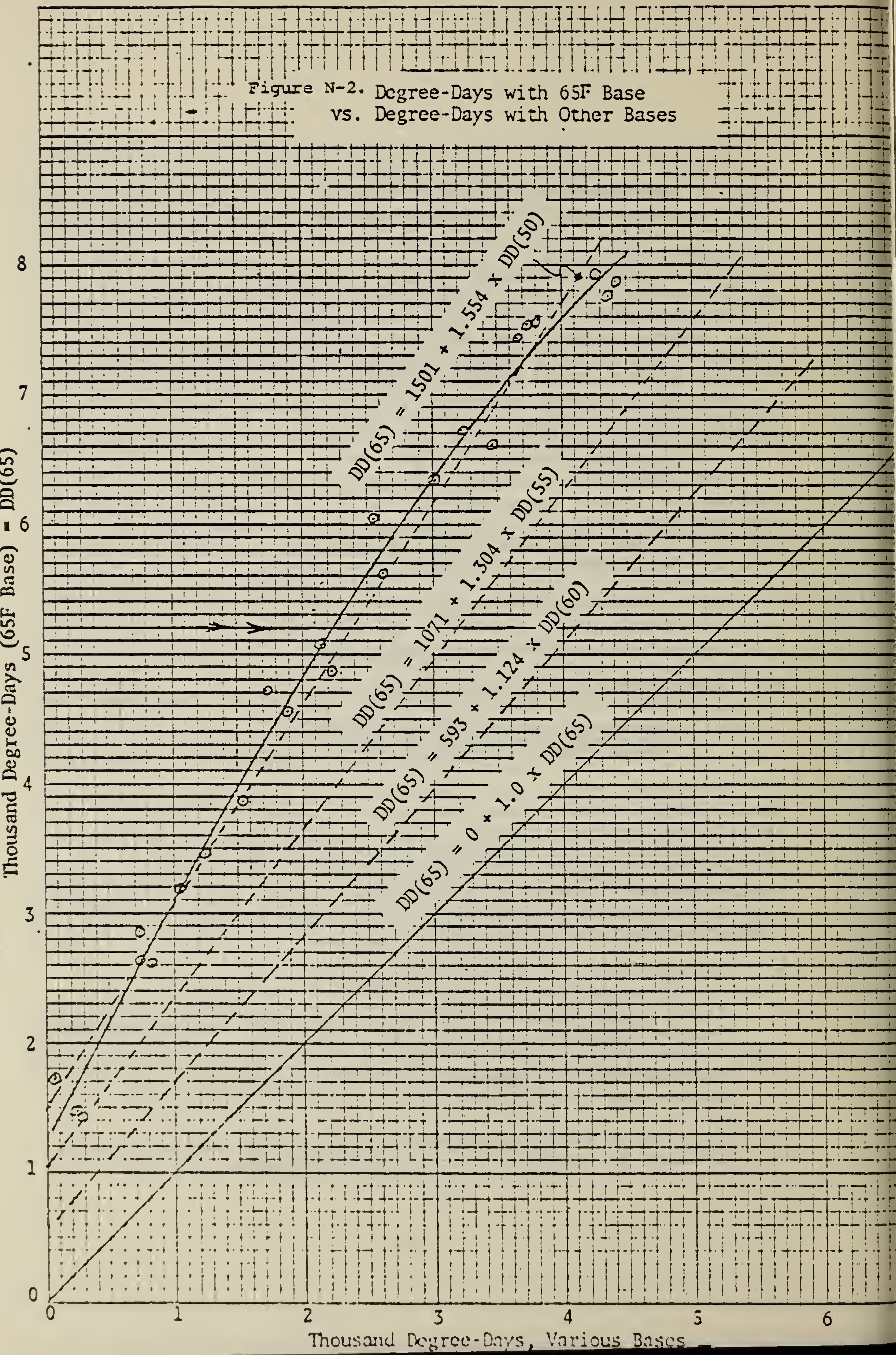
- Assumed average Indoor Temperature = 70 F.

- Pilot Light Hours = 8760 hours per year = 365 days per year x 24 hours per day.

- Average outdoor temperature corresponding to 5200 degree-day location = 42 F.

This is an average temperature which is used in the calculations to correct for the use of outdoor air for

Figure N-2. Degree-Days with 65F Base vs. Degree-Days with Other Bases



combustion in certain furnace systems instead of using air that infiltrates into the house and is raised to the indoor temperature before combustion.

- Ratio of average length of a heating season in hours to the average heating load hours = 2, dimensionless.

This is an assumed factor used in accounting for the heat from a pilot light in the calculation of burner operating hours.

- Average number of non-heating season hours per year that the energy to the pilot light is assumed wasted = 4600 hours per year = 8760 -(2 x 2080).

4.2 Basis

Oversizing Factor:

The oversizing factor of 1.7 is not supported by systematic field studies, nor is any alternative value for this factor. Some commenters on the test procedure criticized the value assumed and used in the test procedure, but did not offer alternatives. It was adopted by DOE on the basis that oversizing practices of the past are being moderated today because of an increasing awareness that oversized equipment without stack dampers is less efficient than more properly sized equipment.

The factor is used in the calculation of annual fuel utilization efficiency in a term accounting for wasted pilot light energy and in a table (Table 4 in the test procedure [64]) that is used to obtain a value for average design heating requirements, knowing the output capacity of the furnace or boiler.

No data are available to support an estimate of the uncertainty in this factor.

Indoor Temperature:

Seventy degrees Fahrenheit is a commonly used indoor temperature assumption in heating system analyses [134]. Results of a survey conducted before the oil embargo in 1973 indicate that approximately 80 percent of the households in the survey have thermostat or valve temperature controls. Those without temperature control include seven million households (mostly renters) who nonetheless pay for space heat. Survey results (Table 3-14 in reference 134) on daytime and nighttime temperatures are given below. The reported daytime winter temperatures did not vary appreciably with climate, but the nighttime winter temperatures did. About 60 percent of all households in the coldest climate zone had indoor winter temperatures above 70 F at night. It appears from the table that in 1973, median temperatures were approximately 72 F during the day and 70 F at night. Assuming some response to rising energy costs since 1973, the use of a 70 F median indoor temperature appears reasonable. Since details of the survey [134] have not been obtained, an estimate of uncertainty is not made.

Table N-1. Indoor temperature control and preference in winter, by heating degree days, 1973 (percent of households) [Table 3-14 of Reference 134]

| Winter indoor temperature characteristics | Heating degree days | | | |
|---|---|---|---|---|
| | All households | <3500 | 3500-5499 | 5500+ |
| All households | 100 | 100 | 100 | 100 |
| With thermostat or valve | 81 | 70 | 86 | 87 |
| Temperature during day[a] | | | | |
| Under 70° | 12 | 12 | 14 | 10 |
| 70°-72° | 52 | 51 | 51 | 56 |
| 73° or higher | 33 | 34 | 33 | 33 |
| Don't know | 2 | 4 | 2 | 2 |
| Temperature at night | | | | |
| Under 70° | 45 | 51 | 49 | 38 |
| 70°-72° | 35 | 30 | 33 | 41 |
| 73° or higher | 16 | 13 | 15 | 19 |
| Don't know | 4 | 7 | 3 | 2 |

[a] For households with thermostats or valves.
Source: Washington Center for Metropolitan Studies' Life-styles and Energy Surveys.

