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Residential Conservation Service

Model Audit Manual

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ORNL/CON-103

Energy Division

RESIDENTIAL CONSERVATION SERVICE

MODEL AUDIT MANUAL

Date Published—October 1983

Prepared for the

Office of Building Energy Research and Development
U.S. DEPARTMENT OF ENERGY

Prepared by the

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Abstract

A model energy audit procedure was developed for the U.S. Department of Energy Residential Conservation Service (RCS) Program. The program requires that large gas and electric utilities offer onsite energy audits to residential customers. The auditor must inspect the residence, calculate cost and saving estimates for region-specific conservation and renewable resource energy-saving measures, and present the estimates to the customer on the site and in person. The measures include shell modifications, heating and cooling equipment modifications, active and passive solar measures, and small wind machines.

The Model Audit is a free technical assistance resource for voluntary use by utilities. The manual contains procedures for customer interviews, residence inspections, and cost and saving calculations. Data forms, calculation aids, weather and other data, and a section on presenting results to the customer are included. Other elements of the audit, such as behavior of the auditor, customer motivation, and safety considerations, are included in a companion document, *RCS Auditor Training Manual*.

The Model Audit was developed from the following criteria: all conservation and renewable resource measures are covered by a single integrated audit procedure; the audit can be completed in 2.5 hours in most cases; and no computers, infrared viewers, or other costly or bulky equipment items are required. The cost and savings estimates for each measure are calculated independently of each other.

Whenever possible, the customer's energy use data are employed to estimate building heating and cooling loads. Otherwise, energy loads through the building shell are estimated by a modified degree-day procedure. Infiltration loads are estimated by an air-change method. The rate of air change is estimated semiquantitatively by observing cracks around windows, doors, sill plates, etc. The estimation of energy savings from furnace and air-conditioning modification or replacement is based on empirical data. Tabulated information is provided for estimating seasonal efficiencies of furnaces, heat pumps, and air conditioners according to type and year of manufacture.

A simple viewing device is used to quantify the winter and summer shading on the south wall of the structure. The F-chart method was used to generate the procedures for estimating savings for active solar measures, and the thermal performance of passive solar measures are estimated by the collector load ratio procedure. Economically optimized solar saving fractions have been precalculated for specific regions but can be adjusted for site-specific considerations. A simplified method for estimating the size and capacity of an appropriate small wind energy conversion device was developed. The procedure makes use of average wind speed and site-specific estimates of the effect of terrain and obstructions on the effective wind resource.

This revision incorporates updates issued on the original February 1980 version: improved calculational procedures for cooling load, replacement air conditioners, solar domestic hot water, thermosiphon air panels, sunspaces, and new procedures for several state-added measures.

B. Introduction

B.1 HISTORY OF THE RESIDENTIAL CONSERVATION SERVICE PROGRAM

The establishment of the Residential Conservation Service (RCS) Program was mandated by the enactment of the National Energy Conservation Policy Act (NECPA), which was signed into law November 9, 1978. Title II, Part I, of NECPA directed the U.S. Department of Energy (DOE) to issue regulations requiring large electric and natural gas utilities to offer onsite residential energy audits and other related services to customers living in single-family dwellings or multifamily buildings with four or fewer dwelling units. Pursuant to this law, DOE issued proposed regulations on March 19, 1979, and final regulations on November 7, 1979. The regulations directed state agencies chosen by each governor as "lead agencies" (usually the energy office or public service commission) to develop RCS plans outlining the utilities' responsibilities.

On November 12, 1981, DOE issued a revised proposed rule which reduced the regulatory requirements imposed on states and utilities participating in the program by the previous RCS rules. The proposed rule detailing the Federal RCS (Standby) Plan was withdrawn. A revised final rule was issued on June 25, 1982. Table B.1 lists the major regulations issued by DOE pertaining to RCS and other related programs.

B.2 OBJECTIVE

The Model Audit was developed as an integral part of DOE's technical assistance to states, utilities, and home heating suppliers. The Oak Ridge National Laboratory, the Solar Energy Research Institute, the Rocky Flats Wind Energy Program, and several consulting firms have been responsible for designing the audit procedures. The Model Audit does not represent a DOE standard for auditing but is one of many acceptable procedures for residential energy inspections.

To facilitate the development of audit procedures by program participants, the Model Audit in draft form was initially distributed to lead agencies and utilities in February 1980. At that time, a few sections were incomplete. After further research, testing, and validation, several calculation procedures were revised and the incomplete sections were finalized. Recipients of the Model Audit received this information as it was developed in the form of update packages. This version of the Model Audit has integrated components of the draft Model Audit and additional revisions or updates. This version also includes new material dealing with (1) optional cooling loads calculation, (2) replacement air conditioners, (3) solar domestic hot water, (4) thermosiphon air panels, (5) sunspaces, and (6) several state-added measures.

Table B.1. RCS regulatory history

Date	Regulatory action and description
January 9, 1979	Advance notice of proposed rulemaking
March 19, 1979	Proposed rulemaking and public hearings
November 7, 1979	Final rule
August 11, 1980	Corrections to final rule and interpretation of Title V, Subpart B, of the ESA
September 24, 1980	Final rules establishing requirements for (1) certification of installers and inspectors of furnace modifications and renewable resource devices and (2) material and installation standards which had previously been reserved. Interim rule for installation standards for automatic intermittent ignition devices
September 25, 1980	Interim final rule establishing material standards for urea-formaldehyde (u-f) foam insulation
October 8, 1980	Proposed rulemaking and public hearing to incorporation statutory changes made to the RCS program by the ESA
January 6, 1981	Final technical amendments to RCS
January 9, 1981	Proposed rulemaking for the federal RCS plan
January 16, 1981	Proposed rulemaking for the CACS program
November 12, 1981	Proposed revisions to existing rules and withdrawal of the proposed federal RCS and CACS rules
June 25, 1982	Revised RCS rule
November 24, 1982	Revised proposed CACS rule and final amendments to the RCS rule
November 26, 1982	Proposed federal standby RCS plan

B.3 DEVELOPMENTAL CRITERIA

The ultimate goal was to develop step-by-step audit procedures for residential single-family homes. The structure and content of the audit were influenced by several factors, primarily the requirements of Section 456.307 of the original final rule. The requirements were as follows.

1. The Model Audit had to be a Class A audit (an onsite inspection of the building shell and of the space heating, space cooling, and water heating equipment by a trained auditor).

2. The Model Audit had to address energy-conserving practices associated with the Program. These practices were furnace efficiency maintenance and adjustments; nighttime temperature setback; reduction of thermostat setting in winter; raising of

thermostat setting in summer; water flow reduction in showers and faucets; reduction of hot water temperature; reduction of energy use when a home is unoccupied; plugging of leaks in attics, basements, and fireplaces; repair of leaks in pipes and ducts; efficient use of shading; and other low-cost/no-cost items incorporated in a state plan.

3. The Model Audit had to address retrofit activities or measures associated with the program. These measures were replacement burners, flue opening modifications, automatic ignition devices, replacement furnaces and central air conditioners, ceiling insulation, wall insulation, floor insulation, pipe and duct insulation, water heater insulation, storm/thermal windows and doors, clock thermostats, solar domestic hot water systems, active solar space heating systems, combined active solar space heating and solar domestic hot water systems, replacement solar swimming pool heaters, passive solar direct-gain glazing systems, passive solar indirect-gain systems, passive solar sunspace systems, and wind energy devices.

4. The Model Audit had to contain procedures by which the auditor could determine which of the energy-conserving practices would save energy in the residence, explain such energy-conserving practices to the customer, emphasize the importance of these practices, and recommend that they be performed before installation of any measure.

5. The Model Audit had to contain procedures by which the auditor could determine the applicability of each program measure to the site being inspected.

6. The Model Audit had to contain procedures which permitted the auditor to estimate the installed costs of the recommended actions and ensuing first-year energy savings, expressed as dollar figures.

In addition, the Model Audit had to be cost-effective. An upper limit of $15 as a direct charge to the customer for all RCS services was established by the ESA. The real cost to the utility would be higher; therefore, an effort was made to minimize the time spent on computations. A goal of 2.5 hours of onsite time was set. To optimize the auditor's time, the audit was designed so that many of the same observations and measurements could be used to calculate the costs and savings of several program measures (e.g., weatherization, window treatments, and heating and/or cooling systems). All the calculations were designed to be done without the use of computers or other expensive equipment. Because the Model Audit had to include region-specific information for it to be useable on the local level, data had to be developed for each program measure within each climate zone. The presentation of derived results had to be presented in a way that would be understandable to the customer and would promote customer action.

The research team reviewed existing energy audit calculations in order to locate adequate procedures for incorporation into the Model Audit. These procedures included those developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE),[1-3] the Air Conditioning Contractors of America,[4] the Department of Housing and Urban Development,[5] the Department of Energy's Project Retrotech,[6] and others. Several computer programs were also studied: DOE-2, developed by Lawrence Berkeley Laboratory;[7] NBSLD, by the National Bureau of Standards;[8] and BLAST II, by the U.S. Army Construction Engineering Research Laboratory[9] It was found that the

ASHRAE procedures, or modifications to these procedures, were acceptable for heat loss calculations. The computer programs were too cumbersome for onsite use, although DOE-2 was used by the research team in the development of several procedures. New procedures were needed for infiltration heat loss and gain, for estimating seasonal furnace and air conditioner unit efficiency, and for calculating the energy savings from heating and cooling equipment modifications.

State-of-the-art analysis methods for renewable resource measures were reviewed to identify those procedures which were best suited for RCS use. The F-chart method[10] was selected for the active solar measures because iterative runs could be made easily to generate tables. *The Passive Solar Design Handbook,*[11] volumes 2 and 3, was used to generate region-specific graphs for direct-gain systems, Trombe walls, water walls, and sunspaces. Energy savings from window heat-gain retardants and heat-reflective and heat-absorbing window films were estimated using modified solar heat-gain factors with appropriate shading coefficients.[12] There were no existing appropriate procedures for wind energy conversion systems, solar swimming pool heaters, or thermosiphon air panels. For these measures, new procedures were derived.

B.4 ORGANIZATION OF THE MANUAL

The Model Audit includes three major sections which are highly interactive and interdependent. They are (1) Audit Procedures, (2) Audit Forms, and (3) Data Base/Calculation Aids. A Specifications section and several appendixes are also included.

The Procedures section details the audit process from the moment the auditor arrives at the residence to the time possible options are discussed with the customer. Alternative methods of data collection and manipulation are covered as well as suggestions to aid the auditor, utility, or home heating supplier in making preaudit preparations.

The Audit Forms are data collection and calculation tools. These forms, used with the Procedures, take the auditor through a step-by-step evaluation of the residence. The first four pages, along with the onsite sketch forms, are designed to fulfill the recordkeeping requirements of the original RCS regulations. It is recommended, however, that the entire package be retained by the auditor for a short period of time to provide for an adequate response to possible customer questions.

The Data Base/Calculation Aids provide a wide variety of information needed by the auditor. Parts of this section are nationally applicable and others are region-specific. Some region-specific data can be imprinted on utility-specific forms to reduce the amount of reference materials needed by the auditor. No cost data are included in the Model Audit. States and/or utilities should provide local costs for the measures evaluations.

The Findings and Recommendations section is actually an Audit Results Form. The form fulfills the written presentation of results requirement.

The Specifications section contains the criteria upon which the Model Audit was based. There are two types of specifications for each program measure. The first specifications are the requirements of Section 456.307 of the original RCS Rule. The second type of specifications includes the results of technical and policy decisions. Reference to the specifications for a particular measure can provide an insight into the approach taken in developing auditing procedures for that measure.

Six appendixes provide additional reference materials.

Appendix A lists the counties in each state by HUD/MPS zone. This information is to be used in determining which climate zone data, found in the Data Base Calculation Aids, applies on the local level.

Appendix B is a sample preaudit consumer questionnaire. The purpose of this questionnaire is to reduce the time the auditor must spend collecting onsite data. The questionnaire may be mailed to the customer prior to the audit. The customer can fill in the information that would otherwise be collected during an onsite interview and return the questionnaire before the audit or provide it to the auditor at the time of the audit.

Appendix C is the technical documentation for the Model Audit procedures. References, assumptions, and computational approaches are described. These explanations are intended to promote a better understanding of the Model Audit procedures.

Appendix D is a list of recommended equipment for onsite use by the auditor.

Appendix E is a glossary of terms. Many of the definitions are applicable only within the context of the RCS Program and are taken verbatim from the RCS Rules. Others are definitions of engineering terms that have been included to clarify the material.

Appendix F contains procedures, forms, and documentation for retrofit actions that may have been incorporated into the audit programs on the state level.

B.5 MULTIFAMILY AUDIT PROCEDURES

Audit techniques have been developed to satisfy the regulatory requirements expanding RCS to dwelling units in multifamily buildings which are neither centrally heated nor cooled. This information is presented in the *Residential Conservation Service Model Audit Manual. Multifamily Audit Procedures*, Report Number ORNL/CON-104, available from the National Technical Information Service. Dwellings that are in multifamily buildings that are either centrally heated or cooled are considered under the Commercial and Apartment Conservation Service Program.

The Model Audit procedures, forms, methodology, audit questionnaire, and Data Base/Calculation Aids have been modified for multifamily buildings to include (1) a new procedure for estimating infiltration rates in multifamily buildings, (2) buffer space correction factors for unit dwellings, and (3) a new procedure for the estimation of the heat gain due to solar radiation through windows. Wind energy devices and solar swimming pool heaters are not addressed because of their inapplicability to individual units within multifamily buildings.

B.6 RELATED MATERIALS

Your Home Energy Audit. The First Step to More Energy Efficient Living, was designed as an educational tool to be left by the auditor upon completion of the audit. It describes energy conservation and renewable resource program measures in simple terms, the use of tax credits to offset installation costs, and the Weatherization Assistance program. In addition, it also contains an overview of the RCS program as it existed in 1980. Because the program has changed since then, much of this material is no longer pertinent and has,

therefore, not been included in the Manual. It is available, however, from the Government Printing Office, Superintendent of Documents, Washington, D.C. 20402, (202) 275-2051.

Another facet of DOE's technical assistance efforts was the development of an auditor training program. This task resulted in *The Residential Conservation Service Auditor Training Manual.* Aimed at potential auditors, the document presents a legislative overview of the RCS program, as well as information necessary to conduct a conservation and renewable resource audit on a residential building. It includes directions on how to determine the amount of energy a residential building uses, how to determine the most appropriate conservation and/or renewable resource measures for a particular building, and how to estimate the cost of those measures and savings possible due to their installation. *The Residential Conservation Service Instructor's Manual—Auditor Training, Training Program Management and Instructors Guide* is a companion volume to the *Auditor Training Manual* and was designed to assist individuals responsible for training of auditors and program management. These two manuals were published in accordance with the original RCS Program Regulation of November 7, 1979, and, therefore, contain some dated material. Both documents are available through the Energy Training and Education Center, P.O. Box 58, North Hampton, Massachusetts 01601, (413) 586-8540. The *Auditor Training Manual* is also available under the title *The Residential Energy Audit Manual* from the Fairmont Press, 4025 Pleasantdale Road, Suite 310, Atlanta, Georgia 30340, (404) 447-5314.

The Residential Retrofit Specification/Cost Database—Renewable Resources, Report Number SERI/SP-722-1296, and *The Residential Retrofit Specification/Cost Database—Energy Conservation,* Report Number SERI/SP-254-1788, contain technical specifications for residential retrofits and cost estimates for each of these retrofits for 56 cities. Costs are provided for each system on resident- and contractor-installation. It is presently available from the Solar Energy Research Institute, 1617 Cole Boulevard, Golden, Colorado 80401.

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C. Audit Procedures

C.1 INTRODUCTION

This section is a step-by-step explanation of the RCS Model Audit and contains a description of how to use each of the forms included in this manual. Five task areas are discussed: (1) the interview, (2) observations and measurements, (3) load calculations, (4) measure calculations, and (5) presentation of results to the customer.

C.2 INTERVIEW

The interview should begin with general introductions and a brief description of the RCS Program and the audit. The auditor should ask the resident several questions to determine the resident's energy use habits and to obtain some initial structural and site information. Not every resident or customer will be able to answer all questions. Any information that the customer cannot provide will be collected during the auditor's inspection.

A preaudit questionnaire, which can be mailed to the customer prior to the onsite audit, is provided in Appendix B of this volume. The completed form can either be mailed back to the energy supplier or given to the auditor. The use of this questionnaire will decrease the data collection time and often provide better information than can be obtained during the interview. However, resident response to this questionnaire may not be used as a precondition for an RCS Program Audit.

Table C.1 lists interview data requirements with an explanation of their intended use and a discussion of alternate data sources.

C.3 OBSERVATIONS AND MEASUREMENTS

C.3.1 Site Observation

A large portion of the observation data will be noted on a set of rough sketches. Sketch forms are provided for this purpose (see Sect. E.3). In the case of a south wall elevation, it is recommended that a photograph be used instead of a sketch. A plan view of the house should be placed on the plan sketch sheet. Measure the dimensions of the residence and note them on the plan view. If applicable, sketch the location and the surface dimensions of the swimming pool.

Table C.1. Interview data requirements, use, and alternative sources

Data requirements	Use	Alternative sources
Number of occupants	Solar domestic hot water system	None
Annual electricity use	Wind energy system	Utility data, or estimate based on structural/resident use
Thermostat installation and settings	Clock thermostat and heat load calculations	Visual observation
Number of times outside doors are opened each day	Infiltration load estimates	Inquire about the number of adults, children, and pets in the household and make a subjective judgment
Average seasonal temperatures of unheated buffer areas and if the customer intends to heat these areas in the future	Heating load calculations are corrected according to these estimated temperatures	Default corrections are available in this document (see Sect. C.4.4)
Fireplace damper use habits	Infiltration and customer education	Visual observation
Hot water usage	Solar domestic hot water system	Inspection of appliances (Sect. C.3.2)
Hot water system fuel type	Solar domestic hot water system; water heater insulation	Inspection of equipment
Air conditioner information: type, energy source, age, capacity	Replacement air conditioner; load calculations affecting summer savings for all weatherization measures, heat-absorbing or heat-reflective window and door material, window heat gain retardants	Inspection of equipment
Heating system description: energy source, age, maintenance schedule, distribution system type; pilot light usage; presence of vent damper, electrical ignition device, replacement oil burners; location; secondary system type and fuel	Replacement furnace and furnace modifications; load calculations affecting winter savings for all weatherization, solar heating, and wind measures	Inspection of equipment
Pool heating system fuel	Replacement solar pool heaters	Inspection of equipment
Wall construction	Wall insulation; south wall construction; solid masonry or frame for passive solar	See Sect. C.3.4
Attic information (only if the attic is inaccessible)	Attic insulation; active solar	Assume local building practice based on age and type of house
Floor construction	Floor insulation; passive: direct gain or water wall support	See Sect. C.3.5

Mark on the sketch the orientation of the wall that most nearly faces south. Also note the orientation of the roof if the orientation is different from that of the wall. If the variance from true south is between 0 and 15°, then this is considered a preferred orientation; 15 to 45° is considered acceptable. In the active solar calculations, a different table is used, depending on whether the orientation is preferred or acceptable.

If a wind energy device is a program measure and if the wind resource at the site is at least 10 mph annual average, note a possible location for the device. Check the site to see if a 15-ft-diam cylinder can be accommodated without encroaching on property lines, and note the height of any obstructions at least 30 ft wide within 100 ft of the location. Observe the general terrain surrounding this site in order to describe the roughness and accessibility of the site.

Possible solar obstructions should be identified to determine whether sufficient solar access exists to make solar measures applicable and to *estimate* the proportion of sunlight that will strike a potential collector surface on or near a residence.

Find the wall or roof of the residence facing closest to true south. Stand near this wall at or below the site of a possible solar installation and use the solar viewing device appropriate for your latitude. Several such devices are commercially available. Follow the instructions for the particular device to find the fraction of shading at the site. By subtracting this fraction from 1.0, the unshaded fraction is obtained. This unshaded fraction is referred to as the Prime Solar Fraction (PSF) and is used in the solar calculation procedures for that measure. The PSF value should be based on shading during the months that comprose the heating season for those measures that impact only heating. For solar hot water estimates, an annual PSF should be determined, and for solar swimming pool heaters, a PSF for the months that comprise the swimming season should be determined.

If there are no obstructions, use of the solar viewing device is unnecessary. With experience, the auditor will be able to approximate, without aid, where the sunlight for that latitude is obstructed. The solar viewing device assists in making these determinations and quantifies the result.

If obstructions exist, separate sitings at intervals along the south wall are necessary for use in determining the shading for different potential solar measures. The approach for each separate measure is listed below. The PSFs identified should be noted on the elevation sketch or photograph of the south wall.

- For the *direct gain* estimate, average the heating season PSFs of those sites judged suitable for direct gain.
- For the *indirect gain* estimate, average the heating season PSFs of those sites judged most suitable for indirect gain. Separate averages should be computed for Trombe wall, water wall, and thermosiphon air panel.
- For the *sunspace* estimate, stand about 10 ft in front of the existing wall (where the sunspace wall would be) and average the heating season PSFs from the two ends of the area that is judged suitable for a sunspace.
- For the *solar domestic hot water* estimate, a judgment about collector placement will be made between roof and ground location, based on roof orientation, available area, appearance, and customer preference. In determining the annual PSF for the ground

location, use the indirect gain estimate procedure. If a roof location is judged suitable, estimate the annual PSF on the basis of the sighting taken from the nearest ground locations or, in the case of multiple-story houses, from an appropriate upper-level window if practicable.

- For the *active space heating* or *combined domestic hot water* estimate, use the procedure for the solar domestic hot water estimate.
- For the *replacement pool heater* estimate, use the procedure for the solar domestic hot water estimate, but estimate the PSF during the swimming season only.

Instead of a hand-drawn elevation sketch, it is recommended that a self-developing photograph of the south wall area be used. If such a camera is not available, a rough sketch should note the approximate location of doors, glazing and obstructions on the south-facing roof that would conflict with the installation of solar systems. Using the symbols below, mark the photograph or sketch to indicate the feasible solar locations and the appropriate types of solar technology.

A	active space heating
H	domestic hot water
C	combined active space and domestic hot water
T	indirect gain, Trombe wall
TAP	indirect gain, thermosiphon air panel
W	indirect gain, water wall
D	direct gain
S	attached sunspace
WHGR	window heat gain retardants
P	swimming pool heating

For the optional cooling (load and) cost calculations (Sect. C.4.6.2), estimate the Prime Solar Fraction (PSF), as described above, for all exterior window orientations. To aid in the determination of the PSF, viewing devices similar to the solar viewing device described above are available for south-facing walls. For orientations other than south, the auditor should make the best estimates possible.

C.3.2 System Observations

The daily hot water demand per resident may be determined by an inspection of the major appliances. If the resident did not indicate the appliances during the interview, look for a dishwater and/or washing machine. On the interview form, note 10 gpd/person if there is neither a dishwasher nor a washing machine; 15 gpd/person if there is only a dishwasher; 20 gpd/person if there is only a washing machine; and 25 gpd/person if both appliances are present.

If the resident was unable to supply a description of the heating and cooling systems during the interview, the auditor must collect these data by inspection. A flue gas analysis may be performed (but is not required) at this time. All oil-fired boilers must be inspected to determine if they are wet-base boilers. The approximate length of any accessible

uninsulated hydronic heating pipe in unconditioned space should be noted. Estimate the length and uninsulated percentage of ductwork in unconditioned space. This percentage should be relative to the ductwork of the total system.

Note the nameplate input and output ratings for the primary heating unit. A flue gas analysis may be performed for any fossil-fueled heating system at the discretion of the auditor. A flue gas analysis may be necessary for some unconventional or hybrid heating systems. Note the output rating and Energy Efficiency Ratio (EER) of any central air conditioning system. If the EER is not indicated on the nameplate, it may be approximated by using the Default EER Table in the data base or by the following methodology: note the voltage and running load amps or full load amps (RLA or FLA) for the compressor unit on the nameplate of the air conditioner. Note the voltage and amps for the outdoor condenser fan and for the indoor (house) fan. Check to see whether there is more than one compressor motor or condenser fan motor. Also, be sure that the compressor motor or any other motors are not specially marked as three-phase (very few units will be three-phase). Multiplying each amp rating by the number of motors and by the voltage will give the volt-amps for each component. If any components are three-phase, multiply that number of volt-amps by 1.7 (the square root of three) to obtain the actual volt-amps for that component. Add the number of volt-amps for each component (the indoor fan, outdoor fan, and compressor motors) to obtain the total input volt-amps. Assume a power factor of 0.9, and multiply the total volt-amps by 0.9 to obtain the total input watts.

The other number needed is the Btu/h output of the air conditioning system at full load, which is the same as the rating of the unit. The Btu/h rating equals the number of tons times 12,000.

The EER equals the Btu/h output rating divided by the total input watts determined previously. This calculation is a good estimate of the actual EER.

C.3.3 Ceiling/Attic Observations

Inspect the attic insulation to determine its type, condition, and U-value. If the attic insulation is nonuniform, note the different areas on the plan view sketch. While inspecting the interior side of the roof, notice any indication of moisture damage, delaminated sheathing material, or fungus growth. Also, check for any obvious structural problems which could affect the possible support of a solar array.

Infiltration bypasses are passages by which air leaves a conditioned space and escapes to the attic. Auditors will be trained to identify these situations, such as an open interior wall cavity. Examine the ceiling for cracks and for plumbing, wiring, flue, or other penetrations. Check ceiling light fixtures to see whether they are recessed or not. Check for an attic access door or hatch, and see whether it is weather stripped or not. The auditor should note these items for use on the infiltration evaluation sheet.

C.3.4 Wall Observations

Wall insulation can be inspected by (1) knocking on the wall and listening for the hollow quality of the sound, (2) removing an electrical cover plate and using a plastic or

insulated probe, (3) looking down into a wall cavity from the attic, (4) using the homeowner's estimate of present wall insulation, or (5) assuming a typical building structure for your locality based on the age and type of the house.

Using one of these techniques and the U-value tables found in the Data Base/Calculation Aids (Sect. E.2), note the current insulation type, R-value, and overall U-value.

If there is not significant wall insulation present (the wall insulation measure must then be evaluated) or if the utility data are insufficient and a heat load calculation will be made, the gross wall area must be estimated. This estimate is made by multiplying the perimeter of the residence (taken from the site sketch) by the height of the exterior walls.

The ceiling/wall, floor/wall, and wall corner joints on the exterior walls must be examined to determine their condition. Check electrical boxes (outlets or switches) on exterior walls for gaskets. Check for wall penetrations such as pipes or dryer vents. Exterior walls generally contribute more to infiltration than the other categories on the evaluation sheet, and, unless the auditor knows that the joints are definitely well caulked and sealed, the wall should not be checked as *good* on the infiltration evaluation sheet.

C.3.5 Floor Observations

If possible, check for floor insulation. If present, note the type and U-value. If floor insulation is nonuniform, note the different areas on the plan view sketch. If visual inspection of the floor insulation is not possible, assume a typical construction based on the age and type of the residence.

The auditor should note whether ductwork penetrates the floor. The infiltration evaluation sheet should be marked for these observations in conjunction with observation of any system ductwork.

C.3.6 Doors and Windows

The doors and windows table in the audit forms provides information for the evaluation of storm or thermal windows and doors, caulking, weather stripping, window heat gain retardants, heat-reflective and heat-absorbing window or door materials, and total heating and cooling loads. The four major orientations of the residence should be noted in the first column of the doors and windows table. The glazing area should be identified for each orientation. The PSF needs to be determined only if one is using the optional cooling calculation prodecure (Sect. C.4.6.2). Windows are designated as "large" or "small" on the basis of the auditor's visual estimate of whether they are bigger than 12 ft^2 or smaller than 12 ft^2. The number of windows with single glazing or multiple glazing should be noted. The auditor should mark the appropriate box to indicate needed caulking, weather stripping, etc., for each window as he walks around the residence. He should also note the fit of the windows and doors at this time and mark these observations on the infiltration evaluation sheet. Treat large glass doors as equivalent to three large windows.

By multiplying the number of windows by the area factors (given on the doors and windows table), the oriented area of single-pane and multiple-pane windows is calculated.

The far right column of this table represents the total glazed area for each of the four orientations. Located at the bottom of the table are the total multiple-paned area and total single-paned area.

A similar table is provided for doors.

Calculate the net wall area by subtracting the window and door areas from the gross wall area.

C.3.7 Caulking Requirements

During the course of the structural inspection, the auditor should note where caulking is obviously required other than around windows and doors. Possible locations for these caulking requirements include fixed joints, underneath baseboards and electrical plates, around pipes and wires entering a building, and around dryer vents and exhaust fans in exterior walls.

C.3.8 Final Infiltration Observations

Check the foundation for any visible cracks. Inspect basement/crawl space/garage windows for sealing and caulking. Check the fit of the basement/crawlspace/garage entrance and all apertures to conditioned space (including trapdoors and water, electrical, and sewage openings). Mark these observations on the infiltration evaluation form.

If any item on the evaluation sheet is inapplicable (e.g., there is no fireplace) check the box which represents the best, or tightest, condition. The sum of the boxes checked should always be equal to eight. Substitute the number of good, average, and poor boxes checked into the equation at the bottom of the evaluation sheet. Calculate the air-change factor.

C.4 CALCULATIONS FOR LOADS AND EFFICIENCIES

C.4.1 Infiltration Losses and Gains

Using the infiltration calculations sheet, fill in the blanks in the following manner. The total floor area (in square feet) of conditioned space is entered. This area should equal the volume of the conditioned space divided by 8 (ft), the assumed ceiling height. The winter/summer wind factors, terrain factors, and heat gain/loss factors are all taken from the Data Base/Calculation Aids and are regionally specific. The terrain factor includes the assumed 8-ft ceiling height.

Multiply these factors as shown on the calculation sheet to determine the net infiltration losses and gains in Btu/h·°F. Note that the summer gains are only calculated if a significant portion of the house is air conditioned.

C.4.2 Heating and Cooling Unit Efficiencies

Seasonal efficiencies of heating and cooling units are obtained from the Data Base/Calculation Aids (Sect. E.5). These efficiencies should be noted on the System Data forms.

The default energy efficiency ratios (EERs) for central air conditioners should only be used in the determination of seasonal EERs (SEERs) for the evaluation of savings for energy conservation measures other than replacement central air conditioners. For that measure, the manufacturer's data should be obtained. This information can be obtained from the unit nameplate, a manufacturer's brochure, or an equipment directory such as the Air Conditioning and Refrigeration Institute (ARI) Directory. Two procedures are provided for determining seasonal efficiency. One method uses the ARI values directly; the other is based on weather-related parameters developed from DOE-2.1A modeling. The latter will result in lower seasonal efficiencies in most regions of the country. If the existing unit is oversized (usual case), an additional correction is required for the SEER. The percent oversize can be determined from the ratio of unit capacity to design load. The design load equals the Cooling Energy Use Rate (CEUR) times the design temperature difference, where the design temperature difference equals the locally determined design temperature minus 65°F. Using the "corrected CEUR" from the optional cooling calculations (see Sect. C.4.6.2), the design load is calculated as above, except the "base" temperature used to calculate the cooling degree-days is subtracted from the design temperature to determine the design temperature difference. If the unit capacity is 36,000 Btu/h and the design load is 24,000 Btu/h, the ratio of 36,000/24,000 equals 1.5, and the unit is 50% oversized.

C.4.3 Load Estimation from Previous Energy Use Data

The most representative method of determining the heating and cooling costs for a residence is by examination of actual billing data from the firm or utility that supplies heating and cooling energy to the residence. The analysis of the billing data should be done prior to the audit. Comparing the actual energy use with the heating degree-days (HDD) or cooling degree-days (CDD) for each billing period should yield an equation of the form shown below.

$$\text{Heating energy use} = H_1 \times \text{HDD} + H_2,$$

$$\text{Cooling energy use} = C_1 \times \text{CDD} + C_2.$$

These are equations of the lines where H_1 and C_1 are constants with units of fuel usage/degree-day. The method for obtaining these equations is by standard statistical analysis (linear regression). The HDD that are commonly available and those given in the Data Base/Calculation Aids have a 65°F base. The HDD which are used for the Model Audit are the 65°F base HDD times the correction factor given in Table C.2 (*corrected* HDD). These correction factors are taken from the *ASHRAE Fundamentals Handbook* (1981). The constant, H_1, should be determined by using *corrected* HDD for each billing period to assure uniformity with the other calculations.

Table C.2. Heating degree-day correction factors

HDD, 65° base	1000	2000	3000	5000	7000	9000
Correction factor	0.80	0.75	0.70	0.60	0.63	0.66

It is also helpful to have the data points plotted graphically to allow for quick inspection of unusual billing periods. If a customer takes a vacation during the heating season, that billing period may have to be ignored in the analysis. Other factors may cause significant changes for specific billing periods which would require careful inspection during the degree-day analysis to minimize error. Utilities with minimum billing practices, service charges, or meter charges must be certain that only the actual amount of energy consumed is used for these calculations.

The quantity H_1, when converted to units of Btu/h·°F, is the heating energy supply rate (HESR):

$$\text{HESR} = H_1 \times \text{heating value of the fuel} \div 24 \text{ h/d} .$$

Likewise, the quantity C_1 becomes the cooling energy supply rate (CESR)

$$\text{CESR} = C_1 \times \text{heating value of the fuel} \div 24 \text{ h/d} .$$

Some typical heating values for fuels are as follows:

- electricity—3400 Btu/kWh,
- gas—103,000 Btu/100 ft^3,
- No. 2 fuel oil (distillate)—138,000 Btu/gal, and
- propane—95,000 Btu/gal.

The energy supply rate is related to the building usage requirement by the mechanical equipment seasonal efficiency; that is,

$$\text{HESR} = \text{HEUR/furnace seasonal efficiency},$$

$$\text{CESR} = \text{CEUR/air conditioner seasonal efficiency},$$

where HEUR and CEUR are the heating and cooling energy use rates, respectively, calculated from building heat loss coefficients when utility data are not available (see Sect. C.4.5). The latter method should be used only if reasonable estimates cannot be made from the energy usage data.

The HEUR is needed for many of the renewable resource savings estimates. The CEUR is used for replacement air-conditioner evaluations. When utility data are not available, CEUR is calculated (by the method in Sect. C.4.5) to estimate the seasonal cooling cost.

When the loads are determined from usage data, the seasonal costs are calculated directly from the quantities H_1 and C_1:

$$\text{HSC} = H_1 \times \text{corrected HDD (seasonal average)} \times \text{local fuel cost},$$

$$\text{CSC} = C_1 \times \text{CDD (seasonal average)} \times \text{local fuel cost},$$

where HSC is the heating seasonal cost and CSC is the cooling seasonal cost. HESR, CESR, HSC, and CSC are determined prior to the audit, if possible.

C.4.4 U-Value Correction Factors

When an unconditioned space such as a garage or crawlspace is next to a conditioned space, a correction factor is used to allow for the effect this "buffer space" may have on the building load. The definition of this factor is the ratio of the temperature difference on a winter design day between the conditioned space and the "buffer space" to the temperature difference between the conditioned space and the outdoor winter design temperature. The factor is then multiplied by the U-value of the affected shell component. Although the factor is multiplied by the U-value, the correction is a temperature correction. The best source for an estimate of the temperature in these "buffer spaces" is conversation with the customer. If the customer cannot provide these temperature estimates (noted in the interview), the auditor may use a default value from Table C.3 (revised with this publication). Regional adjustments may be made to this table.

Table C.3. Examples of typical correction factors

	Winter	Summer
Attic		
• Uninsulated ceiling	0.7	1.5
• Insulated ceiling (R-11 or more)	0.8	1.7
Basement or crawlspace		
• Uninsulated ceiling	0.4	0.0
• Insulated ceiling (R-11 or more)	0.5	0.0
Adjacent garage		
• Uninsulated buffer wall	0.7	1.5
• Insulated buffer wall	0.8	1.7
Garage beneath conditioned space		
• Uninsulated buffer wall	0.5	1.0
• Insulated buffer wall	0.6	1.0

If the customer mentioned (during the interview) an intention to condition a buffer space in the near future, this space should be treated as a conditioned space in the determination of the building heating and cooling loads. A conditioned space is defined as a space that is deliberately supplied with energy. Basements and areas that are closed off should be treated as buffer spaces for best results.

These "U-value correction factors" will also be needed during the evaluation of various insulation measures. There is a space in the evaluation form for each measure for the inclusion of this factor if appropriate.

C.4.5 Alternate Building Load Calculations

If the billing data are unavailable or inadequate, the seasonal heating and cooling (if significant air conditioning is present) loads must be calculated. Calculation sheets for this

purpose are included in the Audit Forms (see Sect. D). Begin by calculating the heat loss/gain for the following building components: exterior walls, walls below grade (loss only), ceiling, floors above grade, basement or crawl space floors (loss only), slab on grade (loss only), windows, and exterior doors.

These loss/gain components are calculated by multiplying the area by the U-value by the correction factor. Typical U-values are listed in the Data Base/Calculation Aids (see Sect. E.2). Floors over unconditioned space and perimeter slabs contribute only to the heating load, not the cooling load.

Subtotal these shell components of the HEUR and, if significant air conditioning is present, the CEUR. The gross infiltration loads must be added to these subtotals to obtain the total HEUR and CEUR.

The gross infiltration loads are determined from the air change factor previously calculated. The actual number of air changes is calculated from the air change factor (see Sect. C.3.8) using the following linear relationship:

$$\text{air changes} = 0.95 \times \text{air change factor} - 0.16.$$

The gross infiltration loads are calculated by using the ratio of the air changes to "air change factor −1."

The infiltration loads and shell component loads are then added to determine the building loads (HEUR and CEUR).

C.4.6 Seasonal Heating and Cooling Costs

An optional method for calculating seasonal cooling costs is given at the end of this section. Seasonal costs are calculated by using the equations given below. The auditor may choose to use either a hand calculator or the nomogram (Sect. E.6) to solve these equations.

- seasonal heating cost = HEUR (Btu/h·°F) × A,
- seasonal cooling cost = CEUR (Btu/h·°F) × B,
- seasonal heating savings = measure heat-loss factor (Btu/h·°F) × A, and
- seasonal cooling savings = measure heat-gain factor (Btu/h·°F) × B.

where

$$A = \textit{corrected}\ \text{HDD} \times \text{fuel cost} \times 24 \div \eta \div 10^6,$$

$$B = \text{CDD} \times \text{fuel cost} \times 24 \div \eta \div 10^6, \text{ and}$$

η = seasonal efficiency of heating or cooling system.

The auditor should note that different units may be used. The final answer should be the energy cost or savings for a season for heating or cooling.

The local fuel cost for electricity, natural gas, oil, and propane is calculated in units of dollars per million Btu ($/MBtu):

$$\text{electricity cost (\$/MBtu)} = 2.94 \times \text{local electricity cost (¢/kWh)},$$

$$\text{gas cost (\$/MBtu)} = 0.971 \times \text{local gas cost (\$/1,000 ft}^3\text{)},$$

oil cost ($/MBtu) = 0.072 × local oil cost (¢/gal),

propane cost ($/MBtu) = 0.105 × local propane cost (¢/gal) .

C.4.6.1 Use of the Nomogram

Heating and cooling seasonal costs may be calculated by using the seasonal heating and cooling cost nomogram as follows.

Calculate the local fuel cost as described above. Determine the number of CDD for cooling season calculations or *corrected* HDD for heating season calculations. Mark the number of CDD or *corrected* HDD on the scale titled "DEGREE-DAYS." Mark the heat gain (HEUR) or loss (CEUR), if significant air conditioning is present, (Btu/h·°F) for the residence on the scale titled "HEAT LOSS/GAIN." Connect these two marks with a straight line.

Mark the residence cooling or heating system seasonal efficiency in percent on the scale titled "EFFICIENCY." Mark the local fuel cost in $/MBtu on the scale titled "FUEL COST." Connect these two marks with a straight line.

Connect the point of intersection on the efficiency/cost intermediate scale with the point of intersection on the seasonal load intermediate scale with a straight line. Read the seasonal cooling or heating cost in dollars at the intersection of this line with the scale titled "SEASONAL COST."

The nomogram provides a direct readout of seasonal heating or cooling cost if the value marked on the "HEAT LOSS/GAIN" scale is between 100 and 1,000 Btu/h·°F. The nomogram can be used to calculate the seasonal cost for any value of heat loss or gain provided the value read from the "SEASONAL COST" scale is adjusted by the same multiple of ten as the "HEAT LOSS/GAIN" scale. For example, the "HEAT LOSS/GAIN" scale could be used to represent values from one to ten Btu/h·°F provided the values read from the "SEASONAL COST" scale are divided by 100.

The nomogram provides a direct readout of seasonal heating or cooling cost for values of heating or cooling degree-days from 100 to 10,000. If the value marked on the "DEGREE-DAYS" scale is between 100 and 1,000, the seasonal cost in dollars is read from the left-hand side of the "SEASONAL COST" scale. If the value marked on the "DEGREE-DAYS" scale is between 1,000 and 10,000, the seasonal cost in dollars is read from the right-hand side of the "SEASONAL COST" scale.

C.4.6.2 Optional Cooling Calculations

An optional cooling seasonal (load and) cost calculation is provided for a more accurate determination of seasonal cooling cost (when significant air conditioning is present) than is afforded by the simple CDD method described above. This optional method requires additional calculative effort. Seasonal totals of cooling degree-days (CDD) using two different reference temperatures must be selected by the auditor (these values are not in the data base and should be provided locally). Cooling degree-days calculated at a reference temperature equal to the indoor temperature maintained in the house (setpoint) and cooling degree-days at a temperature (base) that accounts for the internal loads and sensible cooling

from air infiltration are required.* The auditor should select the "base" CDD at a temperature 6°F lower than the "setpoint" temperature unless a local determination is made of the relationship between these two CDD base temperatures.

First, the sensible and latent gross infiltration loads are calculated. Next, the corrected sensible infiltration load is calculated. Solar heat gain is calculated from a Solar Gain Factor (SGF), based on the Cooling Collector Load Ratio (CCLR) for each window orientation. The CCLR values are used to enter the graphs in the Data Base/Calculation Aids (Sect. E.4) to determine the SGF. The graphs are based on a PSF value of 1.0. If the PSF value for a particular orientation is less than 1.0, two SGF values must be read from the chart for that wall. First, read the value for the CCLR for that orientation, and then read the value for the same CCLR for a north orientation. Perform the indicated calculation to determine the SGF for that orientation. For a PSF value of 1.0, the SGF value from the chart for that orientation is used directly as the SGF for that wall. Add the SGF values for each orientation to obtain the SGF for the residence.

Perform the calculations indicated on the forms to obtain solar gain, corrected CEUR, and CEUR factor. The cooling seasonal energy use (kWh) is calculated directly from this factor. The seasonal energy cost is calculated from the seasonal energy use.

C.5 CALCULATIONS FOR MEASURES

All local cost information for the measures on either a per unit or per square foot basis should be filled out prior to the audit, both for contractor and customer installation.

Heating savings for all measures should be evaluated by using the *corrected* HDD (Sect. C.4.3).

Summer savings due to air conditioning for all measures except replacement air conditioning are done only if significant air conditioning is already in place. The cost and savings for replacement air conditioning are done if central air conditioning is already in place.

Annual maintenance costs should be provided only if the evaluated measure will likely cause a substantial change in present maintenance costs.

C.5.1 Caulking

Using the Caulking Table provided in the audit forms, multiply the number of small windows needing caulking (as noted on the Doors and Windows Table) by 12 linear feet and the number of large windows needing caulking by 16 linear feet. The number of doors that need caulking is multiplied by 20 linear feet. These values, plus the length of any other cracks that need caulking, are added to provide the total caulking linear feet required. This total is then multiplied by the local cost per linear foot of contractor- and customer-installed caulking.

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*The range of reasonable values the auditor needs to consider for the CDD reference temperatures are from 65 to 80°F.

The savings due to caulking is 20% of the total maximum infiltration savings. This number is multiplied by 80% to represent the low end of the savings range. The factor 0.16 reflects these values (0.2 times 0.8). The high savings estimate is obtained by multiplying the low value by 1.5. Multiplying the low estimate by 1.5 is equivalent to multiplying the expected average savings by 1.2 for a 20% higher estimate.

C.5.2 Weather Stripping

Weather stripping costs are calculated in the same way as caulking costs—per linear foot, based on the number of windows (large and small) and doors noted as being in need of weather stripping.

The savings attributed to weather stripping are calculated in the same way as those due to caulking, except the net infiltration loss/gain is estimated to be 10% of the total maximum infiltration savings.

C.5.3 Ceiling/Attic Insulation

If the attic insulation is nonuniform, use the spaces provided to calculate the costs for the differing areas and the incremental R-values. Costs are calculated by multiplying the area (square feet) times the incremental R-value times the cost (dollars per square foot per R). The total cost for all the areas is then summed.

The savings for ceiling insulation are calculated by summing the products of: change in U-values times the area times the U-value correction factor (if appropriate, see Sect. C.4.4) for each area for each season (since the correction factor can be different for the two seasons). Take the difference between the total heat loss/gain rate (Btu/h·°F) of existing insulation and the total heat loss/gain rate of the improved insulation to be installed and calculate the seasonal savings (see Sect. C.4.6).

C.5.4 Wall Insulation

If ANY wall insulation is present, this measure is NOT evaluated. The net wall area was previously calculated by subtracting the window and door areas from the gross wall area. Costs and savings for wall insulation are then calculated in the same manner as for ceiling insulation.

C.5.5 Floor Insulation

If ANY floor insulation is present, this measure is NOT evaluated.

Using the floor area shown in the plan view, calculate the costs and savings for floor insulation in the same manner as for ceiling insulation.

C.5.6 Water Heater Insulation

Water heater insulation is evaluated only if the present water heater is expected to last at least three more years. Many new water heaters are well insulated, and additional insulation may not prove to be cost-effective. However, not all new water heaters are insulated well enough, and additional insulation would be cost-effective. Local evaluation of which new water heater models can have a cost-effective retrofit installation of insulation will have to be made.

