OVERVIEW OF THE DOE-2

BUILDING ENERGY ANALYSIS PROGRAM

Version 2.1D

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Summary

The DOE-2 building energy analysis program was designed to assist engineers and architects in the performance of design studies of whole-building energy use under actual weather conditions. Program development was guided by several objectives:

1) that the description of the building entered by the user be readily understood by non-computer scientists,

2) that the calculations be based upon well-established algorithms,

3) that the program permit the simulation of commonly available heating, ventilating, and air-conditioning (HVAC) equipment,

4) that the costs of running the program be minimal, and

5) that the predicted energy use of a building be acceptably close to measured values.

These objectives have been met. We present here an overview of the DOE-2.1D version of the program. An annotated example of DOE-2 input and output is shown in the Appendix.

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BACKGROUND

In 1976, both the U.S. Energy Research and Development Administration (ERDA) and the California Energy Commission (CEC) determined that existing building energy analysis programs were inadequate for the non-academic practitioner and that development of a new public-domain program should be undertaken. A project was established among several national laboratories (Lawrence Berkeley Laboratory (LBL), Argonne National Laboratory and Los Alamos National Laboratory), and Consultants Computation Bureau, a private company; project leadership was centered at LBL. In 1976, the project produced a program called Cal-ERDA. At that point the joint CEC/ERDA sponsorship came to an end and ERDA was absorbed into the new U.S. Department of Energy (DOE). A slightly improved version of the program, developed with the support of the DOE Office of Buildings and Community Systems, was called DOE-1 and became the first of a series of versions leading to a much more sophisticated program called DOE-2. The latest version of DOE-2, called DOE-2.1D, was released in 1989.

Program Structure
DOE-2 consists of two major sections, as shown in Fig. 1.

1. An input processor called the Building Description Language (BDL) Program that accepts user-provided data for the building.

2. Simulation subprograms called LOADS, SYSTEMS, PLANT, and ECONOMICS that use the input data plus hourly weather information to calculate the hourly energy performance of the building.

In addition, DOE-2 contains

1. Reporting programs that print the results of the calculations.

2. A weather data processor that accepts a tape of hourly weather information for a particular city and puts it in a form the simulation subprograms can use.

3. A library of materials that can be enlarged by the user.

4. A library of response factors for common wall and roof constructions that can be added to by the user.

5. A program for calculating wall and roof response factors.

6. A program for calculating room weighting factors.

Simulation Approach
A building, examined thermodynamically, involves non-linear flows of energy through and among all of its surfaces and enclosed volumes, driven by a variety of heat sources. Mathematically, this corresponds to a set of coupled integral-differential equations with complex boundary and initial conditions. The function of a program like DOE-2 is to simulate the thermodynamic behavior of the building by approximately solving the mathematical equations.

DOE-2 PROGRAM FLOW
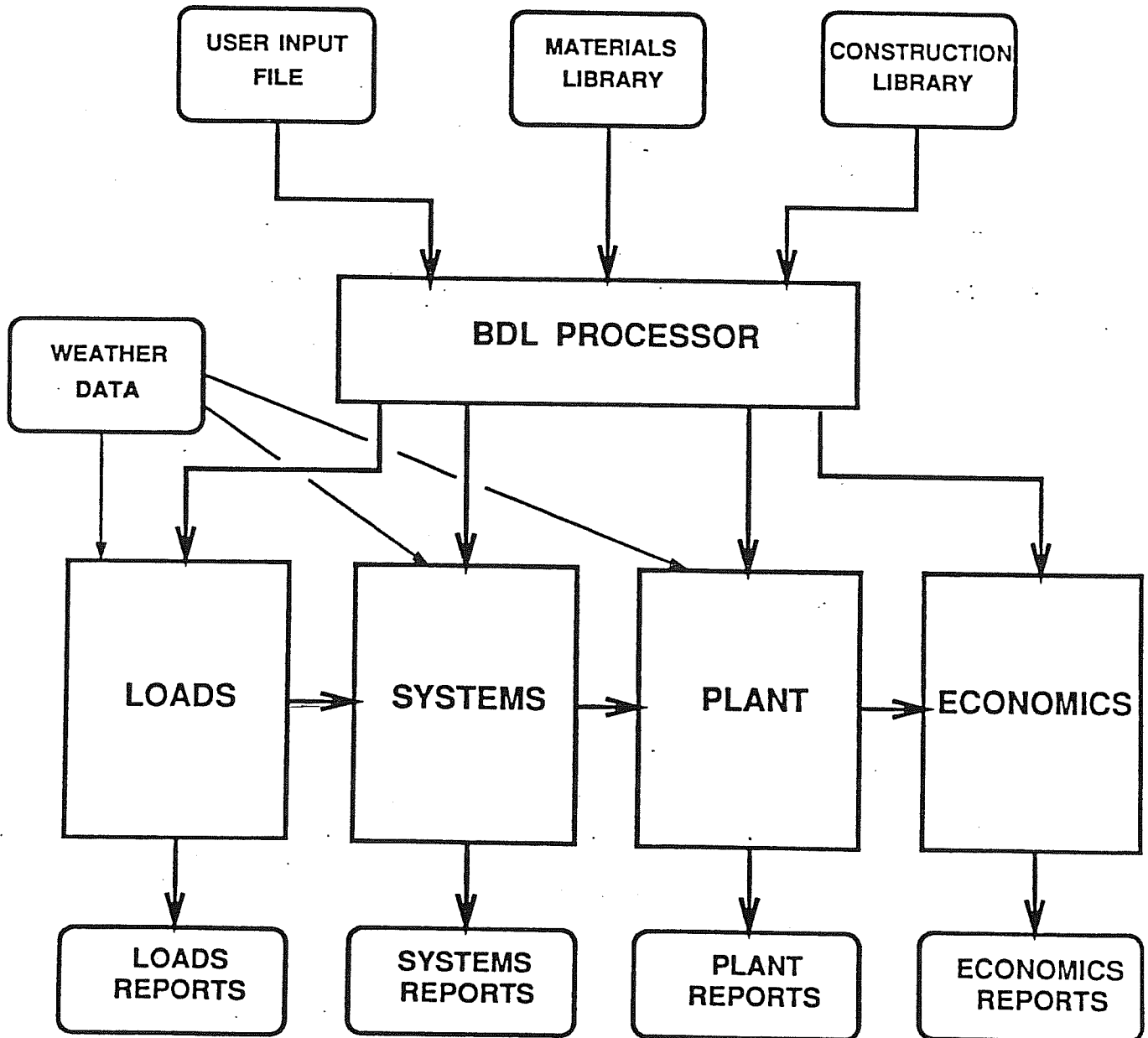
Figure 1:   The DOE-2 Program