Newman [135] presents some data on temperature variations from floor to ceiling and room to room in a house where USDA was experimenting with wall insulation treatments and heating systems. Depending on the room, average temperature differences between a point four inches above the floor to the ceiling ranged from 2 to 11 degrees F. Differences between the four-foot level and the ceiling ranged from -0.2 F to +1.8 F, while room-to-room differences at the four-foot level were in the 0 F to 2 F range. In a full scale heating simulation in an NBS test chamber [130], a house with warm air inlets near the ceiling showed floor to ceiling temperature differences of 20 F to 25 F in first floor rooms. Thus, other than for engineering calculation purposes, it is recommended that the precision of statements about room temperatures be treated with restraint. It appears unwarranted to expect a whole house to have an average temperature within one or two degrees of the thermostat setting, even assuming that the thermostat is accurate.

Pilot Light Hours:

It is assumed for the purposes of the test procedure that the pilot light is on all the time, or 365 days per year x 24 hours per day = 8760 hours per year.

Average Temperature of Combustion Air from Outdoors:

Temperature data are available [56] in terms of the average number of hours per year for a given location that the outdoor temperature is in each of a succession of five-degree "bins." Using these hours as weights, the average outdoor air temperature during a heating season corresponding to a 5200 degree-day per year location is 42 F, within a rounding error of one-half a degree Fahrenheit.

Ratio of Heating Season Hours to Heating Load Hours:

The definition of a heating season is somewhat indefinite, but includes the calendar period during which a furnace may reasonably get a call for heat. Because of heat storage characteristics of house structures and contents, transient excursions of outdoor air temperatures below 65 F even lasting as long as 6 to 12 hours may not result in a call for heat from the central heating system. Hence, the heating season is shorter than the period during which there are any excursions at all below 65 F.

It was elected to estimate the lengths of the heating and nonheating seasons in terms of heating load hours, HLH, using the assumption that the number of hours in the heating season is twice HLH. Thus, when HLH = 2080 hours per year, the nonheating season is

8760 - 2 x 2080 = 4600 hours per year.

The uncertainty in the assumed factor of 2 has not been evaluated.

5. Impact Assessment of Uncertainties

Since the consumer-dependent variables and their uncertainties enter the calculation of estimated annual operating cost, EAOC, in complicated ways, the approach that will be taken is to assume and discuss a base case. Formulas come from the test procedure.

Base Case:

Fuel: gas

$Q_{IN}$ = 136 000 Btu per hour.

$n_{ss}$ = 0.75 = steady-state efficiency = $Q_{OUT}/Q_{IN}$.

$Q_P$ = 1000 Btu per hour.

$C_F$ = unit cost of gas = \$0.207 per therm (100 000 Btu).

$C_E$ = unit cost of electricity = \$0.038 per kWh.

PE + yBE = auxiliary electric power = 0.5 kW = 1.7 kBtu per hour.

$n_u$ = part load fuel utilization efficiency = 70 percent.

$Q_{OUT}$ = 102 kBtu per hour.

HLH = annual heating load hours = 2080 hours per year.

C = 0.77.

ADHR = average design heating requirement = 60 kBtu per hour.

Sizing Factor, SF = 1.7 $Q_{OUT}$/ADHR.

$$EAOC = E_F \times C_F + E_{AE} \times C_E$$

$$= \frac{((Q_{IN} - Q_P) \times BOH + (8760 \times Q_P)) \times C_F}{100\ 000} + (PE + yBE) \times C_E. \quad (2)$$

$$BOH = A \times C \times 2080 \times ADHR - B \times 2080, \quad (3)$$

where

$$A = \frac{100\ 000}{341\ 300 \times (PE + yBE) + (Q_{IN} - Q_P) \times \eta_u} \quad (4)$$

$$= \frac{100\ 000}{341\ 300 \times 0.5 + (136\ 000 - 1000) \times 70}$$

$$= 0.010394$$

$$B = \frac{2 \times Q_P \times \eta_u \times A}{100\ 000} = \frac{2 \times 1000 \times 70 \times 0.010394}{100\ 000} = 0.01455 \quad (5)$$

Then

$$BOH = 998.9 - 30.3 = 968.6 \text{ hours per year} \quad (6)$$ and

$$EAOC = ((136\ 000 - 1000) \times 969 + 8760 \times 1000) \times \frac{0.207}{100\ 000} + 0.5 \times 969 \times 0.038$$

= \$270.79 (furnace fuel) + \$18.13 (pilot fuel) + \$18.41 (electricity)

= \$307.33 per year, which would be reported as

= \$307 per year. (7)

It can be seen from the cost components in Equation 7 that $\frac{307.33 - 18.13}{307.33} = 0.941$, or about 94 percent of the annual operating cost in this case is proportional to BOH, which, by Equation 3 is proportional to HLH = 2080 hours per year, and which, in turn, is proportional to degree-days and C, and inversely proportional to the design temperature difference. (See Equation 1.)

Assuming an uncertainty in HLH of 8 hours per year, an uncertainty in EAOC of 307 x 0.94 x 8/2080 = \$1.11 per year, would result.

Increasing the design temperature difference decreases EAOC. Evaluated at the base case conditions, the EAOC decreases by 307 x 0.94/60 = $4.81 per year per degree increase in the design temperature difference.

A one percent change in C (i.e., by 0.0077) loads to a change in EAOC of 307 x 0.94 x 0.0077 = $2.22 per year.

A one degree change in indoor temperature is estimated to change HLH by 72 hours per year under base case conditions and change EAOC by 307 x 0.94 x 72/2080 = $9.99 per year.

The effect on EAOC of an error in sizing factor, SF, is much less susceptible to calculation than for HLH or C. If the pilot light gas consumption is proportional to furnace size, which it may not be, then an error in SF will mean a proportional error in the energy wasted by the pilot light during the non-heating season. In the base case example, the wasted pilot fuel costs approximately $9.52 per year and an error in SF would change EAOC in proportion to this cost.

The other main area in which SF can affect efficiency, and hence EAOC is in the amount of heat lost during the cooling phase after heating cycles and during the periods when the burner is off. Cool-down losses are primarily proportional to the mass of metal brought to a high temperature during the burning phase. This loss is mainly expected to be proportional to SF on the assumption that furnace mass is essentially proportional to heat output rate. Similarly, losses during the time that the furnace is off are assumed to be proportional to SF. Neither the validity of these assumptions nor the numerical importance of the losses has been examined.