Water heater insulation is evaluated by using the data from the special worksheet in the Data Base/Calculation Aids (see Sect. E.7) on energy costs for domestic hot water. This cost (per million Btu) is entered in the space provided.

If the water heater is in a conditioned space, go to the table in Sect. E.7 titled "Conditioned Space Water Heater Insulation, Annual Hours above 65°" and look up the number of hours for your region. Use this number of hours in the table titled "Conditioned Space Water Heater Correction Factor" (also in the Data Base/Calculation Aids, Sect. E.7) to obtain the correction factor required if the water heater is in a conditioned space. This correction factor is a regional constant and should be identified prior to the audit. Remember that if a water heater is in an unconditioned space, the correction factor is equal to 1.

The first-year savings range is estimated by multiplying the energy cost times the conditioned space correction factor times two (in units of million Btu per year) for the low estimate. The high estimate, reflected by the factor 1.5, is due to saving three million Btu per year.

C.5.7 Duct and Pipe Insulation

Duct insulation is evaluated only if there are uninsulated ducts in unconditioned areas.

The duct insulation cost is determined as a function of the approximate uninsulated duct length (noted in Sect. C.3.2 of the observations). Local costs should be provided on a per foot basis, assuming some "average" duct diameter.

First-year savings for duct insulation are based on the percentage of uninsulated ductwork that is in an unconditioned space. The proposed insulation R-value is used in the formula provided in the audit forms to determine a fraction. This fraction is multiplied by the percentage of uninsulated ductwork and the seasonal heating and cooling costs to obtain the lower end of the first-year savings range. This product is multiplied by 2 to determine the upper range of savings.

Note: Enter the percentage of ducting in the table, not the fraction (e.g., 32%, not 0.32).

Hydronic heating pipe insulation is only evaluated if such pipes are uninsulated and in unconditioned areas. This length of uninsulated pipe (noted in the observations in Sect. C.3.2) is multiplied by the fixed factor given on the audit form times the annual heating cost. This low savings estimate is multiplied by 2.5 to identify the high savings estimate. The local costs should be provided on a per foot basis.

C.5.8 Storm or Thermal Windows

The affected glazing area is estimated by taking the sum of the number of single-glazed large windows (large and small windows were defined in Sect. C.3.6) times 16 ft^2 and the number of single-glazed small windows times 9 ft^2. This area was calculated in the Doors and Windows Table.

Local storm and thermal window costs should be provided for average "small" (less than 12 ft^2) and "large" (greater than 12 ft^2) windows. These costs should be multiplied times the number of large and small single-glazed windows noted on the Doors and Windows Table (see Sect. C.3.6).

The first-year savings for storm or thermal windows is calculated as the sum of the savings due to reduced infiltration and conductive heat losses (gains). The changes in the conductive heat losses (and heat gains, if significant air conditioning is present) (Btu/h·°F) are calculated as the product of the affected area and the change in U-value. (Typical U-values for windows are given in Sect. E.2.) Use this product to calculate the seasonal savings (see Sect. C.4.6).

The reduction in infiltration losses due to the installations of storm or thermal windows is equal to the reduction in infiltration losses caused by weather stripping the windows. This reduction is calculated by dividing the perimeter of the windows needing weather stripping by the total perimeter of all windows and doors needing weather stripping. The low end of the infiltration savings is calculated by using the low end of the weather stripping savings range.

C.5.9 Storm or Thermal Doors

Estimates for storm or thermal doors are calculated by using the procedure described for storm or thermal windows except that the cost of only storm or thermal doors is provided. Door area is calculated by multiplying the number of doors times 21 ft^2 per average door. The infiltration savings are similar to those for windows but are based on weather stripping the doors rather than the windows.

C.5.10 Heat-Reflective and Heat-Absorbing Window or Door Material

This section is included within Sect. C.5.22.

C.5.11 Clock Thermostat

The clock thermostat first-year savings are calculated by using a fixed factor taken from the Temperature Setback Table (a function of HDD) found in the Data Base/Calculation Aids (see Sect. E.7). This factor is then multiplied by the present heating cost.

C.5.12 Load Management

Each utility must determine the proper algorithms for load management devices appropriate to the utility's rate structure.

C.5.13 Replacement Heating System

A replacement heating system will be evaluated only if the present heating system is more than five years old. Heat pumps are considered only if the present primary heating system is electric.

The replacement heating system costs and annual maintenance costs are identified prior to the audit. The low estimate for first-year savings is calculated by multiplying the present heating cost by the quantity 1 minus the results of dividing the present seasonal efficiency (PSE) by new seasonal efficiency (NSE) and then multiplying by 0.8.

$$\text{savings} = \text{present seasonal cost}\,[1 - (\text{PSE}/\text{NSE})]0.8\,.$$

The 0.8 factor gives the low (−20%) estimate.

Both the present heating cost and the present seasonal efficiency are taken from the System Data Table (see Sects. C.4.2 and C.4.3). The high estimate is obtained by multiplying this low estimate by 1.5. (Multiplying the low estimate by 1.5 is equivalent to multiplying the expected average by 1.2 for a +20% estimate.) Only high-efficiency replacement units should be considered.

C.5.14 Oil Burner Replacement

Providing the cost of a customer-installed replacement oil burner is prohibited. If the heating unit already has a retention head burner, or if it is a boiler of the wet-base type, the first-year savings will be $0. Otherwise, the first-year savings will be 10 to 18% of the present annual heating cost.

C.5.15 Vent Dampers

Vent dampers are evaluated only if combustion air is taken from a conditioned space. Supplying the cost of a customer-installed vent damper is prohibited. Multiply the present heating cost by 7% and 10% to obtain the first-year savings range.

C.5.16 Electrical or Mechanical Ignition Systems

Electric or mechanical ignition systems are only evaluated for gas furnaces currently equipped with pilot lights. Supplying the cost of customer-installed systems is prohibited. The first-year savings are calculated by multiplying the local gas cost (dollars per million Btu) times the energy savings factor for intermittent ignition devices (million Btu per year) found in the Data Base/Calculation Aids. A 20% low and high range is given by multiplying this average savings first by 0.8 and this product by 1.5.

C.5.17 Replacement Central Air Conditioner

Replacement air conditioners are evaluated only if the present central air conditioning unit is more than five years old. The replacement air conditioner cost and maintenance are identified prior to the audit. The first-year savings are calculated by multiplying the present cooling cost by the quantity 1 minus the results of dividing the PSE by NSE and then multiplying by 0.8. This 0.8 factor gives the low (−20%) estimate.

$$\text{Savings} = \text{present cooling cost}\,[1 - \text{PSE/NSE}]0.8\,.$$

Both the present cooling cost and the PSE are taken from the System Data Table (see Sects. C.4.2 through C.4.6). The high savings estimate is obtained by multiplying the low value by 1.5. Multiplying the low estimate by 1.5 is equivalent to multiplying the expected average by 1.2 for a +20% estimate. Only high-efficiency replacement units should be considered except in areas with very high humidity, where such a unit may not have adequate latent cooling capacity. A replacement unit should be properly sized (not oversized).

C.5.18 Solar Domestic Hot Water

An evaluation for this measure is made only if a solar collector location was identified with an annual Prime Solar Fraction (PSF; see Sect. C.3.1) greater than the minimum PSF value listed on the Region-Specific Solar Factors page in the Data Base/Calculation Aids (Sect. E.8).

The proposed location for the collectors is identified from the sketch or photograph of the south wall. If a ground-mounted collector array is proposed, the location can be identified from the sketch of the house plan or of the overall site.

On the audit form, the first two entries are the number of occupants and the consumption rate of domestic hot water (in gallons per day per person). (The consumption rate is determined as described in Sect. C.3.2.) Both of these items are obtained from the interview form. These numbers are then multiplied to estimate the total daily load (in gallons). This value is translated to the annual energy requirements (in millions of Btu) by using the Solar Domestic Hot Water tables in the Data Base/Calculation Aids (Sect. E.8). Next, enter on the form the target Solar Savings Fraction (SSF) value, obtained from the Region Specific Solar Factors page in the Data Base/Calculation Aids. To find the collector area required for this SSF, refer to the Solar Domestic Hot Water tables. Select the appropriate table on the basis of whether the orientation of the proposed collector location is "Preferred" (0 to 15° from due south) or "Acceptable" (15 to 45° from due south). Find the appropriate value of total daily hot water use in the column labeled "RES USE GPD" and follow this row across to the column that corresponds to the target SSF value. This value represents the required collector area. (In the table, collector areas smaller than 15 ft^2 are omitted because commercial collectors are generally unavailable in this size range.) This value is converted to the adjusted collector area by dividing by the PSF.

Before the audit procedure is continued, a comparison must be made between the adjusted collector area and the area available for the collectors. If the available area is greater than or equal to the adjusted collector area, then the computation can continue. If,

however, the available area is less than the adjusted collector area, then a lower SSF value must be determined. To do this, multiply the available area by the PSF. Then, in the Solar Domestic Hot Water Table and in the row corresponding to the value of total daily load, locate the number that is closest to but does not exceed the (available area × PSF) product. This value replaces the original required collector area value. To obtain the new value of the adjusted area, divide the new required area by the PSF. Finally, replace the target SSF value with the lower SSF found at the top of the new column in the table.

Next, record on the form the local energy cost for the fuel used to heat hot water ($/10^6 Btu) and the appropriate value of the auxiliary (existing water heater) efficiency. Default efficiencies are listed in the table on the form according to the fuel type of the original water heater. Then, the annual energy cost is computed by multiplying the energy cost by the annual energy use and dividing by the auxiliary efficiency. The result is then multiplied by the SSF value to obtain the first-year savings (in dollars).

Before the cost of the system can be estimated, determine whether or not the collector array must be racked by using the Slope Comparator page from the Region Specific Solar Factors. This chart indicates what tilt angles are acceptable and determines whether or not the house's roof tilt falls in the acceptable range. Then estimate the cost. Generally, system costs are expressed in terms of a fixed amount (to represent pump, controller, tank, etc.) plus a variable amount (to represent the area of installed solar collector). The costs for racked and unracked systems will be different. To compute the total cost, use the local costs, both fixed and variable, for the type of system recommended. Multiply the adjusted area by the variable cost ($/ft^2 of collector) and add the product to the fixed cost.

C.5.19 Active Solar Space Heating

An evaluation for this measure is made only if a collector location was identified with a PSF (heating season) greater than the minimum PSF and the existing heating system for the residence is other than steam distribution, electric radiant heating, or electric resistance baseboard.

The proposed location for the collectors is identified from the south wall sketch or photograph (or site sketch for ground-mounted collectors). The projected (horizontal) area of the south-facing roof is estimated by the length and width measurements taken during sketch preparation. The area compensator is obtained from the Slope Comparator in the Data Base/Calculation Aids, and the actual area is calculated by multiplying the projected area by the area compensator. The effective area for the collector is determined by multiplying the actual area by the PSF (identified for this location during the observations; see Sect. C.3.2). The seasonal HEUR is entered (see Sect. C.4.3) and multiplied by 0.9 to obtain the efficient HEUR.

The efficient HEUR is used in the Solar Space Heating Tables in the Data Base/Calculation Aids (Sect. E.8). These tables list required collector areas based on efficient HEUR, preferred or acceptable orientation, SSF and an assumed PSF of 1.0.

Using the regionally appropriate target SSF and the observed orientation, preferred or acceptable, look up the collector area required for the given orientation and efficient HEUR. If this area is smaller than the previously calculated effective area, note this SSF for the savings calculations. The actual area (which equals the required collector area divided by the PSF) should be noted for the cost calculations.

If, however, the required collector area for the target SSF is larger than the effective area, choose a smaller SSF. Repeat this step until an appropriate SSF is is identified. Note this SSF and the actual area (which equals the corresponding required collector area divided by the PSF) for the cost and savings calculations.

The existing annual heating cost is found in the Systems Data Table and then recorded. The first-year savings are calculated by multiplying the SSF by the adjusted annual heating costs. The contractor cost is calculated by multiplying the actual area by local cost in dollars per square foot of installed collector and adding the fixed portion of system cost. A calculation for collectors that are not tilted properly is included and uses different cost values in consideration of the rack that is required. If a ground-mounted collector loop terminates more than a short distance from the residence, additional installation costs, based on local data, should be added.

C.5.20 Combined Active Solar Space Heating and Domestic Hot Water Systems

An evaluation for this measure is made only if the existing heating system for the residence is other than steam distribution, electric radiant heating, or electric resistance baseboard, and the heating season PSF at the proposed location is greater than the minimum PSF.

All steps are the same as for the Active Solar Space Heating procedure with the exception that the annual energy cost is calculated by adding the adjusted annual space heating and the annual hot water energy costs. The reference in the Data Base/Calculation Aids will be the Combined Solar Space and Domestic Hot Water Heating Table.

C.5.21 Replacement Solar Pool Heating

This measure is evaluated only if a heated pool is located on the site, and the swimming season PSF at the proposed location is greater than the minimum PSF.

The proposed location for the collectors is identified from the south wall sketch or photograph (or site sketch for ground-mounted collectors). The pool surface area is calculated by using the dimensions from the visual inspection. The projected area (horizontal area) for the collector location is also calculated by using dimensions from the visual inspection. The area compensator is obtained from the Slope Comparator in the Data Base/Calculation Aids, and the actual area is calculated by multiplying the projected area by the area compensator. The PSF was determined during the observations (see Sect. C.3.1), and the effective area for the collector is calculated by multiplying this PSF by the actual area.

A comparison is then made between the calculated effective area and the largest collector area shown in the Solar Replacement Pool Heater table in the Data Base/Calculation Aids (Sect E.8) for that pool size. Use the appropriate tables for a covered or uncovered pool and the column best describing wind shelter at the pool location. The heading of the subcolumn that lists an area figure smaller than but closest to the calculated effective area is the SSF value that will be used in the savings calculations. The collector area thus found in the table is divided by the PSF to obtain the actual area needed, which is recorded for use in the cost calculations.

The pool heating load is determined from the same table. The annual pool heating cost is determined by multiplying the pool heating load by the local cost for the type of fuel used. The first-year savings figure is calculated by multiplying the SSF by the annual pool heating cost. The costs for resident-installation (which is the cost of the materials only) and contractor-installation are calculated by multiplying the actual collector area by local costs in dollars per square foot and adding the fixed portion of system cost. A different cost figure is used if the collectors are to be racked.

C.5.22 Passive Solar Window Heat Gain Retardants and Heat-Reflective and Heat-Absorbing Window or Door Material

A window heat gain retardant (WHGR) evaluation is made only if the residence has substantial energy use for air conditioning. (General "comfort" information that does not include cost savings may still be provided in the absence of substantial energy use for cooling.)

The location for placement of WHGR or reflective films at different orientations are identified on the plan sketch or elevation sketch or photo. The square feet of glazed area at each orientation is multiplied by the appropriate shading factor (listed in Table C.4) to obtain "effective areas" in square feet.

Table C.4. Summer shading factors

Shading condition	Shading factor
Moderate	0.5
Light	0.75
Unobstructed	1.00

The effective areas are multiplied by the reflecting or absorbing factors, resulting in the annual energy savings due to the application of reflecting or absorbing materials. The effective areas multiplied by the WHGR factors result in the annual energy savings due to the installation of WHGRs.

The first-year dollar savings for these measures are calculated by multiplying the appropriate energy savings by the local energy cost for the type of cooling energy to be displaced and dividing by the cooling system seasonal efficiency. The cost of the measure is calculated by multiplying the square feet of glazed area by the cost per square foot for either resident or contractor installation.

C.5.23 Passive Solar Direct Gain Glazing System

A direct gain evaluation is made only if the heating season Prime Solar Fraction (PSF; see Sect. C.3.1) at the proposed location(s) exceeds the minimum PSF noted on the Region-Specific Solar Factors page in the Data Base/Calculation Aids (Sect. E.8) and if an adequate area in the south-facing wall exists for the addition of windows. (If the windows that exist

create winter overheating, investigate the potential for adding mass to the interior.) The location for the additional glazed area is identified from the south wall sketch or photograph.

On the form, the HEUR of the residence is entered from the Systems Data Table in the audit forms. The HEUR is then multiplied by 0.021. The added glazing area in square feet is determined by visual inspection and is the sum of the potential retrofit areas on the south-facing wall. An average heating season PSF is determined from the solar window device for the various locations being analyzed. An orientation factor is then selected from Table C.5 based upon the orientation of the dwelling.

Table C.5. Orientation factor

Orientation from south	Correction factor
0 to 15°	1.00
15 to 30°	0.95
30 to 45°	0.85

The effective area of glazing is determined by multiplying the added glazing area by the PSF and by the orientation factor. A Collector Load Ratio (CLR) is determined by dividing the effective area by the quantity (HEUR × 0.021). Using the Passive Solar Measures graph for the appropriate location, the CLR value is found on the x-axis, and the corresponding Solar Savings Fraction (SSF) value is found on the y-axis. [These graphs are in the Data Base/Calculation Aids section (Sect. C.9).] The SSF is recorded on the audit form. Next, the annual heating cost is entered, and the first-year savings are calculated by multiplying the SSF by the adjusted annual heating cost. The Direct Gain system costs are calculated by multiplying given values for local costs in dollars per square foot by the square feet of glazing area for both customer- and contractor-installed systems.

C.5.24 Passive Solar Indirect Gain Systems

- *Trombe Wall*

  A Trombe wall evaluation is made only if the average heating season Prime Solar Fraction (PSF; see Sect C.3.1) at the proposed location(s) is greater than the minimum PSF noted on the Region-Specific Solar Factors page in the Data Base/Calculation Aids, if the south-facing wall is of solid masonry with no air spaces, and if adequate area exists on the south-facing wall for the addition of Trombe wall glazing.

  All calculation steps are the same as for the Direct Gain procedure with the exception of determination of the SSF, which will be derived from the Trombe wall curve on the Passive Solar Measures graph in the Data Base/Calculation Aids (Sect. E.9).

- *Water Wall*

  A water wall evaluation is made only if the average heating season PSF at the proposed location(s) is greater than the minimum PSF noted on the Region-Specific Solar Factors page in the Data Base/Calculation Aids, if the floor of the dwelling is slab-on-grade or

of adequate structural integrity, and if adequate area exists in the south-facing wall for the addition of water wall glazing.

All calculation steps are the same as for the Direct Gain procedure with the exception of determination of the SSF, which will be derived from the water wall curve on the Passive Solar Measures graph in the Data Base/Calculation Aids (Sect. E.9).

- *Thermosiphon Air Panel (TAP)*
  A TAP evaluation is made only if the average heating season PSF at the proposed location(s) is greater than the minimum PSF noted on the Region-Specific Solar Factors page in the Data Base/Calculation Aids, the south-facing wall is other than *solid* masonry, and adequate area exists on the south-facing wall for the addition of a TAP system (minimum 6 ft, vertical). The location for the proposed TAP area is identified from the sketch or photograph of the south-facing wall. The potential TAP area (ft^2) to be glazed is determined by visual inspection and is the sum of possible retrofit areas on the south-facing wall.

  All calculation steps are the same as for the Direct Gain procedure with the exception of determination of the SSF, which will be derived from the TAP performance graph in the Data Base/Calculation Aids (Sect. E.9).

C.5.25 Passive Solar Sunspace Systems

A sunspace evaluation is made only if the average heating season Prime Solar Fraction (PSF; see Sect. C.3.1) at the proposed location(s) is greater than the minimum PSF noted on the Region-Specific Solar Factors page in the Data Base/Calculation Aids and adequate ground area exists in front of or beside a south-facing wall for the addition of a sunspace.

The selected location for the sunspace is identified from the elevation sketch or photograph of the south wall. An average heating season PSF is determined at the proposed location of the south-facing vertical wall of the sunspace.

On the Sunspace Audit form, first enter the heating energy use rate (HEUR), which is obtained from the Systems Data section. The HEUR is then multiplied by 0.021. Next, record the sunspace collector area, which is defined as the area of existing south-facing wall to be covered by the sunspace. Determine the effective area by multiplying the collector area by the PSF. The Collector Load Ratio (CLR) is determined by dividing the effective area by the quantity (HEUR $\times$ 0.021). The Solar Savings Fraction (SSF) is determined from the appropriate Sunspace Performance graph in the Data Base/Calculation Aids (Sect. E.9), where SSF is plotted as a function of CLR for the 146 HUD/MPS climate zones in the United States. Next, a sunspace performance correction factor is selected from Table C.6, depending upon the orientation of the proposed sunspace.

Table C.6. Sunspace Performance Correction Factors

Orientation from south	Correction factor
0 to 15°	1.00
15 to 30°	0.95
30 to 45°	0.90

The adjusted SSF is determined by multiplying the SSF by the performance correction factor. Next, the annual heating cost (in dollars) is entered, and the first-year savings are calculated by multiplying the adjusted SSF by the adjusted annual heating cost. The sunspace system costs are calculated by multiplying given values for local costs ($/ft^2) by the area of existing south wall to be covered by the sunspace. Costs for both customer- and contractor-installed systems are then calculated by multiplying the proposed sunspace area by the local costs ($/ft^2).

Care must be taken in computing costs that both the sunspace area and costs are based on the same unit. Two options exist: either the sunspace wall area (as entered on the audit form) can be used with costs expressed in $/ft^2 of *wall* area, or the sunspace *floor* area (derived from the *wall* area entered on the form) can be used with costs expressed in $/ft^2 of *floor* area.

C.5.26 Wind Energy Devices

The average annual wind speed, measured at a height of 35 ft, is first recorded. The nearest measuring station is used for this value, or the wind atlas data if available. If the wind atlas data is used, the median speed for that class is used [Data Base/Calculation Aids (Sect. E.10)]. If the annual average wind speed at a site is less than 10 mph, a wind audit is not begun. The terrain code for the area (Data Base/Calculation Aids) is recorded, as well as the height of the tallest obstruction (over 30 ft wide, within 100 ft) noted in any direction during the outside observation. Also noted should be a site for a tower, an obstruction-free cylinder with a diameter of 15 ft. If such a free-space cylinder cannot be located without property-line encroachment, the audis is discontinued.

If the tallest obstruction is 55 ft or taller, the audit is discontinued. Otherwise, the minimum tower height will be either 40, 60, or 80 ft, whichever is nearest a height of 25 ft plus the tallest noted obstruction.

The roughness of the site, as defined in the Data Base/Calculation Aids, is then used with the proposed tower height to obtain the correction factor for height and roughness. Another correction factor, for terrain shelter, is obtained from the Data Base/Calculation Aids, and both factors are multiplied together by the original wind speed to obtain the adjusted wind speed at the site. If this adjusted speed is less than 10 mph, the audit is discontinued.

Current annual kWh use is recorded from the utility records, if available, or estimated for the combination of structure/resident use. The target annual wind speed output is one-half this annual use, and the wind system expected to deliver an output nearest the target is selected from the Data Base/Calculation Aids. (If there is more than one system with output close to the target, select the system with the lowest cost.) Its code number, output, and cost figures are recorded.

Calculation of savings will depend on buy-back rates offered by the utility. If the buy-back rate is different from the rate at which electricity is sold, an estimated one-half of the electricity generated will be bought back at this different rate, while one-half will offset electricity at the usual rate. A range of savings will be 80 to 120% of the sum of the two components.

If the buy-back rate is "net," that is, the same as the selling rate, the first-year savings estimate will range from 80 to 120% of the product of the selected wind system annual output (kWh) multiplied by the cost of electricity in dollars per kWh.

C.6 PRESENTATION OF RESULTS

After the calculations have been completed, discuss the audit results with the residents while the "Audit Results" form is being filled out (a sample form is shown in Sect. F). Applicable energy conserving practices should be reviewed first, and the cost-effectiveness of implementing these practices should be emphasized. Those program measures which have been found to be applicable to the site should then be discussed. During this review, indicate which measures are eligible for federal, state, or local tax credits.

Questions should be answered at this time. Explain the RCS program benefits and services available to the resident. Provide the customer with lists of qualified suppliers, contractors, and lenders.

Leave a copy of the Audit Results form with the resident. Collect the rest of the appropriate data and calculation sheets for record-keeping purposes.

D. Audit Forms

INTERVIEW

[1] NAME _____ DATE _____

[2] ADDRESS _____ ACCOUNT NO. _____

[3] UTILITY OR FUEL DISTRIBUTOR _____

[4] ANNUAL ELECTRIC USAGE _____ (KWH) NO. OF PERMANENT OCCUPANTS _____

[5] DOES RESIDENCE HAVE A THERMOSTAT? YES ☐ NO ☐ CLOCK ☐

[6] IF NO, HOW IS TEMPERATURE CONTROLLED? _____

[7] THERMOSTAT SETTINGS: WINTER-DAY_____°F NIGHT_____°F
SUMMER-DAY_____°F NIGHT_____°F

[8] ARE OUTSIDE DOORS OPENED EACH DAY? <1-6 ☐ 6-13 ☐ >13 TIMES☐

[9] NO. OF FIREPLACE(S) _____ DAMPER(S) CLOSED ..... YES ☐ NO ☐

[10] HOT WATER USAGE: 10 GDP ☐ 15 GDP ☐ 20 GDP ☐ 25 GDP ☐

[11] ENERGY SOURCE(S) OIL ☐ GAS ☐ ELECTRIC ☐ OTHER ☐

[12] AIR CONDITIONER: CENTRAL ☐ ROOM ☐ NONE ☐

[13] ENERGY SOURCE OF CENTRAL A/C: ..... ELECTRIC ☐ GAS ☐

[14] AGE OF CENTRAL A/C _____(YEARS)

[15] CAPACITY OF CENTRAL A/C _____

[16] HEATING SYSTEM DESCRIPTION (ENERGY SOURCE, AGE, MAINTENANCE SCHEDULE):

_____

_____

[17] IF FUEL IS GAS, DO YOU TURN OFF PILOT IN SUMMER? YES ☐ NO ☐

[18] IF FUEL IS GAS, HAS A VENT DAMPER BEEN INSTALLED? YES ☐ NO ☐

[19] HAS ELECTRICAL OR MECHANICAL IGNITION BEEN INSTALLED? YES ☐ NO ☐

[20] IF FUEL IS OIL, HAS A REPLACEMENT BURNER BEEN INSTALLED? YES ☐ NO ☐

[21] IF YES, TYPE AND AGE OF REPLACEMENT BURNERS _____

[22] HEATING SYSTEM LOCATION _____

[23] IF SECONDARY SYSTEM IN PLACE, DESCRIBE (FUEL) _____

[24] SWIMMING POOL HEATING SYSTEM: NONE ☐ GAS ☐ ELECTRIC ☐ PROPANE ☐
OTHER ☐

[25] WALL CONSTRUCTION DESCRIPTION _____

[26] ARE WALLS INSULATED: YES ☐ NO ☐

[27] IF YES, HOW MUCH AND TYPE INSULATION _____

_____

[28] IS ATTIC ACCESSIBLE? YES ☐ NO ☐
(IF YES, SKIP THE NEXT TWO QUESTIONS)

[29] CEILING CONSTRUCTION DESCRIPTION _____

[30] CEILING INSULATION (AMOUNT AND TYPE) _____

[31] FLOOR CONSTRUCTION DESCRIPTION _____

[32] FLOOR INSULATION (AMOUNT AND TYPE) _____

[33] UNHEATED BUFFER SPACE(S) TEMPERATURE(S) _____°F

[34] WATER HEATER LOCATION CONDITIONED SPACE ☐ UNCONDITIONED SPACE ☐

OBSERVATIONS AND MEASUREMENTS

[1] IF HEATING UNIT IS AN OIL-FIRED BOILER, IS IT WET BASE TYPE? YES ☐ NO ☐
[2] LENGTH OF UNINSULATED ACCESSIBLE HYDRONIC HEATING PIPE IN UNCONDITIONED SPACE _____ FT.
[3] ESTIMATED PERCENTAGE OF UNINSULATED DUCTS IN UNCONDITIONED SPACE: _____ %
[4] ESTIMATED LENGTH OF UNINSULATED DUCTS IN UNCONDITIONED SPACE: _____ FT.
[5] RATING OF CENTRAL A/C _____ A/C EER RATING: _____
[6] HEATING SYSTEM RATINGS: INPUT: _____ OUTPUT: _____

FLUE GAS ANALYSIS

[7] COMBUSTION INLET AIR TEMPERATURE _____ °F OXYGEN _____ %
[8] EXHAUST AIR TEMPERATURE _____ °F CARBON DIOXIDE _____ %
[9] COMBUSTION EFFICIENCY _____ %
[10] OBSERVATIONS: _____

CEILING/ATTIC INSULATION

	AREA	AREA (FT²)	INSULATION (R)	TYPE INSULATION	OVERALL U-VALUE
[11]	1				
[12]	2				
[13]	3				

WALL INSULATION

	AREA	GROSS AREA (FT²)	INSULATION (R)	TYPE INSULATION	OVERALL U-VALUE
[14]	1				

DATA SOURCE REFERENCE: PAGE NUMBER (P), LINE NUMBER (L). NUMBERS APPEARING IN PARENTHESES ( ) FOLLOWING LINE NUMBERS REPRESENT THE COLUMN NUMBER. ALL REFERENCES ARE CONFINED TO THIS SECTION (AUDIT FORMS).

FLOOR INSULATION

	AREA	AREA (FT²)	INSULATION (R)	TYPE INSULATION	OVERALL U-VALUE
[1]	1				
[2]	2				

DOORS AND WINDOWS

		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
					NUMBER					AREA		
		ORIENTATION	PSF	SIZE	OTHER	SINGLE PANE	NEED CAULKING	NEED WEATHER-STRIPPING	AREA FACTOR	OTHER PANE ④ × ⑧	SINGLE PANE ⑤ × ⑧	TOTAL ORIENTED ⑨ + ⑩
[3]	GLASS			SMALL					9			
[4]				LARGE					16			
[3]				SMALL					9			
[4]				LARGE					16			
[3]				SMALL					9			
[4]				LARGE					16			
[3]				SMALL					9			
[4]				LARGE					16			
[5]									TOTALS			

		①	②	③	④	⑤	⑥	⑦
		NUMBER					AREA	
	NON-GLASS DOORS	REGULAR DOOR	STORM OR THERMAL DOOR	NEED CAULKING	NEED WEATHER-STRIPPING	FACTOR	REGULAR DOOR ① × ⑤	STORM OR THERMAL DOOR ② × ⑤
[6]						21		

[7] OTHER CAULKING REQUIREMENTS _____

_____

NET WALL AREA

	GROSS WALL AREA FT²	TOTAL GLASS AREA FT²	NON-GLASS DOOR AREA FT²	NET WALL AREA FT² ① − (② + ③)
[8]	P2,L14	P3,L5(10)	P3,L6	

INFILTRATION

	BUILDING COMPONENT	GOOD	AVERAGE	POOR
[1]	WINDOWS AND DOORS	☐ WINDOW AND DOOR FRAMES CAULKED. WINDOW AND DOOR SASHES WELL FITTING AND WEATHERSTRIPPED OR STORM WINDOWS AND DOORS WITH GOOD FIT.	☐ WINDOW AND DOOR FRAMES CAULKED OR WINDOW AND DOOR SASHES WEATHERSTRIPPED OR POORLY FITTING STORM DOORS AND WINDOWS.	☐ NO CAULKING ON WINDOW AND DOOR FRAMES. NO WEATHERSTRIPPING. NO STORM DOORS OR WINDOWS
[2]	WALLS AND ELECTRICAL OUTLETS	☐ CEILING AND FLOOR JOINTS AND CORNERS WELL SEALED. ELECTRICAL OUTLETS WITH GASKETS. NO HOLES AROUND PLUMBING PENETRATIONS.	☐ SOME CRACKS IN CEILING AND FLOOR JOINTS AND CORNERS. NO GASKETS ON ELECTRICAL OUTLETS. LESS THAN THREE PLUMBING PENETRATIONS WITH HOLES AROUND THEM.	☐ MANY CRACKS IN CEILING AND FLOOR JOINTS AND CORNERS. NO GASKETS ON ELECTRICAL OUTLETS. THREE OR MORE PLUMBING PENETRATIONS WITH HOLES AROUND THEM.
[3]	ATTIC FLOOR (CEILING)	☐ NO CRACKS IN ATTIC FLOOR. NO AIR SHAFTS AROUND FLUES. NO HOLES AROUND DUCTS, PIPES OR WIRING PENETRATING ATTIC FLOOR. NO RECESSED LIGHT FIXTURES. NO TRAP DOOR OR WEATHERSTRIPPED TRAP DOOR TO ATTIC.	☐ SOME CRACKS IN ATTIC FLOOR. NO AIR SHAFTS AROUND FLUES. SOME HOLES AROUND DUCTS. PIPES OR WIRING PENETRATING ATTIC FLOOR. LESS THAN THREE RECESSED LIGHT FIXTURES. UNWEATHERSTRIPPED TRAP DOOR TO ATTIC	☐ MANY CRACKS IN ATTIC FLOOR. AIR SHAFTS AROUND FLUES. HOLE AROUND DUCTS. PIPES OR WIRING PENETRATING ATTIC FLOOR. MORE THAN THREE RECESSED LIGHT FIXTURES. UNCOVERED ATTIC ACCESS.
[4]	HEATING SYSTEM & WATER HEATER	☐ BOTH FURNACE AND WATER HEATER ELECTRIC. IF FOSSIL FUEL-FIRED, BOTH IN UNCONDITIONED SPACE.	☐ ONE FOSSIL FUEL-FIRED UNIT IN LIVING SPACE WITH VENT DAMPER. THE OTHER IN UNCONDITIONED SPACE.	☐ AT LEAST ONE FOSSIL FUEL-FIRED UNIT IN LIVING SPACE WITHOUT VENT DAMPER.
[5]	FIREPLACE OR WOOD STOVE	☐ SEALED COMBUSTION WOOD STOVE OR FIREPLACE WITH WELL FITTING DAMPER AND GLASS DOORS OR NO FIREPLACE.	☐ POORLY SEALED WOOD STOVE OR FIREPLACE WITH EITHER WELL FITTING DAMPER OR GLASS DOORS.	☐ BOTH A WOOD STOVE AND FIREPLACE OR A FIREPLACE WITH POORLY FITTING DAMPER AND NO GLASS DOORS.
[6]	DUCTWORK AND FLOOR	☐ NO DUCTWORK AND FEW FLOOR PENETRATIONS OR ALL DUCTWORK IN CONDITIONED SPACE AND NO FLOOR PENETRATIONS.	☐ DUCTWORK IN CONDITIONED BASEMENT AND FEW FLOOR PENETRATIONS.	☐ DUCTWORK IN UNCONDITIONED SPACE AND MANY FLOOR PENETRATIONS.
[7]	VENTS IN CONDITIONED SPACE	☐ NO UNDAMPERED VENTS AND LESS THAN THREE DAMPERED VENTS.	☐ LESS THAN THREE UNDAMPERED VENTS OR AT LEAST THREE DAMPERED VENTS.	☐ MORE THAN THREE UNDAMPERED VENTS.
[8]	LIFESTYLE	☐ LESS THAN SIX ENTRANCES AND EXITS PER DAY.	☐ SIX TO THIRTEEN ENTRANCES AND EXITS PER DAY.	☐ MORE THAN THIRTEEN ENTRANCES AND EXITS PER DAY.
[9]	TOTALS	☐ +	☐ +	☐ = 8
		P4,L9	P4,L9	P4,L9

[10] [_____ (TOTAL OF GOOD) + (_____ (TOTAL OF AVERAGE) × 2) + (_____ (TOTAL OF POOR) × 3)] ÷ 8 = _____ (AIR CHANGE FACTOR)

CALCULATIONS FOR LOADS AND EFFICIENCIES

INFILTRATION CALCULATIONS

LOSS CALCULATION

	① TOTAL CONDITIONED FLOOR AREA (FT²)	② WINTER WIND FACTOR	③ TERRAIN FACTOR (FT/HR)	④ HEAT LOSS FACTOR	⑤ (AIR CHANGE FACTOR -1)	⑥ NET INFILTRATION HEAT LOSS (BTU/HR-°F) ① × ② × ③ × ④ × ⑤	⑦ MAXIMUM SAVINGS (FROM NOMOGRAPH) ($)
[1]							
	SKETCH	DB/CA	DB/CA	DB/CA	P4,L10		

GAIN CALCULATION

	① TOTAL CONDITIONED FLOOR AREA (FT²)	② SUMMER WIND FACTOR	③ TERRAIN FACTOR (FT/HR)	④ HEAT GAIN FACTOR	⑤ (AIR CHANGE FACTOR -1)	⑥ NET INFILTRATION HEAT GAIN (BTU/HR-°F) ① × ② × ③ × ④ × ⑤	⑦a MAXIMUM SAVINGS (FROM NOMOGRAPH) ($)
[2]							
	P5,L1	DB/CA	DB/CA	DB/CA	P4,L10		

[3] TOTAL ⑦ + ⑦a _____

HEATING AND COOLING SYSTEM DATA

LOADS DETERMINED FROM ENERGY USE DATA

	① HEATING SEASONAL COST (HSC) ($)	② HEATING ENERGY SUPPLY RATE (HESR) (BTU/HR-°F)	③ FURNACE SEASONAL EFFICIENCY (%)	④ HEUR (BTU/HR-°F) ② × ③ ÷ 100
[4]				
			DB/CA	

	① COOLING SEASONAL COST (CSC) ($)	② COOLING ENERGY SUPPLY RATE (CESR) (BTU/HR-°F)	③ AIR CONDITIONER SEASONAL EFFICIENCY (%)	④ CEUR (BTU/HR-°F) ② × ③ ÷ 100
[5]			DB/CA	

LOADS CALCULATED FROM BUILDING CHARACTERISTICS

	① HEUR (BTU/HR-°F)	② FURNACE SEASONAL EFFICIENCY (%)	③ HEATING SEASONAL COST (HSC) (FROM NOMOGRAPH) ($)
[4]	P5a,L5	DB/CA	

	① CEUR (BTU/HR-°F)	② AIR CONDITIONER SEASONAL EFFICIENCY (%)	③ COOLING SEASONAL COST (CSC) (FROM NOMOGRAPH) ($)
[5]	P5a,L5	DB/CA	

BUILDING HEATING/COOLING LOAD

AIR CHANGES

	① AIR-CHANGE FACTOR	② AIR CHANGES (① X 0.95) – 0.16
[1]		

P4,L10

GROSS INFILTRATION LOADS

		① NET	② AIR CHANGES	③ AIR-CHANGE FACTOR – 1	④ GROSS (BTU/HR-°F) ① X ② ÷ ③
[2]	INFILTRATION LOSS	[P5,L1]	P5a,L1		
[3]	INFILTRATION GAIN	[P5,L2]			

BUILDING LOADS

COMPONENT		AREA (FT^2) OR SLAB PERIMETER	U-VALUE	CORRECTION FACTOR	BTU/HR-°F HEUR*/CEUR*	
SINGLE-PANE GLASS						
OTHER GLASS						
DOORS	TYPE 1					
	TYPE 2					
NET WALLS	AREA 1					
	AREA 2					
	AREA 3					
ROOF/ CEILING	AREA 1					
	AREA 2					
	AREA 3					
FLOORS OVER UNCONDITIONED SPACE	AREA 1					
	AREA 2					
SLAB PERIMETER	AREA 1					
	AREA 2					
[4]				SUBTOTALS		
				GROSS INFILTRATION GAIN		
				GROSS INFILTRATION LOSS		
[5]				TOTAL		

*HEATING ENERGY USE RATE AND COOLING ENERGY USE RATE

OPTIONAL COOLING CALCULATIONS

INFILTRATION HEAT GAIN

	① COOLING DEGREE-DAYS AT SET POINT	② COOLING DEGREE-DAYS AT BASE	③ SENSIBLE HEAT GAIN FACTOR	④ HEAT GAIN FACTOR	⑤ GROSS INFILTRATION GAIN (BTU/HR-°F)	⑥ SENSIBLE INFILTRATION GAIN (BTU/HR-°F) ③ ÷ ④ × ⑤	⑦ LATENT INFILTRATION GAIN (BTU/HR-°F) ⑤ − ⑥	⑧ CORRECTED SENSIBLE GAIN (BTU/HR-°F) ① ÷ ② × ⑥
[1]								
	LOCAL DATA	LOCAL DATA	DB/CA	DB/CA	P5a,L3			

SOLAR HEAT GAIN

COOLING COLLECTOR LOAD RATIO

	① ORIENTATION	② GLAZED AREA (FT^2)	③ CEUR	④ CCLR 41.7 × ② ÷ ③
[2]				
[3]				
[4]				
[5]				
		P3,L3/4	P5a,L5	

SOLAR GAIN FACTOR

	① ORIENTATION	② CCLR	③ PSF	④ SGF for PSF = 1 ORIENTATION	⑤ SGF for PSF = 1 NORTH	⑥ DIRECT GAIN COMPONENT [(④ − 0.9 × ⑤)] × ③	⑦ SGF [(0.9 × ⑤)] + ⑥
[6]		P5b,L2					
[7]		P5b,L3					
[8]		P5b,L4					
[9]		P5b,L5					
[10]			P3,L3/4	DB/CA	DB/CA	TOTAL	

CORRECTED CEUR

	① CEUR (BTU/HR-°F)	② SGF	③ SOLAR GAIN (BTU/HR-°F) ① × ②	④ SHELL GAIN (BTU/HR-°F)	⑤ CORRECTED SENSIBLE GAIN (BTU/HR-°F)	⑥ LATENT INFILTRATION GAIN (BTU/HR-°F)	⑦ CORRECTED CEUR (BTU/HR-°F) ③ + ④ + ⑤ + ⑥	⑧ CEUR FACTOR ⑦ ÷ 1000
[11]								
	P5a,L5	P5b,L10		P5a,L4	P5b,L1	P5b,L1		

COOLING SEASONAL COST

	① CEUR FACTOR	② COOLING DEGREE-DAYS AT BASE	③ AIR CONDITIONER SEER	④ COOLING ENERGY USE (KWH) ① × ② ÷ ③ × 24	⑤ COOLING ENERGY COST ($/KWH)	⑥ COOLING SEASONAL COST ($) ④ × ⑤
[12]						
	P5b,L11	P5b,L1	DB/CA		LOCAL DATA	

CALCULATIONS FOR MEASURES

CAULKING

	MEASURE	① NUMBER NEEDING CAULKING	② FACTOR	③ LINEAR FEET ① × ②
[1]	SMALL WINDOWS	P3,L3	12	
[2]	LARGE WINDOWS	P3,L4	16	
[3]	DOORS	P3,L6	20	
[4]	OTHER (LINEAR FEET)			P3,L7
[5]	TOTAL			

	① TOTAL LINEAR FEET	② CONTRACTOR		④ RESIDENT	
		COST/FOOT	TOTAL COST ① × ②	COST/FOOT	TOTAL COST ① × ④
[6]		$	$	$	$

P6,L5

	① TOTAL MAXIMUM INFILTRATION SAVINGS	② FACTOR	③ FIRST YEAR SAVINGS LOW ① × ②	④	⑤ HIGH ③ × ④
[7]	$	0.16	$	1.5	$

P5,L3

WEATHERSTRIPPING

	MEASURE	① NUMBER	② FACTOR	③ LINEAR FEET ① × ②	TOTAL LINEAR FT. WINDOW
[1]	SMALL WINDOWS	P3,L3	12		
[2]	LARGE WINDOWS	P3,L4	16		
[3]	DOORS	P3,L6	20		
[4]	TOTAL				

	① TOTAL LINEAR FEET	② CONTRACTOR COST/FOOT	③ CONTRACTOR TOTAL/COST ① × ②	④ RESIDENT COST/FOOT	⑤ RESIDENT TOTAL COST ① × ④
[5]		$	$	$	$

P7,L4

WEATHERSTRIPPING

	① TOTAL MAXIMUM INFILTRATION SAVINGS	② FACTOR	③ FIRST YEAR SAVINGS LOW ① × ②	④	⑤ FIRST YEAR SAVINGS HIGH ③ × ④
[6]	$	0.08	$	1.5	$

P5,L3

CEILING–WALL–FLOOR INSULATION

COST

INSULATION MEASURE	① LOCATION	② INCREASER	③ AREA (FT²)	⑤ CONTRACTOR COST/FT²	⑤ CONTRACTOR TOTAL COST ③ × ④	⑥ RESIDENT COST/FT²	⑥ RESIDENT TOTAL COST ③ × ⑥
CEILING	1		P2,L11				
	2		P2,L12				
	3		P2,L13				
TOTAL CEILING COST					$		$
WALL	1		P3,L8		$		
FLOOR	1		P3,L1				
	2		P3,L2				
TOTAL FLOOR COST					$		$

HEAT SAVINGS

INSULATION MEASURE	LOCATION	① AREA (FT²)	EXISTING U-VALUE	② / ②a WINTER CORR. FACTOR	② / ②a SUMMER CORR. U-VAL.	IMPROVED U-VALUE	③ / ③a WINTER CORR. FACTOR	③ / ③a SUMMER CORR. U-VAL.	ENERGY SAVINGS (BTU/HR·°F) LOSS ① × (② − ③)	GAIN ① × (②a − ③a)	
CEILING	1	P2,L11	P2,L11			DB/CA					
	2	P2,L12	P2,L12			DB/CA					
	3	P2,L13	P2,L13			DB/CA					
TOTAL CEILING HEAT LOSS/GAIN SAVINGS (BTU/HR·°F)											CEILING
WALL	1	P3,L8	P2,L14			DB/CA					WALL
FLOOR	1	P3,L1	P3,L1			DB/CA					
	2	P3,L2	P3,L2			DB/CA					
TOTAL FLDOR HEAT LOSS/GAIN SAVINGS (BTU/HR·°F)											FLOOR

MONETARY SAVINGS

INSULATION MEASURE	① HEATING SAVINGS (FROM NOMOGRAPH)	② COOLING SAVINGS (FROM NOMOGRAPH)	③ TOTAL SAVINGS ① + ②	④ FIRST YEAR SAVINGS FACTOR	⑤ LOW ③ × ④	⑥ FACTOR	⑦ HIGH ⑤ × ⑥
CEILING	$ P8,L12	$ P8,L12	$		$		$
WALL	$ P8,L13	$ P8,L13	$	0.8	$	1.5	$
FLOOR	$ P8,L16		$		$		$