6. Comments

a. The main uncertainties in the EAOC calculations for furnaces are in the degree-day and design temperature difference components of the heating load hour calculation. The items considered most important for field measurement are:

- Indoor control temperatures, including any setback temperatures and durations.

- Outdoor balance point temperatures, which may be regional in character due to variations in general construction practices.

- Design point temperatures, including local variations relative to the reference weather station.

b. A deeper program is suggested, funds permitting, in which the integrated effects of air temperature, heat gains from the sun and losses to the sky at night, infiltration and thermal mass of the structure would be studied. The objective would be to determine from field data the relative importance of such factors and to redevelop practical methods for estimating heating loads.

c. Little or no work is suggested relative to pilot light energy waste.

# APPENDIX O. ENERGY CONSUMPTION CHRACTERISTICS BY INCOME LEVEL [134]

Source: Newman, D., Day, D., <u>The American Energy Consumer</u>.

Permission to copy was obtained verbally from Ford Foundation and the Center for Municipal and Metropolitan Research of the National Capital Area, which is the successor to Washington Center for Metropolitan Studies.

Income levels were defined in terms of approximate average 1972 annual incomes per household as follows: poor - $2500, lower middle - $8000, upper middle - $14 000 and well-off - $24 500. The poor, lower middle, upper middle and well-off are 18, 42, 19 and 20 percent, respectively, of all households. The following tables are taken directly from The American Energy Consumer. The size of the survey taken by the Washington Center for Metropolitan Studies was not given.

Table 5-2. Household Characteristics by Income, 1973 (percent of households)

| *Household characteristics* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households | 100 | 100 | 100 | 100 |
| Life cycle | | | | |
| Head less than 45 | 33 | 41 | 56 | 48 |
| With children | 26 | 28 | 47 | 39 |
| Without children | 7 | 13 | 9 | 8 |
| 45 to 64 | 21 | 34 | 38 | 47 |
| 65 and over | 45 | 25 | 6 | 5 |
| Persons in household | | | | |
| 1 | 37 | 21 | 4 | 1 |
| 2 | 19 | 36 | 22 | 22 |
| 3 | 14 | 17 | 20 | 21 |
| 4 | 9 | 14 | 29 | 26 |
| 5 or more | 21 | 12 | 26 | 29 |
| Household structure | | | | |
| Husband/wife | 41 | 66 | 90 | 93 |
| Other | 59 | 34 | 10 | 7 |
| Number of earners | | | | |
| None | 56 | 25 | 3 | 2 |
| 1 | 33 | 53 | 47 | 42 |
| 2 or more | 11 | 23 | 51 | 56 |
| College educated household head | 12 | 25 | 38 | 58 |
| Head prof. or mgr. | 7 | 20 | 34 | 56 |
| Own home | 47 | 62 | 76 | 89 |
| Own other property | 7 | 17 | 23 | 31 |
| Head black | 23 | 8 | 5 | 3 |

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-3. Amount of Natural Gas and Electricity Used for Space Heating, and Fuel Oil Cost, by Income, 1972-1973

| *Fuel used for space heating* | *Poor* | *Lower middle* | *Upper middle* | *Well off* | *Number of households (millions)* |
|---|---|---|---|---|---|
| | Average Btu's per household (millions)[a] | | | | |
| Natural gas | 132 | 142 | 154 | 184 | 41.3 |
| Electricity | 144 | 210 | 275 | 291 | 6.0 |
| | Btu index[a] (poor = 100) | | | | |
| Natural gas | 100 | 108 | 117 | 139 | 41.3 |
| Electricity | 100 | 146 | 191 | 202 | 6.0 |
| | Percent of households[b] | | | | |
| Yearly cost of fuel oil | 100 | 100 | 100 | 100 | 10.0 |
| Under $200 | 49 | 40 | 40 | 32 | 4.1 |
| $200 and over | 51 | 60 | 60 | 68 | 5.9 |

[a]Only households using the fuel for space heating are included. The fuel probably is used by the households in other tasks (water heating, cooking) as well. The fuel consumed in these other tasks is included.

[b]Households paying for fuel oil and reporting the cost.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-4. Type of Space Heating Fuel Used, by Income, 1973 (percent of households)

| *Space heating fuel* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households[a] | 100 | 100 | 100 | 100 |
| Natural gas | 54 | 62 | 62 | 61 |
| Fuel oil[b] | 23 | 22 | 22 | 28 |
| Electricity | 8 | 9 | 11 | 7 |
| Bottled gas | 9 | 5 | 4 | 4 |
| Other and none | 9 | 3 | 2 | [c] |

[a]The different fuels add to more than 100 because some households use more than one fuel for heating.

[b]Includes kerosene.

[c]Less than 0.5 percent.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-5. Climate and Housing Characteristics, by Income, 1973 (percent of households)

| *Climate and structural characteristics* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households | 100 | 100 | 100 | 100 |
| Climate under 3,500 heating degree days | 41 | 33 | 29 | 25 |
| Apartment | 32 | 26 | 13 | 8 |
| Less than 5 rooms | 47 | 35 | 18 | 8 |
| Living room less than 200 sq. ft. | 62 | 55 | 36 | 29 |
| Less than 15 windows | 82 | 73 | 67 | 45 |
| No picture window | 70 | 56 | 38 | 29 |
| Some storm windows | 31 | 49 | 54 | 63 |
| Protected doors[a] | 41 | 53 | 58 | 70 |
| Basement in single-family homes | 31 | 45 | 52 | 61 |
| Insulation in single-family homes[b] | 41 | 78 | 86 | 94 |

[a]Includes entrances with storm doors and doors opening on to apartment hallways and other heated areas.

[b]Excludes unknowns.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-6. Index of Average Amount of Natural Gas Used per Household by Climate, Selected Structural Characteristics, and Income, 1972-1973 (Poor households = 100)

| *Climate and structural characteristics* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households | 100 | 109 | 120 | 147 |
| 3,500-5,499 degree days | 100 | 109 | 130 | 160 |
| Single-family home | 100 | 115 | 123 | 146 |
| 10-14 windows | 100 | 107 | 115 | 128 |
| Some storm windows | 100 | 94 | 100 | 118 |
| No storm windows | 100 | 119 | 131 | 174 |
| Foundation other than basement | 100 | 121 | 124 | 139 |
| No insulation | 100 | 109 | 142[a] | [b] |

[a]Results subject to substantial variation because of the small number of interviews in this group.

[b]Not reported because number of interviews too small for statistical stability.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-9. Index of Average Amount of Natural Gas Used per Household by Winter Room Temperature and Its Control, by Income, 1972-1973 (Poor households = 100)

| *Temperature characteristics and control* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households | 100 | 109 | 120 | 147 |
| Usual day temperature | | | | |
| 70°-72° | 100 | 120 | 134 | 162 |
| 73°-75° | 100 | 83 | 85[a] | 113[a] |
| Usual night temperature | | | | |
| Less than 65° | 100 | 90 | 115[a] | 145[a] |
| Bedroom window at night | | | | |
| Open | 100 | 126 | 160 | 175 |
| Not open | 100 | 109 | 112 | 146 |

[a]Results subject to substantial variation because of the small number of interviews in this group.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-10. Households with Selected Appliances, by Income, 1973 (percent)

| *Appliance* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| Stove | 95 | 97 | 99 | 98 |
| Refrigerator | 98 | 100 | 100 | 100 |
| Manual defrost | 74 | 51 | 39 | 30 |
| Frost-free[a] | 24 | 48 | 60 | 69 |
| Freezer | 23 | 30 | 38 | 47 |
| Clothes washer | 62 | 73 | 89 | 91 |
| Wringer | 18 | 9 | 5 | 1 |
| Automatic[a] | 44 | 64 | 84 | 90 |
| Clothes dryer | 24 | 45 | 70 | 80 |
| Dishwasher | 3 | 13 | 39 | 55 |
| Television–any type | 94 | 96 | 98 | 98 |
| Color | 27 | 48 | 63 | 74 |

[a]Households which reported having both versions of the appliance are included in this group only.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-11. Household Home Lighting Habits, by Income, 1973 (percent of households)

| *Home lighting habits*[a] | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| All households | 100 | 100 | 100 | 100 |
| Number of rooms lit in the evening | | | | |
| 0–1 | 63 | 53 | 38 | 32 |
| 2 | 24 | 31 | 35 | 31 |
| 3 or more | 13 | 16 | 27 | 37 |
| Lights on all night | 30 | 35 | 41 | 42 |
| Buy bulbs of 75 watts or less | 70 | 61 | 50 | 46 |

[a]Excludes unknowns.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

Table 5-12. Air Conditioning Characteristics, by Income, 1973

| *Air conditioning characteristics* | *Poor* | *Lower middle* | *Upper middle* | *Well off* |
|---|---|---|---|---|
| | | Percent | | |
| All households | 100 | 100 | 100 | 100 |
| Air conditioning | 22 | 45 | 58 | 64 |
| Window | 18 | 34 | 39 | 33 |
| Central | 4 | 10 | 19 | 32 |
| None | 78 | 55 | 42 | 36 |
| All households living in area with less than 1,000 cooling degree days | 100 | 100 | 100 | 100 |
| Air conditioning | 9 | 27 | 42 | 51 |
| None | 91 | 73 | 58 | 49 |
| All households living in area with 1,000 cooling degree days or more | 100 | 100 | 100 | 100 |
| Air conditioning | 31 | 58 | 71 | 76 |
| None | 69 | 42 | 29 | 24 |
| All households with air conditioning | 100 | 100 | 100 | 100 |
| 1-3 rooms cooled | 56 | 44 | 28 | 26 |
| 4 or more | 44 | 56 | 72 | 74 |
| All households | 100 | 100 | 100 | 100 |
| Buy air conditioner that: | | | | |
| Costs $50 *less* and $20/yr *more* to operate | 15 | 8 | 7 | 5 |
| Costs $50 *more* and $20/yr *less* to operate | 70 | 86 | 93 | 93 |
| Don't know/No answer | 16 | 6 | 1 | 2 |
| | ... Btu index (electricity; poor = 100) | | | |
| All households | 100 | 147 | 196 | 225 |
| Air conditioning | | | | |
| Some | 100[a] | 124 | 143 | 157 |
| None | 100 | 123 | 188 | 221 |

[a]Results subject to substantial variation because of the small number of interviews in the group.

*Source:* Washington Center for Metropolitan Studies' Lifestyles and Energy Surveys.

## APPENDIX P. REFERENCES AND BIBLIOGRAPHY


1. Air-Conditioning and Refrigeration Institute, Recommendations of the ARI Humidifiers Section for a Test Procedure, Efficiency Calculation and Method of Calculating Annual Energy Cost to Meet the Humidifier Requirement of PL 94-163, A Letter to M. Meyerson of the Product Systems Analysis Division, National Bureau of Standards, February 23, 1977.

2. American Gas Association, House-Heat, A Reference Book on the Application of Gas to House-Heating (American Gas Association, New York, N.Y. 1930).

3. __________, Gas Facts--A Statistical Record of the Gas Utility Industry (two years) (American Gas Association, Arlington, Va.), 1975, 1976.

4. American Society of Heating, Refrigerating and Air-Conditioning Engineer, Inc., American Society of Heating, Refrigerating and Air-Conditioning Engineers Guide and Data Book, (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1972).

5. __________, Systems Handbook (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1976).

6. __________, Handbook of Fundamentals (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1972).

7. Association of Home Appliance Manufacturers, Summary of Mean (Average) AHAM 4-Quarter Energy Data by Family Size from AHAM Range Energy Consumption Field Test (kWh/year), Association of Home Appliance Manufacturers, Chicago, Illinois, 1976.

8. __________, Report on Energy Consumption--Dehumidifiers, Based on Units Produced During the Calendar Year 1972 (Association of Home Appliance Manufacturers, Chicago, Illinois).

9. __________, Report on Energy Consumption--Clothes Washers (Association of Home Appliance Manufacturers, Chicago, Illinois, 1972).

10. __________, An American National Standard: Room Air-Conditioners (Association of Home Appliance Manufacturers, Chicago, Illinois, December 21, 1972).

11. __________, Cleaning Products Usage Data, A letter to J. Harrison, National Bureau of Standards, Washington, D.C., September 12, 1974.

12. __________, Standard Test Method for Measuring Energy Consumption of Household Clothes Washers, AHAM Standard HLW-2EC, Chicago, Illinois, December 1975.

13. __________, Graphs Depicting Frequency of Use for Room Air-Conditioners, Clothes Dryers, Dishwashers and Clothes Washers (Association of Home Appliance Manufacturers, Chicago, Illinois, July 29, 1976).

14. __________, Proposed AHAM Standard Test Method for Measuring Energy Consumption of Electric and Gas Ovens and Surface Units and Microwave Ovens (ER-5EC) (Association of Home Appliance Manufacturers, Chicago, Illinois, August 2, 1976.

15. __________, Report on Energy Consumption Survey--Clothes Washers, (Association of Home Appliance Manufacturers, Chicago, Illinois, September 10, 1976).

16. __________, Meeting Changing Lifestyles (28 National Home Appliance Conference, Executive West Hotel, Louisville. Illinois, October 7-8, 1976).

17. __________, Summarization of AHAM Range Energy Consumption Field Data, (Association of Home Appliance Manufacturers, Chicago, Illinois.

18. __________, Values Used for Base Data on Ranges, A letter to J. Smith of the Federal Energy Administration, Washington, D.C., August 9, 1977.

19. __________, Better Homes and Gardens Dishwasher User Survey, A letter to W. Walsh, Jr., Federal Energy Administration, Washington, D.C., September 2, 1977.

20. __________, Summary of Results of AHAM's Dryer Energy Usage Field Test, A letter to J. A. Smith, Department of Energy, Washington, D.C., April 26, 1978.