WATER HEATER INSULATION

[1] COST OF CONTRACTOR–INSTALLED WATER HEATER INSULATION $ _____
[2] COST OF HOMEOWNER–INSTALLED WATER HEATER INSULATION $ _____

	①	②	③	④	⑤	⑥
	HOT WATER ENERGY COST ($/$10^6$BTU)	CONDITIONED SPACE CORRECTION FACTOR	10^6 BTU	FIRST YEAR SAVINGS		
				LOW ①×②×③		HIGH ④×⑤
[3]			2	$	1.5	$
	DB/CA	DB/CA				

DUCT INSULATION

	①	②	③	④	⑤
	LENGTH TO BE INSULATED (FT)	CONTRACTOR		RESIDENT	
		COST/FT	TOTAL COST ①×②	COST/FT	TOTAL COST ①×④
[4]		$	$	$	$
	P2,L4				

	①	②	③	④	⑤	⑥	⑦	⑧
	R VALUE OF PROPOSED DUCT INSULATION	$0.003\left(\frac{\Delta R}{\Delta R+1}\right)$	PERCENT OF DUCTING TO BE INSULATED (%)	PRESENT ANNUAL HEATING & COOLING COSTS		FIRST YEAR SAVINGS		
						LOW ②×③×④×⑤		HIGH ⑥×⑦
[5]					0.5	$	2	$
			P2,L3	P5,L4,5				

HYDRONIC HEATING PIPE INSULATION

	①	②	③	④	⑤
	LENGTH TO BE INSULATED (FT)	CONTRACTOR		RESIDENT	
		COST/FT	TOTAL COST ①×②	COST/FT	TOTAL COST ①×④
[6]		$	$	$	$
	P2,L2				

	①	②	③	④	⑤	⑥
	PRESENT HEATING COST	LENGTH TO BE INSULATED (FT)	FACTOR	FIRST YEAR SAVINGS		
				LOW ①×②×③		HIGH ④×⑤
[7]	$		0.0004	$	2.5	$
	P5,L4	P2,L2				

STORM OR THERMAL WINDOWS

	STORM/THERMAL WINDOWS	① NO.	② CONTRACTOR COST/WINDOW	③ CONTRACTOR TOTAL COST ① × ②	④ RESIDENT COST/WINDOW	⑤ RESIDENT TOTAL COST ① × ④
[1]	SMALL WINDOWS	P3,L3(4)	$	$	$	$
[2]	LARGE WINDOWS	P3,L4(4)	$	$	$	$
[3]	TOTALS			$		$

	⑥ MEASURE	⑦ EXISTING U-VALUE (BTU/HR-FT²-°F)	⑧ IMPROVED U-VALUE (BTU/HR-FT²-°F)	⑨ AREA (FT²)	⑩ HEAT LOSS/ GAIN SAVINGS (BTU/HR – °F) (⑦ – ⑧) × ⑨
[4]	STORM/ THERMAL WINDOWS				
		DB/CA	DB/CA	P3,L5(9)	

	① FIRST YEAR WEATHERSTRIPPING SAVINGS (LOW)	② WINDOW WEATHERSTRIPPING LINEAR FT	③ TOTAL WEATHERSTRIPPING LINEAR FT	④ FACTOR	⑤ STORM/THERMAL WINDOW INFILTRATION SAVINGS ① ×(② ÷ ③)× ④
[5]				1.25	
	P7,L6	P7,L2	P7,L4		

	⑥ HEATING SAVINGS (FROM NOMOGRAPH)	⑦ COOLING SAVINGS (FROM NOMOGRAPH)	⑧ TOTAL SAVINGS ⑤ + ⑥ + ⑦	⑨ FACTOR	⑩ FIRST YEAR SAVINGS LOW ⑧ × ⑨	⑪	⑫ HIGH ⑩ × ⑪
[6]				0.8	$	1.5	$
	P10,L4	P10,L4					

STORM OR THERMAL DOORS

	①	②	③	④	⑤	⑥
	NUMBER OF DOORS	AREA (FT^2)	CONTRACTOR		RESIDENT	
			COST/UNIT	TOTAL COST ① × ③	COST/UNIT	TOTAL COST ① × ⑤
[1]			$	$	$	$
	P3,L6(1)	P3,L6(6)				

	⑦	⑧	⑨	⑩
	MEASURE	EXISTING U-VALUE (BTU/HR-FT^2-°F)	IMPROVED U-VALUE (BTU/HR-FT^2-°F)	HEAT LOSS/GAIN (BTU/HR-°F) ② × (⑧ − ⑨)
[2]	STORM/THERMAL DOORS			
		DB/CA	DB/CA	

	①	②	③	④	⑤
	FIRST YEAR WEATHERSTRIPPING SAVINGS (LOW)	DOOR WEATHERSTRIPPING LINEAR FEET	TOTAL WEATHERSTRIPPING LINEAR FEET	FACTOR	STORM/THERMAL DOOR WEATHERSTRIPPING SAVINGS ① × (② + ③) × ④
[3]				1.25	
	P7,L6	P7,L3	P7,L4		

	⑥	⑦	⑧	⑨	⑩	⑪	⑫
	HEATING SAVINGS (FROM NOMOGRAPH)	COOLING SAVINGS (FROM NOMOGRAPH)	TOTAL SAVINGS ⑤ + ⑥ + ⑦	FACTOR	FIRST YEAR SAVINGS		
					LOW ⑧ × ⑨		HIGH ⑩ × ⑪
[4]				0.8	$	1.5	$
	P11,L2	P11,L2					

HEAT REFLECTIVE AND HEAT ABSORBING WINDOW OR DOOR MATERIAL

WINDOW HEAT GAIN RETARDANTS (See Page D-14)

CLOCK THERMOSTAT

[1] COST OF CONTRACTOR-INSTALLED CLOCK THERMOSTAT $ _____

[2] COST OF HOMEOWNER-INSTALLED CLOCK THERMOSTAT $ _____

TOTAL FIRST-YEAR ENERGY COST SAVINGS WITH 8 HOURS SET BACK, IF PRACTICE IS NOT ALREADY APPLIED:

	① SETBACK (°F)	② PERCENT SAVINGS (%)	③ HEATING SEASONAL COST	④ FACTOR	⑤ FIRST YEAR SAVINGS LOW ② × ③ × ④	⑥	⑦ FIRST YEAR SAVINGS HIGH ⑤ × ⑥
[3]	5	DB/CA	P5,L4		$		$
[4]	10	DB/CA		0.008	$	1.5	$
[5]	15	DB/CA			$		$

HEATING AND AIR CONDITIONING MODIFICATIONS

	MEASURES	① FIRST YEAR (LOW) SAVINGS CALCULATION: PRESENT SEASONAL OR ENERGY COST	② FIRST YEAR (LOW) SAVINGS CALCULATION: MULTIPLIER	③ FIRST YEAR SAVINGS LOW ① × ②	④ FIRST YEAR SAVINGS FACTOR	⑤ FIRST YEAR SAVINGS HIGH ③ × ④	⑥ INSTALLED COST	⑦ ANNUAL MAINT COST
[6]	REPL'MNT HEATING SYSTEM	SEASONAL HEATING P5,L4	0.8 × (1 – ___PSE/___NSE)* P5,L4	$	1.5	$	$	$
[7]	OIL BURNER REPL'MNT (SEE NOTE 1)		0.1	$	1.8	$	$	$
[8]	FLUE OPENING MOD. (VENT DAMPERS)		0.07	$	1.4	$	$	$
[9]	ELECT OR MECH. IGNITION SYSTEMS	ENERGY (GAS) ($ PER 10^6BTU)	0.8 × ( ) DB/CA	$	1.5	$	$	$
[10]	REPL'MNT CENTRAL AIR CONDI-TIONER	SEASONAL COOLING P5,L6	0.8 × (1 – ___PSE/___NSE)* P5,L4	$	1.5	$	$	$

NOTE 1: SAVINGS = $0 IF UNIT IS A WET BASE BOILER OR HAS A ROTARY CUP BURNER

*PSE – PRESENT SEASONAL EFFICIENCY

NSE – NEW SEASONAL EFFICIENCY

SOLAR DOMESTIC HOT WATER

	①	②	③	④	⑤	⑥	⑦	⑧
	NUMBER OF OCCUP'NTS	USE (GDP)	DAILY LOAD (GALLONS) ① × ②	ANNUAL ENERGY REQUIREMENTS (MILLION BTU)	SSF	AREA REQUIRED (FT²)	PSF	ADJUSTED AREA (FT²) ⑥ ÷ ⑦
[1]								
	P1,L4	P1,L10		DB/CA	DB/CA		SKETCH	

	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
	LOCAL ENERGY COST ($/MILLION BTU)	AUXILIARY EFFICIENCY	ANNUAL ENERGY COST ($) ④ × ⑨ ÷ ⑩	FIRST YR $ SAVED ⑤ × ⑪	RESIDENT INSTALLED COST: $_____ + ⑧ × $____/FT²	CONTRACTOR INSTALLED COST: $_____ + ⑧ × $____/FT²	RESIDENT INSTALLED (RACK) COST $_____ + ⑧ × $____/FT²	CONTRACTOR INSTALLED (RACK) COST $_____ + ⑧ × $____/FT²
[2]								

VALUES	
Natural Gas	0.51
Oil	0.52
Electricity	0.84

ACTIVE SOLAR SPACE HEATING AND COMBINED SPACE AND HOT WATER

		①	②	③	④	⑤	⑥	⑦	⑧
		PROJECTED AREA	SLOPE COMPEN-SATOR	ACTUAL AREA ① × ②	PSF	EFFECTIVE AREA ③ × ④	HEUR	EFFICIENT HEUR ⑥ × 0.9	SSF
[3]	ACTIVE (A)	SKETCH	DB/CA		SKETCH		P5,L4	DB/CA	DB/CA
[4]	COMBINED (C)								
		SKETCH	DB/CA		SKETCH				DB/CA

		⑨	⑩	⑪	⑫	⑬	⑭
		ANNUAL HEATING COST	ANNUAL HOT WATER COST	TOTAL HEATING COST ⑨ + ⑩	FIRST YR $ SAVED ⑧ × ⑪	CONTRACTOR COST $_____ + ③ × ____/FT²	CONTRACTOR RACK COST $_____ + ③ × ____/FT²
[5]	ACTIVE (A)						
[6]	COMBINED (C)						
		P5,L4	P13,L2				

SOLAR POOL HEATING

	①	②	③	④	⑤	⑥	⑦	⑧	⑨
	POOL AREA (FT²)	PROJECTED COLLECTOR AREA (FT²)	SLOPE COMPEN-SATOR	ACTUAL AREA ② × ③	PSF	EFFECTIVE AREA (FT²) ② × ③ × ⑤	SSF	POOL HEATING LOAD (MILLION BTU/YR.)	LOCAL ENERGY COST ($/MILLION BTU)
[1]									
	SKETCH	SKETCH	DB/CA		SKETCH		DB/CA	DB/CA	

	⑩	⑪	⑫	⑬	⑭	⑮
	POOL HEATING COST $ /YR. ⑧ × ⑨	FIRST YR. $ SAVED ⑦ × ⑩	RESIDENT INSTALLED COST $ + ④ × $__ /FT²	CONTRACTOR INSTALLED COST $ + ④ × $__ /FT²	RESIDENT INSTALLED (RACK)COST $ + ④ × $__ /FT²	CONTRACTOR INSTALLED (RACK)COST $ + ④ × $___ /FT²
[2]						

WINDOW HEAT GAIN RETARDANTS (WHGR) AND HEAT REFLECTING (HR) AND HEAT ABSORBING (HA) WINDOW OR DOOR MATERIAL

	①	②	③	④	⑤	⑥	⑦	⑧
	ORIEN-TATION	GLAZED AREA (FT²)	SUMMER SHADING FACTOR	EFFECTIVE AREA ② × ③	WHGR FACTOR	HR/HA FACTOR	ANNUAL ENERGY SAVINGS-WHGR ④ × ⑤	ANNUAL ENERGY SAVINGS-HR/HA ④ × ⑥
[3]	P3,L4	P3,L4(10)	PROCEDURES		DB/CA	DB/CA		
[4]	P3,L4	P3,L4(10)	PROCEDURES		DB/CA	DB/CA		
[5]	P3,L4	P3,L4(10)	PROCEDURES		DB/CA	DB/CA		
[6]	TOTAL					TOTAL		

	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
	ENERGY COST $/10⁶BTU	COOLING SYSTEM SEASONAL EFFICIENCY	1st YR $ SAVED-WHGR ⑦ × ⑨ ÷ ⑩	1st YR $ SAVED-HR/HA ⑧ × ⑨ ÷ ⑩	RESIDENT INSTALLED COST-WHGR ② × $___/FT²	CONTRACTOR INSTALLED COST-WHGR ② × $___/FT²	RESIDENT INSTALLED COST-HR/HA ② × $___/FT²	CONTRACTOR INSTALLED COST-HR/HA ② × $___/FT²
[7]								
		P5,L5						

DIRECT AND INDIRECT GAIN

		1	2	3	4	5	6	7	8
		HEUR	HEUR X 0.021	AREA TO BE GLAZED (FT^2)	PSF	ORIENTATION FACTOR	EFFECTIVE AREA (FT^2) 3 X 4 X 5	CLR 6 ÷ 2	SSF
[1]	DIRECT GAIN				SKETCH	PROCEDURES			DB/CA
[2]	INDIRECT TROMBE				SKETCH	PROCEDURES			DB/CA
[3]	WATER				SKETCH	PROCEDURES			DB/CA
[4]	TAP				SKETCH	PROCEDURES			DB/CA
		P5,L4							

	9	10	11	12	13	14	15
	ANNUAL HEATING COST ($)	ADJUSTED ANNUAL HEATING COST 9 X 0.9	FIRST-YEAR $ SAVED 8 X 10	RESIDENT-INSTALLED UNIT COST ($/$FT^2$)	RESIDENT-INSTALLED SYSTEM COST 3 X 12	CONTRACTOR-INSTALLED UNIT COST ($/$FT^2$)	CONTRACTOR-INSTALLED SYSTEM COST 3 X 14
[5]							
[6]							
[7]							
[8]							
	P5,L4						

SUNSPACE

	1	2	3	4	5	6	7
	HEUR	HEUR X 0.021	SOUTH WALL AREA TO BE COVERED (FT^2)	PSF	EFFECTIVE AREA 3 X 4	CLR 5 ÷ 2	SSF
[1]							
	P5,L4			SKETCH			DB/CA

	8	9	10	11	12	13	14
	PERFORMANCE CORRECTION FACTOR	ADJUSTED SSF 7 X 8	ANNUAL HEATING COST ($)	ADJUSTED ANNUAL HEATING COST 10 X 0.9	FIRST-YEAR $ SAVED 9 X 11	RESIDENT-INSTALLED COST 3 X $___ /$ft^2$	CONTRACTOR-INSTALLED COST 3 X $___ /$ft^2$
[2]							
	PROCEDURES		P5,L4				

WIND ENERGY DEVICES

	①	②	③*	④	⑤	⑥	⑦*
	AVERAGE ANNUAL WIND SPEED (@ 35 FT.)	TERRAIN CODE (NUMBER)	HEIGHT OF TALLEST OBSTRUCTION (FT.)	MINIMUM TOWER HEIGHT (FT.)	HEIGHT/ ROUGHNESS FACTOR	TERRAIN SHELTER FACTOR	ADJUSTED WIND SPEED ① × ⑤ × ⑥
[1]				(CIRCLE) 40 60 80			
	DB/CA	DB/CA	SKETCH		DB/CA	DB/CA	

	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮
	CURRENT ANNUAL KWH USE	TARGET ANNUAL WIND SYSTEM OUTPUT (KWH) ⑧ × .5	SELECTED WIND SYSTEM	ANNUAL WIND SYSTEM OUTPUT	INSTALLED SYSTEM COST	INSTALLED TOWER COST	INSTALLED TOTAL COST ⑫ + ⑬	ANNUAL MAINT. COST
[2]								
	P1,L4		DB/CA	DB/CA				

DIFFERENT SELL AND BUYBACK TARIFFS

	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓
	CURRENT ELECTRIC RATE ($/KWH)	AVERAGE BUYBACK RATE ($/KWH)	BUYBACK SAVINGS ⑪ × ⑰ × 0.5	DISPLACED ENERGY SAVINGS ⑪ × ⑯ × 0.5	FACTOR	FIRST YR SAVINGS-LOW ⑱ + ⑲ × ⑳	FACTOR	FIRST YR SAVINGS-HIGH ㉑ × ㉒
[3]					0.8		1.5	

NET TARIFF

	⑯a	⑳a	㉑a	㉒a	㉓a
	CURRENT ELECTRIC RATE ($/KWH)	FACTOR	FIRST YR SAVINGS-LOW ⑪ × ⑯a × ⑳a	FACTOR	FIRST YR SAVINGS-HIGH ㉑a × ㉒a
[4]		0.8		1.5	

*-GO/NO GO DECISION POINTS

E. Data Base/Calculation Aids

E.1 CLIMATIC DATA

Section E.1 is reproduced in its entirety on microfiche (see the inside of the back cover). The most representative climatic data stations by state and HUD/MPS regions are listed below.

Most representative climatic data stations by state and HUD/MPS region

State	HUD/MPS region	Most representative climatic data station and station number
Alabama	2	Tallahassee, FL (43)
	3	Meridian, MS (85)
Alaska	8	Adak, AK (74)
Arizona	1	Phoenix, AZ (91)
	2	Phoenix, AZ (91)
	3	Phoenix, AZ (91)
	4	Phoenix, AZ (91)
	5	Prescott, AZ (56)
	6	Winslow, AZ (29)
	7	Bryce Canyon, UT (54)
Arkansas	3	Shreveport, LA (9)
	4	Ft. Smith, AR (10)
California	2	Daggett, CA (55)
	3	Fresno, CA (90)
	4	Red Bluff, CA (38)
	5	Red Bluff, CA (38)
	6	Red Bluff, CA (38)
	7	Lovelock, NV (60)
	8	Burns, OR (69)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
Colorado	6	Amarillo, TX (28)
	7	Grand Junction, CO (33)
	8	Eagle, CO (52)
Connecticut	6	Boston, MA (96)
Delaware	4	Philadelphia, PA (4)
District of Columbia	4	Norfolk, VA (3)
Florida	1	Tampa, FL (2)
	2	Tallahassee, FL (43)
Georgia	2	Tallahassee, FL (43)
	3	Columbia, SC (7)
	4	Chattanooga, TN (11)
Hawaii	1	Honolulu, HI (49)
Idaho	7	Pocatello, ID (36)
	8	Boise, ID (42)
Illinois	4	Evansville, IN (44)
	5	Kansas City, MO (23)
	6	Indianapolis, IN (45)
	7	Lacrossee, WI (25)
Indiana	4	Evansville, IN (44)
	5	Indianapolis, IN (45)
	6	Indianapolis, IN (45)
	7	Grand Rapids, MI (47)
Iowa	6	Sioux City, IA (26)
	7	Sioux City, IA (26)
	8	Sioux City, IA (26)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
Kansas	4	Kansas City, MO (23)
	5	Wichita, KS (32)
	6	Dodge City, KS (89)
	7	Dodge City, KS (89)
Kentucky	4	Evansville, IN (44)
	5	Indianapolis, IN (45)
	6	Columbus, OH (19)
Louisiana	2	Lake Charles, LA (94)
	3	Shreveport, LA (9)
Maine	8	Caribou, ME (99)
Maryland	4	Norfolk, VA (3)
	5	Philadelphia, PA (4)
	6	Charleston, WV (6)
Massachusetts	6	Boston, MA (96)
	7	Portland, ME (16)
Michigan	7	Grand Rapids, MI (47)
	8	Grand Rapids, MI (47)
Minnesota	8	Fargo, ND (24)
Mississippi	2	Meridian, MS (85)
	3	Meridian, MS (85)
Missouri	4	Springfield, MO (14)
	5	Kansas City, MO (23)
	6	Kansas City, MO (23)
Montana	8	Cut Bank, MT (59)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
Nebraska	6	Kansas City, MO (23)
	7	Sioux City, IA (26)
	8	Scottsbluff, NB (41)
Nevada	2	Tonopah, NV (53)
	3	Tonopah, NV (53)
	4	Tonopah, NV (53)
	5	Tonopah, NV (53)
	6	Tonopah, NV (53)
	7	Lovelock, NV (60)
	8	Elko, NV (86)
New Hampshire	7	Portland, ME (16)
	8	Burlington, VT (15)
New Jersey	5	Philadelphia, PA (4)
	6	Philadelphia, PA (4)
New Mexico	3	El Paso, TX (92)
	4	El Paso, TX (92)
	5	Roswell, NM (98)
	6	Albuquerque, NM (93)
	7	Albuquerque, NM (93)
	8	Eagle, CO (52)
New York	6	Boston, MA (96)
	7	Wilkes Barre, PA (17)
	8	Binghamton, NY (1)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
North Carolina	2	Charleston, SC (95)
	3	Charleston, SC (95)
	4	Richmond, VA (5)
	5	Charleston, WV (6)
North Dakota	8	Fargo, ND (24)
Ohio	5	Columbus, OH (19)
	6	Columbus, OH (19)
	7	Indianapolis, IN (45)
Oklahoma	3	Dallas, TX (88)
	4	Tulsa, OK (13)
	5	Dodge City, KS (89)
	6	Amarillo, TX (28)
Oregon	4	Salem, OR (39)
	5	Salem, OR (39)
	6	Burns, OR (69)
	7	Burns, OR (69)
	8	Burns, OR (69)
Pennsylvania	5	Philadelphia, PA (4)
	6	Wilkes Barre, PA (17)
	7	Binghamton, NY (1)
	8	Binghamton, NY (1)
Rhode Island	6	Boston, MA (96)
South Carolina	2	Charleston, SC (95)
	3	Columbia, SC (7)
	4	Chattanooga, TN (11)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
South Dakota	7	Sioux City, IA (26)
	8	Sioux City, IA (26)
Tennessee	3	Memphis, TN (8)
	4	Memphis, TN (8)
	5	Charleston, WV (6)
Texas	1	Kingsville, TX (73)
	2	San Angelo, TX (27)
	3	Wichita Falls, TX (12)
	4	Amarillo, TX (28)
	5	Amarillo, TX (28)
Utah	5	Grand Junction, CO (33)
	6	Bryce Canyon, UT (54)
	7	Salt Lake City, UT (71)
	8	Salt Lake City, UT (71)
Vermont	7	Portland, ME (16)
	8	Burlington, VT (15)
Virginia	3	Norfolk,VA (3)
	4	Richmond, VA (5)
	5	Richmond, VA (5)
	6	Charleston, WV (6)
Washington	6	Tacoma, WA (100)
	7	Spokane, WA (37)
	8	Yakima, WA (40)
West Virginia	5	Charleston, WV (6)
	6	Charleston, WV (6)

Climatic data stations (continued)

State	HUD/MPS region	Most representative climatic data station and station number
Wisconsin	7	Lacrosse, WI (25)
	8	Lacrosse, WI (25)
Wyoming	7	Scottsbluff, NB (41)
	8	Rocksprings, WY (57)
Puerto Rico	1	San Juan, PR (66)

E.2 U-VALUES

All U-values in this section are given in units of Btu/h·ft^2·°F. The units for R-values are the reciprocals of the U-values.

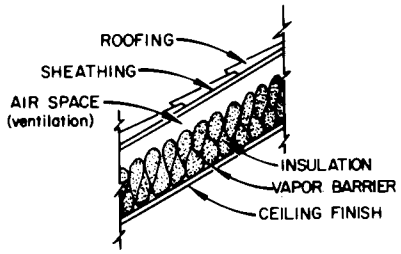
Insulation R-value table

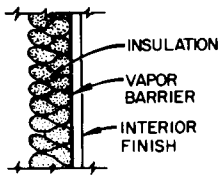
Insulation	R-value per inch of thickness
Fiberglass (rigid)	3.0
Fiberglass (low-density batt)	3.3 to 3.0
Fiberglass (high-density batt)	4.0
Mineral wool (low-density batt)	3.7
Polystyrene (foam-bead board, 1 lb/ft^3)	4.0
Polystyrene (foam board, 2 lb/ft^3)	5.1
Polyurethane (foam board, 2 lb/ft^3), fresh	7.6
Polyurethane (foam board, 2 lb/ft^3), aged	5.8
Polyurethane (foamed in place, 1.6 to 2 lb/ft^3)	6.7
Urea formaldehyde (foam, 0.6 to 0.8 lb/ft^3)	4.2
Cellulose (loose fill, 2 to 2.5 lb/ft^3)	3.7
Mineral and glass (loose fill)	3.0 to 2.5

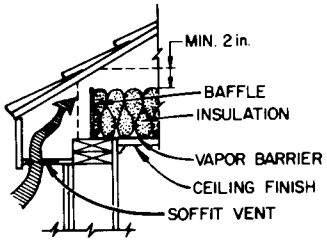
OVERALL U-VALUE TABLES

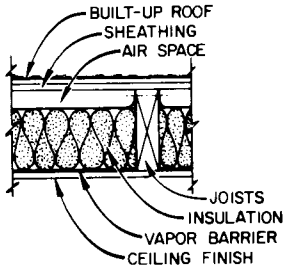
The R-value of only the insulation - not the overall assembly - appears in parentheses

1. Ceiling Assembly

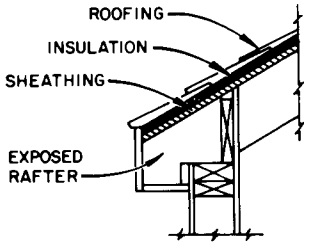








AMOUNT OF INSULATION (in.)	CAVITY						KNEE WALL				UNFINISHED ATTIC FLOOR						FLAT ROOF					
	0	2	3.5	6	9	12	0	2	3.5	6	0	2	3.5	6	9	12	0	2	3.5	6	9	12
FIBERGLASS BATT	.31(0)	.10(7)	.073(11)	.046(19)	.031(30)	.025(38)	.57(0)	.11(7)	.078(11)	.048(19)	.54(0)	.13(7)	.087(11)	.051(19)	.033(30)	.026(38)	.30(0)	.097(7)	.070(11)	.045(19)	.030(30)	.024(38)
UREA-BASED FOAM									.059(15)													
CELLULOSE											.54(0)	.13(7)	.074(13)	.044(22)	.030(33)	.022(44)	.30	.097(7)	.061(13)	.039(22)	.028(33)	.021(44)
LOOSE FIBERGLASS											.54(0)	.18(5)	.10(9)	.064(15)	.044(22)	.033(30)	.30(0)	.12(5)	.081(9)	.055(15)	.040(22)	.030(30
LOOSE MINERAL WOOL											.54(0)	.18(5)	.095(10)	.060(16)	.039(25)	.030(33)	.30(0)	.12(5)	.075(10)	.052(16)	.035(25)	.028(33)



PLANK AND BEAM

NO INSULATION .54

FOR ADDITIONAL (rigid-board) INSULATION OR SHEATHING WITH A HIGH R-VALUE, THE OVERALL U-VALUE OF THE ASSEMBLY IS CALCULATED AS SHOWN BELOW. THIS IS SHOWN ESPECIALLY FOR THE "PLANK-AND-BEAM" AND "FLAT-ROOF" CONSTRUCTIONS. THE R-VALUE OF THE INSULATION CAN BE DETERMINED FROM THE INSULATION R-VALUE TABLE.

$$\text{OVERALL U-VALUE} = \frac{1}{\frac{1}{\text{U FROM TABLE}} + R_{\text{INSULATION}}}$$

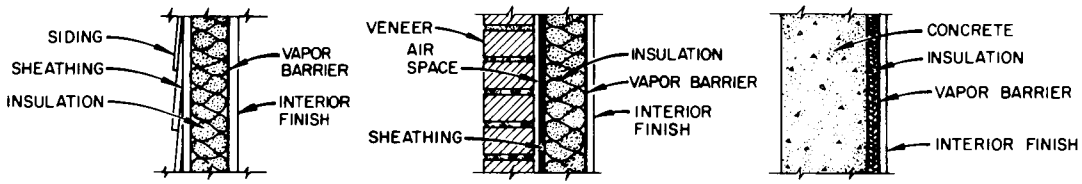
(1) READ THE U-VALUE FROM THIS TABLE FOR THE CONSTRUCTION AS TABULATED.
(2) TAKE THE RECIPROCAL OF THIS U-VALUE FOR THE OVERALL R OF THE CONSTRUCTION AS TABULATED.
(3) ADD THE R OF THE EXTRA INSULATION OBSERVED TO THE R FROM STEP 2.
(4) TAKE THE RECIPROCAL OF STEP 3 FOR THE OVERALL U-VALUE OF THE ASSEMBLY.

ORNL-DWG 80-8601R

OVERALL U-VALUE TABLES

The R-value of only the insulation-not the overall assembly-appears in parentheses

2. Overall Wall Assembly-Exterior Walls

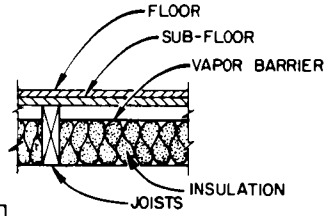


AMOUNT OF INSULATION (in.)	CAVITY INSULATION 0	2	3.5	6	BRICK or STONE VENEER or BLOCK with BRICK, BLOCK or CONCRETE WALL (studded out) 0	2	3.5	6	POURED CONCRETE or BLOCK WALL (not studded out)
FIBERGLASS BATT	.30(0)	.11(7)	.075(11)	.047(19)	.26(0)	.10(7)	.071(11)	.045(19)	NO INSULATION
UREA-BASED FOAM	.30(0)		.058(15)	.040(23)	.26(0)		.055(15)	.038(23)	ABOVE GRADE .50
CELLULOSE	.30(0)	.11(7)	.065(13)	.041(22)	.26(0)	.10(7)	.063(13)	.040(22)	BELOW GRADE .20
LOOSE FIBERGLASS	.30(0)	.14(5)	.088(9)	.058(15)	.26(0)	.12(5)	.083(9)	.055(15)	
LOOSE MINERAL WOOL	.30(0)	.14(5)	.081(10)	.055(16)	.26(0)	.12(5)	.077(10)	.053(16)	

FOR ADDITIONAL (rigid-board) INSULATION OR SHEATHING WITH A HIGH R-VALUE, USE THE PROCEDURE SHOWN UNDER "ROOF/CEILING ASSEMBLY" TO CALCULATE THE OVERALL U OF THE WALL ASSEMBLY.

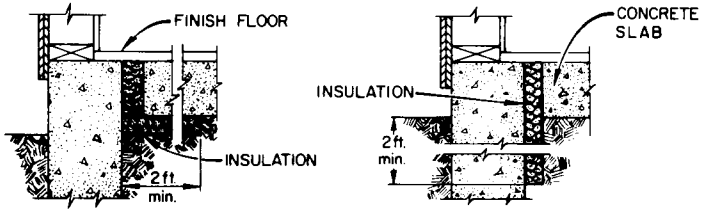
$$\text{OVERALL U-VALUE} = \frac{1}{\frac{1}{\text{U FROM TABLE}} + R_{\text{INSULATION}}}$$

3. Floors Over Unconditioned Spaces



AMOUNT OF FIBERGLASS BATT INSULATION (in.)	0	2	3.5	6
WITHOUT CARPET	.37(0)	.10(7)	.073(11)	.046(19)
WITH CARPET	.23(0)	.088(7)	.065(11)	.043(19)

4. Slab on Grade



AMOUNT OF INSULATION (in.)	NOTE: UNITS ARE Btu/hr·ft·°F 0	1	2	0	1	2
UNHEATED SLAB	.78(0)	.56(3)	.50(6)	.78(0)	.59(3)	.53(6)
HEATED SLAB		1.1(3)	.93(6)		1.1(3)	1.0(6)

U-values of vertical panels (exterior windows, sliding patio doors, and partitions)

Type of panel	U-value
Glass	
Single pane	1.10
Double pane	
3/16-in. air space	0.62
1/4-in. air space	0.58
1/2-in. air space	0.48
Triple pane	
1/4-in. air space	0.33
1/2-in. air space	0.28
Storm windows	
1- to 4-in. air space	0.50
Plastic sheet	
Single glazed	
1/8-in. thick	1.06
1/4-in. thick	0.96
1/2-in. thick	0.81
Insulating unit, double	
1/4-in. air space	0.55
1/2-in. air space	0.43
Glass block	
6×6×4 in. thick	0.60
8×8×4 in. thick	0.56
8×8×4 in. thick, with cavity divider	0.48
12×12×4 in. thick	0.52
12×12×4 in. thick, with cavity divider	0.44
12×12×2 in. thick	0.60

U-values of horizontal panels (skylights)

Type of panel	U-value
Glass	
Single pane	1.23
Double pane	
3/16-in. air space	0.70
1/4-in. air space	0.65
1/2-in. air space	0.59
Glass block	
11×11×3 in. thick, with cavity divider	0.53
12×12×4 in. thick, with cavity divider	0.51
Plastic bubbles[a]	
Single wall	1.15
Double wall	0.70

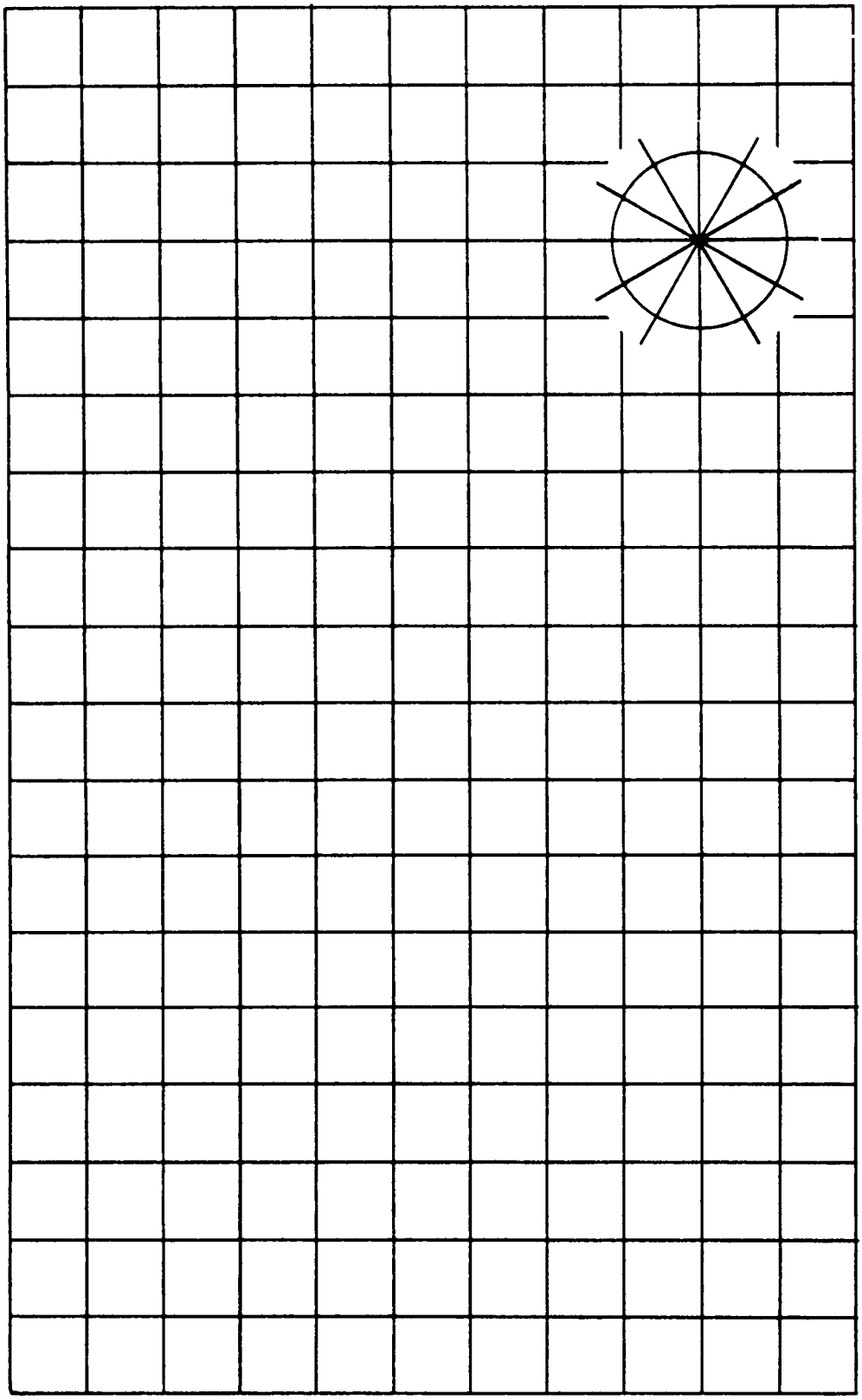
[a]Based on area of opening, not total surface area.

U-values of slab doors by type of door

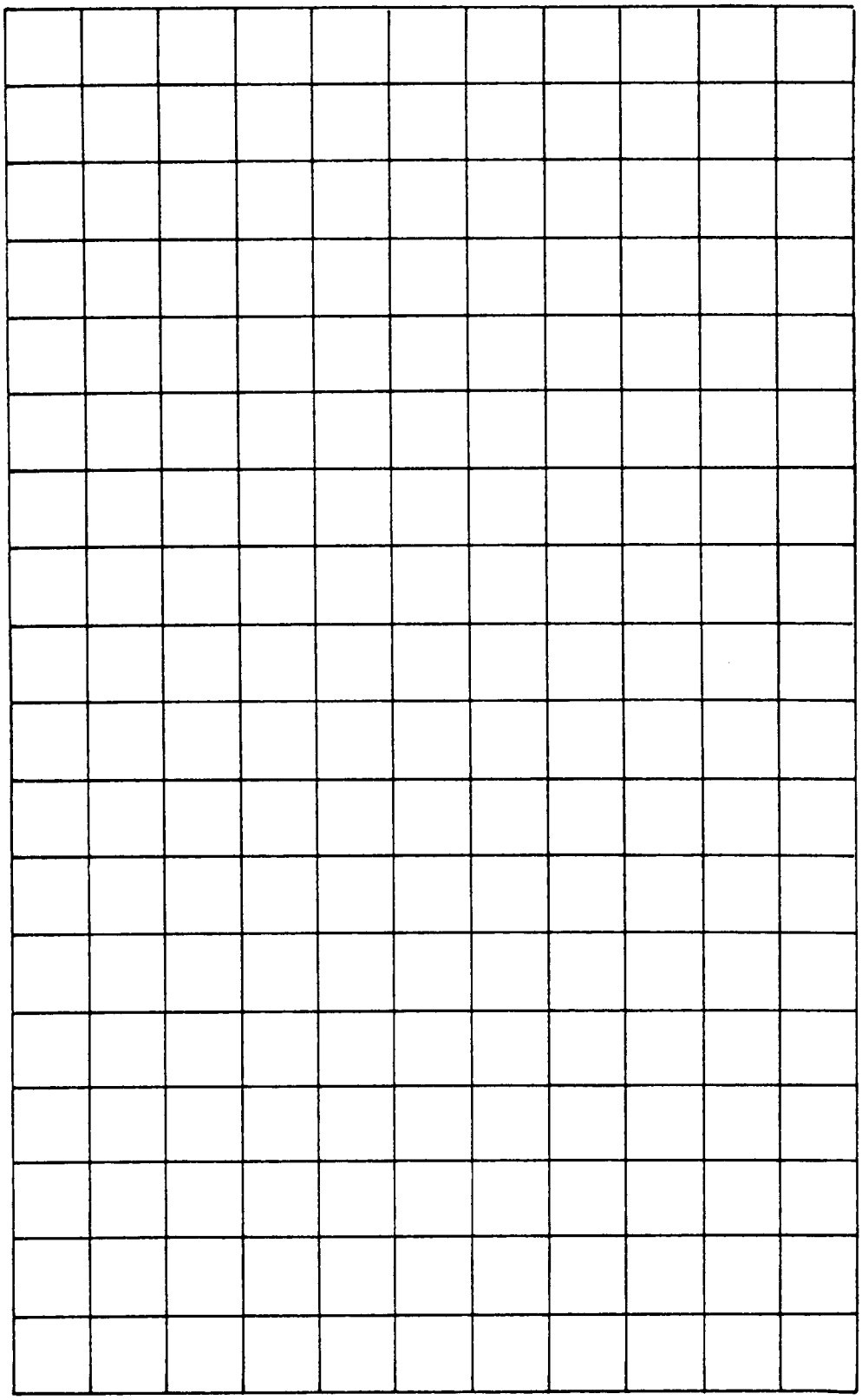
Solid wood	No storm	Wood storm	Metal storm
1 in. thick	0.62	0.30	0.38
1.25 in. thick	0.53	0.28	0.34
1.5 in. thick	0.47	0.27	0.33
2 in. thick	0.42	0.24	0.29

Metal door (thickness)	Mineral fiber core	Solid urethane foam core	Solid polystyrene foam core
1.75 in.	0.57	0.19	0.45

E.3 SKETCH SHEETS



HOUSE PLAN VIEW



ELEVATION VIEW

E.4 LOAD CALCULATIONS

Infiltration wind factors

State	HUD/MPS zone	Heating degree-days	Winter wind factor	Summer wind factor
Alabama	2	1,000 - 2,500	0.473	0.440
Alabama	3	2,500 - 3,500	0.447	0.360
Alaska	8	7,000 - 20,000	0.973	0.813
Arizona	1	10 - 1,000	0.407	0.473
Arizona	2	1,000 - 2,500	0.407	0.473
Arizona	3	2,500 - 3,500	0.407	0.473
Arizona	4	3,500 - 4,500	0.407	0.473
Arizona	5	4,500 - 5,000	0.553	0.600
Arizona	6	5,000 - 6,000	0.540	0.627
Arizona	7	6,000 - 7,000	0.507	0.500
Arkansas	3	2,500 - 3,500	0.627	0.520
Arkansas	4	3,500 - 4,500	0.533	0.460
California	2	1,000 - 2,500	0.687	0.887
California	3	2,500 - 3,500	0.380	0.487
California	4	3,500 - 4,500	0.607	0.587
California	5	4,500 - 5,000	0.607	0.587
California	6	5,000 - 6,000	0.607	0.587
California	7	6,000 - 7,000	0.407	0.527
California	8	7,000 - 10,000	0.420	0.507
Colorado	6	5,000 - 6,000	0.913	0.887
Colorado	7	6,000 - 7,000	0.500	0.633
Colorado	8	7,000 - 10,000	0.360	0.407
Connecticut	6	5,000 - 6,000	0.933	0.807
Delaware	4	3,500 - 4,500	0.673	0.573
D.C.	4	3,500 - 4,500	0.747	0.627
Florida	1	10 - 1,000	0.633	0.560
Florida	2	1,000 - 2,500	0.467	0.387
Georgia	2	1,000 - 2,500	0.613	0.560
Georgia	3	2,500 - 3,500	0.473	0.440
Georgia	4	3,500 - 4,500	0.447	0.360
Hawaii	1	10 - 1,000	0.747	0.880
Idaho	7	6,000 - 7,000	0.707	0.660
Idaho	8	7,000 - 10,000	0.587	0.573
Illinois	4	3,500 - 4,500	0.593	0.460
Illinois	5	4,500 - 5,000	0.680	0.633
Illinois	6	5,000 - 6,000	0.687	0.547
Illinois	7	6,000 - 7,000	0.607	0.553
Indiana	4	3,500 - 4,500	0.593	0.460
Indiana	5	4,500 - 5,000	0.687	0.547
Indiana	6	5,000 - 6,000	0.687	0.547
Indiana	7	6,000 - 7,000	0.700	0.587
Iowa	6	5,000 - 6,000	0.767	0.700
Iowa	7	6,000 - 7,000	0.767	0.700
Iowa	8	7,000 - 10,000	0.767	0.700
Kansas	4	3,500 - 4,500	0.680	0.633
Kansas	5	4,500 - 5,000	0.867	0.820
Kansas	6	5,000 - 6,000	0.927	0.900
Kansas	7	6,000 - 7,000	0.927	0.900
Kentucky	4	3,500 - 4,500	0.593	0.460
Kentucky	5	4,500 - 5,000	0.687	0.547
Kentucky	6	5,000 - 6,000	0.633	0.493
Louisiana	2	1,000 - 2,500	0.607	0.473
Louisiana	3	2,500 - 3,500	0.627	0.520

Infiltration wind factors (continued)