21. Barney, D. L. (General Electric Company), FEA Hearing on Appliances Energy Efficiency Improvement Targets for Clothes Washers, Washington, D.C., June 2, 1976.

22. Beard, W. L., Cost/Benefit Analysis of Higher Efficiency Room Air-Conditioners, (Whirlpool Corporation, Benton Harbor, Michigan, June 9, 1976).

23. ________, "A Method for Calculating Energy Consumption of a Room Air-Conditioner," American Society of Heating, Refrigerating and Air-Conditioning Engineers Transactions 83, 1 (New York, N.Y., 1977).

24. ________, Dehumidifiers--Proposed Test Procedure, Comments on The Federal Energy Administration Proposed Test Procedures for Dehumidifiers, Whirlpool Corporation, Evansville, Indiana, July 27, 1977.

25. Berlin, G. L., Proposed Energy Efficiency Improvement Target for Humidifiers, Statement by the Humidifier Institute at Federal Energy Administration Hearing, September 14, 1977.

26. Blanck, W. H., Jr., Proposed Energy Consumption Test Procedure and Sampling Plan--Room Humidifiers, Statement presented by the Association of Home Appliance Manufacturers at the Federal Energy Administration Hearing, July 27, 1977.

27. ___________, Proposed Rulemaking Regarding Energy Efficiency Improvement Targets for Dehumidifiers, Statement presented by the Association of Home Appliance Manufacturers at the Federal Energy Administration Hearing, Washington, D.C., September 14, 1977.

28. __________, Proposed Energy Consumption Test Procedure and Sampling Plan for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, Microwave Ovens and Microwave/Conventional Ranges (Statement to DOE), February 1978.

29. Blumst, W., Appendix A: Residential Customer Load Study Homes with Electric Ranges, Arizona Public Service Company, Phoenix, Arizona, December 1973.

30. Bullock, C. E., Annual Operating Hours for Central Humidifiers, A letter to A. Davies of the Product

Systems Analysis Division of the National Bureau of Standards, Washington, D.C., September 27, 1977.

31. __________, ARI "F" Factors for Central Humidifiers, A letter to E. Kweller of the Product Systems Analysis Division of the National Bureau of Standards, Washington, D.C., March 4, 1977.

32. Bureau of Census, Consumer Buying Indicators, (Bureau of Census, Washington, D.C., January 1974).

33. ________, Selected Data from the 1973 Survey of Purchase and Ownership (Bureau of Census, Washington, D.C.).

34. Chi, J., DEPAF--A Computer Model for Design and Performance Analysis of Furnaces, National Bureau of Standards, Washington, D.C.

35. Chi, J. and Kelly G., Use of a Computer Model to Evaluate Energy Saving Potentials for Gas-Fired Furnaces, National Bureau of Standards, Washington, D.C.

36. __________, "A Method for Estimating the Seasonal Performance of Residential Gas and Oil-Fired Heating Systems," American Society of Heating, Refrigerating and Air-Conditioning Engineers Transactions No. 78-1-3 (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., January 1978).

37. Chi, J., Computer Simulation of Fossil-Fuel-Fired Hydronic Boilers, National Bureau of Standards, Washington, D.C.

38. Consumer Product Safety Commission, "Proposal to Ban: Unvented Gas-Fired Space Heaters," Federal Register 43, 31, 6235-6242 (February 14, 1978).

39. Consumer Reports, "High-Efficiency Air-Conditioners," Consumer Reports, 417-419 (July 1977).

40. __________, "How Much Humidity Does Your House Need?" Consumer Reports, 103 (February 1976).

41. Crow, L. W., "Derivation of Outdoor Design Temperatures from Annual Extremes," American Society of

Heating, Refrigerating and Air-Conditioning Engineers Transactions No. 1863 (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., January 1964).

42. Davies, A., Heating Load Hours, AK, HI, Outlying Areas, A memorandum to J. Harrison of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., February 28, 1978.

43. National Bureau of Standards, Technical Analysis of FEA Hearing Testimony on and Recommended Changes in Test Procedures for Humidifiers, August 29, 1977.

44. Davies, A., NBS Range Metering Data, A memorandum to J. E. Harris of the Product Systems Analysis Division of the National Bureau of Standards, Washington, D.C., September 10, 1976.

45. [Davies, A.], Rationale for Revised Usage Factors for Microwave/Conventional Range Components, A. Davies of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C.

46. ________, Room Air Conditioners Test Procedures--Credit for Energy Saving Options and/or Features, Attachment No. 3, A. Davies of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C.

47. ________, Useful Energy Output Values, A. Davies of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C.

48. Davies. A., Usage, Vented Gas Household Heaters, Memorandum to E. Kweller of the Product Systems Analysis Division of the National Bureau of Standards, Washington, D.C., July 27, 1977.

49. ________, Usage, Vented Gas Household Heaters, Memorandum to E. Kweller of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., August 20, 1976.

50. ________, Additional Data, Humidifier and Dehumidifier Operating Hours, Memorandum to J. Harrison of the Product Systems Analysis Division, National Bureau of Standards, July 15, 1977.

51. [Davies, A.], Basis for the Constants in the Efficiency Equations, A. Davies of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C.

53. Davies, A., Cooling Load Hours, Air Conditioners, Outlying Area, Memorandum to J. Harrison of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., April 10, 1978.

54. ________, Dehumidifier Operating Hours, A memorandum to S. Fischler of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., February 22, 1977.

55. Davis, J. B., Proposed Energy Consumption Test Procedure and Sampling Plan for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens and Microwave Ovens. Statement presented by the Litton Microwave Cooking Products at the Federal Energy Administration Hearing, Washington, D.C., August 11, 1977.

56. Departments of the Air Force, Army, Navy, Engineering Weather Data, (AFM-88-8), June 15, 1967.

57. Department of Energy, "Test Procedures for Water Heaters," Federal Register 42, 192, 54110-54119 (October 4, 1977).

58. ________, "Test Procedures for Humidifiers and Dehumidifiers" (Final), Federal Register 42, 201, 55599-55611 (October 18, 1977).

59. ________, "Test Procedures for Central Air Conditioning" (Final), Federal Register 42, 227, 60150-60157 (November 25, 1977).

60. ________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, Microwave Oven and Microwave/Conventional Ranges and Determination of Further Delay in the Publication of Proposed Test Procedures for Any Other Class of Kitchen Ranges and Ovens," Federal Register 42, 251, 65576-65589 (December 30, 1977).

61. __________, "Proposed Rulemaking Regarding Test Procedures for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, Microwave Ovens, and Microwave/Conventional Ranges; Corrections," Federal Register 43, 31, 6234-6235 (February 14, 1978).

62. __________, "Proposed Rulemaking and Public Hearing Regarding Test Procedure for Water Heaters," Federal Register 43, 64, 13888-13889 (April 3, 1978).

63. __________, "Energy Efficiency Improvement Targets for Nine Types of Appliances," Federal Register 43, 70, 15138-15147 (April 11, 1978).

64. __________, "Test Procedures for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, Microwave Ovens and Microwave/Conventional Ranges, Furnaces and Vented and Unvented Home Heating Equipment," Federal Register 43, 91, 20108-20205 (May 10, 1978).

65. __________, "Test Procedures for Central Air Conditioners; Corrections," Federal Register 43, 108, 24268-24269 (June 5, 1978).

66. Derven, R., and Nichols, C., How to Cut Your Energy Bills, 1-131 (Structures Publishing Company, Farmington, Michigan, 1976).

67. Dole, S. H., Energy Use and Conservation in the Residential Sector: A Regional Analysis (R-1641-NSF).

68. Edison Electric Institute, Annual Energy Requirements of Electric Household Appliances, EEI Pub. #75-61 Rev., Edison Electric Institute, New York, N.Y., 1978.

69. Electrical World, "Air-Conditioner Efficiency Considerations," Electrical World, 56 (June 1, 1973).

70. __________, "Appliance Use Figures Need Revision," Electrical World 188, 3, 50-51 (August 1, 1977).

71. Eppley, D., Proposed Energy Consumption Test Procedure and Sampling Plan for Dishwashers, Statement presented by the Whirlpool Corporation at the Federal Energy Administration Hearing, Washington, D.C.

72. Federal Energy Administration, "Test Procedures for the Energy Conservation Program for Appliances (Room Air Conditioners)," Federal Register 41, 145, 31237-31239 (July 27, 1976).

73. ________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures for Dishwashers," Federal Register 42, 55, 15423-15427 (March 22, 1977).

74. ________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures for Water Heaters, Television Receivers, Refrigerators, Refrigerator-Freezers, Freezers and Clothes Dryers," Federal Register 42, 81, 21576-21593 (April 27, 1977).

75. ________, "Test Procedures for Unvented Home Heating Equipment: Proposed Rulemaking and Public Hearing," Federal Register 42, 91, 23860-23865 (May 11, 1977).

76. ________, "Test Procedures for Automatic and Semi-Automatic Clothes Washers and Determination That Test Procedures Cannot Be Developed for Any Other Class of Clothes Washers" (Proposed), Federal Register 42, 95, 25329-25335 (May 17, 1977).

77. ________, "Proposed Rulemaking Regarding Test Procedures for Television Receivers; Corrections," Federal Register 42, 100, 26430-26431 (May 24, 1977).

78. ________, "Test Procedures for Room Air Conditioners" (Final), Federal Register 42, 105, 27896-27899 (June 1, 1977).

79. ________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures (Humidifiers and Dehumidifiers)," Federal Register 42, 105, 27941-27955 (June 1, 1977).

81. ________, "Notice of Proposed Rulemaking and Public Hearing Regarding Test Procedures for Central Air Conditioners," Federal Register 42, 114, 30101-30108 (June 14, 1977).

82. ________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures for Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, and Microwave Ovens and Determination of Further Delay in the Publication of Proposed Test Procedures for Any Other Class of Kitchen Ranges and Ovens," Federal Register 42, 116, 30627-30637 (June 16, 1977).

83. ________, "Notice of Representative Average Unit Costs of Energy," Federal Register 42, 136, 36549-36550 (July 15, 1977).

84. ________, "Test Procedures for Dishwashers" (Final), Federal Register 42, 152, 39964-39969 (August 8, 1977).

85. ________, "Proposed Test Procedures for Furnaces; Public Hearing," Federal Register 42, 155, 40826-40845 (August 11, 1977).

86. ________, "Notice of Proposed Rulemaking and Public Hearing (Test Procedures for Vented Home Heating Equipment)," Federal Register 42, 169, 43930-43946 (August 31, 1977).

87. ________, "Test Procedures for Electric Refrigerators, Refrigerator-Freezers, Freezers, Clothes Dryers, and Television Sets" (Final), Federal Register 42, 178, 46140-46154 (September 14, 1977).

88. ________, "Test Procedures for Clothes Washers" (Final), Federal Register 42, 188, 49802-49810 (September 28, 1977).

89. ________, "Proposed Rulemaking and Public Hearing Regarding Energy Efficiency Improvement Target for Furnaces," Federal Register 42, 190, 52426-52433 (September 30, 1977).

90. Florida Power and Light Co., Water Heater Residential Survey (excerpts), August 1959 Survey.

91. Gas Appliance Manufacturers Association, Inc., Furnace Efficiency Test Procedures, A letter to the Department of Energy, Washington, D.C., February 15, 1978.

92. The Gas Industry's, Space Heating System Efficiency Improvement Program, Heating Season Status Report 1976/77.

93. Gilman, S. F., and Clausen, W., "Predicting Annual Heating Cost of Residential Heat Pumps," American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Journal (May 1959).

94. Graham, P., Markle, F., Krause, R., and Haas, R., Energy Balance for the Metropolitan Washington Area for

1973 (Metropolitan Washington Council of Governments, Washington, D.C., June 1975).

95. Grimes, J. W., Mulroy, P. E., and Shomaker, B. L., Effect of Usage Conditions on Household Refrigerator-Freezer and Freezer Energy Consumption, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1977.

96. Grot, R., Field Performance of Gas and Electric Water Heaters, National Bureau of Standards, Washington, D.C.

97. Grot, R. and Galowin, L., Preliminary Data on the Field Performance of Storage Type Residential Water Heaters, National Bureau of Standards, Washington, D.C.

98. Harris, W. S., Anderson, G. Y., Fitch, C. H., and Spurling, D. F., "Estimating Energy Requirements for Residential Heating," American Society of Heating, Refrigerating and Air-Conditioning Engineers Journal (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., October 1965).

99. Honeywell Corporation, Reducing Energy Consumption During the Cooling Season--An Analog Computer Study, Honeywell Corporation report # 70-6274 (September 1974).

100. Hudelson, G. D., Proposed Test Procedures for Furnaces, A letter to J. Smith of the Department of Energy, Washington, D.C., October 17, 1977.

101. The Humidifier Institute, Humidifiers--Proposed Test Procedures, A letter to the Executive Communications, Federal Energy Administration, Washington, D.C.

102. Hung. H. K., Estimating Annual Hours of Use of Room Air Conditioners, A memorandum to S. Fischler of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., February 20, 1976.

103. Info Dyne Systems Corporation, Economic Impact Study of the Appliance Efficiency Program (Info Dyne Systems Corporation, Potomac, Maryland, June 30, 1975).

104. Kelly, G., Comments on Test Procedures for Central System Humidifiers, Memorandum to E. Kweller of the

Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., April 6, 1977.

105. Kelly, G. E., and Parken, W. H. Jr., Method of Testing, Rating and Estimating the Seasonal Performance of Central Air-Conditioners and Heat Pumps Operating in the Cooling Mode, National Bureau of Standards, Washington, D.C., April 1978.