State	HUD/MPS zone	Heating degree-days	Winter wind factor	Summer wind factor
Maine	8	7,000 - 10,000	0.753	0.687
Maryland	4	3,500 - 4,500	0.747	0.627
Maryland	5	4,500 - 5,000	0.673	0.573
Maryland	6	5,000 - 6,000	0.467	0.360
Massachusetts	6	5,000 - 6,000	0.933	0.807
Massachusetts	7	6,000 - 7,000	0.620	0.553
Michigan	7	6,000 - 7,000	0.700	0.587
Michigan	8	7,000 - 10,000	0.700	0.587
Minnesota	8	7,000 - 10,000	0.873	0.787
Mississippi	2	1,000 - 2,500	0.447	0.360
Mississippi	3	2,500 - 3,500	0.447	0.360
Missouri	4	3,500 - 4,500	0.780	0.647
Missouri	5	4,500 - 5,000	0.680	0.633
Missouri	6	5,000 - 6,000	0.680	0.633
Montana	8	7,000 - 10,000	0.900	0.760
Nebraska	6	5,000 - 6,000	0.680	0.633
Nebraska	7	6,000 - 7,000	0.767	0.700
Nebraska	8	7,000 - 10,000	0.740	0.693
Nevada	2	1,000 - 2,500	0.653	0.660
Nevada	3	2,500 - 3,500	0.653	0.660
Nevada	4	3,500 - 4,500	0.653	0.660
Nevada	5	4,500 - 5,000	0.653	0.660
Nevada	6	5,000 - 6,000	0.653	0.660
Nevada	7	6,000 - 7,000	0.407	0.527
Nevada	8	7,000 - 10,000	0.373	0.420
New Hampshire	7	6,000 - 7,000	0.620	0.553
New Hampshire	8	7,000 - 10,000	0.593	0.527
New Jersey	5	4,500 - 5,000	0.673	0.573
New Jersey	6	5,000 - 6,000	0.673	0.573
New Mexico	3	2,500 - 3,500	0.627	0.627
New Mexico	4	3,500 - 4,500	0.627	0.627
New Mexico	5	4,500 - 5,000	0.667	0.693
New Mexico	6	5,000 - 6,000	0.573	0.620
New Mexico	7	6,000 - 7,000	0.573	0.620
New Mexico	8	7,000 - 10,000	0.360	0.407
New York	6	5,000 - 6,000	0.933	0.807
New York	7	6,000 - 7,000	0.573	0.507
New York	8	7,000 - 10,000	0.627	0.600
North Carolina	2	1,000 - 2,500	0.613	0.560
North Carolina	3	2,500 - 3,500	0.613	0.560
North Carolina	4	3,500 - 4,500	0.520	0.467
North Carolina	5	4,500 - 5,000	0.467	0.360
North Dakota	8	7,000 - 10,000	0.873	0.787
Ohio	5	4,500 - 5,000	0.633	0.493
Ohio	6	5,000 - 6,000	0.633	0.493
Ohio	7	6,000 - 7,000	0.687	0.547
Oklahoma	3	2,500 - 3,500	0.840	0.540
Oklahoma	4	3,500 - 4,500	0.727	0.660
Oklahoma	5	4,500 - 5,000	0.927	0.900
Oklahoma	6	5,000 - 6,000	0.913	0.887
Oregon	4	3,500 - 4,500	0.500	0.433
Oregon	5	4,500 - 5,000	0.500	0.433
Oregon	6	5,000 - 6,000	0.420	0.507
Oregon	7	6,000 - 7,000	0.420	0.507
Oregon	8	7,000 - 10,000	0.420	0.507

Infiltration wind factors (continued)

State	HUD/MPS zone	Heating degree-days	Winter wind factor	Summer wind factor
Pennsylvania	5	4,500 - 5,000	0.673	0.573
Pennsylvania	6	5,000 - 6,000	0.573	0.507
Pennsylvania	7	6,000 - 7,000	0.627	0.600
Pennsylvania	8	7,000 - 10,000	0.627	0.600
Rhode Island	6	5,000 - 6,000	0.933	0.807
South Carolina	2	1,000 - 2,500	0.613	0.560
South Carolina	3	2,500 - 3,500	0.473	0.440
South Carolina	4	3,500 - 4,500	0.447	0.360
South Dakota	7	6,000 - 7,000	0.767	0.700
South Dakota	8	7,000 - 10,000	0.767	0.700
Tennessee	3	2,500 - 3,500	0.640	0.527
Tennessee	4	3,500 - 4,500	0.640	0.527
Tennessee	5	4,500 - 5,000	0.467	0.360
Texas	1	10 - 1,000	0.613	0.653
Texas	2	1,000 - 2,500	0.707	0.700
Texas	3	2,500 - 3,500	0.767	0.747
Texas	4	3,500 - 4,500	0.913	0.887
Texas	5	4,500 - 5,000	0.913	0.887
Utah	5	4,500 - 5,000	0.500	0.633
Utah	6	5,000 - 6,000	0.507	0.500
Utah	7	6,000 - 7,000	0.567	0.627
Utah	8	7,000 - 10,000	0.567	0.627
Vermont	7	6,000 - 7,000	0.620	0.553
Vermont	8	7,000 - 10,000	0.593	0.527
Virginia	3	2,500 - 3,500	0.747	0.627
Virginia	4	3,500 - 4,500	0.520	0.467
Virginia	5	4,500 - 5,000	0.520	0.467
Virginia	6	5,000 - 6,000	0.467	0.360
Washington	6	5,000 - 6,000	0.640	0.580
Washington	7	6,000 - 7,000	0.593	0.573
Washington	8	7,000 - 10,000	0.453	0.527
West Virginia	5	4,500 - 5,000	0.467	0.360
West Virginia	6	5,000 - 6,000	0.467	0.360
Wisconsin	7	6,000 - 7,000	0.607	0.553
Wisconsin	8	7,000 - 10,000	0.607	0.553
Wyoming	7	6,000 - 7,000	0.740	0.693
Wyoming	8	7,000 - 10,000	0.793	0.687
Puerto Rico	1	10 - 1,000	0.587	0.627

Infiltration terrain factors

Class	Factor
Shielded	4
Average	8
Exposed	12

Infiltration loss/gain factors

State	HUD/MPS zone	Heating degree-days	Heat-loss factor	Heat-gain factor	Sensible heat-gain factor
Alabama	2	1,000 - 2,500	0.020	0.041	0.018
Alabama	3	2,500 - 3,500	0.020	0.044	0.018
Alaska	8	7,000 - 20,000	0.021	0.019	0.019
Arizona	1	10 - 1,000	0.019	0.020	0.017
Arizona	2	1,000 - 2,500	0.019	0.020	0.017
Arizona	3	2,500 - 3,500	0.019	0.020	0.017
Arizona	4	3,500 - 4,500	0.019	0.020	0.017
Arizona	5	4,500 - 5,000	0.020	0.017	0.017
Arizona	6	5,000 - 6,000	0.020	0.017	0.017
Arizona	7	6,000 - 7,000	0.020	0.017	0.017
Arkansas	3	2,500 - 3,500	0.020	0.042	0.018
Arkansas	4	3,500 - 4,500	0.020	0.038	0.018
California	2	1,000 - 2,500	0.019	0.017	0.017
California	3	2,500 - 3,500	0.019	0.017	0.017
California	4	3,500 - 4,500	0.019	0.017	0.017
California	5	4,500 - 5,000	0.019	0.017	0.017
California	6	5,000 - 6,000	0.019	0.017	0.017
California	7	6,000 - 7,000	0.020	0.017	0.017
California	8	7,000 - 10,000	0.021	0.018	0.018
Colorado	6	5,000 - 6,000	0.020	0.020	0.017
Colorado	7	6,000 - 7,000	0.020	0.017	0.017
Colorado	8	7,000 - 10,000	0.020	0.017	0.017
Connecticut	6	5,000 - 6,000	0.020	0.047	0.018
Delaware	4	3,500 - 4,500	0.020	0.048	0.018
D.C.	4	3,500 - 4,500	0.020	0.052	0.018
Florida	1	10 - 1,000	0.019	0.055	0.018
Florida	2	1,000 - 2,500	0.019	0.049	0.018
Georgia	2	1,000 - 2,500	0.020	0.059	0.018
Georgia	3	2,500 - 3,500	0.020	0.041	0.018
Georgia	4	3,500 - 4,500	0.020	0.043	0.018
Hawaii	1	10 - 1,000	0.018	0.061	0.018
Idaho	7	6,000 - 7,000	0.021	0.017	0.017
Idaho	8	7,000 - 10,000	0.020	0.017	0.017
Illinois	4	3,500 - 4,500	0.020	0.046	0.018
Illinois	5	4,500 - 5,000	0.020	0.037	0.018
Illinois	6	5,000 - 6,000	0.021	0.048	0.018
Illinois	7	6,000 - 7,000	0.021	0.052	0.018
Indiana	4	3,500 - 4,500	0.020	0.046	0.018
Indiana	5	4,500 - 5,000	0.021	0.048	0.018
Indiana	6	5,000 - 6,000	0.021	0.048	0.018
Indiana	7	6,000 - 7,000	0.020	0.047	0.018
Iowa	6	5,000 - 6,000	0.021	0.046	0.018
Iowa	7	6,000 - 7,000	0.021	0.046	0.018
Iowa	8	7,000 - 10,000	0.021	0.046	0.018
Kansas	4	3,500 - 4,500	0.020	0.037	0.018
Kansas	5	4,500 - 5,000	0.020	0.031	0.018
Kansas	6	5,000 - 6,000	0.020	0.025	0.017
Kansas	7	6,000 - 7,000	0.020	0.025	0.017
Kentucky	4	3,500 - 4,500	0.020	0.046	0.018
Kentucky	5	4,500 - 5,000	0.021	0.048	0.018
Kentucky	6	5,000 - 6,000	0.020	0.045	0.018
Louisiana	2	1,000 - 2,500	0.019	0.049	0.018
Louisiana	3	2,500 - 3,500	0.020	0.042	0.018

Infiltration loss/gain factors (continued)

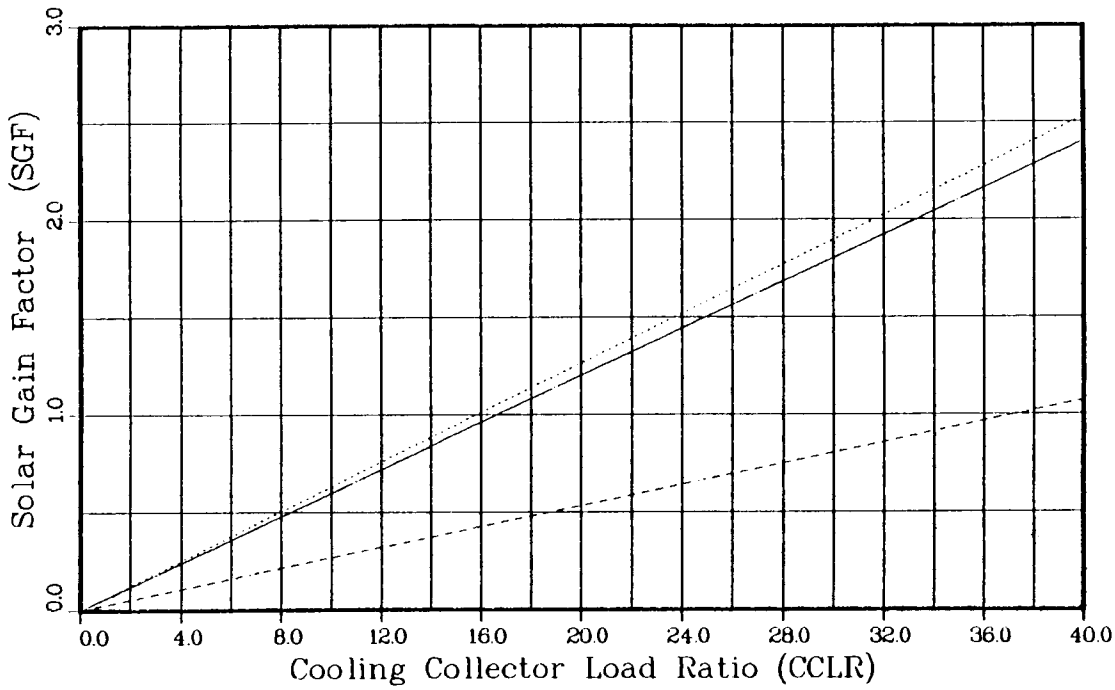
State	HUD/MPS zone	Heating degree-days	Heat-loss factor	Heat-gain factor	Sensible heat-gain factor
Maine	8	7,000 - 10,000	0.021	0.059	0.018
Maryland	4	3,500 - 4,500	0.020	0.052	0.018
Maryland	5	4,500 - 5,000	0.020	0.048	0.018
Maryland	6	5,000 - 6,000	0.020	0.045	0.018
Massachusetts	6	5,000 - 6,000	0.020	0.047	0.018
Massachusetts	7	6,000 - 7,000	0.021	0.057	0.018
Michigan	7	6,000 - 7,000	0.020	0.047	0.018
Michigan	8	7,000 - 10,000	0.020	0.047	0.018
Minnesota	8	7,000 - 10,000	0.022	0.044	0.018
Mississippi	2	1,000 - 2,500	0.020	0.044	0.018
Mississippi	3	2,500 - 3,500	0.020	0.044	0.018
Missouri	4	3,500 - 4,500	0.020	0.043	0.018
Missouri	5	4,500 - 5,000	0.020	0.037	0.018
Missouri	6	5,000 - 6,000	0.020	0.037	0.018
Montana	8	7,000 - 10,000	0.022	0.018	0.018
Nebraska	6	5,000 - 6,000	0.020	0.037	0.018
Nebraska	7	6,000 - 7,000	0.021	0.046	0.018
Nebraska	8	7,000 - 10,000	0.021	0.018	0.018
Nevada	2	1,000 - 2,500	0.020	0.017	0.017
Nevada	3	2,500 - 3,500	0.020	0.017	0.017
Nevada	4	3,500 - 4,500	0.020	0.017	0.017
Nevada	5	4,500 - 5,000	0.020	0.017	0.017
Nevada	6	5,000 - 6,000	0.020	0.017	0.017
Nevada	7	6,000 - 7,000	0.020	0.017	0.017
Nevada	8	7,000 - 10,000	0.021	0.017	0.017
New Hampshire	7	6,000 - 7,000	0.021	0.057	0.018
New Hampshire	8	7,000 - 10,000	0.021	0.051	0.018
New Jersey	5	4,500 - 5,000	0.020	0.048	0.018
New Jersey	6	5,000 - 6,000	0.020	0.048	0.018
New Mexico	3	2,500 - 3,500	0.020	0.017	0.017
New Mexico	4	3,500 - 4,500	0.020	0.017	0.017
New Mexico	5	4,500 - 5,000	0.020	0.017	0.017
New Mexico	6	5,000 - 6,000	0.020	0.017	0.017
New Mexico	7	6,000 - 7,000	0.020	0.017	0.017
New Mexico	8	7,000 - 10,000	0.020	0.017	0.017
New York	6	5,000 - 6,000	0.020	0.047	0.018
New York	7	6,000 - 7,000	0.020	0.047	0.018
New York	8	7,000 - 10,000	0.021	0.064	0.018
North Carolina	2	1,000 - 2,500	0.020	0.059	0.018
North Carolina	3	2,500 - 3,500	0.020	0.059	0.018
North Carolina	4	3,500 - 4,500	0.020	0.049	0.018
North Carolina	5	4,500 - 5,000	0.020	0.045	0.018
North Dakota	8	7,000 - 10,000	0.022	0.044	0.018
Ohio	5	4,500 - 5,000	0.020	0.045	0.018
Ohio	6	5,000 - 6,000	0.020	0.045	0.018
Ohio	7	6,000 - 7,000	0.021	0.048	0.018
Oklahoma	3	2,500 - 3,500	0.020	0.033	0.018
Oklahoma	4	3,500 - 4,500	0.020	0.036	0.018
Oklahoma	5	4,500 - 5,000	0.020	0.025	0.017
Oklahoma	6	5,000 - 6,000	0.020	0.020	0.017
Oregon	4	3,500 - 4,500	0.020	0.022	0.018
Oregon	5	4,500 - 5,000	0.020	0.022	0.018
Oregon	6	5,000 - 6,000	0.021	0.018	0.018
Oregon	7	6,000 - 7,000	0.021	0.018	0.018
Oregon	8	7,000 - 10,000	0.021	0.018	0.018

Infiltration loss/gain factors (continued)

State	HUD/MPS zone	Heating degree-days	Heat-loss factor	Heat-gain factor	Sensible heat-gain factor
Pennsylvania	5	4,500 - 5,000	0.020	0.048	0.018
Pennsylvania	6	5,000 - 6,000	0.020	0.047	0.018
Pennsylvania	7	6,000 - 7,000	0.021	0.064	0.018
Pennsylvania	8	7,000 - 10,000	0.021	0.064	0.018
Rhode Island	6	5,000 - 6,000	0.020	0.047	0.018
South Carolina	2	1,000 - 2,500	0.020	0.059	0.018
South Carolina	3	2,500 - 3,500	0.020	0.041	0.018
South Carolina	4	3,500 - 4,500	0.020	0.043	0.018
South Dakota	7	6,000 - 7,000	0.021	0.046	0.018
South Dakota	8	7,000 - 10,000	0.021	0.046	0.018
Tennessee	3	2,500 - 3,500	0.020	0.044	0.018
Tennessee	4	3,500 - 4,500	0.020	0.044	0.018
Tennessee	5	4,500 - 5,000	0.020	0.045	0.018
Texas	1	10 - 1,000	0.019	0.049	0.018
Texas	2	1,000 - 2,500	0.020	0.025	0.017
Texas	3	2,500 - 3,500	0.020	0.027	0.017
Texas	4	3,500 - 4,500	0.020	0.020	0.017
Texas	5	4,500 - 5,000	0.020	0.020	0.017
Utah	5	4,500 - 5,000	0.020	0.017	0.017
Utah	6	5,000 - 6,000	0.020	0.017	0.017
Utah	7	6,000 - 7,000	0.020	0.017	0.017
Utah	8	7,000 - 10,000	0.020	0.017	0.017
Vermont	7	6,000 - 7,000	0.021	0.057	0.018
Vermont	8	7,000 - 10,000	0.021	0.051	0.018
Virginia	3	2,500 - 3,500	0.020	0.052	0.018
Virginia	4	3,500 - 4,500	0.020	0.049	0.018
Virginia	5	4,500 - 5,000	0.020	0.049	0.018
Virginia	6	5,000 - 6,000	0.020	0.045	0.018
Washington	6	5,000 - 6,000	0.020	0.018	0.018
Washington	7	6,000 - 7,000	0.021	0.018	0.018
Washington	8	7,000 - 10,000	0.020	0.017	0.017
West Virginia	5	4,500 - 5,000	0.020	0.045	0.018
West Virginia	6	5,000 - 6,000	0.020	0.045	0.018
Wisconsin	7	6,000 - 7,000	0.021	0.052	0.018
Wisconsin	8	7,000 - 10,000	0.021	0.052	0.018
Wyoming	7	6,000 - 7,000	0.021	0.018	0.018
Wyoming	8	7,000 - 10,000	0.021	0.018	0.018
Puerto Rico	1	10 - 1,000	0.018	0.073	0.018

Optional Cooling Calculation

The data for the Solar Gain Factor (SGF) in the optional cooling calculations are on microfiche. See the inside of the back cover. An example is given below.



STATE CA

HUD/MPS 4

LEGEND

———— SOUTH

..... EAST/WEST

- - - - - - NORTH

E.5 EFFICIENCIES

Default heating system steady-state efficiencies

Gas-fired equipment	Percentage
Boiler	80
Duct furnace	80
Central furnace (indoor installation)	80
Central furnace (outdoor installation)	75
Direct vent wall furnace	75
Vented wall furnace	70
Vented room heater	70

Oil-fired equipment	Conventional burner (%)	Improved burner (%)
Boiler—dry base	70	75
Boiler—wet base	80	81
Central furnace	82	85
Floor furnace	72	75
Wall furnace	72	75

Seasonal heating system efficiencies[a]

Steady-state efficiency (%)	Seasonal efficiency[b] (%)			
	Type I	Type II	Type III	Type IV
65	59	56	52	49
70	63	60	56	53
72	65	62	58	55
75	68	65	60	57
80	72	69	64	61
82	74	71	66	62
85	77	74	68	65
90	82	78	72	68

[a]The definitions of Types I–IV are as shown below.

Type I: Oil-fired furnace/boiler
Gas-fired furnace/boiler with vent dampers and intermittent ignition device

Type II: Gas-fired furnace/boiler with vent damper and pilot light

Type III: Gas-fired furnace/boiler with an intermittent ignition device and no vent damper

Type IV: Gas-fired furnace/boiler with pilot light and no vent damper

[b]Type II efficiencies may be used for outdoor Type IV installations.

Seasonal efficiencies for heat pumps[a]

Annual heating degree-days	Seasonal efficiency (%)
500	220
1000	210
2000	200
3000	180
4000	170
5000	150
6000	140
7000	130
8000	110

[a]Adapted from EPRI report EA-793, Project 432-1, Vol. 1, p. S-3, June 1978.

Determination of seasonal efficiency for central air conditioners

Direct use of ARI efficiency values	Calculation of efficiency values developed from DOE-2.1A Modeling
Step 1a: Select appropriate EER or SEER value from the ARI Directory or other source as available. Default EER values are given below. Where only EER values are available, let SEER = EER for this procedure.	**Step 1b**: Select appropriate EER value from the ARI Directory or other source as available. Default EER values are given below. Where only published SEER values are available, let EER = SEER for this procedure.

Year of manufacture	EER
After 1982	8.2
1980–1982	8.0
1978–1980	7.6
1976–1978	7.2
1972–1976	6.5
Before 1972	6.0

Step 2a: Proceed to Step 3.

Step 2b: Select weather-related multiplier from map (next page). Then perform the following calculation:

SEER = EER × multiplier.

Step 3: Seasonal efficiency = SEER × 100/3.412. For gas air conditioners, assume a seasonal efficiency of 45%.

SEER	Seasonal efficiency (%)
3.0	88
3.5	103
4.0	117
4.5	132
5.0	147
5.5	161
6.0	176
6.5	190
7.0	205
7.5	220
8.0	234
8.5	249
9.0	264
9.5	278
10.0	293
10.5	308
11.0	322
11.5	337
12.0	352

Step 4: Oversize multiplier = 1 − (0.002 × %oversize). For oversize units, multiply seasonal efficiency obtained in Step 3 by oversize multiplier to obtain final seasonal efficiency value.

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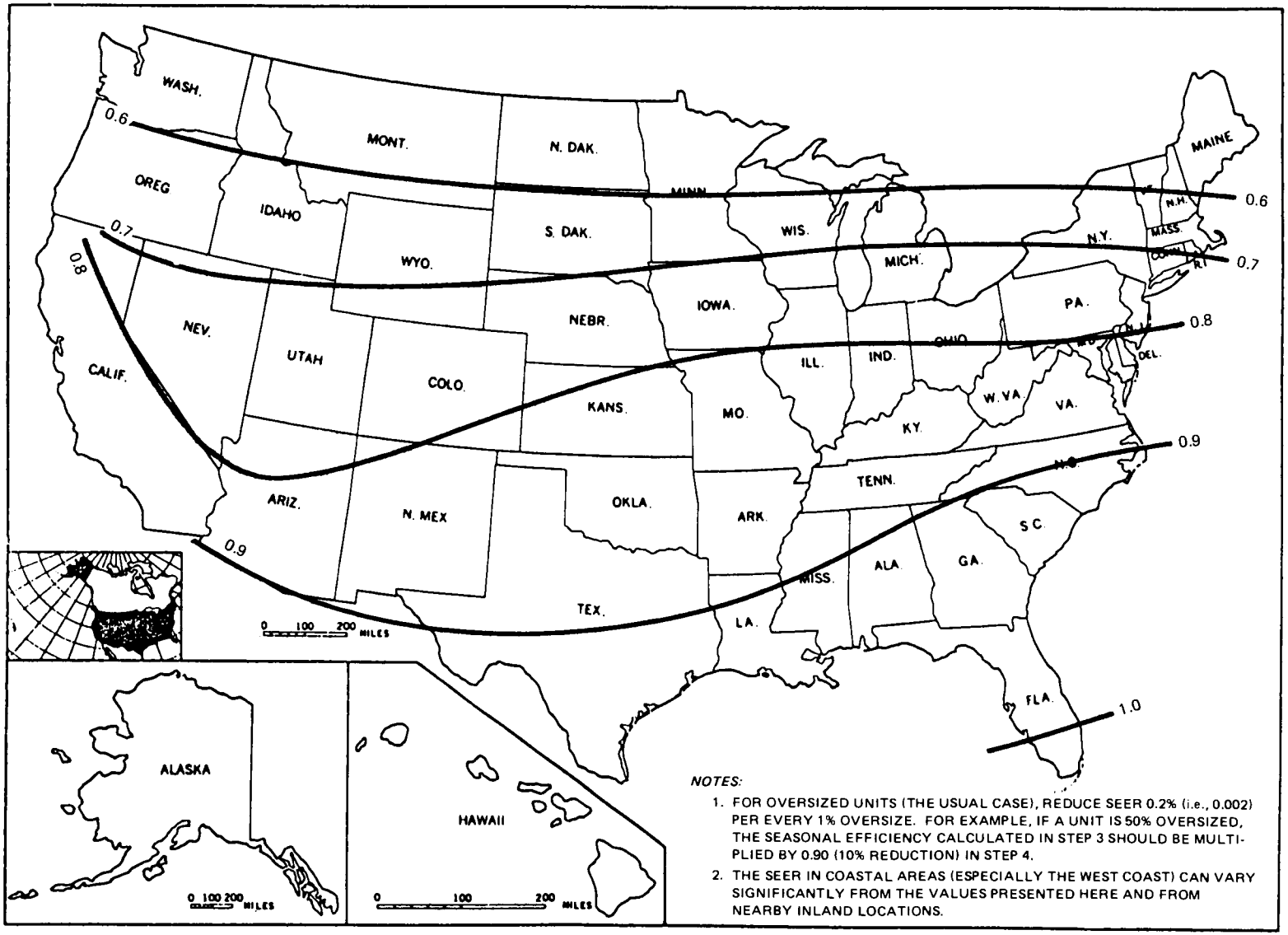
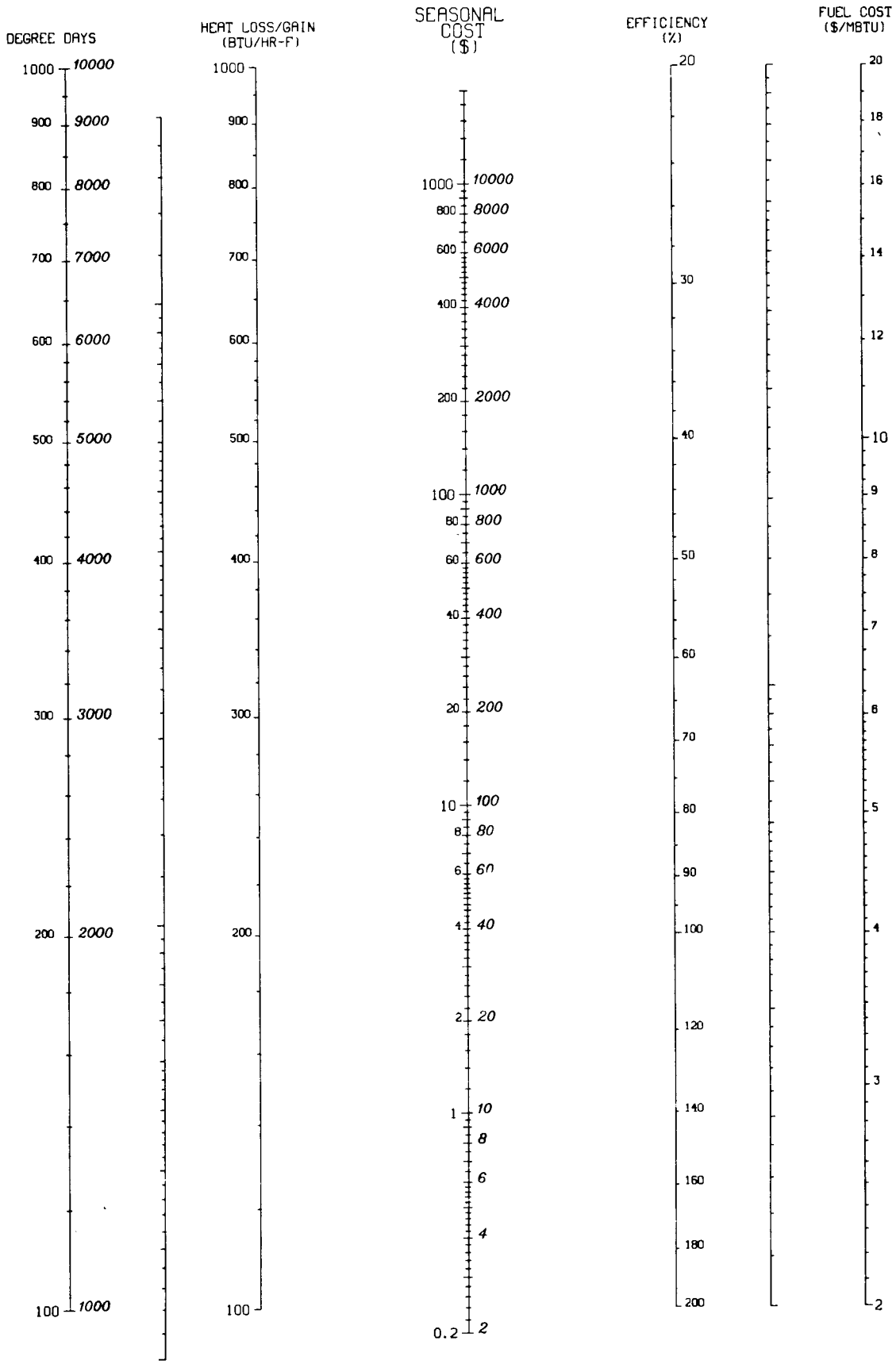


Fig. E.5.1. Multiplier for EER to determine SEER for an air conditioning unit of proper size.

E.6 HEATING/COOLING NOMOGRAM

Because most copiers produce some distortion, using a copy made from another copy of this page may reduce the accuracy unacceptably.


DEGREE DAYS
1000 10000
900 9000
800 8000
700 7000
600 6000
500 5000
400 4000
300 3000
200 2000
100 1000
HEAT LOSS/GAIN (BTU/HR-F)
1000
900
800
700
600
500
400
300
200
100
SEASONAL COST ($)
1000 10000
800 8000
600 6000
400 4000
200 2000
100 1000
80 800
60 600
40 400
20 200
10 100
8 80
6 60
4 40
2 20
1 10
8
6
4
0.2 2
EFFICIENCY (%)
20
30
40
50
60
70
80
90
100
120
140
160
180
200
FUEL COST ($/MBTU)
20
18
16
14
12
10
9
8
7
6
5
4
3
2

E.7. ENERGY CONSERVATION MEASURES

Domestic hot water measure—energy cost

Fuel type	Multiplier		Local fuel cost		Energy cost ($/10^6 Btu)
Electricity	3.0	×	_____ (¢/kwh)	=	_____
Natural gas	0.14	×	_____ [¢/(100 ft^3)]	=	_____
No. 2 fuel oil (distillate)	0.10	×	_____ (¢/gal)	=	_____
LP gas	0.15	×	_____ (¢/gal)	=	_____

Conditioned space water heater insulation (annual hours above 65°F)

State	HUD/MPS zone	Hours	Weather station
Alabama	2	4445	Columbia, SC
Alabama	3	4460	Meridian, MS
Alaska	8	10	Adak, AK
Arizona	1	5350	Phoenix, AZ
Arizona	2	5350	Phoenix,AZ
Arizona	3	5350	Phoenix, AZ
Arizona	4	5350	Phoenix, AZ
Arizona	5	3275	Prescott, AZ
Arizona	6	2435	Winslow, AZ
Arizona	7	1600	Bryce Canyon, UT
Arkansas	3	4840	Shreveport, LA
Arkansas	4	4175	Fort Smith, AR
California	2	3520	Daggett, CA
California	3	3480	Fresno, CA
California	4	3290	Red Bluff, CA
California	5	3290	Red Bluff, CA
California	6	3290	Red Bluff, CA
California	7	2560	Lovelock, NV
California	8	2290	Burns, OR
Colorado	6	3375	Amarillo, TX
Colorado	7	2890	Grand Junction, CO
Colorado	8	1870	Eagle, CO
Connecticut	6	2260	Boston, MA
Delaware	4	1545	Philadelphia, PA
D.C.	4	2960	Norfolk, VA
Florida	1	5360	Tampa, FL
Florida	2	5385	Tallahassee, FL
Georgia	2	5385	Tallahassee, FL
Georgia	3	4445	Columbia, SC
Georgia	4	3845	Chattanooga, TN

Conditioned space water heater insulation (continued)

State	HUD/MPS zone	Hours	Weather station
Hawaii	1	4285	Honolulu, HI
Idaho	7	1920	Pocatello, ID
Idaho	8	2035	Boise, ID
Illinois	4	3420	Evansville, IN
Illinois	5	3580	Kansas City, MO
Illinois	6	2945	Indianapolis, IN
Illinois	7	2310	Lacrosse, WI
Indiana	4	3420	Evansville, IN
Indiana	5	2945	Indianapolis, IN
Indiana	6	2945	Indianapolis, IN
Indiana	7	2185	Grand Rapids, MI
Iowa	6	2695	Sioux City, IA
Iowa	7	2695	Sioux City, IA
Iowa	8	2695	Sioux City, IA
Kansas	4	3580	Kansas City, MO
Kansas	5	3450	Wichita, KS
Kansas	6	3220	Dodge City, KS
Kansas	7	3220	Dodge City, KS
Kentucky	4	3420	Evansville, IN
Kentucky	5	2945	Indianapolis, IN
Kentucky	6	2815	Columbus, OH
Louisiana	2	5470	Lake Charles, LA
Louisiana	3	4840	Shreveport, LA
Maine	8	1060	Caribou, ME
Maryland	4	2960	Norfolk, VA
Maryland	5	1545	Philadelphia, PA
Maryland	6	3335	Charleston, WV
Massachusetts	6	2260	Boston, MA
Massachusetts	7	1220	Portland, ME
Michigan	7	2185	Grand Rapids, MI
Michigan	8	2185	Grand Rapids, MI
Minnesota	8	1895	Fargo, ND
Mississippi	2	4460	Meridian, MS
Mississippi	3	4460	Meridian, MS
Missouri	4	3400	Springfield, MO
Missouri	5	3580	Kansas City, MO
Missouri	6	3580	Kansas City, MO
Montana	8	1540	Cut Bank, MT
Nebraska	6	3580	Kansas City, MO
Nebraska	7	2695	Sioux City, IA
Nebraska	8	2140	Scottsbluff, NB
Nevada	2	2390	Tonopah, NV
Nevada	3	2390	Tonopah, NV
Nevada	4	2390	Tonopah, NV
Nevada	5	2390	Tonopah, NV
Nevada	6	2390	Tonopah, NV
Nevada	7	2560	Lovelock, NV
Nevada	8	2230	Elko, NV
New Hampshire	7	1220	Portland, ME
New Hampshire	8	1845	Burlington, VT
New Jersey	5	1545	Philadelphia, PA
New Jersey	6	1545	Philadelphia, PA

Conditioned space water heater insulation (continued)

State	HUD/MPS zone	Hours	Weather station
New Mexico	3	4490	El Paso, TX
New Mexico	4	4490	El Paso, TX
New Mexico	5	3985	Roswell, NM
New Mexico	6	3340	Albuquerque, NM
New Mexico	7	3340	Albuquerque, NM
New Mexico	8	1870	Eagle, CO
New York	6	2260	Boston, MA
New York	7	2235	Wilkes-Barre, PA
New York	8	1080	Binghamton, NY
North Carolina	2	4660	Charleston, SC
North Carolina	3	4660	Charleston, SC
North Carolina	4	3460	Richmond, VA
North Carolina	5	3335	Charleston, WV
North Dakota	8	1895	Fargo, ND
Ohio	5	2815	Columbus, OH
Ohio	6	2815	Columbus, OH
Ohio	7	2945	Indiannapolis, IN
Oklahoma	3	4865	Dallas, TX
Oklahoma	4	4005	Tulsa, OK
Oklahoma	5	3220	Dodge City, KS
Oklahoma	6	3375	Amarillo, TX
Oregon	4	1525	Salem, OR
Oregon	5	1525	Salem, OR
Oregon	6	2290	Burns, OR
Oregon	7	2290	Burns, OR
Oregon	8	2290	Burns, OR
Pennsylvania	5	1545	Philadelphia, PA
Pennsylvania	6	2235	Wilkes-Barre, PA
Pennsylvania	7	1080	Binghamton, NY
Pennsylvania	8	1080	Binghamton, NY
Rhode Island	6	2260	Boston, MA
South Carolina	2	4660	Charleston, SC
South Carolina	3	4445	Columbia, SC
South Carolina	4	3845	Chattanooga, TN
South Dakota	7	2695	Sioux City, IA
South Dakota	8	2695	Sioux City, IA
Tennessee	3	4265	Memphis, TN
Tennessee	4	4265	Memphis, TN
Tennessee	5	3335	Charleston, WV
Texas	1	6350	Kingsville, TX
Texas	2	4570	San Angelo, TX
Texas	3	4345	Wichita Falls, TX
Texas	4	3375	Amarillo, TX
Texas	5	3375	Amarillo, TX
Utah	5	2890	Grand Junction, CO
Utah	6	1600	Bryce Canyon, UT
Utah	7	2535	Salt Lake City, UT
Utah	8	2535	Salt Lake City, UT
Vermont	7	1220	Portland, ME
Vermont	8	1845	Burlington, VT
Virginia	3	2960	Norfolk, VA
Virginia	4	3460	Richmond, VA
Virginia	5	3460	Richmond, VA
Virginia	6	3335	Charleston, WV

Conditioned space water heater insulation (continued)

State	HUD/MPS zone	Hours	Weather station
Washington	6	885	Tacoma, WA
Washington	7	1620	Spokane, WA
Washington	8	2230	Yakima, WA
West Virginia	5	3335	Charleston, WV
West Virginia	6	3335	Charleston, WV
Wisconsin	7	2310	Lacrosse, WI
Wisconsin	8	2310	Lacrosse, WI
Wyoming	7	2140	Scottsbluff, NB
Wyoming	8	1450	Rock Springs, WY
Puerto Rico	1	8750	San Juan, PR

Conditioned space water heater insulation correction factor[a]

Number of hours per year greater than 65°F	Correction factor
8000	0.90
6000	0.70
4000	0.45
3000	0.35
1000	0.10

[a]Values may be interpolated.

Residential heating savings with an 8-h nighttime period in which thermostats are set back

HUD/MPS region	Percent savings		
	Set back 5°F	Set back 10°F	Set back 15°F
1	14	19	21
2	11	15	17
3	10	14	16
4,5	9	12	14
6,7	8	11	12
8	7	10	11

Energy savings for intermittent ignition devices

HUD/MPS region	Savings (10^6 Btu)	
	Continuous pilot	Pilot on only during heating season
1	6.7	0.4
2	6.2	1.1
3	5.7	1.7
4	5.3	2.3
5	5.2	2.5
6	5.1	2.6
7	5.0	2.7
8	4.9	2.8

E.8 SOLAR FACTORS AND ACTIVE SOLAR MEASURES

The data for the active solar measures are on microfiche. See the inside of the back cover. Examples are given below.

California
HUD/MPS 4

REGION SPECIFIC SOLAR FACTORS

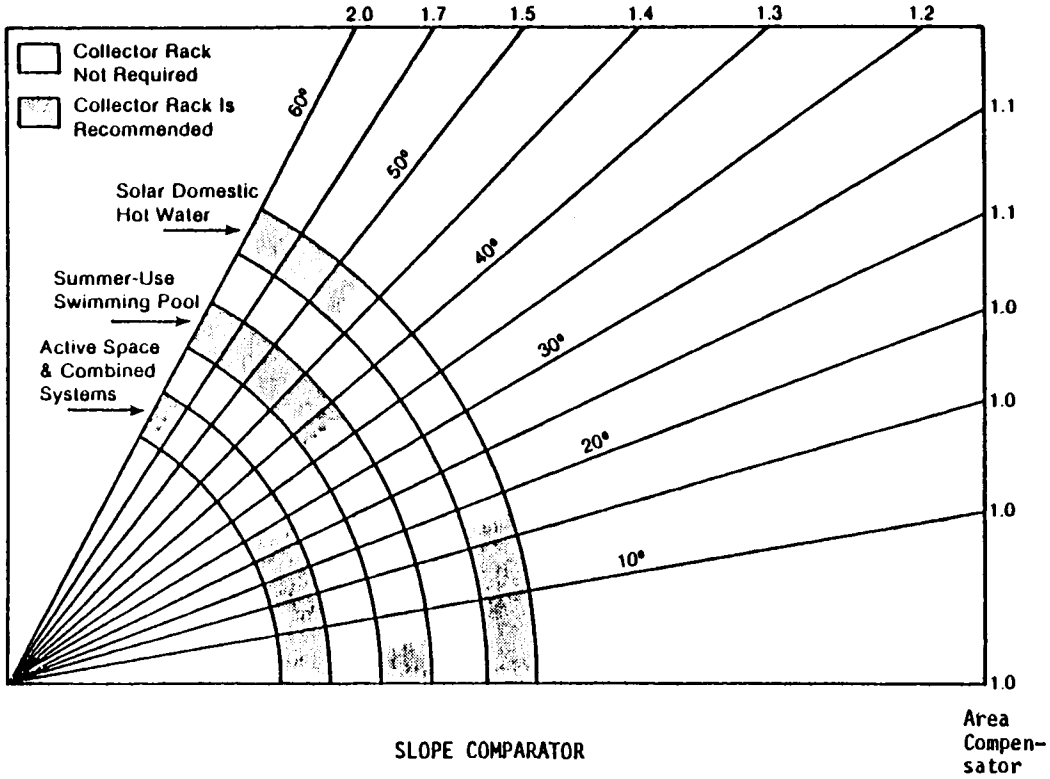
ACTIVE MEASURES

1. Solar Domestic Hot Water (SDHW)
   Minimum PSF: .50 Target SSF: .70
2. Combined Space and Domestic Hot Water
   Minimum PSF: .90 Target SSF: .40
3. Active Space Heating
   Minimum PSF: .90 Target SSF: .30
4. Replacement Pool Heating
   Minimum PSF: .30

PASSIVE MEASURES

1. Direct Gain Minimum PSF: .40
2. Indirect Gain Trombe Wall Minimum PSF: .40
3. Indirect Gain Water Wall Minimum PSF: .40
4. Indirect Gain Thermosiphon Air Panel (TAP) Minimum PSF: .40
   energy saved (10^6 Btu/ft^2/yr) .04
5. Sunspace Minimum PSF: .40

	South	East/West	North
6. Window Heat Gain Retardants energy saved (10^6 Btu/ft^2/yr)	.12	.15	.05
7. Heat Reflecting Window and Door Material energy saved (10^6 Btu/ft^2/yr)	.09	.11	.04
8. Heat Absorbing Window and Door Material energy saved (10^6 Btu/ft^2/yr)	.03	.03	.01



SLOPE COMPARATOR

FOR USE BETWEEN 28° AND 36° LATITUDE

SOLAR DOMESTIC HOT WATER

PREFERRED ORIENTATION 0 - 15 DEGREES FROM TRUE SOUTH

RES USE GPD	ANN USE MILL BTU	COLLECTOR AREA REQUIRED (SQ FT) FOR PRIME SOLAR FRACTION (PSF) = 1.0 .2 SSF	.3 SSF	.4 SSF	.5 SSF	.6 SSF	.7 SSF	.8 SSF	.9 SSF
20	3						16	23	37
30	5					17	24	35	58
40	7				17	23	32	48	75
50	9			15	21	29	40	58	93
60	10			19	26	35	46	73	117
70	12		15	22	30	40	54	81	133
80	14		17	25	34	45	63	99	150
90	16		19	28	38	52	70	105	174
100	17		22	31	42	58	80	115	183
110	19	15	24	34	46	62	84	128	212
120	21	16	26	37	51	69	95	147	229
130	22	18	28	41	55	73	104	155	253
140	24	19	31	43	59	81	107	167	264
150	26	21	33	46	64	86	117	185	280
160	28	22	34	50	68	90	125	192	302
170	29	23	37	53	73	97	131	198	323
180	31	25	39	56	76	102	141	207	331
190	33	26	41	59	81	107	150	232	353

STATE CA
HUD/MPS 4

SOLAR DOMESTIC HOT WATER

ACCEPTABLE ORIENTATION 15 - 45 DEGREES FROM TRUE SOUTH

RES USE GPD	ANN USE MILL BTU	COLLECTOR AREA REQUIRED (SQ FT) FOR PRIME SOLAR FRACTION (PSF) = 1.0 .2 SSF	.3 SSF	.4 SSF	.5 SSF	.6 SSF	.7 SSF	.8 SSF	.9 SSF
20	3						16	26	39
30	5					18	25	38	61
40	7				17	23	32	51	78
50	9			16	22	30	41	64	99
60	10			19	26	35	49	76	120
70	12		15	22	30	42	58	93	145
80	14		18	26	35	47	65	101	161
90	16		20	28	39	52	75	119	186
100	17		22	32	43	59	81	134	200
110	19	15	24	35	48	64	91	143	225
120	21	16	26	38	52	70	101	153	235
130	22	18	29	41	57	77	108	168	265
140	24	19	31	45	60	83	118	185	280
150	26	21	33	48	66	88	123	190	301
160	28	22	35	51	69	95	130	213	321
170	29	23	37	54	74	101	144	226	348
180	31	25	40	58	78	106	149	231	352
190	33	26	42	60	82	113	155	253	372

STATE CA
HUD/MPS 4

SOLAR SPACE HEATING

PREFERRED ORIENTATION 0 - 15 DEGREES FROM TRUE SOUTH

EFF HEAT BTU /HR-FT	COLLECTOR AREA REQUIRED (SQ FT) FOR PRIME SOLAR FRACTION (PSF) = 1.0						
	.3 SSF	.4 SSF	.5 SSF	.6 SSF	.7 SSF	.8 SSF	.9 SSF
300	53	98	146	214	312	447	602
400	83	132	200	297	413	587	818
500	105	163	251	367	522	754	983
600	127	195	292	429	621	890	1196
700	145	234	351	505	737	1044	1424
800	165	263	399	592	862	1168	1623
900	186	302	438	650	958	1339	1792
1000	210	327	501	732	1039	1496	2097
1100	229	365	540	809	1154	1609	2209
1200	254	399	593	862	1244	1774	2372
1300	273	429	641	949	1368	1896	2641
1400	293	467	699	1006	1463	2065	2906
1500	313	497	747	1092	1586	2187	3073
1600	332	526	796	1178	1709	2307	3191
1700	352	565	834	1217	1823	2494	3373
1800	371	603	892	1312	1916	2660	3535
1900	391	623	930	1389	1992	2734	3899
2000	420	652	998	1455	2132	3020	4175
2100	439	691	1036	1493	2245	3130	4282
2200	459	729	1074	1607	2356	3239	4338

STATE CA
HDD/HDS 1

SOLAR SPACE HEATING

ACCEPTABLE ORIENTATION 15 - 45 DEGREES FROM TRUE SOUTH

EFF HEAT BTU /HR-FT	COLLECTOR AREA REQUIRED (SQ FT) FOR PRIME SOLAR FRACTION (PSF) = 1.0						
	.3 SSF	.4 SSF	.5 SSF	.6 SSF	.7 SSF	.8 SSF	.9 SSF
300	68	110	168	246	353	498	643
400	90	149	227	333	469	643	973
500	112	180	278	413	547	818	1124
600	137	219	336	491	703	972	1277
700	161	258	394	568	919	1125	1580
800	161	297	452	665	934	1315	1769
900	205	331	506	737	1044	1424	2027
1000	225	361	554	824	1168	1623	2223
1100	254	409	602	910	1292	1746	2343
1200	273	438	670	977	1435	1962	2556
1300	293	477	728	1073	1529	2130	2970
1400	322	516	786	1169	1624	2224	3109
1500	342	555	824	1245	1775	2372	3254
1600	361	594	901	1321	1850	2595	3472
1700	391	623	930	1388	1992	2734	3607
1800	410	661	1007	1464	2142	2931	4041
1900	430	700	1046	1573	2254	3065	4219
2000	449	739	1122	1654	2328	3211	4360
2100	473	768	1151	1759	2505	3384	4528
2200	508	816	1237	1843	2588	3611	4748

STATE CA
HDD/HDS 1

SOLAR POOL HEATING
COLLECTOR AREA REQUIRED AND HEAT LOSS

COVERED POOL

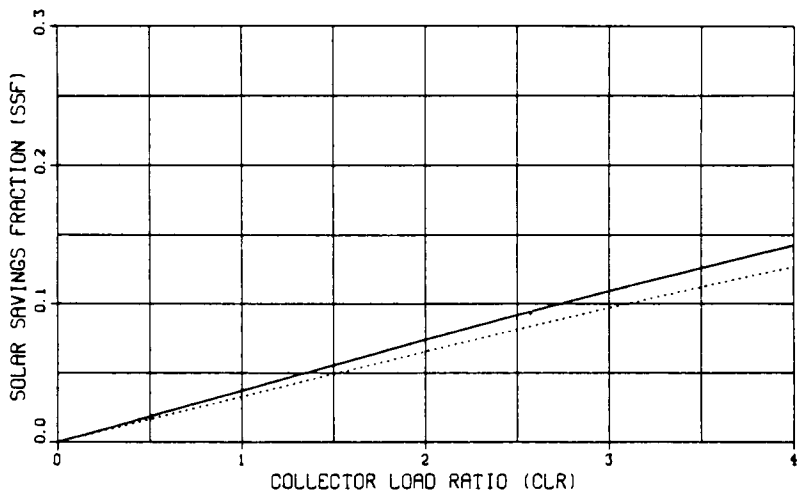
Pool Area (ft^2)	WELL SHIELDED FROM WIND				MODERATELY SHIELDED FROM WIND				OPEN TO WIND			
	Annual Btu ($x10^6$)	0.3 SSF	0.4 SSF	0.5 SSF	Annual Btu ($x10^6$)	0.3 SSF	0.4 SSF	0.5 SSF	Annual Btu ($x10^6$)	0.3 SSF	0.4 SSF	0.5 SSF
300									2	2	2	3
350									2	2	3	3
400									3	2	3	4
450									3	3	3	4
500									3	3	4	5
550									3	3	4	5
600									4	3	4	6
650									4	4	5	6
700									4	4	5	7
750									5	4	6	7
800									5	4	6	7

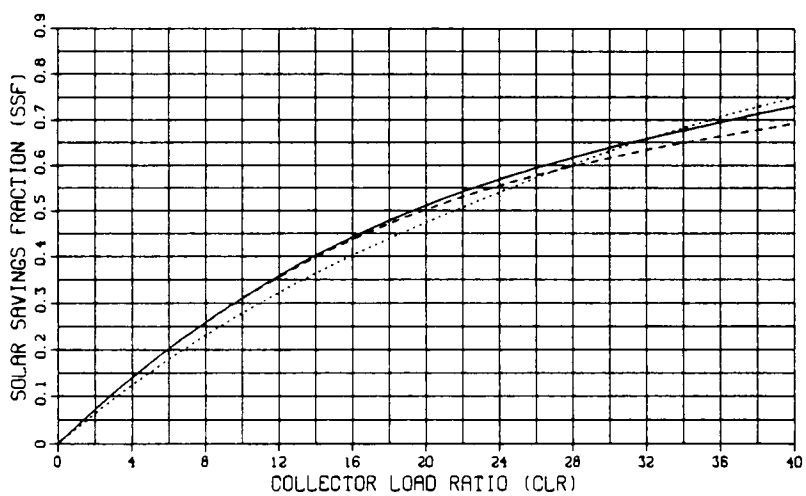
State: California
HUD/MPS 4

E.9 PASSIVE SOLAR MEASURES

The data for the passive solar measures are on microfiche. See the inside of the back cover. An example is given below.

PASSIVE SOLAR MEASURES

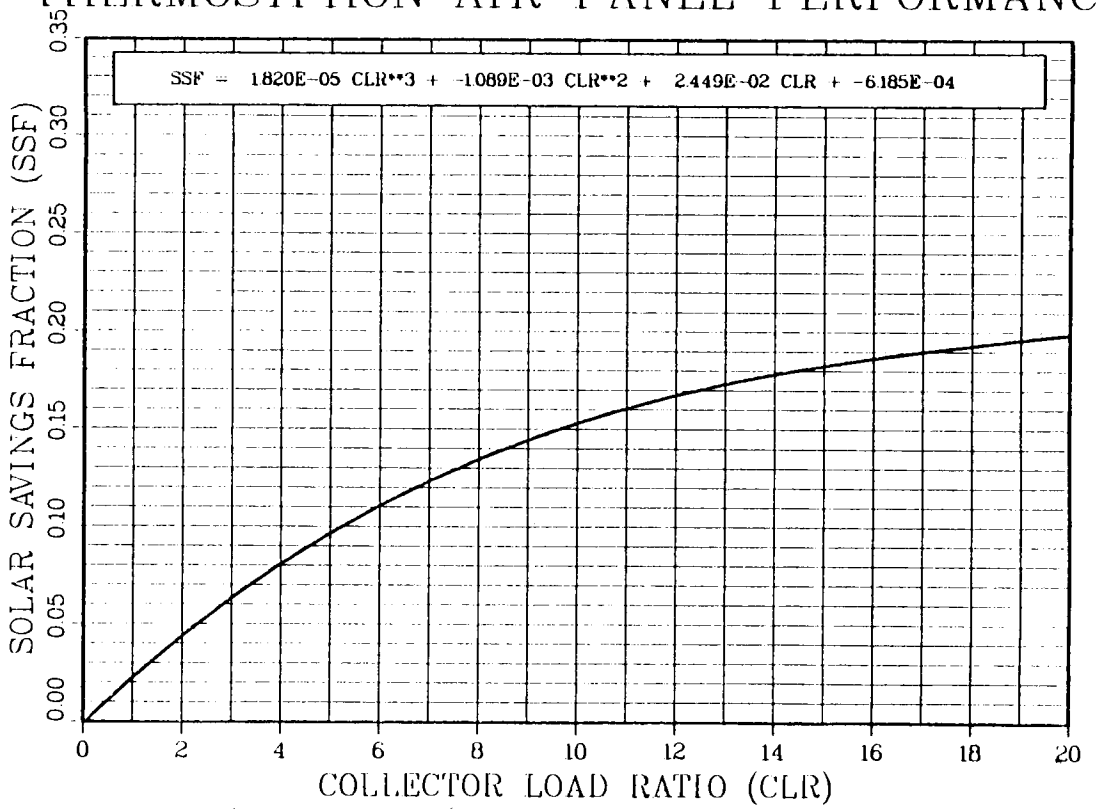




STATE CA
HUD/MPS 4

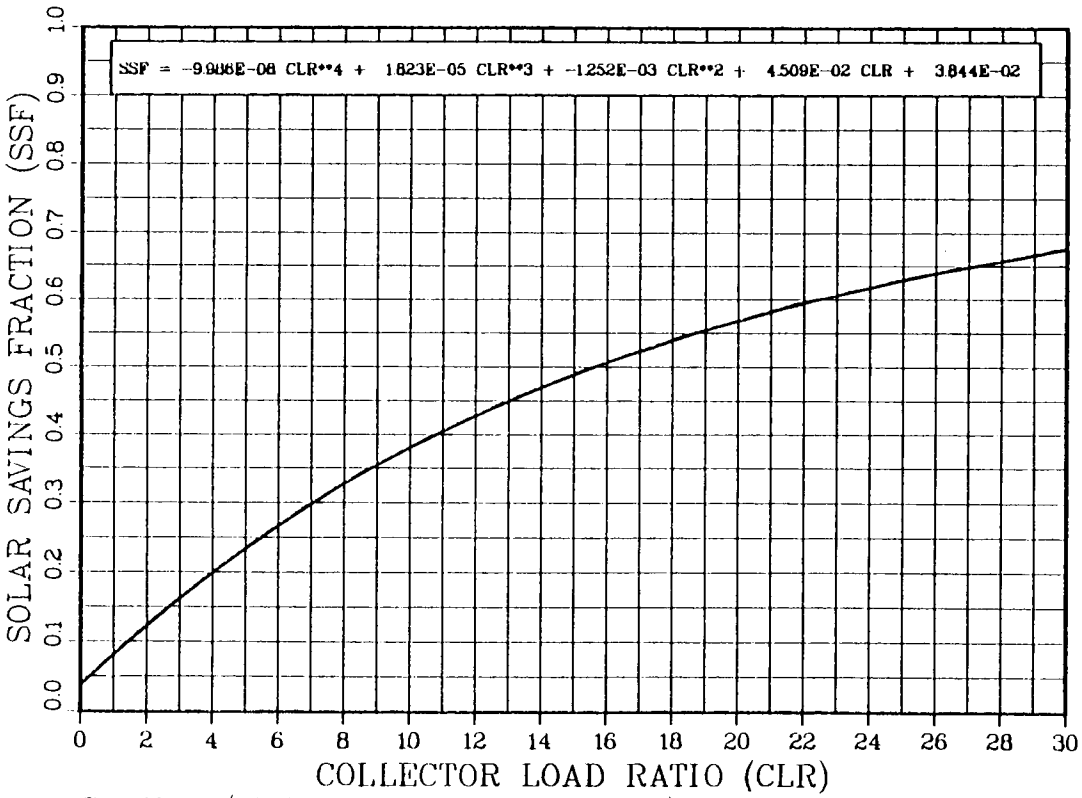
LEGEND
DIRECT GAIN MEDIUM CONSTRUCTION
DIRECT GAIN LIGHT CONSTRUCTION
AVERAGE OF WATER WALL AND TROMBE WALL

THERMOSIPHON AIR PANEL PERFORMANCE



CA HUD/MPS 4 (RED BLUFF CA)

SUNSPACE PERFORMANCE



CA HUD/MPS 4 (RED BLUFF CA)

E.10 WIND ENERGY MEASURES

The data for the wind energy measures are on microfiche. See the inside of the back cover. An example and the remaining data for these measures are given below.

AVERAGE ANNUAL WIND SPEEDS
(Adjusted to 35' Height)

State: California

Station	Wind Speed (MPH)	Station	Wind Speed (MPH)	Station	Wind Speed (MPH)
Alameda	8.3	Livermore	6.5	Sacramento/MC.	6.7
Arcata	6.9	Long Beach	7.2	Salinas	8.1
Bakersfield	6.7	Los Alamitos	5.6	San Bernardino	3.8
Beale	6.5	Los Angeles	7.8	San Clemente	7.8
Bishop	9.0	Merced/Castle	6.7	Sandberg	13.7
Blue Canyon	8.1	Miramar	5.6	San Diego/INT.	7.2
Blythe	8.1	Mojave	9.4	San Diego	6.7
Burbank	5.6	Montague	7.6	San Francisco	11.0
Burney	6.5	Monterey	6.0	San Jose	8.3
Camp Pendleton	5.6	Mount Laguna	22.0	San Nicholas	11.9
China Lake	7.2	Mount Shasta	6.5	San Pedro	5.4
Chula Vista	6.3	Mount Wilson	9.6	San Rafael/HA.	5.6
Concord	9.6	Needles	8.5	Santa Ana	8.5
Crescent City	9.9	Oakland	9.2	Santa Barbara	5.2
Cuddeback	7.6	Oakland	9.0	Santa Catalina	7.2
Daggett	11.6	Oceanside	7.4	Santa Maria	8.3
Donner Summit	14.3	Ontario	8.1	Santa Maria	9.9
Edwards	9.4	Oxnard	5.4	Santa Rosa	7.4
El Centro	8.5	Palmdale	10.3	Silver Lake	8.7
El Toro	6.0	Paso Robles	6.7	Stockton	8.7
Fairfield/TRV.	11.4	Point Arguello	9.0	Sunnyvale/MOF.	6.3
Fort Ord	6.5	Point Mugu	6.9	Thermal	8.7
Fresno	6.7	Red Bluff	9.2	Ukiah	4.3
Fresno	6.5	River/MAR.	4.7	Vandenberg/CO.	7.6
Imperial Beach	6.7	Sacramento	8.5	Vandenberg	10.8
Indio	7.2	Sacramento	8.3	Victorville/G.	8.7
Jolon	3.4	Sacramento/MA.	6.5	Williams	8.3
Lemoore	6.5				

ADJUSTMENT FACTOR FOR TOWER HEIGHT

AND SURFACE ROUGHNESS

ROUGHNESS CHARACTER OF SITE	TOWER HEIGHT 40	60	80
OCEAN, SAND	1.5	1.6	1.6
GRASS, CROPS	1.2	1.2	1.3
LOW WOODS, RURAL	1.0	1.1	1.2
HIGH WOODS, SUBURBS	0.8	0.9	0.9
FOREST, CITY	0.6	0.7	0.7

TERRAIN SHELTER ADJUSTMENT FACTOR

TERRAIN CODE	BETTER EXPOSURE	TYPICAL EXPOSURE	SLIGHTLY SHELTERED	VERY SHELTERED
1 (Plains)	1.	1.	1.	1.
2 (Rolling Plains)	1.1	1.	0.9	0.9
3 (Hills)	1.1	1.	0.9	0.7
4 (Dense Hills)	1.2	1.	0.8	0.6
5 (Open Mountains)	1.2	1.	0.7	0.5
6 (Mountains)	1.2	1.	0.6	0.3

COST / ANNUAL ENERGY OUTPUT (KWH)
OF GENERIC WIND SYSTEMS

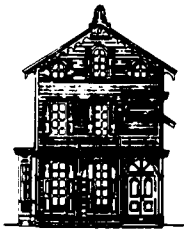
WIND SYSTEMS (SWECS)*	2KW	4KW	6KW	8KW	10KW
INSTALLED SWECS COST ($)*	4200	6800	8600	11200	12400
INSTALLED TOWER COST ($)-40'*			1800		
INSTALLED TOWER COST ($)-60'*			2400		
INSTALLED TOWER COST ($)-80'*			2800		
MAINTENANCE COST ($)*	100	100	150	150	200
ROTOR DIAMETER	12'	16'	25'	30'	32'
RATED POWER	2KW	4KW	6KW	8KW	10KW
RATED WIND SPEED (MPH)	20	20	20	20	20
CUT-IN SPEED (MPH)	9	9	9	9	9

ADJUSTED ANNUAL AVERAGE WIND SPEED (MPH)	SWECS ANNUAL OUTPUT ON KWH				
10	2800	4000	5900	7800	9800
10.5	3200	4700	7000	9300	11600
11	3600	5400	8100	10700	13300
11.5	4000	6100	9100	12000	14900
12	4500	6800	10000	13300	16600
12.5	4800	7500	11100	14700	18500
13	5200	8200	12300	16400	20400
13.5	5600	8900	13400	17900	22300
14	6000	9600	14200	18800	24200
14.5	6400	10300	15600	20900	26200
15	6800	11100	16800	22500	28100
15.5	7100	11800	17900	24000	30100
16	7400	12600	19100	25600	32000
16.5	7700	13200	20500	27800	34000
17	7900	13800	21200	28600	36000
17.5	8200	14400	22100	29800	37500
18	8500	15000	22700	30400	38000
18.5	8650	15500	23500	31500	39400
19	8800	16000	24300	32600	40900
19.5	8950	16500	25100	33700	42300
20	9100	17000	25900	34800	43800

*Estimate - manufacturers should be consulted for specific machines and machine costs.

F. Findings and Recommendations

This section is a sample Audit Results form, which can be given to the customer at the conclusion of an RCS audit and which contains the specific cost and savings information that result from the audit of that customer's house.



Audit Results

Residential Conservation Service
Home Energy Audit

Your Utility Company

LOGO

Prepared for: _____

Address: _____

Telephone: _____ Date: _____

Auditor: _____

Telephone: _____

Your present annual energy costs are estimated to be:

Heating: $_____ Hot water: $_____ Cooling: $_____

These are used as the basis for your audit savings estimates.

Energy Conservation Practices

The following suggestions have little or no cost and yet can be the most effective steps you can take to reduce your energy bills. The Department of Energy estimates that average customers who follow these suggestions may save up to 25% of their energy costs. Your auditor has indicated which of these suggestions would make sense in your home. See your utility company's Program Announcement for individual estimates of savings. Try these before you spend money on more expensive energy-saving ideas!

- ◯ Modify furnace efficiency by cleaning and adjusting combustion efficiency of gas or oil furnaces, cleaning or replacing air filters, lowering bonnet or plenum thermostats to 80° F on gas or oil furnaces, and turning off the pilot light on gas furnaces in summer.
- ◯ Lower nighttime thermostat setting to 55° F in winter.
- ◯ Lower daytime thermostat setting to 68° F in winter.
- ◯ Raise thermostat setting of air conditioner to 78° F in summer.
- ◯ Reduce water flow in showers and faucets with flow-limiting devices.
- ◯ Reduce hot water temperature by lowering the thermostat setting to 120° F and reduce use of heated water for clothes washing.
- ◯ Reduce energy use when not at home.
- ◯ Plug leaks in attics, basements and fireplaces.
- ◯ Seal leaks in pipes and ducts.
- ◯ Use shades and drapes to allow sunlight to enter and to keep out cold.

See "Your Home Energy Audit: The First Step to More Energy-Efficient Living" for more information about these energy-conserving practices.

A checked box indicates that these practices could be done in your home for energy savings.

		CONSERVATION MEASURES		ESTIMATES		
		MEASURE	CURRENT STATUS	Self-installed costs	Contractor-installed costs	First year energy cost savings
Tightening up	1	Caulking	☐			
	2	Weatherstripping	☐			
Insulation	3	Ceiling/attic insulation existing type, present depth, present R value	☐			
	4	Wall insulation	☐			
	5	Floor insulation	☐			
	6	Water heater insulation	☐			
	7	Duct/pipe insulation	☐			
Windows doors	8	Storm/thermal windows/doors	☐			
	9	Heat reflective/ absorbing material	☐			
Heating system	10	Clock thermostat	☐			
	11	Electric load management devices	☐			
	12	Replacement furnaces, boilers, or heat pumps	☐			
	13	Replacement oil burner	☐			
	14	Vent damper	☐			
	15	Electric ignition system	☐			
Cooling system	16	Replacement central air conditioners	☐			
		RENEWABLE RESOURCE MEASURES				
Active systems	17	Solar hot water heater	☐			
	18	Solar heating system	☐			
	19	Combined solar hot water and heating system	☐			
	20	Replacement solar swimming pool heater	☐			
Passive systems	21	Direct gain glazing systems	☐			
	22	Indirect gain systems	☐			
	23	Solar greenhouse	☐			
	24	Window heat gain retardant devices	☐			
Wind	25	Wind energy system	☐			$ to $ at mph

COMMENTS:

A checked box indicates that these measures could be done in your home for energy savings.

Read your RCS booklet for information about these measures and which ones may be eligible for federal income tax credits.

Prepared for _____

Address _____

Phone _____

Auditor _____

Date _____

COMMENTS

1 location

2 location

3 location

4 total wall area, thickness and type

5 insulated area, thickness and type

6

7 ducts or pipes

8 windows, doors, number, size

9 orientation, area in ft^2, meets ____% of cooling need

10

11 type of device, annual maintenance cost

12 annual maintenance cost

13 annual maintenance cost

14

15

16

☐ Roof needs inspection before solar installation ☐ Roof seems normal*

17 Collector area _____ ft^2 Storage tank _____ gals. Meets _____ % annual need

18 Collector area _____ ft^2 Storage tank _____ gals. Meets _____ % annual need

19 Collector area _____ ft^2 Storage tank _____ gals. Meets _____ % annual need

20 Collector area _____ ft^2 Storage tank _____ gals. Meets _____ % annual need

21 Meets _____ % annual need Size _____ X _____

22 ☐ Water wall ☐ Thermosyphon air panel
☐ Trombe wall Size _____ X _____ Meets _____ % annual need

23 Meets _____ % annual need Size _____ X _____ X _____

24 ☐ Awning ☐ Roll-up shades ☐ Solar screens ☐ Rigid movable insulation ☐ Films
Useful area _____ ft^2 Offsets _____ % cooling need

25 See Wind Energy System form

COMMENTS:

Active Solar: freeze protection, site preparation, physical connections needed with existing heating system.

Passive Solar: collection storage characteristics.

*NOTE: The audit roof inspection has not been a structural assessment.

TAX INCENTIVE WORKSHEET

This worksheet presents examples of how tax incentives can reduce your costs for energy conservation and renewable resource measures. The figures below are calculated for two of the measures appropriate for your home.

ENERGY CONSERVATION MEASURE _____

Estimated contractor installed* cost (up to $2,000)	$ _____	
Less 15% of installed cost	– _____	Federal income tax credit
Less _____% of installed cost	– _____	State tax credit
Total cost to consumer (after tax returns submitted)	$ [ ]	

RENEWABLE RESOURCE MEASURE _____

Estimated contractor installed cost (up to $10,000)	$ _____	
Less 40% of installed cost	– _____	Federal income tax credit
Less _____% of installed cost	– _____	State tax credit
Total cost to consumer (after tax returns submitted)	$ [ ]	

*Material cost for self-installed measures is also eligible for federal tax incentives.

NOTES:

(1) Each measure will save a certain amount of your energy costs, but savings are not in every case simply additive. Different measures that affect the heating system, for example, may overlap in their savings effect on your utility bill. When you decide to install appropriate measures and these result in significant energy savings, you will realize these savings on your fuel bill.

(2) Auditor's Notes:

G. Specifications

The specifications are on microfiche; see the inside of the back cover. Each specification page is as current as the date given on the form.

Appendix A

Geographic Breakdown of HUD/MPS Zones by State at the County Level

This appendix shows the distribution of counties in each state by HUD/MPS Climatic Zone. The zones were determined by overlaying a national heating degree-day isoline map on a county map of the United States. Each county was assigned to the specific climatic zone in which the largest portion of its geographic area lies. In some instances, states transected by multiple climatic zones do not have counties assigned to every zone. This is attributable to the fact that only small areas of the counties are in those zones. County lists for each state are based on the latest available breakdown of political jurisdictions in the United States.

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Alabama	2	Autauga, Baldwin, Barbour, Bullock, Butler, Choctaw, Clarke, Coffee, Conecuh, Covington, Crenshaw, Dale, Dallas, Elmore, Escamba, Geneva, Henry, Houston, Lee, Lowndes, Macon, Marengo, Mobile, Monroe, Montgomery, Perry, Pike, Russell, Sumter, Washington, Wilcox
	3	Bibb, Blount, Calhoun, Chambers, Cherokee, Chilton, Clay, Cleburne, Colbert, Coosa, Cullman, De Kalb, Etowah, Fayette, Franklin, Greene, Hale, Jackson, Jefferson, Lamar, Lauderdale, Lawrence, Limestone, Madison, Marion, Marshall, Morgan, Pickens, Randolph, St. Clair, Shelby, Talladega, Tallapoosa, Tuscaloosa, Walker, Winston
Alaska	8	All Zone 8.
Arizona		(No Zone 1 counties.)
	2	Cochise, Pima, Pinal, Santa Cruz, Yuma
	3	Gila, Graham, Mancopa, Mohave
	4	Yavapai
		(No Zone 5 counties.)
	6	Apache, Greenlee, Navajo
	7	Coconino
Arkansas	3	Arkansas, Ashley, Bradley, Calhoun, Chicot, Clark, Cleburne, Cleveland, Columbia, Conway, Crittenden, Cross, Dallas, Desha, Drew, Faulkner, Garland, Grant, Hempstead, Hot Spring, Howard, Jefferson, Lafayette, Lee, Lincoln, Little River, Logan, Lonoke, Miller, Monroe, Montgomery, Neveda, Ouachita, Phillips, Pike, Polk, Pope, Prairie, Pulaski, St. Francis, Saline, Sebastian, Sevier, Union, Van Buren, White, Woodruff
	4	Baxter, Benton, Boone, Carroll, Clay, Craighead, Crawford, Franklin, Fulton, Greene, Independence, Izard, Jackson, Johnson, Lawrence, Madison, Marion, Mississippi, Newton, Perry, Poinsett, Randolph, Scott, Searcy, Sharp, Stone, Washington, Yell

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
California	2	Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, Ventura
	3	Alameda, Contra Costa, Fresno, Inyo, Kern, Kings, Lake, Marin, Mariposa, Merced, Monterey, Napa, Sacramento, San Benito, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, Sonoma, Stanislaus, Tulare, Yolo
	4	Colusa, Del Norte, Glenn, Humboldt, Madera, Mendocino, Sutter, Tehama, Trinity
	5	Butte, Yuba
	6	Alpine, Amador, Calaveras, El Dorado, Mono, Nevada, Placer, Shasta, Siskiyou, Tuolumne
	7	Lassen, Modoc, Plumas, Sierra
		(No Zone 8 counties.)
Colorado	6	Arapahoe, Baca, Bent, Cheyenne, Crowley, Elbert, El Paso, Kiowa, Kit Carson, Las Animas, Lincoln, Mesa, Otero, Prowers, Pueblo, Washington
	7	Adams, Delta, Denver, Douglas, Garfield, Huerfano, Jefferson, Logan, Montezuma, Montrose, Morgan, Phillips, Sedgwick, Teller, Weld, Yuma
	8	Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla, Custer, Dolores, Eagle, Fremont, Gilpin, Grand, Gunnison, Hinsdale, Jackson, Lake, La Plata, Larimer, Mineral, Moffat, Ouray, Park, Pitkin, Rio Blanco, Rio Grande, Routt, Saguache, San Juan, San Miguel, Summit
Connecticut	6	All Zone 6.
Delaware	4	All Zone 4.
District of Columbia	4	All Zone 4.

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Florida	1	Brevard, Broward, Charlotte, Citrus, Collier, Dade, De Soto, Flagler, Glades, Hardee, Hendry, Hernando, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Marion, Martin, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, St. Lucie, Sarasota, Seminole, Sumter, Volusia
	2	Alachua, Baker, Bay, Bradford, Calhoun, Clay, Columbia, Dixie, Duval, Escambia, Franklin, Gadsden, Gilchrist, Gulf, Hamilton, Holmes, Jackson, Jefferson, Lafayette, Leon, Levy, Liberty, Madison, Nassau, Okaloosa, Putnam, St. Johns, Santa Rosa, Suwannee, Taylor, Union, Wakulla, Walton, Washington
Georgia	2	Appling, Atkinson, Bacon, Baker, Baldwin, Ben Hill, Berrien, Bibb, Bleckley, Brantley, Brooks, Bryan, Bullock, Burke, Calhoun, Camden, Candler, Charlton, Chartham, Chattahoochee, Clay, Clinch, Coffee, Colquitt, Columbia, Cook, Crawford, Crisp, Decatur, Dodge, Dooly, Dougherty, Early, Echols, Effingham, Emanuel, Evans, Glascock, Glynn, Grady, Hancock, Harris, Houston, Irwin, Jasper, Jeff Davis, Jefferson, Jenkins, Johnson, Jones, Lamar, Lanier, Laurens, Lee, Liberty, Long, Lowndes, McDuffie, McIntosh, Macon, Marion, Meriwether, Miller, Mitchell, Monroe, Montgomery, Muscogee, Peach, Pierce, Pike, Pulaski, Putnam, Quitman, Randolph, Richmond, Schley, Screven, Seminole, Stewart, Sumter, Talbot, Tattnall, Taylor, Telfair, Terrell, Thomas, Tift, Toombs, Treutlen, Troup, Turner, Twiggs, Upson, Ware, Warren, Washington, Wayne, Webster, Wheeler, Wilcox, Wilkinson, Worth
	3	Banks, Barrow, Bartow, Butts, Carroll, Chattooga, Cherokee, Clarke, Clayton, Cobb, Coweta, Dawson, De Kalb, Douglas, Elbert, Fayette, Floyd, Forsyth, Franklin, Fulton, Gordon, Greene, Gwinnett, Hall, Haralson, Hart, Heard, Henry, Jackson, Lincoln, Madison, Morgan, Newton, Oconee, Oglethorpe, Paulding, Pickens, Polk, Rockdale, Spalding, Stephens, Taliaferro, Walker, Walton, Wilkes
	4	Catoosa, Dade, Fannin, Gilmer, Habersham, Lumpkins, Murray, Rabun, Towns, Union, White, Whitfield

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Hawaii	1	All Zone 1.
Idaho	7	Ada, Benewah, Canyon, Cassia, Jerome, Latah, Lewis, Nez Perce, Oneida, Owyhee, Payette, Power, Twin Falls
	8	Adams, Bannock, Bear Lake, Bingham, Blaine, Boise, Bonner, Bonneville, Boundary, Butte, Camas, Caribou, Clark, Clearwater, Custer, Elmore, Franklin, Fremont, Gem, Gooding, Idaho, Jefferson, Kootenai, Lemhi, Lincoln, Madison, Minidoka, Shoshone, Teton, Valley, Washington
Illinois	4	Alexander, Edwards, Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Johnson, Massac, Monroe, Perry, Pope, Pulaski, Randolph, St. Clair, Saline, Union, Wabash, Washington, Wayne, White, Williamson
	5	Bond, Calhoun, Clay, Clinton, Crawford, Cumberland, Effingham, Fayette, Greene, Jasper, Jersey, Lawrence, Macoupin, Madison, Marion, Montgomery, Richland
	6	Adams, Brown, Cass, Champaign, Christian, Clark, Coles, De Witt, Douglas, Edgar, Ford, Fulton, Hancock, Iroquois, Kankakee, Livingston, Logan, McDonough, McLean, Macon, Mason, Menard, Morgan, Moultrie, Peoria, Platt, Pike, Sangamon, Schuyler, Scott, Shelby, Tazewell, Vermilion, Woodford
	7	Boone, Bureau, Carroll, Cook, De Kalb, Du Page, Grundy, Henderson, Henry, Jo Daviess, Kane, Kendall, Knox, Lake, La Salle, Lee, McHenry, Marshall, Mercer, Ogle, Putnam, Rock Island, Stark, Stephenson, Warren, Whiteside, Will, Winnebago
Indiana	4	Gibson, Perry, Posay, Spencer, Vaderburgh, Warrick
	5	Clark, Crawford, Daviess, Dubois, Floyd, Harrison, Jackson, Jefferson, Jennings, Knox, Lawrence, Martin, Ohio, Orange, Pike, Ripley, Scott, Sullivan, Switzerland, Washington

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Indiana cont.	6	Adams, Bartholomew, Benton, Blackford, Boone, Brown, Carroll, Cass, Clay, Clinton, Dearborn, Decatur, Delaware, Fayette, Fountain, Franklin, Grant, Greene, Hamilton, Hancock, Hendricks, Henry, Howard, Huntington, Jay, Johnson, Madison, Marion, Miami, Monroe, Montgomery, Morgan, Newton, Owen, Parke, Putnam, Randolph, Rush, Shelby, Tippecanoe, Tipton, Union, Vermillion, Vigo, Wabash, Warren, Wayne, Wells, White
	7	Allen, DeKalb, Elkhart, Fulton, Jasper, Koscuisko, Lagrange, Lake, La Porte, Marshall, Noble, Porter, Pulaski, St. Joseph, Stark, Steuben, Whitely
Iowa		(No Zone 6 counties.)
	7	Adair, Adams, Appanoose, Audubon, Benton, Boone, Buena Vista, Calhoun, Carroll, Cass, Cedar, Cherokee, Clarke, Clinton, Crawford, Dallas, Davis, Decatur, Des Moines, Fremont, Greene, Guthrie, Hamilton, Hardin, Harrison, Henry, Ida, Iowa, Jackson, Jasper, Jefferson, Johnson, Jones, Keokuk, Lee, Linn, Louisa, Lucas, Madison, Mahaska, Marion, Marshall, Mills, Monona, Monroe, Montgomery, Muscatine, Page, Plymouth, Polk, Pottawattamie, Poweshiek, Ringgold, Sac, Scott, Shelby, Story, Tama, Taylor, Union, Van Buren, Wapello, Warren, Washington, Wayne, Webster, Woodbury
	8	Allamakee, Black Hawk, Bremer, Buchanan, Butler, Cerro Gordo, Chickasaw, Clay, Clayton, Delaware, Dickinson, Dubuque, Emmet, Fayette, Floyd, Franklin, Grundy, Hancock, Howard, Humboldt, Kossuth, Lyon, Mitchell, O'Brien, Osceola, Palo Alto, Pocahontas, Sioux, Winnebago, Winneshiek, Worth, Wright
Kansas	4	Allen, Barber, Bourbon, Butler, Chautaugua, Cherokee, Comanche, Cowley, Crawford, Elk, Greenwood, Harper, Kingman, Labette, Montgomery, Neosho, Sedgwick, Sumner, Wilson, Woodson
	5	Anderson, Chase, Clark, Coffey, Franklin, Harvey, Johnson, Kiowa, Linn, Lyon, Marion, Meade, Miami, Osage, Pratt, Reno, Seward

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Kansas cont.	6	Atchison, Barton, Brown, Clay, Cloud, Dickenson, Doniphan, Douglas, Edwards, Ellis, Ellsworth, Finney, Ford, Geary, Gove, Graham, Grant, Gray, Greeley, Hamilton, Haskell, Hodgeman, Jackson, Jefferson, Jewell, Kearny, Lane, Leavenworth, Lincoln, Logan, McPherson, Marshall, Mitchell, Morris, Morton, Nemaha, Ness, Osborne, Ottawa, Pawnee, Phillips, Pottawatomie, Republic, Rice, Riley, Rooks, Rush, Russell, Saline, Scott, Shawnee, Smith, Stafford, Stanton, Stevens, Trego, Wabaunsee, Wallace, Washington, Wichita, Wyandotte
	7	Cheyenne, Decatur, Norton, Rawlins, Sheridan, Sherman, Thomas
Kentucky	4	Adair, Allen, Ballard, Barren, Bell, Boyle, Breckinridge, Butler, Caldwell, Calloway, Carlisle, Casey, Christian, Clay, Clinton, Crittenden, Cumberland, Daviess, Edmonson, Fulton, Garrard, Graves, Grayson, Green, Hancock, Hardin, Harlan, Hart, Henderson, Hickman, Hopkins, Jackson, Knox, Larue, Laurel, Leslie, Letcher, Lincoln, Livingston, Logan, Lyon, McCracken, McCreary, McLean, Madison, Marion, Marshall, Meade, Mercer, Metcalfe, Monroe, Muhlenberg, Nelson, Ohio, Owsley, Perry, Pulaski, Rockcastle, Russell, Simpson, Taylor, Todd, Trigg, Union, Warren, Washington, Wayne, Webster, Whitley
	5	Anderson, Bath, Boone, Bourbon, Boyd, Bracken, Breathitt, Bulitt, Campbell, Carroll, Carter, Clark, Elliott, Estill, Fayette, Fleming, Floyd, Franklin, Gallatin, Grant, Greenup, Harrison, Henry, Jefferson, Jessamine, Johnson, Kenton, Knott, Lawrence, Lee, Lewis, Magoffin, Martin, Mason, Menifee, Montgomery, Morgan, Nicholas, Oldham, Owen, Pendleton, Pike, Powell, Robertson, Rowan, Scott, Shelby, Spencer, Trimble, Wolfe, Woodford (No Zone 6 counties.)
Louisiana	2	All Zone 2.
Maine	8	All Zone 8.
Maryland	4	Calvert, Caroline, Charles, Dorchester, Prince Georges, Queen Annes, St. Marys,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Maryland cont.	4	Somerset, Talbot, Wicomico, Worcester
	5	Anne Arundel, Baltimore, Carroll, Cecil, Frederick, Harford, Howard, Kent, Montgomery
	6	Allegany, Garrett, Washington
Massachusetts	6	Barnstable, Bristol, Dukes, Nantucket, Norfolk, Plymouth
	7	Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, Suffolk, Worcester
Michigan	7	Allegan, Barry, Berrien, Branch, Calhoun, Cass, Clinton, Eaton, Genessee, Hillsdale, Ingham, Ionia, Jackson, Kalamazoo, Kent, Lenawee, Livingston, Macomb, Monroe, Oakland, Ottawa, St. Joseph, Shiawassee, Van Buren, Washtenaw, Wayne
	8	Alcona, Alger, Alpena, Antrim, Arenac, Baraga, Bay, Benzie, Charlevoix, Cheboygan, Chippewa, Clare, Crawford, Delta, Dickinson, Emmet, Gladwin, Gogebic, Grand Traverse, Gratiot, Houghton, Huron, Iosco, Iron, Isabella, Kalkaska, Keweenaw, Lake, Lapeer, Leelanau, Luce, Mackinac, Manistee, Marquette, Mason, Mecosta, Menominee, Midland, Missaukee, Montcalm, Montmorency, Muskegon, Newaygo, Oceana, Ogemaw, Ontonagon, Osceola, Oscoda, Otsego, Presque Isle, Roscommon, Saginaw, St. Clair, Sanilac, Schoolcraft, Tuscola, Wexford
Minnesota	8	All Zone 8.
Mississippi	2	Adams, Amite, Claiborne, Clarke, Copiah, Covington, Forrest, Franklin, George, Greene, Hancock, Harrison, Hinds, Issaquena, Jackson, Jasper, Jefferson, Jefferson Davis, Jones, Kemper, Lamar, Lauderdale, Lawrence, Leake, Lincoln, Madison, Marion, Neshoba, Newton, Pearl River, Perry, Pike, Rankin, Scott, Sharkey, Simpson, Smith, Stone, Walthall, Warren, Wayne, Wilkinson
	3	Alcom, Attala, Benton, Bolivar, Calhoun, Carroll, Chickasaw, Choctaw, Clay, Coahoma, De Soto, Grenada, Homes, Humphreys, Itawamba, Lafayette, Lee, Leflore, Lowndes, Marshall, Monroe, Montgomery, Noxubee, Oktibbeha,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Mississippi cont.	3	Panola, Pontotoc, Prentiss, Quitman, Sunflower, Tallahatchie, Tate, Tippah, Tishomingo, Tunica, Union, Washington, Webster, Winston, Yalobusha
Missouri	4	Barry, Barton, Bollinger, Butler, Camden, Cape Girardeau, Carter, Cedar, Christian, Crawford, Dade, Dallas, Dent, Douglas, Dunklin, Franklin, Gasconade, Greene, Hickory, Howell, Iron, Jasper, Jefferson, Laciede, Lawrence, McDonald, Madison, Maries, Miller, Mississippi, New Madrid, Newton, Oregon, Ozark, Pemiscot, Perry, Phelps, Polk, Pulaski, Reynolds, Ripley, St. Clair, St. Francis, Ste. Genevieve, Scott, Shannon, Stoddard, Stone, Taney, Texas, Vernon, Washington, Wayne, Webster, Wright
	5	Audrain, Bates, Benton, Boone, Callaway, Cass, Cole, Cooper, Henry, Howard, Jackson, Johnson, Lafayette, Lincoln, Moniteau, Montgomery, Morgan, Osage, Pettis, Pike, St. Charles, St. Louis, Saline, Warren
	6	Adair, Andrew, Atchison, Buchanan, Caldwell, Carroll, Chariton, Clark, Clay, Clinton, Daviess, De Kalb, Gentry, Grundy, Harrison, Holt, Knox, Lewis, Linn, Livingston, Macon, Marion, Mercer, Monroe, Nodaway, Platte, Putnam, Ralls, Randolph, Ray, Schuyler, Scotland, Shelby, Sullivan, Worth
Montana	8	All Zone 8.
Nebraska	6	Fillmore, Gage, Jefferson, Johnson, Nemaha, Nuckolis, Otoe, Pawnee, Richardson, Saline, Thayer, Webster
	7	Adams, Antelope, Arthur, Banner, Blaine, Boone, Boyd, Brown, Buffalo, Burt, Butler, Cass, Cedar, Chase, Cherry, Cheyenne, Clay, Colfax, Cuming, Custer, Dakota, Dawson, Deuel, Dixon, Dodge, Douglas, Dundy, Franklin, Frontier, Fumas, Garden, Farfield, Gosper, Grant, Greeley, Hall, Hamilton, Harlan, Hayes, Hitchcock, Holt, Hooker, Howard, Kearney, Keith, Keya Paha, Imball, Knox, Lancaster, Lincoln, Logan, Loup, McPherson, Madison, Merrick, Morrill, Nance, Perkins, Phelps, Pierce, Platte, Polk, Red Willow, Rock, Sarpy, Saunders, Scotts Bluff, Seward, Sheridan, Sherman, Stanton, Thomas, Thurston, Valley,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Nebraska cont.	7	Washington, Wayne, Wheeler, York
	8	Box Butte, Dawes, Sioux
Nevada		(No Zone 2 counties.)
	3	Clark
		(No Zone 4 counties.)
		(No Zone 5 counties.)
	6	Churchill, Esmeralda, Lincoln, Lyon, Mineral, Nye
	7	Douglas, Lander, Pershing, Storey, White Pine
	8	Elko, Eureka, Humboldt, Washoe
New Hampshire	7	Cheshire, Hillsborough, Rockingham
	8	Belknap, Carroll, Coos, Grafton, Merrimack, Stratford, Sullivan
New Jersey	5	Atlantic, Burlington, Camden, Cumberland, Gloucester, Mercer, Monmouth, Ocean, Salem
	6	Bergen, Cape May, Essex, Hudson, Hunterdon, Middlesex, Morris, Passaic, Somerset, Sussex, Union, Warren
New Mexico	3	Dona Ana, Eddy, Hidalgo, Lea, Luna, Otero
	4	Chaves, Curry, De Baca, Grant, Guadalupe, Lincoln, Quay, Roosevelt, Sierra, Socorro
	5	Bernalillo, Harding
	6	Colfax, Mora, San Miguel, Santa Fe, Torrance, Union
	7	Catron, Los Alamos, McKinley, Sandoval, San Juan, Valencia
	8	Rio Arriba, Taos
New York	6	Bronx, Kings, Nassau, New York, Orange, Putnam, Queens, Rockland, Suffolk, Westchester

HEATING DEGREE-DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
New York cont.	7	Albany, Columbia, Delaware, Dutchess, Greene, Montgomery, Rensselaer, Saratoga, Schenectady, Schoharie, Sullivan, Ulster, Washington
	8	Allegany, Broome, Cattaraugus, Cayuga, Chautauqua, Chemung, Chenango, Clinton, Cortland, Erie, Essex, Franklin, Fulton, Genesee, Hamilton, Herkimer, Jefferson, Lewis, Livingston, Madison, Monroe, Niagara, Oneida, Onandaga, Ontario, Orleans, Oswego, Otsego, Richmond, St. Lawrence, Schuyler, Seneca, Steuben, Tioga, Tompkins, Warren, Wayne, Wyoming, Yates
North Carolina	2	Parts of the southernmost North Carolina counties are in Zone 2.
	3	Anson, Beaufort, Bertie, Bladen, Brunswick, Cabarrus, Camden, Carteret, Chatham, Chowan, Cleveland, Columbus, Craven, Cumberland, Currituck, Dare, Davidson, Duplin, Durham, Edgecombe, Franklin, Gaston, Gates, Greene, Halifax, Harnett, Hertford, Hoke, Hyde, Johnston, Jones, Lee, Lenoir, Lincoln, Martin, Mecklenburg, Montgomery, Moore, Nash, New Hanover, Northampton, Onslow, Orange, Pamlico, Pasquotank, Pender, Perquimans, Pitt, Randolph, Richmond, Robeson, Rowan, Sampson, Scotland, Stanly, Tyrrell, Union, Wake, Warren, Washington, Wayne, Wilson
	4	Alamance, Alexander, Buncombe, Burke, Caldwell, Caswell, Catawba, Cherokee, Clay, Davie, Forsyth, Graham, Granville, Guilford, Henderson, Iredell, Jackson, McDowell, Macon, Person, Polk, Rockingham, Rutherford, Stokes, Surry, Swain, Transylvania, Vance, Wilkes, Yadkin
	5	Alleghany, Ashe, Avery, Haywood, Madison, Mitchell, Watauga, Yancey
North Dakota	8	All Zone 8.
Ohio	5	Parts of southern Ohio counties are in Zone 5.