106. LaFrance, L. J., and Newton, A. B., Seasonal Energy Reduction Through Use of Dual Compressor Systems,

107. Langmead, J. P., GAMA 1972 Base Data for Gas Ranges, A letter to E. Harris of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., November 19, 1976.

108. ________, GAMA 1972 Base Data for Gas Ranges, A letter to J. A. Smith of the Federal Energy Administration, Washington, D.C., November 19, 1976.

109. ________, Gas Range Consumption Data, A letter to E. Harris of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., September 26, 1977.

110. Leonard, R. R., Erickson, G. A., and Jordan, R. C., "Energy Sources and Requirements for Residential Heating," American Society of Heating, Refrigerating and Air-Conditioning Engineers Transactions, No. 1783, 174-203 (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1962).

111. Manian, V. S., and Juchymenko, A., "Energy Usage and Relative Utilization Efficiency of Oil-, Gas-, and Electric-Heated Single-Family Homes," American Society of Heating, Refrigerating and Air-Conditioning Engineers Transactions, No. 2365, 103-119 (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y.).

112. Market Research Corporation of America, National Home Care/Cleaning Census, 1975 New York, N.Y., 1975.

113. Mart, 1978 Lines Include More High Efficiency Models, Mart, 24 (November 15, 1977).

114. Marzetta, L. A., Innovative Features, Clothes Dryers (Project No. 4461120, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., July 25, 1976.

115. Marzetta, L., Clothes Washers and Dryers (Appliance Usage Data Project, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

116. ____________, Usage Data Analysis: Clothes Washers (Appliance Usage Data Project, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

117. ____________, Usage Data Analysis: Clothes Dryers (Appliance Usage Data Project, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

118. ____________, Usage Data Analysis: Dishwashers (Appliance Usage Data Project) Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

119. ____________, Usage Data Analysis: Ranges and Ovens, (Appliance Usage Data Project, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

120. ____________, Usage Data Analysis: Water Heaters (Appliance Usage Data Project, Product Engineering Division), Unpublished manuscript, the National Bureau of Standards, Washington, D.C., 1977.

121. McConnell, R. R., Tobias, J. R., and Nelson, L. W., "Reducing Energy Consumption During the Cooling Season," American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Journal, 61-65 (June 1976).

122. Midwest Research Institute, Energy Efficiency Program for Appliances (Midwest Research Institute, Kansas City, Missouri, November 23, 1976).

123. __________, Patterns of Energy Use By Electrical Appliances Study (Midwest Research Institute, Kansas City, Missouri).

124. Muller, J. G., The Potential for Energy Savings through Reductions in Hot Water Consumption (The Conference on Water Conservation and Sewage Flow Reduction with Water Saving Devices, Pennsylvania State University, University Park, Pa., April 9, 1975).

125. Munger, G. R., Proposed Rules--Energy Conservation Program for Appliances, Statement presented by the Air-Conditioning and Refrigeration Institute at the Federal Energy Administration Hearing, Washington, D.C., June 1, 1977.

126. Murphy, J. A., The Homeowner's Energy Guide--How to Beat the Heating Game, Brockston Publishing Co., 1976.

127. National Association of Home Builders, Insulation Manual: Home Apartments (National Association of Home Builders Research Foundation, Inc., Rockville, Maryland, September 1971).

128. ________, Retrofitting Existing Single-Family Homes for Energy Conservation--A Feasibility Study (National Association of Home Builders Research Foundation, Inc., Rockville, Maryland, March 1975).

129. National Bureau of Standards, NBS Recommendations Regarding Final Targets for Kitchen Ranges and Ovens, National Bureau of Standards, Washington, D.C.

130. ________, "Comparison of Measured and Computer-Predicted Thermal Performance of a Four Bedroom Wood-Frame Townhouse,. Bldg. Sci. Ser. 57, April 1975.

131. ________, NBSIR 76-1029, 4, 24 (March 1976).

132. National Electrical Manufacturers Association, NEMA Manual for Electric Comfort Conditioning (National Electrical Manufacturers Association, New York, N.Y., 1974).

133. Nationwide Consumer Testing Institute, Need Report--The Living Difference Project, Catalogue No. S59973, American Gas Association, Arlington, Va.

134. Newman, D., and Day, D., The American Energy Consumer, Ballinger Publishing Company, Cambridge, Mass., 1975.

135. Newman, J. O., An Economical and Efficient Heating System for Homes, Production Research Report No. 99, United States Department of Agriculture (Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., September 1967).

136. A. C. Nielsen Company, Television 76, A. C. Nielson Company, North Brook, Illinois, 1976.

137. Northern Natural Gas Company, Residential Appliance Gas Consumption; Phase 4: Lincoln, Nebraska, Northern Natural Gas Company, Omaha, Nebraska, July 1973.

139. Pauler, C. J., Proposed Energy Consumption Test Procedure and Sampling for Clothes Dryers, A statement presented by the Whirlpool Corporation at the Federal Energy Administration Hearing, Washington, D.C.

140. Phillips, H., Proposed Energy Consumption Test Procedure and Sampling Plan--Dehumidifiers, A statement presented by the Association of Home Appliance Manufacturers at the Federal Energy Administration Hearing, Washington, D.C., June 27, 1977.

141. Pierson, R., Yearly Energy Utilization Rates for Ranges, A memorandum to E. J. Harris of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., June 6, 1977.

142. Pilati, D. A., Room Air-Conditioner Lifetime Cost Considerations; Annual Operating-Hours and Efficiency, ORNL-NSF-EP-85, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

143. Pacific Gas and Electric Company System, MR&S Dept., Electric Appliances—Average Annual Use (August 1975).

144. The Procter and Gamble Company, Appliances Proposed Energy Efficiency Improvement Targets, A letter to the Executive Communications, Federal Energy Administration, Washington, D.C., June 10, 1976.

145. __________, Consumer Research Studies, A letter to W. H. Walsh, Jr., Federal Energy Administration, Washington, D.C., September 17, 1976.

146. Reardon, J. P., Proposed Labeling Procedure, A letter to Sidney Fischler of the Product Systems Analysis

Division, National Bureau of Standards, Washington, D.C., March 7, 1977.

147. Reed, G. L., Proposed Energy Efficiency Improvement Targets, Statement presented by Auto Flo Company, Division of Masco Corporation at the Federal Energy Administration Hearing, September 14, 1977.

148. Rowe, C. B., Humidifier--Proposed Test Procedure, A letter to the Executive Communications of the Federal Energy Administration, Washington, D.C., July 18, 1977.

149. Shank, S., Energy in the Home--Changing Your Habits, Cooperative Extension Service, HE407, Purdue University, West Lafayette, Indiana.

150. Smith, C. B., Efficient Energy Use (Pergamon Press, Inc., New York, N.Y., 1976).

151. Smith, G. C., The Effect of Automatic Fan vs. Constant Fan on Temperature and Humidity Control with a Friedrich Room Air-Conditioner, A letter to S. Fischler of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., September 30, 1977.