HEATING DEGREE-DAY ZONES
BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Ohio cont.	6	Adams, Allen, Ashland, Athens, Auglaize, Belmont, Brown, Butler, Champaign, Clark, Clemont, Clinton, Coshocton, Crawford, Darke, Delaware, Fairfield, Fayette, Franklin, Galia, Greene, Guernsey, Hamilton, Hardin, Harrison, Highland, Hocking, Holmes, Jackson, Jefferson, Knox, Lawrence, Licking, Logan, Madison, Marion, Meigs, Mercer, Miami, Monroe, Montgomery, Morgan, Morrow, Muskingum, Noble, Perry, Pickaway, Pike, Preble, Richland, Ross, Scioto, Shelby, Tuscarawas, Union, Van Wert, Vinton, Warren, Washington, Wayne, Wyandot
	7	Ashtabula, Carroll, Columbiana, Cuyahoga, Defiance, Eire, Fulton, Geauga, Hancock, Henry, Huron, Lake, Lorain, Lucas, Mahoning, Medina, Ottawa, Paulding, Portage, Putnam, Sandusky, Seneca, Stark, Summit, Trumbull, Williams, Wood
Oklahoma	3	Atoka, Bryan, Caddo, Carter, Choctaw, Coal, Commanche, Cotton, Garvin, Grady, Greer, Harmon, Haskell, Jackson, Jefferson, Johnston, Kiowa, Latimer, Le Flore, Love, McClain, McCurtain, McIntosh, Marshall, Murray, Oktuskee, Oklahoma, Pittsburg, Pontotoc, Pottawatomie, Pushmataha, Seminole, Sequoyah, Stephens, Tillman, Washita
	4	Adair, Alfalfa, Beckham, Blaine, Canadian, Cherokee, Cleveland, Craig, Creek, Custer, Delaware, Dewey, Ellis, Garfield, Grant, Harper, Hughes, Kay, Kingfisher, Lincoln, Logan, Major, Mayes, Muskogee, Noble, Notwata, Okmulgee, Osage, Ottawa, Pawnee, Payne, Roger Mills, Rogers, Tulsa, Wagoner, Washington, Woods, Woodward
	5	Beaver, Texas (No Zone 6 counties.)
Oregon	4	Coos, Curry, Josephine
	5	Benton, Clatsop, Columbia, Douglas, Lane, Lincoln, Polk, Tilamook, Washington, Yamhill
	6	Clackamas, Gilliam, Grant, Jackson, Linn, Marion, Morrow, Multnomah, Umatille

HEATING DEGREE-DAY ZONES
BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Oregon cont.	7	Baker, Hood River, Klamath, Malheur, Sherman, Union, Wallowa, Wasco, Wheeler
	8	Crook, Deschutes, Harney, Jefferson, Lake
Pennsylvania	5	Bucks, Chester, Delaware, Lancaster, Montgomery, Philadelphia, York
	6	Adams, Allegheny, Bedford, Berks, Blair, Cambria, Carbon, Centre, Clearfield, Columbia, Cumberland, Dauphin, Fayette, Franklin, Fulton, Greene, Huntingdon, Indiana, Juniata, Lebanon, Lehigh, Luzerne, Mifflin, Monroe, Montour, Northampton, Northumberland, Perry, Pike, Schuykill, Snyder, Somerset, Union, Washington, Westmoreland
	7	Armstrong, Beaver, Bradford, Butler, Cameron, Clarion, Clinton, Crawford, Elk, Erie, Forest, Jefferson, Lackawanna, Lawrence, Lycoming, Mercer, Sullivan, Susquehanna, Tioga, Venango, Warren, Wayne, Wyoming
	8	McKean, Potter
Rhode Island	6	All Zone 6
South Carolina	2	Aiken, Allendale, Bamberg, Barnwell, Beaufort, Berkeley, Calhoun, Charleston, Clarendon, Colleton, Dorchester, Florence, Georgetown, Hampton, Horry, Jasper, Marion, Orangeburg, Williamsburg
	3	Abbeville, Anderson, Cherokee, Chester, Chesterfield, Darlington, Dillon, Edgefield, Fairfield, Greenville, Greenwood, Kershaw, Lancaster, Laurens, Lee, Lexington, McCormick, Marlboro, Newberry, Richland, Saluda, Spartanburg, Sumter, Union, York
	4	Oconee, Pickens
South Dakota	7	Bennett, Bon Homme, Charles Mix, Clay, Douglas, Gregory, Jackson, Mellette, Shannon, Todd, Tripp, Union, Washabaugh, Yankton

HEATING DEGREE-DAY ZONES
BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
South Dakota cont.	8	Aurora, Beadle, Brookings, Brown, Brule, Buffalo, Butte, Campbell, Clark, Codington, Corson, Custer, Davison, Day, Deuel, Dewey, Edmunds, Fall River, Faulk, Grant, Haakon, Hamlin, Hand, Hanson, Harding, Hughes, Hutchinson, Hyde, Jerauld, Jones, Kingsbury, Lake, Lawrence, Lincoln, Lyman, McCook, McPherson, Marshall, Meade, Miner, Minnehaha, Moody, Pennington, Perkins, Potter, Roberts, Sanbom, Spink, Stanley, Sully, Turner, Walworth, Zeibach
Tennessee	3	Bedford, Chester, Coffee, Crockett, Decatur, Fayette, Franklin, Giles, Grundy, Hardeman, Hardin, Haywood, Henderson, Lauderdale, Lawrence, Lewis, Lincoln, Madison, Marshall, McNairy, Moore, Perry, Shelby, Tipton, Van Buren, Warren, Wayne
	4	Anderson, Benton, Bledsoe, Blount, Bradley, Campbell, Cannon, Carroll, Cheatham, Claiborne, Clay, Cocke, Cumberland, Davidson, De Kalb, Dickson, Dyer, Fentress, Gibson, Grainger, Greene, Hamblen, Hamilton, Hancock, Hawkins

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Tennessee cont.	4	Henry, Hickman, Houston, Humphreys, Jackson, Jefferson, Knox, Lake, Loudon, McMinn, Macon, Marion, Maury, Meigs, Monroe, Montgomery, Morgan, Obion, Overton, Pickett, Polk, Putnam, Rhea, Roane, Robertson, Rutherford, Scott, Sequatchie, Sevier, Smith, Stewart, Sumner, Trousdale, Union, Weakley, White, Williamson, Wilson
	5	Carter, Johnson, Sullivan, Unicoi, Washington
Texas	1	Aransas, Brooks, Cameron, Duval, Hidalgo, Jim Hogg, Jim Wells, Kenedy, Kieberg, Nueces, San Patricio, Starr, Willacy, Zapata
	2	Anderson, Angelina, Atascosa, Austin, Bandora, Bastop, Bee, Bell, Bexar, Bianco, Bosque, Brazoria, Brazos, Breaster, Brown, Burleson, Burnet, Caldwell, Calhoun, Chambers, Cherokee, Coleman, Colorado, Comal, Comanche, Concho, Coryell, Crane, Crockett, Dewitt, Dimmit, Eastland, Edwards, Ellis, Erath, Falls, Fayette, Fort Bend, Freestone, Frio, Galveston, Gillespie, Goliad, Gonzales, Gregg, Grimes, Guadalupe, Hamilton, Hardin, Harris, Harrison, Hays, Henderson, Hill, Hood, Houston, Irion, Jackson, Jasper, Jeff Davis, Jefferson, Johnson, Karnes, Kaufman, Kendall, Kerr, Kimble, Kinney, Lampasas, La Salle, Lavaca, Lee, Leon, Liberty, Limestone, Live Oak, Llano, McCulloch, McLennan, McMullen, Madison, Mason, Matagorda, Maverick, Medina, Menard, Milam, Mills, Montgomery, Nacogdoches, Navarro, Newton, Orange, Panola, Pecos, Polk, Presidio, Reagan, Real, Reeves, Refugio, Robertson, Runnels, Rusk, Sabine, San Augustine, San Jacinto, San Saba, Schleicher, Shelby, Smith, Somervell, Sutton, Terrell, Tom Green, Travis, Trinity, Tyler, Upton, Uvalde, Val Verde, Van Zandt, Victoria, Walker, Waller, Washington, Webb, Wharton, Williamson, Wilson, Zavala
	3	Andrews, Archer, Baylor, Borden, Bowie, Briscoe, Callahan, Camp, Cass, Childress, Clay, Cochran, Coke, Collin, Cooke, Cottle, Crosby, Culberson, Dallas, Dawson, Delta, Denton, Dickens, Ector, El Paso, Fannin, Fisher, Floyd, Foard, Franklin, Gaines, Garza, Glasscock, Grayson, Hale, Hall,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Texas cont.	3	Hardeman, Haskell, Hockley, Hopkins, Howard, Hudspeth, Hunt, Jack, Jones, Kent, King, Knox, Lamar, Lamb, Loving, Lubbock, Lynn, Marion, Martin, Midland, Mitchell, Montague, Morris, Motley, Nolan, Palo Pinto, Parker, Rains, Red River, Rockwall, Scurry, Shackelford, Stephens, Sterling, Stonewall, Tarrant, Taylor, Terry, Throckmorton, Titus, Upshur, Ward, Wichita, Wilbarger, Winkler, Wise, Wood, Yoakum, Young
	4	Armstrong, Bailey, Carson, Castro, Collingsworth, Deaf Smith, Donley, Gray, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Parmer, Potter, Randall, Roberts, Swisher, Wheeler
	5	Dallam, Sherman
Utah		(No Zone 5 counties.)
	6	Davis, Grand, Piute, Salt Lake, Sevier, Washington, Wayne
	7	Beaver, Box Elder, Cache, Emergy, Garfield, Iron, Juab, Kane, Millard, San Juan, Sanpete, Tooele, Utah, Weber
	8	Carbon, Daggett, Duchesne, Morgan, Rich, Summitt, Uintah, Wasatch
Vermont	7	Bennington, Windham
	8	Addison, Caledonia, Chittenden, Essex, Franklin, Grand Isle, Lamoille, Orange, Orleans, Rutland, Washington, Windsor
Virginia	3	Isle of Wight, Nansemond, Northampton, Southampton
	4	Accomack, Albermarle, Amelia, Amherst, Appomattox, Arlington, Bedford, Brunswick, Buckingham, Campbell, Caroline, Charles City, Charlotte, Chesterfield, Cumberland, Dinwiddie, Essex, Fluvanna, Franklin, Gloucester, Goochland, Greensville, Halifax, Hanover, Henrico, Henry, James City, King and Queen, King George, King William, Lancaster, Louisa, Lununburg, Mathews, Mecklenburg, Middlesex, Nelson, New Kent, Northumberland, Nottoway, Orange, Patrick,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Virginia cont.	4	Pittsylvania, Powhatan, Prince Edward, Prince George, Prince William, Richmond, Spotsylvania, Stafford, Surry, Sussex, Westmoreland, York
	5	Alleghany, Augusta, Bath, Bland, Botetourt, Buchanan, Carroll, Craig, Culpeper, Dickenson, Fairfax, Fauquier, Floyd, Giles, Grayson, Greene, Lee, Loudoun, Madison, Montgomery, Page, Pulaski, Rappahannock, Roanoke, Rockbridge, Rockingham, Russell, Scott, Shenandoah, Smyth, Tazewell, Warren, Washington, Wise, Wythe
	6	Clarke, Frederick, Highland
Washington	6	Benton, Clallam, Clark, Cowlitz, Franklin, Grays Harbor, Island, Jefferson, Kitsap, Lewis, Mason, Pacific, Pierce, San Juan, Skagit, Snohomish, Thurston, Wahkiakum, Whatcom
	7	Adams, Asotin, Chelan, Columbia, Garfield, Grant, King, Kittitas, Klickitat, Lincoln, Skamania, Spokane, Walla Walla, Whitman, Yakima
	8	Douglas, Ferry, Okanogan, Pend Oreille, Stevens
West Virginia	5	Boone, Cabell, Jackson, Kanawha, Lincoln, Logan, Mason, Mingo, Putnam, Roane, Wayne
	6	Barbour, Berkeley, Braxton, Brooke, Calhoun, Clay, Doddridge, Fayette, Gilmer, Grant, Greenbrier, Hampshire, Hancock, Hardy, Harrison, Jefferson, Lewis, McDowell, Marion, Marshall, Mercer, Mineral, Monongalia, Monroe, Morgan, Nicholas, Ohio, Pendleton, Pleasants, Pocahontas, Preston, Raleigh, Randolph, Ritchie, Summers, Taylor, Tucker, Tyler, Upshur, Webster, Wetzel, Wirt, Wood, Wyoming
Wisconsin	7	Kenosha, Racine, Rock, Walworth
	8	Adams, Ashland, Barron, Bayfield, Brown, Buffalo, Burnett, Calumet, Chippewa, Clark, Columbia, Crawford, Dane, Dodge, Door, Douglas, Dunn, Eau Claire, Florence, Fond Du Lac, Forest, Grant, Green, Green Lake,

HEATING DEGREE DAY ZONES BY STATE (INCLUDING COUNTIES)

STATE	ZONE	COUNTIES
Wisconsin cont.	8	Iowa, Iron, Jackson, Jefferson, Juneau, Kewaunee, La Crosse, Lafayette, Langlade, Lincoln, Manitowoc, Marathon, Marinette, Marquette, Menominee, Milwaukee, Monroe, Oconton, Oneida, Outaramie, Ozaukee, Pepin, Pierce, Polk, Portage, Price, Richland, Rusk, St. Croix, Sauk, Sawyer, Shawano, Sheboygan, Taylor, Trempealeau, Vernon, Vilas, Washburn, Washington, Waukesha, Waupaca
Wyoming	7	Laramie
	8	Albany, Big Horn, Campbell, Carbon, Converse, Crook, Fremont, Goshen, Hot Springs, Johnson, Lincoln, Natrona, Niobrara, Park, Platte, Sheridan, Sublette, Sweetwater, Teton, Uinta, Washakie, Weston
Puerto Rico	1	All Zone 1.

Appendix B

Consumer Audit Questionnaire

Attached is a questionnaire with cover letter that can be mailed to energy consumers in advance of an audit. The questionnaire is designed to be self-administered. It would be most useful if it were mailed back to the utility company before the audit, so that auditors would know something about the situation they are assigned to audit. Questionnaire information could also affect the selection of audit personnel.

The questionnaire is designed for use by the energy consumer, but it is not designed for efficient use by an auditor. If it were used in its present form by an auditor, clerical assistants might be needed to transfer the data from the questionnaire to a form more useful to the auditor.

If a questionnaire is completed and returned by the consumer, the auditor does not then have to conduct an interview on the covered questions, thus saving onsite audit time for more important consumer interaction.

Model Cover Letter for Audit Questionnaire

Dear _____:

Your Residential Conservation Service (RCS) Program audit is scheduled for (day of week), (date), at (time). Someone will have to be there during the time the energy auditor is at your home, which will be about _____hours.

Enclosed is a questionnaire asking for information about your household. This information is needed for your home energy audit. We'd like you to fill out the questionnaire and mail it back to us as soon as possible. Do not mail it after (date). This will permit the auditor to prepare in advance for your home energy audit. If you do not finish the questionnaire in time to mail it to us, please complete it and give it to the auditor when s/he arrives to conduct your audit.

If you do not complete the questionnaire prior to the audit, the auditor will ask you the questions at the beginning of the audit. The questions need to be answered by you and your auditor for your home energy audit to be completed. Each piece of information is needed for the audit procedures and calculations. So please answer all the questions completely.

Don't be concerned if you don't know the answers to some of the questions. If you are not sure of the answers, you might ask your wife, husband or other family member. But don't worry if no one knows. We don't want you to do anything special. Just give us the information if you happen to know it; otherwise please indicate that you don't know the answer. The auditor will get the information required when s/he visits your home.

Thank you for your participation in the RCS Program. We look forward to meeting with you about your home's energy situation and how to make it better.

Sincerely,

_____
Utility Company Representative

RCS AUDIT QUESTIONNAIRE

Name _____ Date _____

Address _____

_____ Telephone _____

1. How many people live permanently in your home? _____ (# of people)
2. Is there a washing machine in your household?
   [ ] Yes
   [ ] No
3. Is there a dishwasher in your household?
   [ ] Yes
   [ ] No
4. What is the fuel used by your hot water heater? (Check one)
   [ ] Oil
   [ ] Natural gas
   [ ] Electricity
   [ ] Other (please specify) _____
   [ ] Don't know
5. Does your home have a thermostat for a central heating system? (Check one)
   [ ] Yes [SKIP TO 5b]
   [ ] No
   [ ] Don't know [SKIP TO 7]

   5a. (If no) How do you control the temperature of your house?

   _____

   _____

   5b. (If yes) At what temperature do you usually set your thermostat...?

   In winter?

   Usual daytime temperature setting _____ °F

   Usual nighttime temperature setting _____ °F

   In summer?

   [ ] Turn off furnace in summer

   Usual daytime temperature setting _____ °F

   Usual nighttime temperature setting _____ °F

6. Do you have an air conditioning system? (Check one)

[ ] Central air conditioning

[ ] Room air conditioners _____ (# of room air conditioners)

[ ] No (SKIP TO 7)

6a. (If Yes) Is your air conditioner .....? (Check one)

[ ] Electric

[ ] Gas

[ ] Other (please specify) _____

[ ] Don't know

6b. (If Yes) How old is your air conditioner? _____ (# of years)

[ ] Don't know

6c. (If Yes) What is the capacity in tons of your air conditioner?

_____ (# of tons)

[ ] Don't know

6d. (If Yes) At what temperature do you usually set the thermostat on your air conditioner?

Usual daytime temperature setting _____°F

Usual nighttime temperature setting _____°F

Other (please specify) _____

_____

7. About how many times a day are the outside doors to your home opened, on the average?(Check one)

[ ] Less than 6 times a day

[ ] 6 to 13 times a day

[ ] More than 13 times a day

8. During the past 12 months, have you drastically altered your energy use pattern by addition(s) to your house, energy conservation measure(s), or practice(s). If so, describe. _____

_____

_____

_____

9. Does your house have a basement or cellar? (Check one)

[ ] Yes, full basement or cellar

[ ] Yes, partial basement or cellar

[ ] No

10. Do you have an attached garage? (Check one)
    [ ] Yes
    [ ] No

11. Do you have a heated swimming pool? (Check one)
    [ ] Yes
    [ ] No [SKIP TO 12]
    11a. (If yes) What kind of pool heating system do you have? (Check one)
        [ ] Natural gas
        [ ] Electric
        [ ] Other (please specify)_____
        [ ] Don't know

12. What kind of fuel does your primary heating system use? (Check one)
    [ ] Oil
    [ ] Natural gas [SKIP TO 12b]
    [ ] Electricity [SKIP TO 13]
    [ ] Propane [SKIP TO 13]
    [ ] Other (please specify)_____ [SKIP TO 13]
    [ ] Don't know [SKIP TO 13]
    12a. (If oil) Has a replacement burner been installed? (Check one)
        [ ] Yes
        [ ] No
        [ ] Don't know
        [SKIP TO 13]
    12b. (If gas) Has a vent damper been installed? (Check one)
        [ ] Yes
        [ ] No
        [ ] Don't know

13. How is the heat distributed to your house? (Check one)
    [ ] Heating ducts
    [ ] Baseboard
    [ ] Radiators
    [ ] Other (please specify)_____

14. Is your primary heating system located in a heated or unheated area? (Check one)
    [ ] Heated area
    [ ] Unheated area
    [ ] Unsure

15. Do you use any other heating source such as wood stove, heatalator fireplace, room electric heaters, etc.)? (Check one)

[ ] Yes

[ ] No [END OF QUESTIONNAIRE]

[ ] Don't know [END OF QUESTIONNAIRE]

15a. (If yes) What kind of heating is it and what fuel does it use?

Kind of heating_____[ ] Don't know

Fuel Source_____[ ] Don't know

THANK YOU VERY MUCH FOR COMPLETING THIS QUESTIONNAIRE. IT WILL ALLOW THE AUDITOR TO PREPARE FOR YOUR HOME ENERGY AUDIT.

IF YOUR AUDIT APPOINTMENT IS A WEEK OR MORE AWAY, PLEASE MAIL THE QUESTIONNAIRE RIGHT AWAY TO:

(Name and address of utility company)

IF YOUR AUDIT APPOINTMENT IS LESS THAN A WEEK AWAY, PLEASE HOLD THIS QUESTIONNAIRE AND GIVE IT TO YOUR AUDITOR WHEN HE OR SHE ARRIVES.

Appendix C

Methodology Documentation

AC.1 INTRODUCTION

This section describes the methodology behind the model audit procedures (Sect. C). References, assumptions, and computational approaches are listed and discussed.

The explanations contained are intended to forward a more complete understanding of the model audit procedures. This methodology section would be a good starting point for the user attempting to alter any portion of the procedures.

AC.2 CALCULATIONS FOR LOADS AND EFFICIENCIES

AC.2.1 Infiltration Losses and Gains

Infiltration is estimated by using the air-change method described in the *ASHRAE Handbook, 1977, Fundamentals Volume.* Air changes per hour for the existing residence are estimated by use of a subjective evaluation with an appropriately constructed weighting scheme to apportion the infiltration due to various mechanisms. The methodology for estimating air changes is similar to that used by Project RETROTECH. The subjective evaluation of air changes per hour has been developed from weighting factors supplied by Lawrence Berkeley Laboratory, Energy and Environment Division. Lifestyle weighting factors were provided by the University of Massachusetts at Amherst.

The effect of local wind velocity is estimated by multiplying the volume flow rate of infiltrating air from the air-change evaluation by the ratios of average winter and summer wind speeds to a 15-mph wind speed (winter and summer wind factors). Estimated infiltration rates are corrected for structure exposure to the wind by multiplying by a terrain factor supplied by Lawrence Berkeley Laboratory. To streamline the audit calculations, a conversion factor from ft/s to mph was included in the terrain factors, and the factors were multiplied by the winter or summer wind factor to provide a wind exposure correction based on average local wind conditions. The terrain factors also include an assumed ceiling height of 8 ft to transform the house area into a house volume.

Infiltration heat-loss and heat-gain factors were calculated for each climatological zone. These factors represent the sensible heat loss from infiltration in the winter and sensible plus latent heat gain from infiltration in the summer. The heat-loss factors, Q_l, were

calculated by multiplying the specific heat of air c_{p_a} by the density of air, ρ_W, at the winter-design, dry-bulb temperature; that is

$$Q_l = c_{p_a} \rho_W .$$

The density was not corrected for altitude for the loss and gain factors. Therefore, for residences at high altitudes, users will have to make this correction to account for the decrease in infiltration loads due to lower air density. Sensible heat-gain factors, Q_s, were calculated by the expression,

$$Q_s = \rho_s (c_{p_a} + c_{p_v} W) ,$$

where c_{p_v} is the specific heat of water vapor, ρ_s is the density of air at the summer-design, dry-bulb temperature, and W is the humidity ratio at the summer-design conditions. In the range of temperatures examined, the change in enthalpy of moist air per degree of wet-bulb temperature is approximately three times the change in enthalpy per degree of dry-bulb temperature. The heat-gain factor, Q_g, is calculated by the expression,

$$Q_g = Q_s \left(3 \frac{\Delta T_{WB}}{\Delta T_{DB}} \right) ,$$

where ΔT_{WB} is the design wet-bulb temperature difference and ΔT_{DB} is the design dry-bulb temperature difference.

Since the air conditioner will remove no moisture from the air when the air dewpoint is below the temperature of the cooling coil, a humidity ratio check was used to determine whether the above dry-bulb/wet-bulb temperature relationship would be used. When the humidity ratio of the outside air, W, was less than 0.0099 pounds-water/pounds-dry air, Q_g was set equal to Q_s.

AC.2.2 Small and Large Window Designations

A survey of local building suppliers in Tennessee provided area and perimeter data for window and door units available for residential applications. A mean window area of 12 ft^2 (excluding picture windows) was calculated for the windows surveyed. Small windows were defined as those with an area <12 ft^2 and large windows as those with an area ⩾12 ft^2. The average perimeter for windows with an area <12 ft^2 was ≈12 linear feet. The average perimeter for windows with an area ⩾12 ft^2 was ≈16 linear feet. The average perimeter of exterior doors (excluding sliding glass doors) was ≈20 linear feet.

An estimate of the error introduced by assuming average areas for small and large windows was calculated. For windows with an area <12 ft^2, a standard deviation of 1.3 ft^2 from the average area of 9.1 ft^2 was calculated. This deviation represents a 14% excursion from the average area. For windows with an area ⩾12 ft^2, a standard deviation of 1.3 ft^2 from the average area of 15.7 ft^2 was calculated. This deviation represents only an 8% excursion from the average area. For small windows, a standard deviation in perimeter of 1.75 ft from an average of 12 ft was calculated. For large windows, a standard deviation

in perimeter of 2.2 ft from an average of 16 ft was calculated. Thus, deviations in area and perimeter among residential windows are small enough to justify using average values for small and large windows.

AC.2.3 Air Conditioner Efficiency

The default steady-state efficiencies were determined by reviewing past Air Conditioning and Refrigeration Institute (ARI) directories and summaries of historical shipments for each EER range. In the review process, an average was taken across all manufacturers at various points in time, and a table of EER as a function of year of manufacture was constructed.

Two methods of calculating seasonal efficiency are provided in Sect. E.5. The first method involves the use of ARI published values and is not regionally dependent. The second method is based on research documented in *Benefits of Replacing Residential Central Air Conditioning Systems,* ORNL/CON-113 (in preparation), where regional (weather-related) analyses using the DOE Building Energy Use Analysis Program (DOE-2.1A) were performed. This second method has not been experimentally verified. The major variable considered in this research was cycling losses due to operation during partial-load conditions and equipment oversizing. The generalized map in Sect. E.5 provides regionally related corrections to obtain local SEER values, which differ from the ARI values in that they are generally lower and vary from region to region. Local SEERs can be evaluated by modeling typical local constructions with DOE-2.1A or other energy modeling programs.

AC.2.4 Heating and Cooling Loads

AC.2.4.1 Modified Degree-Day Formula

Seasonal heating and cooling costs are calculated by using the modified degree-day formula. The following equation for heating cost is solved by calculator or graphically by use of the nomogram (Sect. E.6),

$$SC_h = \frac{24 HDD Q_L C}{\eta_h U} ,$$

where

SC_h = seasonal heating cost in dollars,
HDD = heating degree-days,
Q_L = heat loss in Btu/(h·°F),
C = unit fuel cost,
η_h = seasonal heating system efficiency,
U = unit conversion [Btu to unit compatible with unit fuel (cost)],
3,400 Btu/kWh of electricity,
1,030 Btu/ft^3 of natural gas,
138,000 Btu/gal of oil,
95,000 Btu/gal of propane.

The following equation for cooling cost is solved by calculator or by use of the nomogram.

$$SC_c = \frac{24 CDD Q_G C}{\eta_c U} ,$$

where

SC_c = seasonal cooling cost in dollars,
CDD = cooling degree-days,
Q_G = heat gain in Btu/(h·°F),
η_c = seasonal cooling system efficiency.

C and U are defined above.

AC.2.4.2 Optional Cooling Calculations

The optional cooling calculations were developed to allow more accurate prediction of seasonal cooling costs. A method for predicting cooling loads from solar gain was developed. This method uses a modification of the CLR procedure (Sect. AC.4.8) to apply this technique to the glazing of a residence to estimate the effects of solar gain through windows on seasonal cooling loads for the residence. A Solar Gain Factor (SGF) is calculated as the sum of solar gain factors for four orientations. These factors are obtained from charts in the Data Base/Calculation Aids of SGF vs CCLR, where CCLR is the Cooling Collector Load Ratio. The CCLR is defined as

$$CCLR = \frac{1000 A_g}{24 CEUR} ,$$

where

A_g = area of glazing for that orientation, ft^2,
CEUR = the sum of conduction gains and infiltration gains, Btu/h·F,
1000 = multiplier for convenience,
24 = h/d.

The charts of SGF vs CCLR were obtained by calculating monthly heat balances for each HUD/MPS zone climatic station. The transmitted radiation was determined as

$$I = I' \tau SC ,$$

where

I = transmitted solar radiation, Btu/d·ft^2·glazing,
I′ = incident solar radiation on a vertical surface, Btu/d·ft^2glazing,
τ = glazing transmittance, assumed to be 0.87,
SC = shading coefficient, assumed to be 0.55.

Values of I′ were determined from the algorithm of Kusuda and Ishii,[1] which was modified to use mean daily solar radiation data.

The effect of external shading is estimated by the relation

$$SGF = 0.9\,N' + (SGF' - 0.9\,N')\,PSF\,,$$

where

SGF′ = SGF for PSF = 1 for the wall (CCLR) of interest,
N′ = SGF′ for that same wall (CCLR), assuming north orientation.

This relation assumes that 90% of the incident solar radiation on an unobstructed north-oriented wall is a reasonable approximation of diffuse sky and reflected ground radiation. PSF is defined in Sect. AC.4.2.

Both the CCLR and the solar load are determined from the CEUR, assuming no reduction of sensible infiltration load, because the solar loading would more closely coincide with higher temperature infiltrating air.

Several houses were modeled with the DOE-2.1A computer program to determine the cooling load behavior and to estimate the cooling energy consumption. This modeling showed that infiltration during the cooling season contributed significant sensible cooling over the season. Therefore, a temperature correction was included in the cooling calculation method to account for the sensible infiltration load. The new cooling calculation method was then checked against an instrumented house which had submetered cooling energy consumption. The new method provides substantially better estimates of seasonal cooling energy consumption than does the previous method.

The most reasonable estimate of the difference between the temperature in the house and the temperature used as the cooling degree-day (CDD) base was determined in the DOE-2.14 calculations to be 6°F. This shift in temperature base accounts for internal loads and the sensible cooling effect that infiltration has for certain outdoor temperatures.

The cooling seasonal cost (CSC) is calculated directly by using the equation

$$CSC = \frac{CEUR' \cdot CDD \cdot 24 \cdot EC}{1000\,SEER}\,,$$

where

CEUR′ = CEUR with solar gain and corrected sensible infiltration included, Btu/h·°F,
CDD = cooling degree-days at the *base* temperature, 6°F lower than the house temperature,
24 = h/d,
EC = electricity cost, $/kWh,
1000 = conversion from W to kW,
SEER = seasonal energy efficiency ratio, Btu/W·h.

Users may wish to determine the values of *base* temperature to use for calculating CDD for their location.

Reference for Section AC.2.4

1. Kusuda, T., and K. Ishii, *Hourly Solar Radiation for Vertical and Horizontal Surfaces on Average Days in the United States and Canada*, National Bureau of Standards, Building Science Series 96, April 1977.

AC.3 CALCULATIONS FOR ENERGY CONSERVATION MEASURES

AC.3.1 Caulking and Weather Stripping

On the basis of data in the *ASHRAE Handbook, 1977 Fundamentals* and weighting factors from Lawrence Berkeley Laboratory, it was estimated that ≈20% of the possible air-change improvement in infiltration could be attributed to caulking and ≈10% to weather stripping.

AC.3.2 Furnace System Modifications

The savings for both oil burner replacement and flue opening modifications are based upon a percentage of the present heating costs of the residence. The range of the percentages used in the estimates are an average of the findings from several papers. These references are listed below.

1. Batey, J. E., et al, *Direct Measurement of Overall Efficiency and Annual Fuel Consumption of Residential Oil-Fired Boilers*, BNL-50853, Brookhaven National Laboratory, Upton, N.Y., January 1978.

2. Bonne, U., et al, *Analysis of New England Oil Burner Data. Effect of Reducing Excess Firing Rate on Seasonal Efficiency*, NBS-514736, Honeywell Corporate Research Center, Bloomington, Minn., August 1975.

3. Bonne, U., et al, "Control of Overall Thermal Efficiency of Combustion Heating Systems," *16th (International) Symposium on Combustion*, MIT, Cambridge, Mass., August 1976.

4. Bonne, U., et al, "Dynamic Computer and Laboratory Simulations of Gas Fired Central Heating Systems," *International Symposium on Simulation Modeling and Decision in Energy Systems*, (IASTED), Montreux, Switzerland, June 1979.

5. Gable, G. K., and K. Koenig, "Seasonal Operating Performance of Gas Heating Systems with Certain Energy-Saving Features," *ASHRAE Trans.* Vol. 83, Part 1 (1977).

6. Memorandum to J. A. Smith at the Department of Energy from G. E. Kelly of the National Bureau of Standards, "Technical Analysis of Public Hearing Testimony Regarding Proposed Energy Efficiency Improvement Targets for Furnaces," Mar. 30, 1978.

7. Richardson, D. L., et al, *An Assessment of Retrofit Automatic Vent Dampers for Residential Heating Systems*, TID-29340, Arthur D. Little, Inc., November 1977.

AC.3.3 Electrical or Mechanical Ignition Systems

The average residential gas furnace pilot light uses $\approx 7 \times 10^6$ Btu/year. With the pilot light off during the summer, the annual pilot light gas consumption was estimated and plotted on Fig. AC.1. This estimation was attained by assuming the number of summer hours, depending on climatic conditions (degree-days), which was then subtracted from the yearly total. These respective hours were then multiplied by the pilot light gas consumption rate (800 Btu/h). Typical savings (from the literature) were used as a basis for a furnace with a continuous pilot located in HUD/MPS Region 8 [SAVINGS (1) curve]. The complement, therefore, served as a reference point for the gas consumption curve of a furnace equipped with an intermittent ignition device (IID). Assuming a constant ratio (typical furnace gas consumption with pilot light off during the summer to typical furnace gas consumption with an IID), the gas consumption for a furnace with an IID was extrapolated for the other degree-day regions. This consumption represents the amount of gas burned while the furnace burner is in operation. The two savings curves were then estimated as follows:

- For a continuous pilot operation, the gas savings curve [SAVINGS (1)] is the difference between the "TYPICAL FURNACE, CONTINUOUS PILOT" curve and the "TYPICAL FURNACE (IID)" curve.
- For a furnace with the pilot off during the summer, the gas savings curve [SAVINGS (2)] is the difference between the "TYPICAL FURNACE, PILOT OFF DURING SUMMER" curve and the "TYPICAL FURNACE (IID)" curve.

References for Section AC.3.3

1. Bonne, U., et al, "Control of Overall Thermal Efficiency of Combustion Heating Systems," Honeywell Corporate Research Center, Bloomington, Minn., August 1976.
2. Bonne, U., et al, "Dynamic and Laboratory Simulations of Gas Fired Central Heating Systems," *International Symposium on Simulation Modeling and Decision in Energy Systems* (IASTED), Montreux, Switzerland, June 1979.
3. Brookhaven National Laboratory, Department of Energy and Environment, Associated Universities, Inc., publication on "Upgrading Oil Home-Heating Systems," Upton, N.Y., September 1979.
4. Gable, G. K., and K. Koening, "Seasonal Operating Performance of Gas Heating Systems with Certain Energy-Saving Features," *ASHRAE Trans.*, Vol. 83, Part 1 (1977).
5. National Bureau of Standards, "Technical Analysis of Public Hearing Testimony Regarding Proposed Energy Efficiency Improvement Targets for Furnaces," report for the Department of Energy, March 1978.

AC.3.4 Shell-Component Insulation Measures

For each shell component, the difference between the existing U-value and the improved U-value of the component is multiplied by the area of the component to obtain a change in

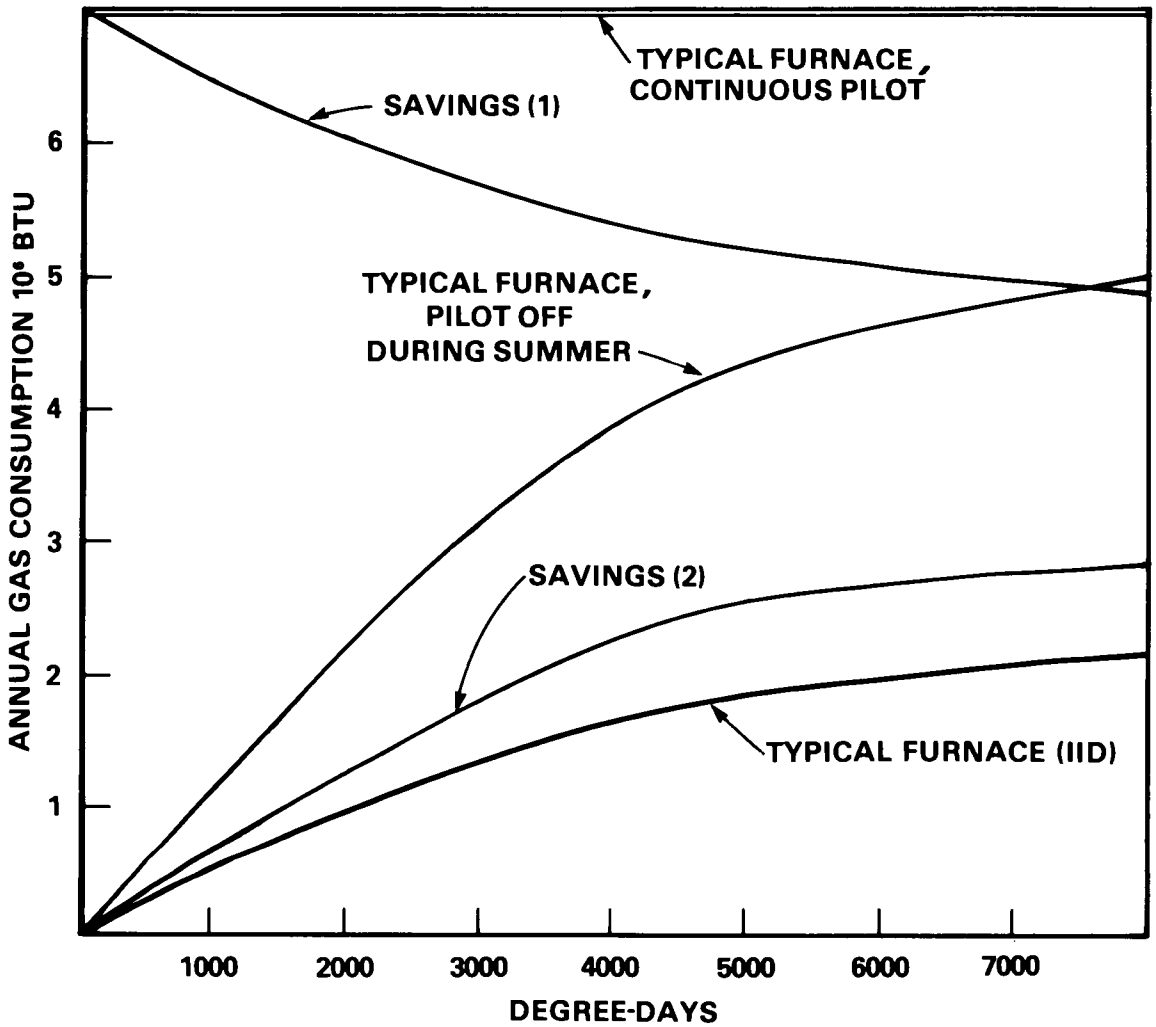


Fig. AC.1. Intermittent ignition device savings for central gas fired furnaces.

heat loss/gain [Btu/(h·°F)] due to the improvement in U-value. The seasonal savings are obtained from the degree-day equation as described in the Model Audit Procedures (Sect. C).

AC.3.5 Hydronic Heating Pipe Insulation

Heat-loss calculations were performed for a hypothetical house with hydronic piping. These calculations resulted in an estimate that 1 ft of exposed pipe in the unconditioned space would increase the seasonal cost by about 0.1% for extreme conditions and 0.04% for milder conditions. These percentages lead to the factors of 0.0001 and 0.0004 multiplied by 2.5 on the audit forms.

The seasonal calculations included the following assumptions.

Extreme case	Mild case
Original U = 2 Btu/(h·ft^2·°F)	same
Insulated pipe U = 0.3 Btu/(h·ft^2·°F)	same
Pipe area ratio = 0.3 ft^2/ft	0.2 ft^2/ft
Temperature difference = 140°F − 60°F = 80°F	same
Seasonal fuel use = 200 × 10^6 Btu/year	60 × 10^6 Btu/year
Number of hours at temperature difference of 80°F = 400 h	100 h

AC.3.6 Duct Insulation

Using Air Conditioning Contractors of America (ACCA) Manual N for heat-loss and heat-gain calculations and correction factors (see Element 5.7 of the Specifications section), duct heat loss or heat gain as a percentage of seasonal cost was determined. Drastic variations occur to this percentage because of the amount of time hot or cold air is flowing in the ducts relative to the total number of hours in a season. Return-air and supply-air duct heat losses vary; but if the area of the return duct is less than 35% of the total duct area, the error is less than other sources of error in the calculation. The heat loss and heat gain also vary according to supply-air temperature, surrounding air temperature, and the shape of the duct.

The estimated percentage of seasonal cost varied from 15 to 30% when 100% of the duct was uninsulated. These percentages lead to the factor of 0.003, which is first multiplied by 0.5 to obtain 15% and then by 2.0 to obtain 30% on the audit forms. The factor for determining savings from added insulation is

$$1 - \frac{1}{\Delta R + 1} = \frac{\Delta R}{\Delta R + 1},$$

where ΔR equals the resistance value of the added insulation. Note: The U-value of a bare duct was assumed to be 1.0 Btu/(h·ft^2·°F).

AC.3.7 Water Heater Insulation

The jacket losses for a 40-gal gas-fired water heater and for an 80-gal electric water heater were calculated for an existing overall R-value of 2.5 and an improved overall R-value

of 10. The yearly heat losses varied from 1.9 to 3.2 $\times$ 10^6 Btu/year (assuming a water temperature of 140°F) rounded to between 2 and 3 $\times$ 10^6 Btu/year, which are the factors on the audit forms.

The system efficiency (not steady-state) for fossil-fuel-fired water heaters is typically 60% but can be as low as 50%. An efficiency of 70% was used for this measure. An efficiency of 99% was used for electric water heaters. These values of 70% and 99% are used because the jacket losses are already accounted for in the savings calculations and, thus, the inclusion of the jacket losses would lower the seasonal efficiencies to 55% for gas and 80% for electric water heaters. The multipliers (Sect. E.7) are

$$1 \times 10^6/[(100¢/\$)(\text{fuel heating value})(\text{efficiency})] .$$

Fuel heating values are shown as follows.

Fuel	Multiplier	Fuel heating value	Energy cost needed
Electricity	3.0	3,400 Btu/kWh	¢/kWh
Natural gas	0.14	103,000 Btu/(100 ft^3)	¢/(100 ft^3)
No. 2 fuel oil	0.10	138,000 Btu/gal	¢/gal
Propane (LP gas)	0.15	95,000 Btu/gal	¢/gal

AC.3.8 Water Heater Insulation Conditioned Space Correction Factor

When a water heater is in a conditioned space, the heat lost from the jacket helps heat the conditioned space during the heating season. If the space is being cooled, this heat is an added load. The correction factor developed ignores this cooling penalty and is based solely on heating hours. The formula for this factor is given below.

$$\text{Correction factor} = 1 - \frac{\text{heating hours}}{8760} .$$

The heating hours are the number of hours per year below 65°F. If there are no heating hours, the savings are approximately the same as if the water heater were in an unconditioned space, since no contribution to heating is ever made.

AC.3.9 Clock Thermostat Setback Factors

A review of current and past literature was made to determine the effect of temperature reduction on annual heating and cooling costs. Nothing has been found in the area of cooling; however, several works regarding heating savings have been found. The results of the various papers were used for this RCS Model Audit saving predictions for an 8-h nocturnal setback from 70°F.

References for Section AC.3.9

1. Koenig, K., "Gas Furnace Size Requirements for Residential Heating Using Thermostat Night Setback," *ASHRAE Trans.* Vol. 84, Part 2 (1978).

2. Nelson, L. W., "Energy Savings Through Thermostat Setback," *ASHRAE J.* (September 1978).

3. Nelson, L. W., "Reducing Fuel Consumption with Night Setback," *ASHRAE J.* (August 1973).

4. Quentzel, D., "Night-Time Thermostat Setback: Fuel Savings in Residential Heating," *ASHRAE J.* (March 1976).

AC.4 CALCULATIONS FOR ACTIVE AND PASSIVE SOLAR MEASURES

AC.4.1 Solar Savings Fraction

The solar savings fraction (SSF) is defined as the fraction of the energy need or load for either water or space heating that will be provided by the solar system. This definition is consistent for all solar systems, both active and passive.

Regional target values of SSF have been set for three types of active solar systems: domestic water heating, active space heating, and combined water and space heating. To a first-order approximation, the regional target value is the most cost-effective portion of the load. Cost-effectiveness has been established by use of the F-Chart Method described in *Solar Heating Design by the F-Chart Method,* W. Beckman, with solar system and economic factors specific to the region. These solar system and economic factors,* established on a regional basis, include

1. collector materials and fabrication,
2. collector performance,
3. collector tilt angle,
4. solar system cost,
5. fuel cost by fuel type, and
6. fuel cost escalators over a 20-year period by fuel type.

Because of the very wide range of costs and performance for acceptable solar swimming pool heating systems, no regional SSF targets were identified for solar replacement swimming pool heaters.

*This section is a summary discussion adapted from an extensive technical report describing the substance and basis of the solar component of the audit. In the interim, questions of a technical nature concerning this portion of the audit can be directed to Thomas Potter, Solar Energy Research Institute, 1617 Cole Boulevard, Golden, Colorado 80401.

AC.4.2 Prime Solar Fraction

The prime solar fraction (PSF) is defined as the fraction of available solar energy at a site that will be received on a vertical wall, on a seasonal or annual basis, as appropriate for the application, during the prime solar hours (nominally, between 9:00 a.m. and 3:00 p.m.). The PSF is, essentially, a measure of the fraction of available solar energy that will be received through any shading created by trees, foliage, or other blockages to the solar radiation.

PSF can be estimated for south walls by the auditor, on the site, using an appropriate measuring device; several such instruments are commercially available. They are latitude-specific, and they show the fraction of total available solar energy by month, hour, and tilt angle (see Sect. C.3.1 for a discussion of the solar window used with the Model Audit).

AC.4.3 Hot Water Consumption

The daily hot water use estimation is based on the consumption of nominal appliances, as established by a survey of manufacturers of water-using residential appliances. These estimates are graduated according to the size of the family.

The energy needed to heat the water to delivery temperature (120°F) is directly dependent upon the temperature of the groundwater, where the groundwater temperature data are those of the nearest National Oceanic and Atmospheric Administration (NOAA) climatic-data reporting station.

AC.4.4 Slope Comparator or Area Compensator

The slope comparator and area compensator are devices for measuring the tilt of a roof and showing the corresponding number by which the projected area of a roof, as indicated on a plan view sketch of the house, must be multiplied to obtain the actual roof area. Mathematically, the values of the area compensator are the reciprocal of the cosine of the roof tilt angle, rounded to two significant figures.

AC.4.5 Efficient HEUR

Several energy-conserving practices are discussed in the RCS Rule. These practices are intended to provide significant reductions in energy use for a modest investment on the part of the resident. The efficient heating energy use rate (HEUR) is intended to reflect the heating energy needs of the residence *after* these energy-conserving practices have been adopted by the resident. Thus, the original HEUR is multiplied by 0.9 to reflect these savings. The changes require only minimal efforts by the resident to reduce energy losses by implementing energy-conserving practices.

AC.4.6 The 0.021 Factor

The 0.021 multiplier in the passive solar calculations is the result of three factors:

1. In order to convert the HEUR value to appropriate units, it is necessary to multiply it by 24 (hours).
2. The use of (24 × HEUR) as the denominator in the Collector Load Ratio (CLR) calculation results in a thousandths figure, which was reported by field trial auditors to be unwieldly. In order to obtain whole numbers for CLR, it was found most convenient to divide 24 by 1000, yielding 0.024.
3. To convert the HEUR to Efficient HEUR, 0.024 was multiplied by 0.9, yielding the final factor of 0.021.

AC.4.7 Orientation Factor

The orientation factor given in the Audit Procedures for passive solar direct gain and indirect gain systems is used when a residence has no vertical surface facing true south. In this situation, solar evaluations are made for the wall(s) which most closely face(s) south. This factor then corrects for the reduction in solar energy incident on this non-south-facing wall. The orientation factor is given as a function of orientation relative to true south.

AC.4.8 Collector Load Ratio

The collector load ratio (CLR) is defined as the ratio of the effective area of a passive collector to the efficient HEUR of the residence (corrected for units). The CLR calculation procedure for the direct gain, Trombe wall and water wall is based upon data from the *Passive Solar Design Handbook*, Volume 2, J. Douglas Balcomb et al, DOE/CS-0127/2, January 1980; the CLR data for sunspaces is derived from Volume 3, R. Jones, ed., DOE/CS-0127/3, July 1982. The CLR is used directly in the determination of the solar contribution of the passive system to satisfy the space heating needs of the residence, through a functional relationship between the CLR and SSF.

AC.4.9 Domestic Hot Water

The solar domestic hot water calculation method is based on the F-Chart 3 computer program. This program, which was derived from a very accurate and detailed simulation of active solar systems, can compute the solar collector area required to meet a wide range of solar fractions. F-Chart 3 performs these calculations on the basis of inputs about the solar system and the climatic conditions.

To generate the regional data, certain assumptions in F-Chart 3 were made regarding the active solar domestic hot water system. First, the collector type was varied according to climate zone:

Collector type	Glazing	Absorber plate	Climate zone
1	Single	Nonselective	0 to 3500 HDD
2	Single	Selective	3500 to 6000 HDD
3	Double	Selective	6000+ HDD

These collector characteristics translate to different values of the collector efficiency parameters $F_r'(\overline{\tau\alpha})$ and $F_r'U_L$. These two parameters describe the optical properties and heat-loss characteristics of the collector, respectively:

Collector type	$F_r'(\overline{\tau\alpha})$ (dimensionless)	$F_r'U_L$ (Btu/h·ft^2·°F)
1	0.65	1.12
2	0.71	0.86
3	0.65	0.67

Second, for several other parameters, typical values were selected to reflect common design practice. Values for the flow rate, heat exchanger effectiveness, and storage capacity were determined in this way. Third, the collector's tilt was set at a value equal to the latitude, and the orientation was assumed to be due south (preferred orientation) or 30° from due south (acceptable orientation). Fourth, the thermostat on the water heater was assumed to be set at 120°F.

Climatic data, including insolation, water main temperatures, and ambient temperatures, were gathered for cities across the United States.

With these assumptions and data, F-Chart 3 was run for a range of water consumption (20 to 190 gpd) and for a range of solar fractions (0.2 to 0.9). For each combination of these two variables, a required collector area was computed. Results specific to each of the 146 HUD/MPS climate zones are summarized in two tables in the Data Base/Calculation Aids (Sect. E.8). The two tables correspond to the two assumed orientations: 0° (preferred) and 30° (acceptable). These tables allow the auditor to quickly size the solar hot water system during the audit and also provide other information necessary to complete the calculations.

AC.4.10 Thermosiphon Air Panel

The revised procedure for Thermosiphon Air Panels (TAPs) is based on the utilizability method presented by Duffie and Beckman,[1] which permits calculation of long-term solar collector performance. An important input required in this method is the instantaneous collector performance, so a preliminary step was to characterize a TAP's instantaneous efficiency. This was then used in computing the long-term performance.

To determine a TAP's instantaneous performance characteristics, efficiency data presented in the literature were analyzed, and the data presented by Duncan[2] were selected as representative. These data are fitted to the standard equation for collector performance:

$$Q_{del} = A_c[F'(\overline{\tau\alpha})Q_{in} - F'U_L(T_{in} - T_a)] \ .$$

where Q_{del} is the heat delivered by the TAP system, and it is a function of the collector area A_c, incident radiation Q_{in}, ambient temperature T_a, and inlet temperature T_{in}. The parameters F', $(\overline{\tau\alpha})$, and U_L represent the effective collector efficiency factor, the transmission-absorption product, and the effective collector heat-loss rate. The data reported by Duncan correspond to parameter values of

$$F'(\overline{\tau\alpha}) = 0.40 \ ,$$
$$F'U_L = 0.46 \text{Btu/h·ft}^2\text{·°F} \ .$$

These values were used in the TAP analysis.

In estimating the long-term TAP performance, a number of simplifying assumptions were made:

1. Collector performance is assumed to be described by the collector equation presented above. Collector inlet temperature (T_{in}) is assumed to be a constant 70°F.

2. Heat delivered by the TAP system is assumed to be distributed evenly throughout the house. The possibility of overheating in the rooms adjacent to the TAP system while underheating other rooms was ignored.

3. No significant thermal storage of TAP energy is assumed. Collected heat is assumed to either contribute immediately to the building heat load or else be vented as waste heat.

4. The total building heating load is calculated on a monthly basis, based on the total heating degree-days for the month with base temperature 65°F and the building load coefficient (BLC) in Btu/d°F. Degree-days are calculated as a function of average monthly temperature, base temperature, and climate parameters according to a method presented by Erbs et al.[3]

5. The building load during the daytime is calculated using a modified degree-day method. It includes the following three steps: (a) average time temperature for the month is found by adding 6°F to the average monthlytemperature. The 6°F value for the difference between daytime temperature and average monthly temperature is based on an analysis of Typical Meterological Year (TMY) data for 15 cities around the country; (b) the total *daytime degree-days*—equal to the monthly sum of base temperature (65°F) minus daytime average temperature for all days for which the average daytime temperature is less than the base temperature— is calculated for each month. This daytime degree-day measure is similar to standard degree-days but is based on daytime temperature instead of daily average temperature. It is calculated using Erbs's method;[3] and (c) average daytime load is found by multiplying the monthly total of *daytime degree-days* by the BCL (in Btu/d°F) and dividing by the total number of hours in the month.

   $$\text{average hourly daytime load} = \text{DD}_{\text{daytime}} \times \text{Btu/day°F} \div (\text{total h/month}) \ .$$

   Note that the denominator in this equation is *total* hours per month because the daytime degree-days total does not reflect the fact that the daytime period is only a portion of the day.

6. Building load is assumed to be constant during the daytime throughout each month. This assumption is used in assessing how much collected energy is used and how much is wasted through overheating.

These values were used in the TAP analysis.

In estimating the long-term TAP performance, a number of simplifying assumptions were made:

1. Collector performance is assumed to be described by the collector equation presented above. Collector inlet temperature (T_{in}) is assumed to be a constant 70°F.

2. Heat delivered by the TAP system is assumed to be distributed evenly throughout the house. The possibility of overheating in the rooms adjacent to the TAP system while underheating other rooms was ignored.

3. No significant thermal storage of TAP energy is assumed. Collected heat is assumed to either contribute immediately to the building heat load or else be vented as waste heat.

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$$\text{average hourly daytime load} = \text{DD}_{\text{daytime}} \times \text{Btu/day°F} \div (\text{total h/month}) .$$

   Note that the denominator in this equation is *total* hours per month because the *daytime degree-days* total does not reflect the fact that the daytime period is only a portion of the day.

6. Building load is assumed to be constant during the daytime throughout each month. This assumption is used in assessing how much collected energy is used and how much is wasted through overheating.

The calculation of the total and daytime building loads is unorthodox compared to the standard degree-day method. It was chosen for its ease of calculation, since the procedure

must be applied across the entire United States. The degree-day method could not be used because of its inability to determine daytime loads. Because the average-temperature method used here tends to underestimate the total load, a relatively high base temperature (65°F) was selected to compensate for this fact.

The assumption of a constant daytime load, with no storage of TAP collector heat, was also chosen as a reasonable estimate that would permit a straight-forward calculation of TAP performance in all climate regions. With these assumptions, it is possible to develop a TAP performance simulation code based on monthly-step calculations and to apply the utilizability method (Duffie and Beckman[2]). The utilizability method allows computation of the long-term TAP performance by calculating the net useful energy supplied. A simple simulation code, based on this method, was run for 97 weather stations across the United States.

To apply these results to the Model Audit, cities were assigned to the 146 HUD/MPS climate zones. Then, the performance data were computed in terms of Collector Load Ratio (CLR) versus Solar Savings Fraction (SSF). CLR is defined as the TAP collector area (in square feet) divided by the building load coefficient (usually expressed in Btu per degree-day), and SSF is the portion of the overall building load met by the TAP system.

Once tabulated in this format, the TAP performance data were graphed, the curves were smoothed, and third-order polynomial curve-fit equations were derived. (In five of the 97 cities, polynomial curve fits were not accurate enough, and the final curves are simply segmented "point-to-point" graphs of the data.)

The results of the analysis provided a TAP performance graph for each of the 146 HUD/MPS climate zones. Auditors use these graphs to find the SSF value that corresponds to a computed CLR value. The SSF value is then used to compute the first-year savings.

References for Section AC.4.10

1. Duffie, W. A., and Beckman, R. A., *Solar Engineering of Thermal Processes*, Wiley and Sons, 1980.

2. Duncan, T., *Investigation of Passive Solar Wall Air Heaters*, Science Applications, Inc., November 1979.

3. Erbs, D. G., Beckman, W. A., and Klein, S. A., "Degree Days for Variable Base Temperatures" in *Proceedings of the Sixth Annual Passive Solar Conference*, J. Hayes and W. Kolar (eds.), American Solar Energy Society, 1981, pp. 387–91.

AC.4.11 Sunspace Systems

The passive solar sunspace calculation method is based on the Load-Collector Ratio (LCR) methodology developed at Los Alamos National Laboratory and presented in the *Passive Solar Design Handbook—Volume Three* (Jones[1]). This method is derived from detailed computer simulations of passive solar systems that have been validated by comparing their results with measured thermal behavior of experimental buildings. The

computer simulations, in turn, form the basis for a set of correlations that relate monthly LCR values to monthly values of SSF, where the SSF is defined as the ratio of the solar savings to the reference load of the house. Finally, the monthly method is extended to the annual performance estimate method. The final result is a set of tables for 219 cities that list the LCR values corresponding to a range of annual SSF values for different reference sunspace designs.

Although the handbook contains tables for 28 different sunspace designs, two were selected as typical retrofit systems. These two designs are designated as "A5" and "A6" in the Los Alamos document. The geometry for both designs is identical, but R9 night insulation is included for climates with 2500 or more heating degree-days. Figure AC.2 shows the assumed sunspace geometry. All other relevant assumptions are listed in the table below.

In applying the Los Alamos work to the Model Audit, first, cities from the handbook's list of 219 were matched with the 146 HUD/MPS climate zones nationwide. In cases where a HUD/MPS zone does not have one of the 219 cities in its geographic area, another representative city was assigned. Second, the LCR values were converted to the CLR format by inverting and multiplying by 1000. (That is, CLR = 1000/LCR.) The factor of 1000 is included to obtain whole numbers rather than values less than 1.0 for CLR, in order to facilitate field calculations. Third, the CLR, SSF data pairs were graphed, the curves were smoothed, and fourth-order polynomial curve-fit equations were generated and printed on the graphs.

A sunspace performance graph of CLR versus SSF for each of the 146 HUD/MPS climate zones resulted from this process. These graphs are included on microfiche in Sect. E.9 of the Data Base/Calculation Aids. The appropriate graph is used in the field by the auditor to find the SSF value for a computed CLR value. The SSF value is then multiplied by the heating energy bill to derive the first-year savings.

Reference for Section AC.4.11

1. Jones, R., ed., *Passive Solar Design Handbook—Volume Three*, Los Alamos National Laboratory, DOE/CS-0127/3, 1982.

Reference sunspace design characteristics

Dimensions

Width: 30 ft
Height: 9 ft (common wall)
Depth: 11.6 ft

Glazing

Tilt: 50° (from horizontal)
Number of panes: Two 1/8-in. panes with a 1/2-in. air gap

Common wall

Construction: Frame wall
Insulation: R20 [20(h·ft^2·°F)/Btu]
Thermocirculation vents: Top and bottom, each with an area equal to 3% of the common wall area; vents are separated by a height of 8 ft

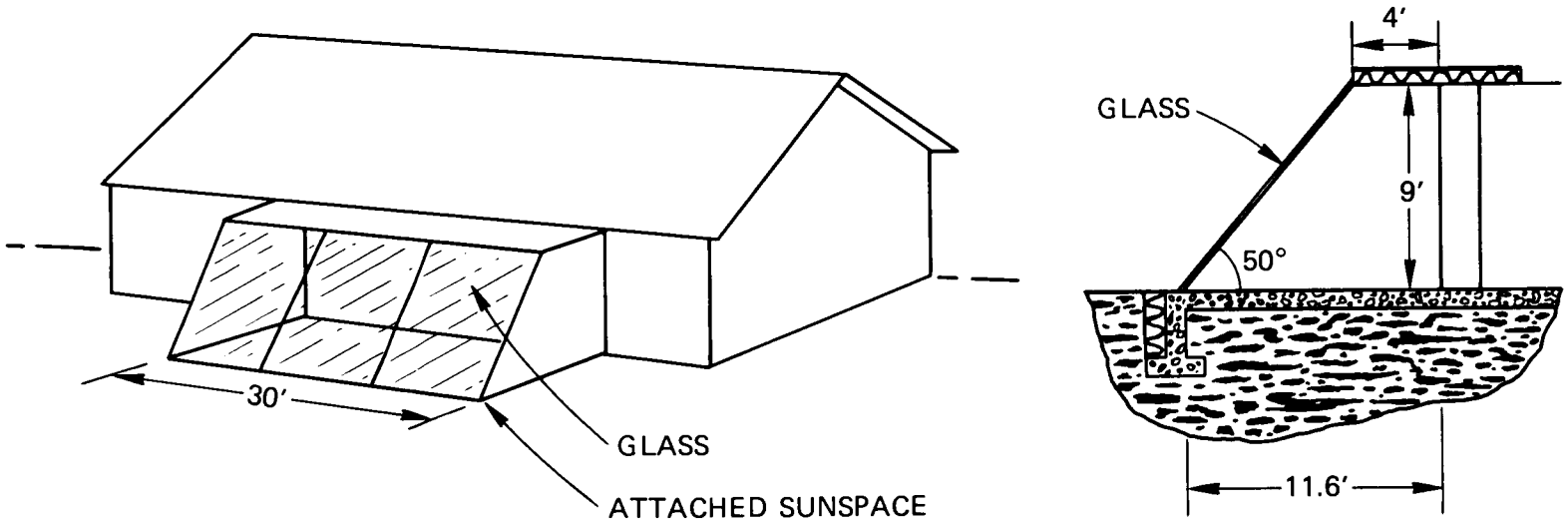

Fig. AC.2. Sunspace geometry.

End walls

Construction: Frame wall
Insulation: R20 [20(h·ft^2·°F)/Btu]

Floor

Construction: Concrete slab, 6 in. thick
Thermal losses: Through soil to fixed deep-ground temperature; through perimeter to ambient temperature

Thermal storage

Type: Water containers
Amount: 1 ft^3 of water per 1 ft^2 of common wall area [62.4 Btu/(ft^2·°F)]

Moveable insulation (when included)

Placement: Covers sunspace glazing
Insulation: R9 [9(h· ft^2·°F)/Btu]
Schedule: Covers glazing from 5:30 p.m. to 7:30 a.m. solar time

Solar absorptance values

Common wall: 0.7
Water containers: 0.9
Floor: 0.8
End walls: 0.3

Infiltration

Air changes per hour: 0.5

Auxiliary heating and ventilation in sunspace

Thermostat heating set-point: 45°F
Ventilation set-point: 95°F

Auxiliary heating and ventilation in adjacent building

Thermostat heating set-point: 65°F
Ventilation/cooling set-point: 75°F

Other assumptions

Ground reflections: 0.3
Sunspace orientation: South
Shading: None

AC.4.12 Summer Shading Factors

The summer shading factors shown in the Audit Procedures section are intended to provide an approximate basis by which the auditor can rapidly account for the potential degradation in effectiveness of the heat-gain retardant devices in blocking the penetration of solar energy into the residence during the summer cooling season. These factors are measures of the extent to which the window is shaded by trees and other vegetation, thereby reducing the incident energy upon the window and potential for the passive solar measure to perform its heat-gain retardant function.

AC.4.13 Window Heat-Gain Retardant and Heat-Reflecting and Heat-Absorbing Materials Annual Energy Savings Factor

Two factors, the window heat-gain retardant annual energy savings factor and the reflecting materials annual energy savings factor, are measures of the extent to which these methods will block the penetration of solar energy into the residence during the summer cooling season. These factors have been determined on the basis of the summer cooling season, by region, and the intensity of the direct and indirect solar radiation incident upon a window as a function of orientation. Calculations have been performed for four orientations: north, south, east, and west. The factors provided in the Data Base/Calculation Aids for the Model Audit are based upon performance data as provided by manufacturers and upon generic data found in the *ASHRAE Handbook, 1977 Fundamentals.*

The third factor, for heat-absorbing materials, derived from the above analysis, is based on manufacturers' descriptions of the materials' performance as solar heat absorbers.

AC.4.14 Pool Heating Energy

The solar energy required to heat a swimming pool during the swimming season was estimated for pools with and without covers. In each case, heat losses from the pool were estimated from evaporation, convection, radiation, and conduction. Separate calculations were made for a pool that is covered when it is not in use and for a pool that is uncovered at all times. The energy required to heat the pool was estimated as that needed to maintain the water at a comfortable swimming temperature (80°F) during the swimming season in a region (i.e., those months during which the average monthly temperature exceeds 60°F).

AC.4.15 Preferred and Acceptable Orientation

Preferred and acceptable orientations refer to the potential locations of solar collectors. A preferred orientation is achieved when the solar collectors can be oriented within 15° of true south, thereby achieving maximum solar gain. An acceptable orientation exists when the collectors must be oriented between 15° and 45° east or west of south, with a corresponding reduction in solar gain.

AC.5 CALCULATIONS FOR WIND ENERGY DEVICES

AC.5.1 Wind Speed Data Base

The best available wind data are desired in order to perform a wind audit at a residential site. The data compiled by Battelle's Pacific Northwest Laboratory are the source of the most reliable data base for the wind energy resource. The 1200 available sites were used to prepare state grid maps to estimate the wind resource at any point in the United States.

AC.5.2 Obstruction Definition

Topographical factors affect both wind intensity and direction. Because the predominant direction of the wind at any individual site may not be the same as the wind direction measured at a random measuring station and because, over a 12-month period, the predominant direction of the wind which provides 75% of the power at a site can be at least 8 of the 16 compass points, any significant obstruction at a site is deemed to have a significant effect on a SWECS installed at the tower heights described by RCS data. Based on data available from Battelle's Pacific Northwest Laboratory work on wind behavior around obstacles, an attempt to quantify the size of a "significant obstruction" for the purposes of RCS was made by Rocky Flats Wind Systems personnel. The least restrictive size that could be applied to a general case was determined to be a 55-ft tall, 30-ft wide structure within 100 ft of the SWECS site.

AC.5.3 Cylinder Siting

The physical operation of a SWECS requires that a horizontal, operational cylinder that represents a free air space through a 360° yaw about the center axis of the machine be available. A 15-ft-diameter cylinder meets the requirements of current commercially available 2- and 4-kW SWECS for physical operation.

AC.5.4 Tower Heights

The availability of towers from commercial firms is such that towers of virtually any height can be bought. Although standard heights are in increments of 10 ft, the availability of freestanding towers in 20-ft increments from major manufacturers and the experience of installations from the DOE field evaluation program point out the availability and usage of towers in the ranges of 40, 60, and 80 ft for most SWECS installations.

AC.5.5 Site-Specific Wind Resource Factors

The analysis, by Battelle's Pacific Northwest Laboratory, of the wind data from the 1200 available nationwide wind-measuring sites identified two factors that could be used to account for the variability of wind resources. These factors combine various effects and are site-dependent.

The Height and Roughness Correction Factor combines the effects of tower height and the surrounding topographical roughness. The original wind data were obtained at a standard 10-m (33-ft) height and were corrected to the 40-, 60-, and 80-ft tower heights. The roughness description addresses the surface effect of the terrain.

The Terrain Shelter Adjustment Factor combines the effects of obstructions to wind of the terrain and the specific exposure of the potential SWECS site. A general descriptive characteristic of the terrain is used. The exposure description varies from very sheltered to better exposure.

AC.5.6 Wind Machine Output

No data exist to match SWECS output from the wind resource at a site with the electrical usage pattern at that site. Because this factor could range potentially from 0 to 100%, the value of 50% has been chosen to represent a typical match.

Appendix D
Auditor's Equipment List

The following is a suggested list of equipment for use on the site by the auditor.

Clipboard
Pencils/Pens
Calculator (four-function)
Straight Edge
Compass
Solar Viewing Device
Plastic Crochet Hook (Size H)
Tape Measures (100 ft or 50 ft and 12 ft)
Flashlight
Screwdrivers (regular and Phillips point)
Step Ladder (6 ft)
Utility Knife
Coveralls
Work Gloves
Particle Face Mask/Respirator
Hand Drill (1/4-in. and 1/8-in. bits)
Sheet Metal Screws
Flue Gas Analyzer
Self-Developing Camera and Film

Appendix E

Glossary of Selected Terms and Definitions of Acronyms and Initialisms

Active solar space heating system	Equipment designed to absorb the sun's energy and to use this energy to heat living space by use of mechanically forced energy transfer, such as fans or pumps
Active solar system	A solar system that requires external mechanical power to move the collected heat
Air change	A measure of the rate at which the air in a building is replaced by outside air from infiltration and ventilation; usually described as air changes per hour
Air duct	A tube or conduit used for conveying air
Air-type collector	A collector that uses air as the heat transfer fluid
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Auxiliary heat	The extra heat provided by a conventional heating system during periods of cloudiness or intense cold when a solar system cannot provide enough heat
Batt insulation	A flexible precut thermal insulation, commonly used as insulation between studs or posts; sometimes has a vapor barrier on one side
Blanket insulation	Thermal insulation, commonly fabricated of fibrous glass material; for properly selected density, can conform to curved or irregular surfaces
Boiler	A closed heating appliance intended to supply hot water or steam for space heating
British thermal unit (Btu)	The quantity of heat needed to raise the temperature of 1 lb of water one 1°F
Building envelope	All external surfaces of a building that are subject to climatic impact

Caulking	A pliable material used to reduce the passage of air and moisture by filling small gaps (a) at fixed joints on a building, (b) underneath baseboards inside a building, (c) in exterior walls at electric outlets, (d) around pipes or wires entering a building, and (e) around dryer vents and exhaust fans in exterior walls. It includes, but is not limited to, materials commonly known as "sealants," "putty," and "glazing compounds"
CDD	Cooling degree-days
Ceiling insulation	A material primarily designed to resist heat flow, which is installed between the conditioned area of a building and an unconditioned attic. Where the conditioned area of a building extends to the roof, the term "ceiling insulation" also applies to such material used between the under side and upperside of the roof. It also includes such material installed on the exterior of the roof
Central heating system	A system in which heat is supplied to areas of a building from a central unit through a network of ducts or pipes
CESR	Cooling energy supply rate
CEUR	Cooling energy use rate
Class A energy audit	An energy audit in which the estimates of costs and savings associated with the installation of retrofit measures are computed on the basis of an onsite inspection of a dwelling by a trained auditor
Class B energy audit	An energy audit in which the estimates of costs and savings associated with the installation of retrofit measures are computed by an outside entity on the basis of information collected by a resident about his or her dwelling or residential building
Clock thermostat	A device which is designed to reduce energy consumption by regulating the demand on the heating or cooling system in which it is installed and which uses (a) a temperature control device for interior spaces incorporating more than one temperature control level and (b) a clock or other automatic mechanism for switching from one control level to another

CLR	Collector load ratio
Coefficient of performance (COP)	The ratio of useful heat output or heat extracted to the total energy input necessary to operate the device or system
Collector	A device that collects solar radiation and converts it to heat
Collector efficiency	The ratio of usable heat energy extracted from a collector to the solar energy striking the cover
Collector load ratio (CLR)	The ratio of effective collector area to the house heating load to be offset
Collector tilt	The angle between the horizontal plane and the solar collector plane
Combined active solar space heating and solar domestic hot water system	Equipment designed to absorb the sun's energy and to use this energy to heat living spaces and water by use of mechanically forced energy transfer
Conditioned space/heated space	A space within a building which is provided with energy to maintain an air temperature or comfort level
Conduction	The flow of heat due to temperature variations within a material
Conventional energy source	Electricity, natural gas, oil, or coal
COP	Coefficient of performance
Covered utility	In any calendar year, a public utility which during the second preceding calendar year had either (a) sales of natural gas for purposes other than resale which exceeded 10 billion cubic feet or (b) sales of electric energy for purposes other than resale which exceeded 750 million kilowatt hours
CSC	Cooling seasonal cost
Daily mean temperature	The average of the maximum and minimum temperatures of a 24-h day
Data base/calculation aids (DB/CA)	A collection of tables, charts, graphs, and calculation tools developed for use in conjunction with the Model Audit
Default	Pertaining to an option or value that is to be assumed when none has been explicitly specified

Degree-day	A unit that represents 1°F deviation from some fixed reference point (usually 65°F) in the mean daily outdoor temperature
Design heating load	The total heat loss from a house under the most severe winter conditions likely to occur; a concept used in the design of buildings and their heating systems
Design temperature	A temperature close to the lowest temperature expected for a location; used to determine the design heating load
Direct gain glazing system	A passive solar system utilizing south-facing (±45°F or true south) panels or glass, fiberglass, or other similar transparent or translucent materials that admit sunlight into the living space where the heat is retained; glazing is either double-paned or single-paned panels equipped with movable insulation
Direct radiation	Solar radiation that comes straight from the sun, casting shadows on a clear day
Double glazing	Two panes of glass or other transparent material
Duct insulation	A material primarily designed to resist heat flow, which is installed on a heating or cooling duct in an unconditioned area of a building
EER	Energy efficiency ratio
Efficient use of shading	An energy-conserving practice using shades or drapes to (a) block sunlight from entering a building in the cooling season, (b) allow sunlight to enter during the heating season, and (c) cover windows tightly at night during the heating season
Electric furnace	A centrally located device which heats air with electric resistance heating elements for heat distribution throughout the dwelling
Electric load management devices	Devices that reduce the maximum kilowatt demand on an electric utility and which are either (a) part of a radio, ripple, or other utility-controlled load-switching system on the customer's premises; (b) clock-controlled load switching devices on major appliances; (c) interlocks and other load-actuated, load-limiting devices; or (d) energy storage devices with control systems

Electric resistance heat	Heat produced by a flow of electricity through high-resistance wire, tape, or film
Electric space heating	Space heating using permanently installed electric heating as the principal source of space heating throughout the dwelling
Electrical or mechanical ignition system	See Intermittent pilot ignition device
Eligible customer	A person who both (a) owns or occupies a residential building or dwelling unit therein (except that the owner of the common area within a residential building containing five or more dwelling units shall not be treated as an eligible customer for the purposes of the common area at this time) and (b) receives a fuel bill from a covered utility or participating home heating supplier for fuel used in such a residential building or dwelling unit therein
Energy audit	An analysis of energy consumption patterns, based either on an onsite inspection of the premises or on information collected by the occupant in response to a questionnaire
Energy conservation measure	The installation of products or materials designed to reduce energy consumption
Energy conserving practices	Low-cost or no-cost modifications to either existing equipment or to energy consumption patterns by residential occupants
Energy efficiency ratio (EER)	The ratio of net capacity output in Btu/h to energy input
ESA	Energy Security Act, Subtitle B of Title V of Public Law 96-294, which amended Part 1 of Title II of the National Energy Conservation Policy Act
Flat-plate collector	A solar collection device in which sunlight is converted to heat on a plane surface without the use of reflecting surfaces to concentrate the rays

Floor insulation	A material primarily designed to resist heat flow, which is installed between the first-level conditioned area of a building and an unconditioned basement, a crawl space, or the outside beneath it; where the first-level conditioned area of a building is on a ground-level concrete slab, the term "floor insulation" also means such material installed around the perimeter of or on the slab. In the case of mobile homes, the term "floor insulation" also means skirting to enclose the space between the building and the ground
Flue	A passage or channel through which the products of combustion from a boiler or furnace are taken to the chimney
Flue-opening modification	An automatically operated damper installed in a gas-fired furnace (often called a vent damper) which (a) is installed downstream from the drafthood and (b) conserves energy by substantially reducing the flow of heated air through the chimney when the furnace is not in operation
Foamed-in-place insulation	Thermal insulation composed of a plastic foam base and usually applied to enclosed cavities
Furnace efficiency maintenance and adjustments	Energy-conserving practices which include (a) cleaning and combustion efficiency adjustment of gas or oil furnaces, (b) periodic cleaning or replacement of air filters on forced-air heating or cooling systems, (c) lowering the bonnet or plenum thermostats to 80°F on a gas or oil forced-air furnace, and (d) turning off the pilot light on a gas furnace during the summer
Furnace efficiency modification	An alteration or replacement designed to improve the energy efficiency of a heating system
Furnace replacement burner (oil)	A device which atomizes the fuel oil, mixes it with air, and ignites the fuel air mixture and is an integral part of an oil-fired furnace or boiler and which, because of its design, achieves a reduction in the oil used from that used by the device which it replaces
Greenhouse	See Solaria/sunspace system
HDD	Heating degree-days

Heat flow	Heat thought of as energy flowing from one substance to another; the amount of heat transferred in a unit of time
Heat pump	A mechanical device that transfers heat from one medium at lower temperature (called the heat source) to another medium at higher temperature (the heat sink), thereby cooling the first and warming the second
Heat-reflective and heat-absorbing window or door material	A window or door glazing material with exceptional heat-absorbing or heat-reflecting properties, or reflective or absorptive films and coatings applied to an existing window or door which thereby result in exceptional heat-absorbing or heat-reflecting properties
Heat sink	A medium to which heat is added
Heat source	A medium from which heat is extracted
Heat storage	A device or medium that absorbs collected heat and stores it for use during periods of cooler temperatures
Heat storage capacity	The ability of a material to store heat
Heat transmission coefficient	The ratio which expresses the thermal conductance of a structure in Btu per square foot per Fahrenheit degree temperature difference between outdoor and indoor temperatures
Heated space/conditioned space	See Conditioned space/heated space
Heating energy use rate (HEUR)	The measurement of the heat loss characteristics of a building in Btu/h·°F
Heating season	The period from early fall to late spring during which additional heat is needed to keep a house comfortable for its occupants
HESR	Heating energy supply rate
HEUR	Heating energy use rate
Home heating supplier	A person who sells or supplies home heating fuel (including No. 2 heating oil, kersosene, butane, and propane) to an eligible customer for consumption in a residential building
HSC	Heating seasonal cost
HUD/MPS	Department of Housing and Urban Development Minimum Property Standards
IID	Intermittent ignition device (see Intermittent pilot ignition device)

Indirect gain systems	Passive solar systems employing the use of south-facing (±45° of true south) panels of glass, fiberglass, or other transparent or translucent materials that transmit sunlight onto thermal walls, ceilings, rockbeds, or containers of water where heat is stored for later use or transferred directly to the living space
Infiltration	The uncontrolled movement of outdoor air into the interior of a building through cracks and/or around windows, doors, walls, roofs, and floors
Insolation	The total amount of solar radiation striking a surface
Intermittent pilot ignition device (IID)	A device which, when installed in a gas-fired furnace or boiler, automatically ignites the gas burner and replaces a gas pilot light
Kilowatt	A measure of power equal to 1000 W
kWh	Kilowatt hours
LASL	Los Alamos Scientific Laboratory
Liquid-type collector	A collector using a liquid as the heat transfer fluid
Loose fill insulation	Thermal insulation installed between surfaces of existing structures by a blowing machine or by hand pouring
Masonry construction (solid)	A building unit constructed with clay, shale, concrete, glass, gypsum, or stone bonded together with mortar or monolithic concrete with no significant air spaces
Measures warranties	(1) The term "manufacturer's measure warranty" means, at a minimum, a written warranty by the manufacturer of an energy conservation or renewable resource measure that the eligible customer for whom the measure is installed, the installation contractor who installs the measure, and the seller of the measure shall be entitled to obtain, within a reasonable period of time and at no charge, appropriate replacement parts or materials for those measures found within one year from the date of installation to be defective due to materials, manufacture, or design. (2) The term "supplier's measure warranty" means, at a minimum, a written warranty (equivalent to that referred to in the beginning of this definition) provided by the supplier of an

Measures warranties (continued)	energy conservation or renewable resource measure to persons who purchase the measure from the supplier. (3) The term "contractor's measure warranty" means, at a minimum, a written warranty by a contractor installing an energy conservation or renewable resource measure that any defect in materials, manufacture, design, or installation found within one year from the date of installation shall be remedied without charge and within a reasonable period of time
Model Audit	An energy audit for residential buildings developed to fulfill RCS program requirements
NBS	National Bureau of Standards
NECPA	National Energy Conservation Policy Act, Part 1 of Title II, Public Law 95-619, as amended by Subtitle B of Title V of the Energy Security Act
New seasonal efficiency (NSE)	The seasonal performance of the best available equipment
Nighttime temperature setback	The manual lowering of the thermostat control setting for the furnace during the heating season to a maximum of 55°F during sleeping hours
Nocturnal or night cooling	The cooling of a building or heat storage device by the radiation of heat to the night sky or by convection
Nonregulated utility	A public utility which is not a regulated utility
NOAA	National Oceanic and Atmospheric Administration
NSE	New seasonal efficiency
ORNL	Oak Ridge National Laboratory
PSE	Present seasonal efficiency
Participating home heating supplier	A home heating supplier that has elected to participate in a State Residential Conservation Service Plan which includes home heating suppliers
Passive solar space heating and cooling systems	Systems that make the most efficient use of, or enhance the use of, natural forces—including solar irradiation, winds, nighttime coolness, and the opportunity to lose heat by radiation to the night sky—to heat or cool living space by the use of conductive, convective, or radiant energy transfer

Percent possible sunshine	The percentage of daytime hours during which there is enough direct solar radiation to cast a shadow
Pipe insulation	A material primarily designed to resist heat flow which is installed on a heating or cooling pipe in an unconditioned area of a building
Plugging leaks in attics, basements, and fireplaces	Energy conserving practices which include (a) installing scrap insulation or other pliable materials in gaps around pipes, ducts, fans, or other items which enter the attic or basement from a heated space; (b) installing fireproof material to plug any holes around any damper in a fireplace; and (c) adding insulation to an attic or basement door
Present seasonal efficiency	The seasonal performance of the equipment currently in place
Prime solar fraction (PSF)	A measure of the proportion of sunlight which is unobstructed at a particular location
Program announcement	The Residential Conservation Service program information and offer of services required to be sent by a covered utility or participating home heating supplier to each eligible customer
Program audit	An energy audit in which the estimates of costs and savings are based on an adequate assessment, including actual measurements or inspections, as appropriate, performed onsite by the auditor, of the building shell and of the space heating, space cooling, and water heating equipment of the residence of an eligible customer. In the case of residential buildings containing more than four dwelling units, the program audit may mean an audit in which the estimates of costs and energy savings are based on a sampling of the types of units in the building.
Program measures	Those energy conservation or renewable resource measures which the assistant secretary has by rule determined to be appropriate by climatic region and building category and which are found in Appendix I to the RCS Rule published in the June 25, 1982, *Federal Register*, or which are determined by a governor to be program measures

PSE	Present seasonal efficiency
PSF	Prime solar fraction
Public utility	Any person, state agency, or federal agency which is engaged in the business of selling natural gas or electric energy, or both, to residential customers for use in residential buildings
R-value	See Resistance
RCS	Residential Conservation Service
Raising thermostat setting in summer	An energy conserving practice composed of setting the thermostat control for an air conditioner to 78°F or higher during the cooling season
Rate	Any price, rate, charge, or classification made, demanded, observed, or received with respect to sales of electric energy or natural gas; any rule, regulation, or practice respecting any such rate, charge, or classification; and any contract pertaining to the sales of electric energy or natural gas
Ratemaking authority	Authority to fix, modify, approve, or disapprove rates
Reducing energy use when a home is unoccupied	Energy-conserving practices composed of (a) reducing the thermostat setting to 55°F when a home is empty for 4 h or longer in the heating season, (b) turning an air conditioner off in the cooling season when no one is home, and (c) turning a water heater off when a home is vacant for 2 d or longer
Reducing hot water temperature	Energy-conserving practices composed of the manual set back of the water heater thermostat setting to 120°F and the reduction of the amount of heated water used for clothes washing
Reducing thermostat settings in winter	An energy-conserving practice involving limiting the maximum thermostat control setting for the furnace to 68°F during the heating season
Reflective insulation	Thermal insulation that reflects infrared or heat rays by means of a polished metallic surface
Regulated utility	A public utility whose rates can be set by a state regulatory authority

Renewable resource measure	The use of an active or passive solar energy system or wind energy device designed to reduce consumption of purchased energy
Replacement central air conditioner	A central air conditioner which replaces an existing central air conditioner of the same fuel type and reduces the amount of fuel consumed because of an increase in efficiency
Replacement furnaces and boilers	Furnaces or boilers, including heat pumps, which replace existing furnaces or boilers of the same fuel type and which reduce the amount of fuel consumed because of an increase in combustion efficiency, improved heat generation, or reduced heat losses
Replacement solar swimming pool heaters	Devices which are used solely for the purpose of using the sun's energy to heat swimming pool water and which replace a swimming pool heater using electricity, gas, or other fossil fuel
Residential buildings	Any building used for residential occupancy which (a) is not a new building to which voluntary performance standards under Sections 304(a) and 305 of the Energy Conservation and Production Act, as amended, apply; (b) has a system for heating or cooling, or both; and (c) contains at least one, but not more than four, dwelling units. After January 1, 1982, the term "residential buildings" also includes any building which contains more than four dwelling units unless such building contains a heating or cooling system, or both, which is a central system.
Resistance (R-value)	The measurement of a material's ability to retard the flow of heat
Retrofit	Modifications made to existing equipment or structures
RF	Rocky Flats Plant
Rigid board insulation	A preformed material in board or block form which provides resistance to heat flow
Sealing leaks in pipes and ducts	Energy-conserving practices composed of (a) installing caulking in any leak in a heating or cooling duct, (b) tightening or plugging any leaking joints in hot water or steam pipes, and (c) replacement of washers in leaking water valves

Seasonal efficiency	The steady-state equipment performance corrected for cycling losses
Seasonal energy efficiency ratio (SEER)	System performance which accounts for cycling energy losses as well as steady-state energy losses
SEER	Seasonal energy efficiency ratio
SERI	Solar Energy Research Institute
Sizing (of Heating Systems)	The heating capacity of a heating system
Slab	The upper part of a reinforced concrete floor which is carried on beams or the concrete mat put on the ground to serve as the floor of a structure with no basement or crawl space underneath
Solar domestic hot water systems (SDHW)	Equipment designed to absorb the sun's energy and to use this energy to heat water for use in a residential building other than for space heating, including thermosiphon hot water heaters
Solar savings fraction	A fraction representing the proportion of present conventional energy use which could be displaced by a solar installation
Solaria/sunspace system	A passive solar system composed of a structure of glass, fiberglass, or similar transparent or translucent material which is attached to the south-facing ($\pm 45°$ of true south) wall of a residential building for the purpose of collecting solar energy and which allows for air circulation to bring heat into the residence and which is able to be closed off from the residential structure at night and during periods of low irradiation
SSF	Solar savings fraction
State measure	An energy-saving measure added by a state's governor to the list of RCS program measures
Storm door	A second door, installed outside or inside a prime door, creating an insulating air space
Storm window	A window or glazing material placed outside or inside an ordinary or prime window, creating an airspace, to provide greater resistance to heat flow than does the prime window alone
SWECS	Small wind energy conversion system

TAP	Thermosiphon Air Panel
Thermal door	A door with resistance to heat flow through the glass area enhanced by affixing two or more sheets of glazing material or a prime exterior door with an R-value of at least 2
Thermal mass or thermal inertia	The tendency of a building material to remain at the same temperature or to fluctuate very slowly; the overall heat storage capacity of a building
Thermal wall	See Trombe wall
Thermal window	A window unit with improved thermal performance through the use of two or more sheets of glazed material affixed to a window frame to create one or more insulated air space(s); it may also have an insulating frame and slash
Thermosiphon air panel	An attached solar collector which uses thermosiphoning to heat air and transfer it to the building
Thermosiphoning	The natural process that causes a fluid (water or air) to circulate in a closed circuit because of variations in the fluid density resulting from a temperature differential
Trombe wall (thermal wall)	An exterior wall (usually masonry) with sufficient thermal storage mass and insolation to which glazing is added; this approach increases the amount of solar heat available to heat the building
U-value	See Heat transmission coefficient
Unconditioned space	An area in a building that has deliberately not been provided with heat to maintain an air temperature or comfort level
Vapor barrier	A moisture-impervious layer or coating which prevents the passage of moisture or vapor into a material or structure
Vent damper	See Flue-opening modification
Ventilation	The process of supplying or removing air to or from an interior space
Wall insulation	A material primarily designed to resist heat flow which is installed within or on the walls between conditioned areas of a building and unconditioned areas of a building or the outside

Water flow reduction in showers and faucets	The energy-conserving practice of placing a device in a shower head or faucet to limit the maximum flow to 3 gal/min or of replacing existing shower heads or faucets with those having built-in provisions for limiting the maximum flow to 3 gal/min
Water heater insulation	A material primarily designed to resist heat flow which is suitable for wrapping around the exterior surface of the water heater casing
Water wall	An exterior wall with sufficient glazed area and insolation behind which large containers of water are placed; the water serves as the thermal storage mass, which increases the amount of solar heat available to heat the building
Weather stripping	Narrow strips of material placed over or in moveable joints of windows and doors to reduce the passage of air and moisture
WHGR	Window heat gain retardant
Wind energy devices	Equipment that uses wind energy to produce energy in any form for residential purposes
Window heat gain retardants	Those mechanisms which significantly reduce summer heat gain through windows in the summer by use of devices such as awnings, insulated rollup shades (external or internal), or metal or plastic solar screens
Window heat loss retardants	Those mechanisms which significantly reduce winter heat loss through windows by use of external or internal devices, such as insulated rollup shades or movable rigid insulation, that cover the windows during the winter both at night and when no appreciable amount of sunlight is entering the window during the day

Appendix F
State-Added Measures

AF.1 ADD-ON HEAT PUMP

AF.1.1 Procedure

Add-on heat pump (AOHP) is the addition of an electric heat pump to an existing fossil-fuel-fired warm air furnace. The auditor should first determine whether an add-on heat pump is appropriate for the residence investigated. The most obvious conditions for an economically beneficial application is a home with existing air conditioning in combination with a gas- or oil-fired warm air furnace. The usual situation for this combination of heating/cooling equipment is a split-system air conditioning unit with the air conditioner evaporator mounted downstream from the furnace bonnet (heat exchanger). The heat pump would replace the air conditioning unit with the indoor coil of the heat pump replacing the air conditioner evaporator coil. If the two coils are not the same size, there may be additional retrofitting costs. However, the existing ducting, including insulation, and fan size should be sufficient because the heat pump selection is generally based on cooling capacity requirements which, in turn, are likely to be reduced because of other energy-saving measures recommended in the RCS program. It is important to refrain from oversizing the unit even if a larger heat pump would decrease overall heating season operating costs because these savings can be offset by reduced cooling efficiencies due to increased cycling losses. There may be exceptions in regions with high heating-to-cooling load ratios.

If the residence is presently not air conditioned, the existing ducting and air flow capacity are likely to be too small and the ducts may not be insulated sufficiently to prevent condensation (sweating) during the cooling mode of operation. This could add a significant cost for retrofit. The homeowner should, in this case, also be consulted about the desirability of adding air conditioning, which, if used, will increase the annual utility costs.

Because a heat pump is a dual-purpose machine, careful consideration should be given to the allocation of capital costs between heating and cooling. For instance, if a central air conditioner *needs* to be replaced and an AOHP is purchased to replace it, then the annual savings should be compared to the incremental additional cost of the AOHP above the replacement air conditioner, not to the full cost of the heat pump.

The auditor will require a utility-supplied AOHP data base (utility DB) for each specific area having common fuel costs, electricity costs, and weather conditions. This data base will consist of (1) curves of annual savings divided by design heating load as a function of

steady-state furnace efficiency and heat pump COP and (2) correction factors for furnace oversize.

The nameplate furnace capacity, measured or estimated steady-state furnace efficiency, the HEUR and CEUR from previous audit calculations, and local heating and cooling design temperatures are recorded on the calculation sheet. The heating and cooling design loads are determined by multiplying the HEUR and CEUR by the respective design day temperature difference. The design day temperature difference should equal the difference between outside design temperature and the residence balance point temperature (65°F), unless a local determination is made of the most appropriate indoor temperature value. The balance point temperature, in this case assumed to be 65°F, is the outdoor temperature below which, on a long-term average, heating is required.