152. __________, Manufacturer's Role--How Air-Conditioner Design Offers Energy Conservation Options (Association of Home Appliance Manufacturers, October 7-8, 1976).

153. Spielvogel, L. G. Inc., Comments on the Proposed Test Procedures for Furnaces, A letter to the Executive Communications, Federal Energy Administration, Washington, D.C., September 26, 1977.

154. Statistical Abstract of United States, 97th Edition, U.S. Department of Commerce, September 1976.

155. __________, 98th Edition, September 1977.

156. Tansil, J., Residential Consumption of Electricity: 1950-1970 (Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1973).

157. The Tappan Company, Comments on Cooking Appliance Efficiency Improvement Targets, A letter to J. A. Smith of the Federal Energy Administration, Washington, D.C., August 23, 1977.

158. _____________, Summary of Comments on FEA Test Procedures for Humidifiers, A letter to the Executive Communications, Federal Energy Administration, Washington, D.C., July 19, 1977.

159. Thompson, J. L., Proposed Test Procedures on Humidifiers, Statements presented by the Carrier Corporation at the Federal Energy Commission Hearing, Washington, D.C., July 27, 1977).

160. Walton Laboratories, Humidifier--Proposed Test Procedure, A letter to the Executive Communications of the Federal Energy Administration, Washington, D.C., July 19, 1977.

161. Weller, B., Oil Equipment Production Data, A letter to A. Davies of the Product Systems Analysis Division, National Bureau of Standards, Washington, D.C., December 2, 1977.

162. Werden, R. G., "Weather Data vs. Operating Costs," American Society of Heating, Refrigerating and Air-Conditioning Engineers Journal (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., October 1964).

163. National Bureau of Standards, Appliance Energy Efficiency Improvement Target for Dishwashers, March 11, 1977.

164. Oklahoma Gas and Electric Company, Field Study--Electric Clothes Dryer Energy Consumption, 1971.

165. Market Facts, Inc., The Appliance Ownership and Stock Survey, October 1977.

166. National Bureau of Standards, Test Procedure Review--Water Heaters, April 21, 1977.

167. Mutch, J. J., Residential Water Heating: Fuel Conservation, Economics and Public Policy, Rand Corporation, May 1974.

168. A. D. Little, Study of Energy Saving Options for Refrigerators and Water Heaters, May 1978.

169. Weizeorick, J. T., A letter to S. Fischler, NBS, Progress Report on the AHAM Room Air Conditioner Hours of Operation Program, Association of Home Appliance Manufacturers, August 16, 1976.

170. Billboard Publications, Inc., Merchandising Week, February 24, 1975.

171. Association of Home Appliance Manufacturers, A letter from W. H. Blanck, Jr. to J. E. Harris, NBS, Summary of (Electric Range) Energy Consumption Data, June 24, 1976.

172. ___________, A letter from W. T. Blanck, Jr. to J. E. Harris, NBS, Kitchen Range and Oven Test Procedures, December 7, 1976.

173. ___________, Test Method Development--Energy Consumption--kWh/year, AHAM Field Test--Family of 4, undated.

174. ___________, Report on Energy Consumption Survey--Conventional Electric Ovens, Cooking Tops and Ranges, February 24, 1978.

175. Davies, A. D. and Fechter, J. V., Statistics of Household Microwave Oven Use, National Bureau of Standards (in review).

176. American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Handbook and Product Directory--1975 Equipment, 1975.

177. Merchandising, 1976 Statistical and Marketing Report, March 1976.

178. American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Handbook and Product Directory--1973 Systems, 1973.

179. National Bureau of Standards, Test Procedure Review--Central Air Conditioners, July 12, 1977.

180. American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Handbook and Product Directory--1970, 1970.

181. Strock, C., The Degree-Day--A Fuel Estimating Unit, Heating and Ventilating, March 1954.

182. American Gas Association, House Heating, 1930.

183. Department of Energy, "Test Procedures for Water Heaters (Final Rule)," Federal Register 43, 70, 48986 (October 19, 1978).

184. __________, "Proposed Rulemaking and Public Hearing Regarding Test Procedures for Central Air Conditioners, Including Heat Pumps (Proposed Rule)," Federal Register 44, 77, 23468-506 (April 19, 1979).

185. __________, "Representative Average Unit Costs of Energy," Federal Register 44, 125, 37534-5 (June 27, 1979).

186. __________, "Test Procedures for Central Air Conditioners, Including Heat Pumps (Final Rule)," Federal Register 44, 249 (December 27, 1979).

NBS-114A (REV. 9-78)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBSIR 80-1994 | 2. Gov't. Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|

**4. TITLE AND SUBTITLE**

HOUSEHOLD APPLIANCE USAGE DATA

**5. Publication Date**
February 1980

**6. Performing Organization Code**


**7. AUTHOR(S)**

Alan D. Davies; Rudolph V. Kelly; Alvin C. Lewis; Colonel D. Lovett; Theodore J. Wang


**8. Performing Organ. Report No.**


**9. PERFORMING ORGANIZATION NAME AND ADDRESS**

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234


**10. Project/Task/Work Unit No.**

**11. Contract/Grant No.**

**12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS** *(Street, City, State, ZIP)*

The Department of Energy
Washington, D.C. 20545

**13. Type of Report & Period Covered**
Final

**14. Sponsoring Agency Code**

**15. SUPPLEMENTARY NOTES**

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

**16. ABSTRACT** *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*


The Energy Policy and Conservation Act (EPCA) requires the development of test procedures for the measurement of the energy efficiencies and the computation of Estimated Annual Operating Costs (EAOC's) of consumer products covered by the EPCA. These products are refrigerators, refrigerator-freezers, dishwashers, clothes dryers, water heaters, room air conditioners, home heating equipment, television sets, kitchen ranges and ovens, clothes washers, humidifiers, dehumidifiers, central air conditioners and furnaces.

Each test procedure contains one or more factors that are determined by the consumer and include such items as uses per year, outdoor and indoor environment, household operating practices and ground water temperature. This report is a compilation of the sources and background for the consumer usage factors contained in the current test procedures. Uncertainties in these factors are discussed, and for selected base cases, the corresponding uncertainties in EAOC's are computed. A substantial bibliography is included.

The purpose of the report is to provide perspective in selecting usage factors for future study and refinement. The items found to be most in need of refinement were factors bearing on temperature and humidity control and on water heating, both on national and regional bases.


**17. KEY WORDS** *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*


Appliances; conservation; costs; energy; EPCA; residential; usage


| 18. AVAILABILITY | 19. SECURITY CLASS (THIS REPORT) | 21. NO. OF PRINTED PAGES |
|---|---|---|
| [X] Unlimited | UNCLASSIFIED | 137 |
| ☐ For Official Distribution. Do Not Release to NTIS | 20. SECURITY CLASS (THIS PAGE) | 22. Price |
| ☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003- | UNCLASSIFIED | $10.00 |
| [X] Order From National Technical Information Service (NTIS), Springfield, VA. 22161 | | |

USCOMM-DC