The heat pump size (capacity) at 47°F is estimated to be equal to the cooling capacity required. This relationship between heating and cooling will vary with heat pump models, but it is a good approximation without knowing which model heat pump the homeowners will eventually select. The annual heating season savings divided by the heating design load is determined from a set of curves provided by the utility (utility DB) for the steady-state furnace efficiency and heat pump COP selected by the auditor as reasonable, on the basis of availability in the area. The annual savings are then evaluated, as indicated, by correcting for furnace oversize and multiplying by the heating season design load. An example of the furnace oversize correction factor table and the "annual savings divided by design heating load" curves are shown in the methodology section (Sect. AF.1.3).

AF.1.2 Forms

The forms for add-on heat pumps are on the following pages.

AF.1.3 Methodology

The savings for an AOHP were based on a technical assessment[1] performed by Oak Ridge National Laboratory (ORNL). The technical assessment indicated that the AOHP can be cost-effective when the existing furnace is not highly efficient and/or electricity prices are not excessively high. In general, applying the AOHP to existing oil-fired furnaces currently results in better paybacks than applying the AOHP to gas-fired furnaces because of the fuel price differential. The widely fluctuating price of both gas and oil, as well as electricity prices, should be updated regularly since these price changes can significantly affect the savings.

To be generic and regionally independent, this procedure assumes that the residence is air conditioned in combination with a gas or oil furnace. It further assumes that the AOHP selection will be optimally sized for cooling and that the heating capacity of the heat pump at 47°F equals the ARI-rated cooling capacity. This relationship between heating and cooling will vary with heat pump models, but it is a good approximation without knowing which heat pump model the homeowners will eventually select. This procedure evaluates savings for heating only. Additional benefits gained by the simultaneous upgrading of the air conditioner efficiency (see Replacement Air Conditioner measure, Sect. C.5.17) should be considered.

AF.1.2 FORMS

ADD-ON HEAT PUMP

① Nameplate Furnace Capacity (Btu/hr)	② Steady-State Furnace Efficiency %	②a Furnace Heating Capacity Btu/hr ①x②÷ 100	③ Heat Pump COP(47)

④ HEUR (Btu/hr·°F)	⑤ CEUR (Btu/hr·°F)	⑥ Heating Season Design Temp. (°F)	⑦ Cooling Season Design Temp. (°F)	⑧ Heating Season Design Load (Btu/hr) ④x [65 -⑥]	⑨ Cooling Season Design Load (Btu/hr) ⑤x [⑦- 65]
P.D-5,L4	P.D-5,L5	Local Data	Local Data		

⑩ Heat Pump Capacity (47) (Btu/hr) ⑨	⑪ Heat Pump Capacity / Heating Design Load ⑩÷⑧	⑫ Annual Savings / Heating Design Load	⑬ Furnace Oversize ②a÷⑧
		Utility DB	

⑭ Furnace Oversize Correction Factor	⑮ Annual Savings ($) ⑫x ⑭x ⑧
Utility DB	

③

⑯ Cost of Adding Heat Pump $_____ [Based on COP(47) of ____]

The procedure uses a data base (input data) developed by the utility for each specific area having common fuel costs, electricity costs, and weather conditions. This data base can be easily developed by using the computer program described in the report, ORNL/CON-116[1] and consists of a set of curves showing the ratio of annual savings in dollars divided by the design heating load of the residence (Btu/h at design conditions) as a function of steady-state furnace efficiency and heat pump COP. Sample curves are shown in Fig. AF.1.1. Cycling losses of both the furnace and heat pump are handled within the computer program. Sample furnace capacity correction factors are shown in the table below.

Sample furnace capacity correction factors[a]

Furnace oversize	Correction factor (CF)
2.25	1.21
2.00	1.15
1.75	1.08
1.50	1.00
1.25	0.90
1.00	0.79

[a]These factors were developed for Washington, D.C., and, therefore, may not be applicable for other locations.

The computer program is based on the bin hour procedure. This procedure was selected as a compromise between the needs for simplicity and for accuracy in estimating annual dollar savings. The use of bin weather data allows for accounting of the temperature-dependent behavior of heat pumps and furnaces with much less effort than would be required if hourly weather data were used. Further, bin weather data, which represent average weather, are readily available for a large number of cities. Bin weather data consist of the average number of hours per year during which the air temperature is within specific 5-degree-wide bins. For example, the number of hours in the 42°F bin is the number of hours in a year in which the outdoor air temperature is equal to or greater than 40°F and less than 45°F. These data are available from *ASHRAE Handbook, 1977, Fundamentals Volume*, and from Air Force Manual 88-29, *Engineering Weather Data*.

On the basis of local conditions, including fuel costs, the computer program compares operating costs for the furnace alone with costs using the AOHP for each bin temperature. When the furnace alone operates more economically for a specific bin temperature, the heat pump is not used.

Optimum sizing of the AOHP as a function of design load will vary with locality. This is usually determined by the relative sizes of the peak cooling and heating loads; heat pumps

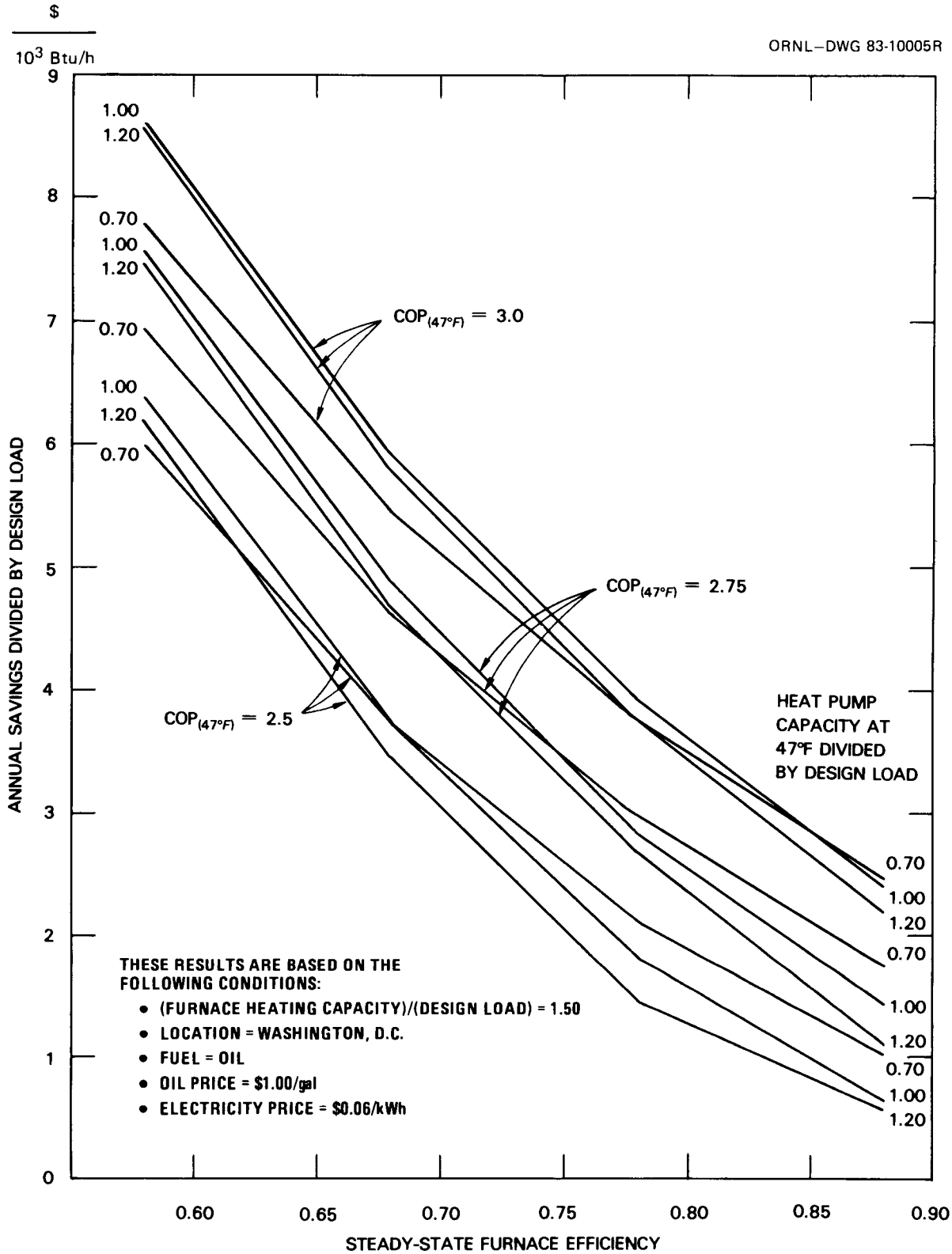

Fig. AF.1.1. Annual savings divided by design load as a function of steady-state furnace efficiency (abscissa) and heat pump COP (parameter).

are often sized to satisfy the peak cooling load. A method of determining the sensitivity of heat pump capacity on annual savings is described in the ORNL report.[1] It was found that the annual savings are relatively insensitive to heat pump capacity for values of heat pump capacity at 47°F divided by design load (HPC47/DL) between 0.7 and 1.2 for the case tested.

Furnace size is a variable that is not known until the audit is in process. The utility-developed data base is thus determined for a given furnace oversize (furnace heating capacity divided by design load), and correction factors are provided for other values of oversize. The size of both the heat pump and the furnace, as compared to the design load, significantly affects the seasonal efficiency because of cycling losses.

Reference for Section AF.1.3

1. McCold, L. N., *Development of an Add-on Heat Pump Savings Estimation Procedure*, ORNL/CON-116, Oak Ridge National Laboratory, Oak Ridge, Tenn., to be published.

AF.2 DESUPERHEATER FOR SUPPLYING DOMESTIC HOT WATER

AF.2.1 Procedure

A desuperheater is a conservation measure that can be retrofitted to a heat pump or a central air conditioner to obtain energy for heating domestic hot water (DHW). Cost savings result from heating the hot water with the desuperheater instead of the electric resistance element in the hot water tank. The computations given here are only for supplementing the hot water energy generated by electric resistance water heaters. The auditor needs to check to see if the residents already have an 80-gal water heater or if there is enough room to add a second tank to provide a total of 80 gal of storage. In addition, there should be adequate space for the heat reclaimer equipment. If these conditions are not met, this measure should not be evaluated. There are two installation options: (1) a single 80-gal (minimum) heater with the bottom heating element disconnected or (2) two 40-gal (minimum) tanks piped in series (one to serve as a storage tank with both heating elements disconnected) to be used in conjunction with the heat reclaimer. Suggested piping arrangements for the single and double tanks are shown in Figs. AF.2.1 and AF.2.2, respectively.

The following describes three procedures for determining savings by use of a desuperheater: Sect. AF.2.1.1 describes the retrofit of a desuperheater to a heat pump in a location where the utility has constant electric rates, Sect. AF.2.1.2 describes the retrofit of a desuperheater to a heat pump in a location where the utility has different seasonal rates, and Sect. AF.2.1.3 describes the retrofit of a desuperheater to central air conditioners. Several pieces of data that are available from the Data Base/Calculation Aids (DB/CA) section (Sect. E) and/or that have been calculated previously (Sect. D) should be entered on the calculation sheet for this measure. These include summer and winter (if appropriate) electric price, HEUR, corrected heating degree-days (HDD) as described in Audit Procedures (Sect. C.4), CEUR (or CESR from utility data also described in Audit Procedures), and air conditioner efficiency. Seasonal heating energy is determined by multiplying HEUR by HDD and by 24 divided by 10^6. If utility data are used to obtain seasonal cooling cost, CEUR is

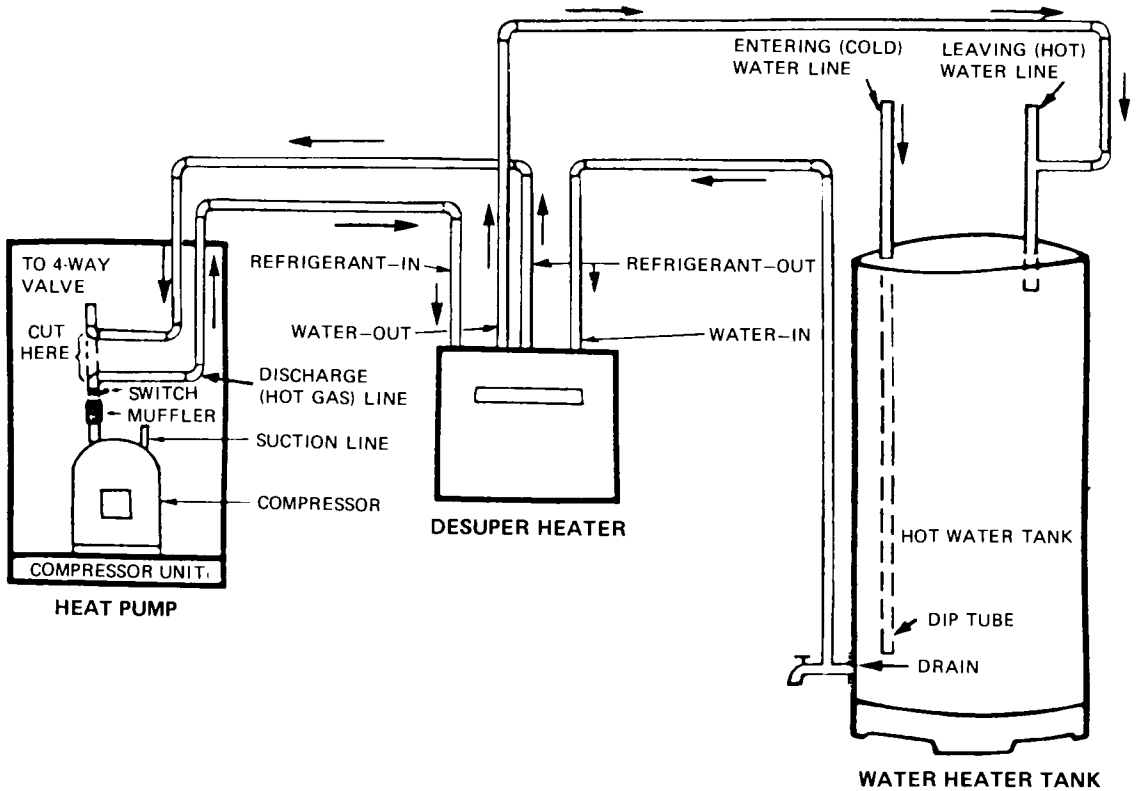

Fig. AF.2.1 Recommended installation method.

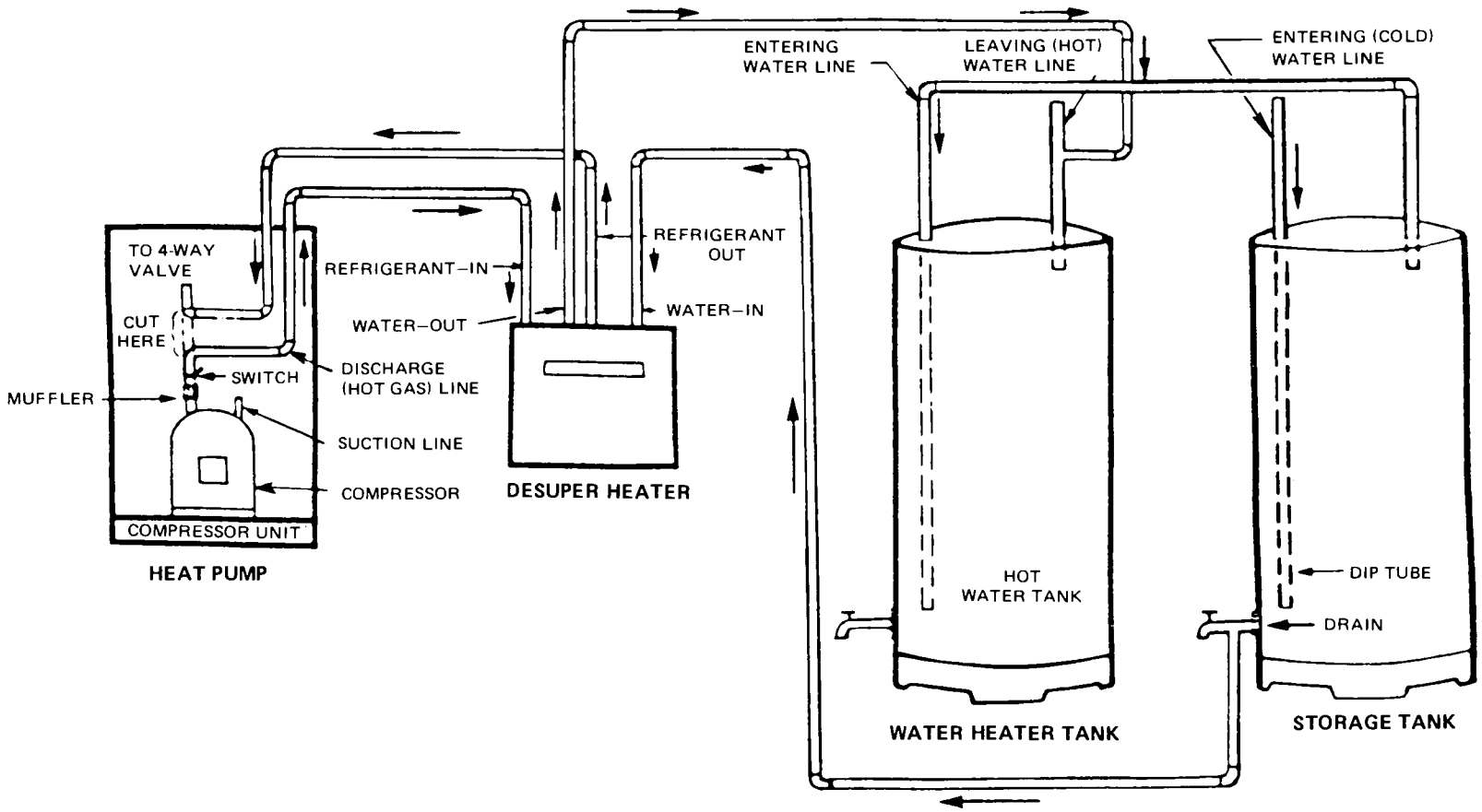

Fig. AF.2.2. Alternate installation method.

derived by multiplying CESR by the air conditioner seasonal efficiency. However, if CEUR was calculated directly (see Audit Procedures), then enter the CEUR. The seasonal cooling energy is determined by multiplying the CEUR by the appropriate cooling degree-days and by 24 divided by 10^6. The appropriate degree-day selection for each CEUR selection is described in Audit Procedures. The annual hot water energy is taken from the DB/CA (Sect. E.8) on the basis of daily hot water use (gallons per day per occupant times the number of occupants) identified in the interview (page D-1). The hot water energy is converted to kWh units by dividing Btu's by 3412. The water usage adjustment factor is determined as indicated on the calculation sheet.

AF.2.1.1 Desuperheater Retrofitted to a Heat Pump—Utility with Constant Electric Rates

The following calculation assumes no seasonal change in electric rates (the summer price of electricity is the same as the winter price of electricity). Determine the fractional savings (fraction of annual hot water energy) by using the data calculational aid (Fig. AF.2.3). Enter Fig. AF.2.3 with the annual summer cooling and winter heating energy requirements to obtain the fractional (decimal) energy savings. The annual energy savings is then determined by multiplying the fractional savings by the annual electric hot water energy and by the water usage adjustment factor. The annual dollar savings are then determined by multiplying the annual energy savings by the price of electricity. The low and high first-year savings are calculated and entered on the audit form.

AF.2.1.2 Desuperheater Retrofitted to a Heat Pump—Utility with Different Seasonal Rates

The following calculation is for regions having different seasonal electric rates. Enter the winter price of electricity on the calculational sheet. Determine the fractional savings as in Sect. AF.2.1.1 by using the calculational aid (Fig. AF.2.3). The summer portion of total savings is determined from the calculational aid (Fig. AF.2.4). The summer energy savings are then determined by multiplying the fractional savings by the summer savings portion by the annual hot water energy and by the water usage adjustment factor. Next, calculate the winter portion of total savings, which is one minus the summer portion of savings previously determined from Fig. AF.2.4. The winter energy savings are then calculated by multiplying the fractional savings by the winter portion of savings by the annual electric hot water energy and by the water usage adjustment factor. The summer dollar savings are calculated by multiplying the summer energy savings by the summer price of electricity. The winter dollar savings are calculated by multiplying the winter energy savings by the winter price of electricity. The annual savings are the sum of the summer and winter savings. The final step is the calculation of the low and high first-year savings.

AF.2.1.3 Desuperheater Retrofitted to a Central Air Conditioner

When a desuperheater is installed on a central air conditioner, electric resistance hot water heater energy is saved only in the summer season. The fractional savings (annual) are

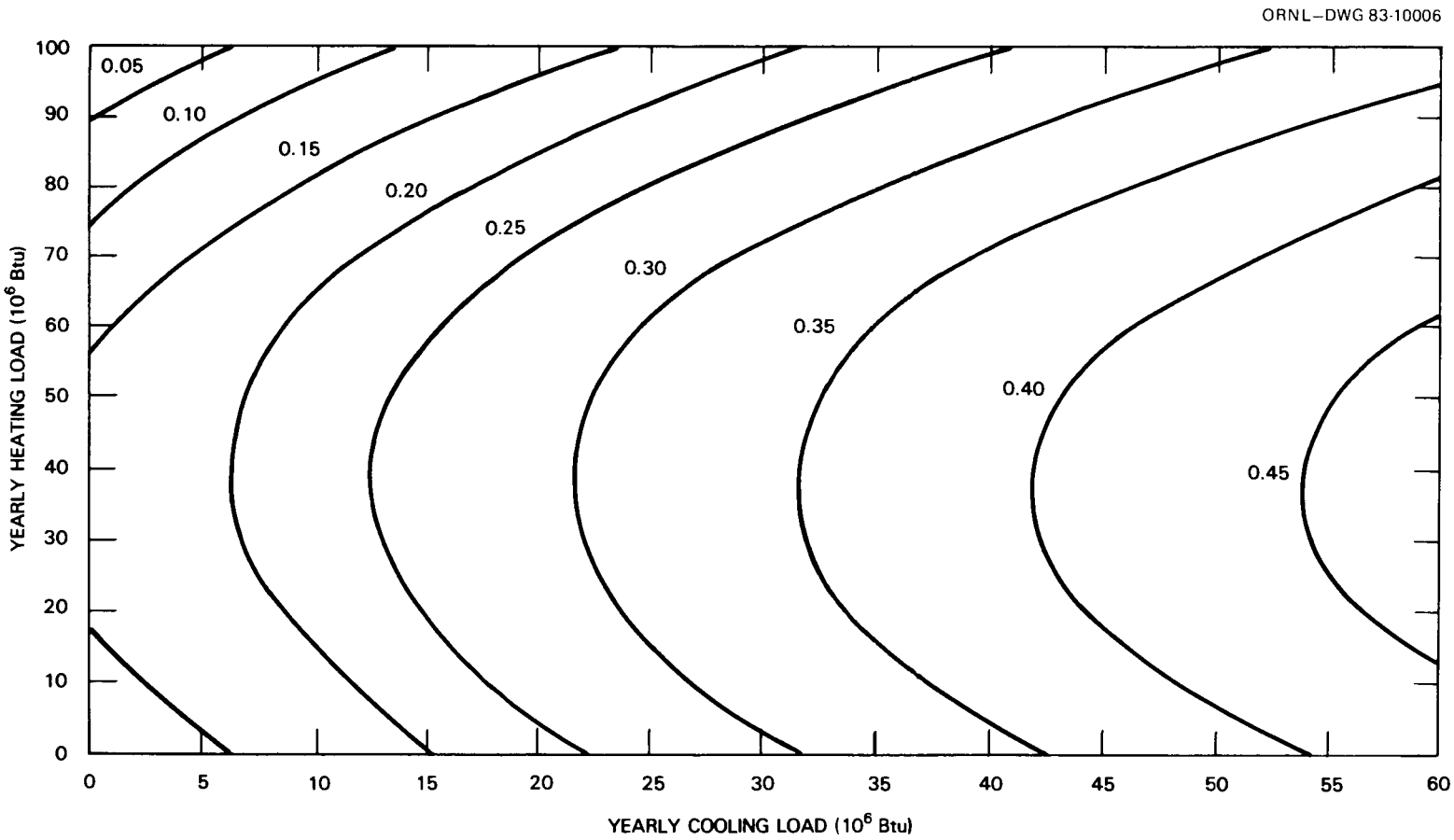

Fig. AF.2.3. Fraction of water heating savings as function of cooling and heating loads.

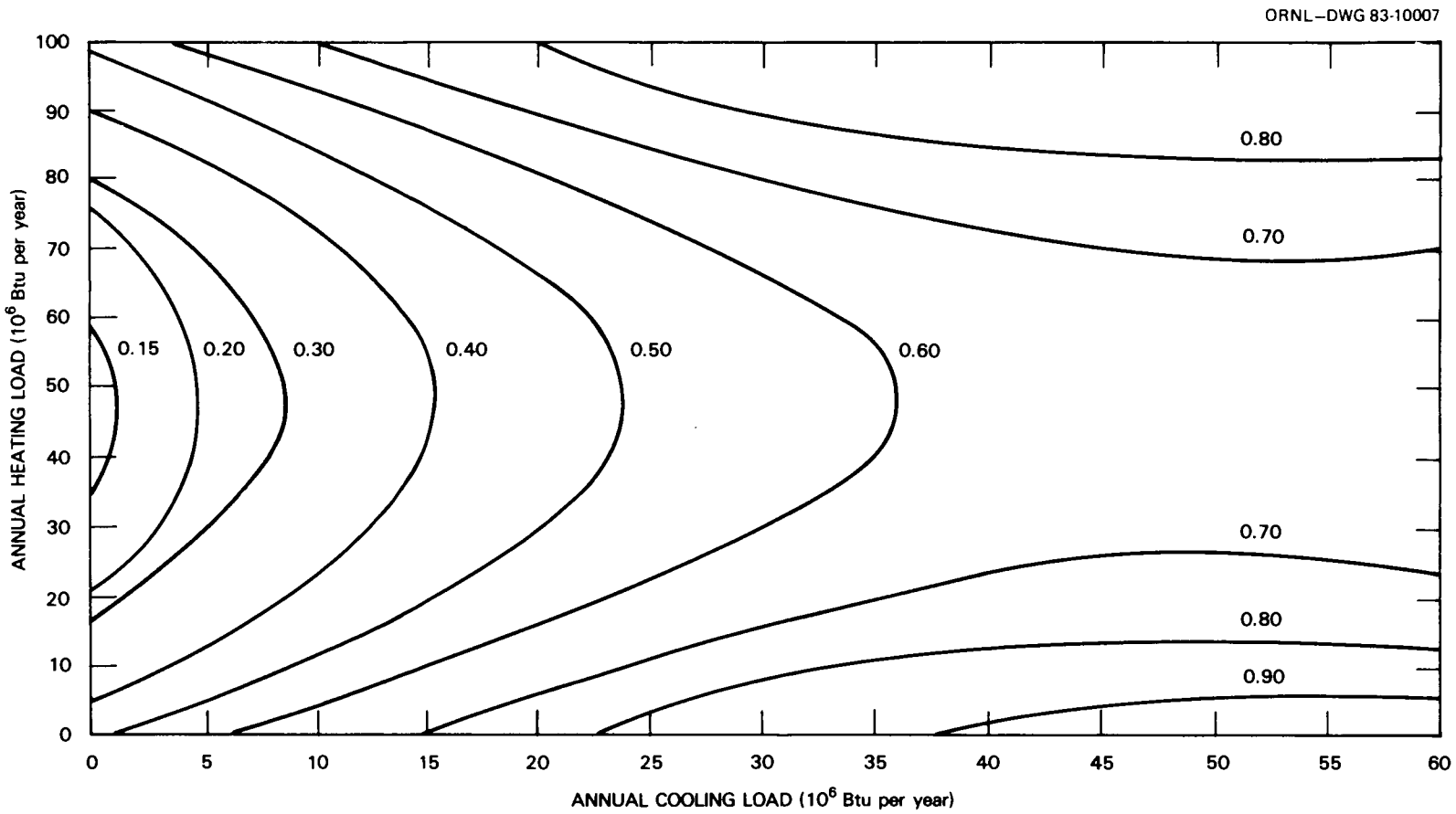

Fig. AF.2.4. Fraction of water heating savings occurring in summer for house insulation at HUD minimum level.

determined as in Sect. AF.2.1.1, by using the calculational aid (Fig. AF.2.3). The summer portion of the total savings is determined by using the calculational aid (Fig. AF.2.4). The summer energy savings are then determined by multiplying the fractional savings by the portion of summer savings by the annual electric hot water energy and by the water usage adjustment factor. The summer dollar savings, which are also the annual savings, are then determined by multiplying the summer energy savings by the summer electric price. The low and high first-year savings are calculated and entered on the audit form.

AF.2.2 Forms

The forms for desuperheaters are on the following pages.

AF.2.3 Methodology

The procedure for estimating savings for a desuperheater is based on a technical assessment[1] performed by the Oak Ridge National Laboratory. The technical assessment indicated that, in general, a heat reclaimer device is not economically competitive if gas or oil is used for water heating at the present time (1983). Therefore, the audit method developed concentrates solely on applications where electric resistance water heating is the competitor. The technical assessment also concludes that the economic potential is a strong function of annual heating and cooling loads and water usage. The level of insulation in and size of the residence are relatively insignificant and can be ignored.

The method developed consists of the following steps:

1. As part of the audit procedure, determine the annual heating and cooling loads for the house.
2. Determine the fractional water heating energy savings.
3. Adjust the savings to account for water usage.
4. If the utility offers a split rate, use the heating and cooling loads individually to determine the winter and summer kWh savings. If central A/C is being evaluated, determine the summer savings only.
5. Determine the annual energy savings (kWh) by using the fractional savings and the normal water heating demand estimated in the audit procedure.
6. Using the annual energy savings and local electricity rates, determine the annual dollar savings.

The fractional savings (step 2) are determined by using Fig. AF.2.3. This figure was derived from the technical assessment using a modified bin analysis technique for several areas of the country. With the annual summer and winter loads known, the fractional savings (FS) value is read from the appropriate figures. The water usage adjustment factor (WUAF) is given by

$$\mathrm{WUAF} = 0.0096\,(\mathrm{HWU}) + 0.28\,,$$

DESUPERHEATERS FOR SUPPLYING DOMESTIC HOT WATER

①	②	③	④	⑤	⑥
Summer Electric Price $/kWh	HEUR (Btu/hr.°F)	Corrected Heating Degree Days (HDD)	Seasonal Heating Energy (10^6 Btu) ② x ③ x 24 ÷ 10^6	CESR (utility data) (Btu/hr.°F)	Air Conditioner Seasonal Efficiency (%)
Local Data	P.D-5, L4	Local Data		Procedures	P.D-5, L5

⑦a or	⑦b	⑧	⑨
CEUR (utility data) (Btu/hr.°F) ⑤ x ⑥ ÷ 100	CEUR (calculated) (Btu/hr.°F)	Appropriate Cooling Degree-Days (CDD)	Seasonal Cooling Energy (10^6 Btu) ⑦ x ⑧ x 24 ÷ 10^6
	P.D-5, L5	Local Data	

⑩	⑪	⑫	⑬
Average Daily Hot Water Consumption (gal/day)	Annual Hot Water Energy (10^6 Btu)	Annual Electric Hot Water Energy ⑪ ÷ 3412 ÷ 0.85 (kWh)	Water Usage Adjustment Factor 0.0096 x ⑩ + 0.28
	DB/CA		

I Desuperheater Retrofitted to a Heat Pump - Constant Electric Rates

⑭	⑮	⑯	⑰	⑱
Fractional Savings (decimal)	Annual Energy Savings (kWh) ⑭ x ⑫ x ⑬	Annual Savings ($/yr) ⑮ x ①	Low First-Year Savings ($) 0.8 x ⑯	High First-Year Savings ($) 1.5 x ⑰
Fig. AF.2.3				

II Desuperheater Retrofitted to a Heat Pump - Utility with Different Seasonal Rates

⑲	⑳	㉑	㉒	㉓	㉔
Winter Electric Price ($/kWh)	Fractional Savings (decimal)	Summer Portion of Total Savings (decimal)	Summer Energy Savings (kWh) ⑳ x ㉑ x ⑫ x ⑬	Winter Portion of Total Savings (decimal) 1.0 - ㉑	Winter Energy Savings (kWh) ⑳ x ㉓ x ⑫ x ⑬
Local Data	Fig AF.2.3	Fig. AF.2.4			

㉕	㉖	㉗	㉘	㉙
Summer Savings ($) ㉒ x ①	Winter Savings ($) ㉔ x ⑲	Annual Savings ($) ㉕ + ㉖	Low First-Year Savings ($) 0.8 x ㉗	High First-Year Savings ($) 1.5 x ㉘

III Desuperheater Retrofitted to Central Air Conditioner

㉚	㉛	㉜	㉝	㉞	㉟
Fractional Savings (decimal)	Summer Portion of Total Savings (decimal)	Summer Energy Savings (kWh) ㉚ x ㉛ x ⑫ x ⑬	Annual Savings ($) ㉜ x ①	Low First-Year Savings ($) 0.8 x ㉝	High First-Year Savings ($) 1.5 x ㉞
Fig. AF.2.3	Fig. AF.2.4				

where HWU is the average daily hot water consumption in gallons. This equation was derived from the results given in the technical assessment. The valid range of the expression is from 25 to 75 gpd. The annual fractional savings are then given by multiplying FS by WUAF.

In some areas, utility rates change from summer to winter. In such cases, it is important to know the winter and summer savings so the appropriate utility rate can be applied to each season. It is also necessary to determine the summer savings in those cases where the heat reclaimer is being evaluated in conjunction with a central air conditioning unit. In these instances, the fraction of total savings accrued in summer (FRAC) is read from Fig. AF.2.4, which was also derived from the technical assessment. The summer fractional savings (SFS) is then given by

$$SFS = (FS)(WUAF)(FRAC)$$

and the winter fractional savings (WFS) is given by

$$WFS = (FS)(WUAF)(1 - FRAC) .$$

The actual energy savings is calculated by multiplying the fractional savings (WFS and SFS) by the estimated annual energy consumption for water heating (WHEC) as determined in the audit. For situations where only the annual energy savings (AES) is of interest, the appropriate formula is

$$AES = (FS)(WUAF)(WHEC) ,$$

where WHS and AES are given in kWh. In cases where the summer (SES) and winter (WES) savings are required, they are given by

$$SES = (SFS)(WHEC)$$

and

$$WES = (WFS)(WHEC) ,$$

where SES, WFS, and WHEC are in kWh.

The annual monetary savings (AS) is given by

$$AS = (AES)(EC) ,$$

where EC is the local utility rate in $/kWh. In the situation where the summer rate differs from the winter rate, the annual savings is given by

$$AS = (SES)(SEC) + (WES)(WEC),$$

where SEC and WEC are the summer and winter rates, respectively. If the heat reclaimer is to be used in conjunction with a central air conditioner, only the summer portion of the above expression applies.

Lifestyle effects (e.g., lower indoor thermostat setting, night setback) were not explicitly examined in the analysis. However, this is not a significant limitation on the application of the assessment results because most lifestyle effects will manifest themselves in the estimation of the annual heating or cooling load. Thus, they will be accounted for in the estimation of energy savings because these values are inputs to the evaluation procedure.

Reference for Section AF.2.3

1. Olszewski, M., and E. C. Fontana, *Heat Pump Desuperheater for Supplying Domestic Hot Water*, ORNL/CON-114, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1983.

AF.3 HEAT PUMP WATER HEATER

AF.3.1 Procedure

A heat pump water heater (HPWH) may only replace an electric water heater. The auditor should check to see that adequate space (which includes the minimum clearances recommended by the manufacturer) exists to install a retrofit HPWH. Adequate ventilation must be available to obtain all the savings for cooling a conditioned space during the cooling season. An annual COP of 2.2 is used for the HPWH.

AF.3.1.1 Conditioned/unconditioned space

The energy costs determined previously for the heating/cooling seasonal cost calculations should be entered on the calculation sheet. The electric cost is the same as the cooling fuel cost when cooling is by electric air conditioner. The number of heating months and cooling months should be determined from billing data (or local weather data if necessary). The annual hot water energy delivered can be taken from Sect. E.8 of the Data Base/Calculation Aids on the basis of the daily hot water use (gallons per day per occupant times the number of occupants) identified during the interview (page D-1). Heating and cooling seasonal efficiencies and the seasonal cooling cost can be taken from page D-5.

The heating and cooling efficiencies are then converted to decimal fractions, and the reciprocal is taken. Heating season energy losses from the house conditioned space (energy removed to heat the hot water) are calculated, and the cost of this energy is determined. This energy represents an added cost for heating water with a heat pump. Cooling season energy benefits for the house conditioned space (energy removed to heat the hot water) are calculated, and the cost of this energy is determined. This energy represents a potential cost savings for heating water with a heat pump during the cooling season. If the calculated cooling season savings are more than the actual seasonal cooling cost, the seasonal cooling cost is entered as the "actual cooling savings." If the calculated savings are less than the seasonal cooling cost, the calculated savings are entered as the "actual cooling savings."

The cost savings resulting from heating water with a heat pump instead of electric resistance elements are calculated, and this savings and the added heating cost and cooling savings are totaled for a net cost change. The low and high first-year savings are calculated and entered on the audit form.

The constant C is introduced to the calculation procedure to account for the HPWH installed in the conditioned space or in the unconditioned space. The constant is derived as follows:

- For HPWH in the conditioned space,
  $C = 0.55$; that is, 55% of the energy required to heat the water is input to the evaporator, and the remaining 45% is from the power line.
- For HPWH in the unconditioned space,
  $C = (0.55 \times 0.52) = 0.28$; that is, of the 55% energy required by the evaporator, 52% is obtained from an adjacent conditioned space.

An HPWH should not be installed in an unconditioned space that is small or cold (below 55°F) in the winter. The removal of energy in a small space or a space that is cold in the winter may drop the air temperature in that space below 45°F. These units have no capability to defrost, and the possibility of damage exists with an evaporator that has an ice buildup.

AF.3.1.2 Outdoors

The electric cost is determined. Annual hot water energy is taken from Sect. E.7 of the Data Base/Calculation Aids. Cost savings from heating water with a heat pump and the low and high first-year savings are calculated and entered on the audit form.

An HPWH should not be installed outdoors where the temperature might fall below 50°F for more than a few hours at a time. These units have no capability to defrost, and the possibility of damage exists with an evaporator that has an ice buildup. The only acceptable HUD/MPS zones for an outdoor installation are Hawaii-1 and Puerto Rico-1.

AF.3.2 Forms

The forms for heat pump water heaters are on the following pages.

AF.3.3 Methodology

Savings were determined for a HPWH installed three different ways. First, the HPWH is installed in a conditioned space. In the second case, the HPWH is installed in an unconditioned space such as an unheated basement or utility room. The third and simplest case assumes that the HPWH is installed outdoors.

In the first case, energy is taken from the conditioned space. During the heating season, this energy must be supplied by the residential heating system. Energy taken from the indoor air by the HPWH during the cooling season reduces the residential cooling load. Thus,

net saving = water heating savings + cooling season savings − heating season losses.

The water heater savings ($) are

$$\text{hot water unit energy cost} \times 0.55 \times \text{WE},$$

HEAT PUMP WATER HEATER

CONDITIONED AND UNCONDITIONED SPACE

NOTE: C = 0.55 for HPWH in conditioned space
C = 0.28 for HPWH in unconditioned space

①	②	③	④	⑤	⑥	⑦
Heating Fuel Cost ($/10^6 Btu)	Cooling Fuel Cost ($/10^6 Btu)	Electric Cost ($/10^6 Btu)	No. of Heating Months	No. of Cooling Months	Heating Seasonal Efficiency (%)	Cooling Seasonal Efficiency (%)

⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮
Seasonal Cooling Cost ($)	Annual Hot Water Energy Delivered (10^6 Btu)	Annual Hot Water Energy Input (10^6 Btu) ⑨ ÷ 0.85	Heating Efficiency Factor 100 ÷ ⑥	Cooling Efficiency Factor 100 ÷ ⑦	Heating Season Losses ④ x ⑩ x C/12 (10^6 Btu)	Extra Heating Cost ① x ⑪ x ⑬ ($/yr)	Cooling Season Benefits ⑤ x ⑩ x C/12 (10^6 Btu)

DB/CA

⑯	⑰	⑱	⑲	⑳	㉑
Extra Cooling Savings ② x ⑫ x ⑮	Actual Cooling Savings if ⑯ > ⑧ Savings = ⑧ ($/yr)	Water Heating Savings ③ x ⑩ x 0.55 ($/yr)	Total Savings & Losses ⑰ + ⑱ - ⑭ ($/yr)	Low First-Yr Savings 0.8 x ⑲ ($)	High First-Yr Savings 1.5 x ⑳ ($)

OUTDOORS

①	②	③	④	⑤	⑥
Electric Cost ($/10^6 Btu)	Annual Hot Water Energy Delivered (10^6 Btu)	Annual Hot Water Energy Input (10^6 Btu) ② ÷ 0.85	Water Heater Savings ① x ③ x 0.55 ($/yr)	Low First-Yr Savings 0.8 x ④ ($)	High First-Yr Savings 1.5 x ⑤ ($)

DB/CA

where WE is the hot water energy use per year. Cooling season savings ($) are

$$N_C/12 \times \text{WE} \times 1/\eta_C \times \text{unit cooling energy cost} \times 0.55 ,$$

where WE is defined above, N_C is the number of cooling months per year and η_C is the seasonal efficiency of the cooling system. The heating losses ($) are

$$N_H/12 \times \text{WE} \times 1/\eta_H \times \text{unit heating energy cost} \times 0.55 ,$$

where N_H is the number of heating months per year and η_H is the seasonal efficiency of the heating system.

The second case with the HPWH located in the unconditioned space is more complicated. During the heating season, a portion of the energy required to heat the water is removed from an adjacent conditioned space. The remaining energy is removed from the unconditioned space. Energy taken from the conditioned space during the heating season must be supplied by the residential heating system. During the cooling season, the HPWH reduces the air conditioning load by reducing the temperature in the unconditioned space. The net cost saving is

$$\text{net saving} = \text{water heating savings} + \text{cooling season savings} - \text{heating season losses} .$$

The water heating savings ($) are

$$\text{hot water unit energy cost} \times \text{WE} \times 0.55 ,$$

where WE is again the hot water energy use per year. Calculations have shown that aproximately 50% of the total waste heat required to heat the water is obtained by an additional heat loss from adjacent conditioned spaces. The heating season losses ($) are

$$N_H/12 \times \text{WE} \times 1/\eta_H \times \text{unit heating energy cost} \times 0.55 \times 0.5,$$

or

$$N_H/12 \times \text{WE} \times 1/\eta_H \times \text{unit heating energy cost} \times 0.28 .$$

The cooling season savings ($) are

$$N_C/12 \times \text{WE} \times 1/\eta_C \times \text{unit cooling energy cost} \times 0.28 .$$

In the third case, heat is removed from the outdoors to heat the water to 120°F. Energy cost savings ($) for this case are

$$\text{energy cost} \times \text{annual hot water energy use} \times (1 - 1/\text{COP}) ,$$

where COP is the annual coefficient of performance. A COP of 2.2 was assumed to be representative of current technology. This assumption was based on information from the

Oak Ridge National Laboratory (Virgil Haynes, Oak Ridge National Laboratory, verbal communication, April 1980), which indicated that an annual COP of 2.1 was possible for a 120°F supply temperature, and from estimates from Energy Utilization Systems, Inc. (R. L. Dunning, Energy Utilization Systems, Inc., written correspondence to Dan Quigley, Department of Energy, April 14, 1980), which indicated that a range of 2.0 to 2.6 was possible, depending on air and water temperature. A COP of 2.2 means that the quantity (1 − 1/COP) is approximately equal to 0.55. Thus, 45% of the energy necessary to heat the water comes from electrical input to the compressor, and the remaining 55% of the required energy is removed from the surrounding air.

AF.4 INSULATED SHUTTERS AND BLINDS

AF.4.1 Procedure

The number of large and small windows is entered on the data table, and the areas for each are calculated by multiplying by the appropriate factors provided. Using local data, the cost is obtained by multiplying the window areas by the cost per square foot.

The heat loss savings is the product of the change in U-values and the total window area. Appropriate U-values must be supplied for locally available materials. Heating savings are then determined from the degree-day equation.

The infiltration heat loss is determined as 20% of the product of the maximum infiltration heating savings and the ratio of recommended window weather stripping to total recommended weather stripping. Total savings is the sum of the infiltration and heating savings. The factor of 0.48 (0.6 × 0.8) is provided for computing the low first-year savings which, when multiplied by 1.5, becomes the high first-year savings. The 0.6 factor accounts for nighttime heating energy use as a fraction of total heating energy use.

AF.4.2 Forms

The forms for insulated shutters and blinds are on the following pages.

AF.4.3 Methodology

The percentage of hours below 65°F occurring between the hours of 6 p.m. and 6 a.m. was determined from the weather tapes for many cities across the country. This ratio was found to be approximately 60%. Additionally, no savings were assumed for the summer months. Thus, the savings were calculated as 60% of the ΔUA and infiltration savings for the heating season.

INSULATED SHUTTERS AND BLINDS

	No.	Factor	Area (ft^2)	Contractor Cost/ ft^2	Contractor Total Cost	Resident Cost/ ft^2	Resident Total Cost
Large windows		9					
Small windows		12					
Totals					$		$

① Existing U-Value (Btu/hr·ft^2·°F)	② Improved U-Value (Btu/hr·ft^2·°F)	③ Area (ft^2)	④ Heat Loss Savings (Btu/hr·°F) (①-②) x ③

① Maximum Heating Infiltration Savings	② Window Weatherstripping (ft)	③ Total Weatherstripping (ft)	④ Factor	⑤ Window Infiltration Savings (① x ② ÷ ③) x ④
$			0.20	$

⑥ Heating Savings	Total Savings ⑤ + ⑥	Factor	First-Year Savings Low	xxxxx xxxxx	First-Year Savings High
$	$	0.48	$	1.5	

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