DOE-2 performs its energy use analysis of buildings in four sequential steps.

First is the calculation of heat loss and gain to the building spaces and the heating and cooling loads imposed upon the building HVAC systems. This calculation is carried out for a space temperature fixed in time and is commonly called the LOADS calculation.

It answers the question: how much heat addition or extraction is required to maintain the space at a constant temperature as the outside weather conditions and internal activity vary in time and the building mass absorbs and releases heat?

Second is the SYSTEMS calculation of the energy addition and extraction to be supplied at the coils by the HVAC system in order to meet the varying temperature set-points and humidity criteria subject to the schedules of fans, boilers and chillers, and to outside air requirements. This calculation results in the demand for energy that is made on the primary energy sources of the building.

This step answers the question: How are the accumulative heat extraction and addition rates modified, when the characteristics of the HVAC system, the time-varying temperature set-points, and the heating, cooling and fan schedules are all taken into account?

Third is the determination of the fuel requirements of primary equipment such as boilers and chillers, and the electric generators, etc., in the attempt to supply the energy demand of the HVAC systems.

This is the PLANT calculation. It answers the question: how much fuel and electrical input is required by the HVAC system given the efficiency and operating characteristics of the plant equipment and components?

Fourth is the calculation, by ECONOMICS, of the cost of fuel and electricity, taking into account the building's utility rate schedule.

The continuous time dependence of energy flows is approximated by making the calculation in hourly time intervals even though phenomena may occur with a time constant that is smaller than one hour. Averaging algorithms have been developed that correct the net energy consumption effect of more rapidly changing events, such as temperature controllers.

THE DOE-2 SIMULATION SUB-PROGRAMS:
LOADS, SYSTEMS, PLANT and ECONOMICS

LOADS

General Considerations

The LOADS program computes the hourly cooling and heating loads for each space of the building. A *load* is defined as the rate at which energy must be added to or removed from a space to maintain a constant air temperature in the space. A *space* is a user-defined subsection of the building. It can correspond to an actual room, or it may be much larger or smaller, depending upon the level of detail appropriate to the simulation.

The space loads are obtained by a two-step process. First, the heat gains (or losses) are calculated; then the space loads are obtained from the space heat gains, taking into account the storage of heat in the thermal mass of the space. A *space heat gain* is defined as the rate at which energy enters or is generated within a space in a given moment. The space heat gain is divided into radiative and convective components, depending on the manner in which the energy is transported into or generated within the space. The components are:

     solar heat gain from radiation through windows and skylights,

     heat conduction through walls, roofs, windows, and doors in contact with the outside air,

     infiltration air (unintended ventilation),

     heat conduction through walls and floors in contact with the ground,

     heat conduction through interior walls, floors, ceilings, and partitions,

     heat gain from occupants,

     heat gain from lights,

     heat gain from equipment.

The calculation of heat conduction through walls involves solving a one dimensional diffusion equation each hour. In DOE-2 the equation is presolved for each wall or roof using triangular temperature pulses as excitation functions. The resulting solutions, called *response factors* are then used in the hourly simulation modulated by the actual indoor and outdoor temperatures. This approach assumes that the wall properties, including inside film coefficients, do not change during the simulation.

The solar gain calculation starts with the direct and diffuse solar radiation components, which are obtained from measured data or computed from a cloud cover model, taking

into account the actual position of the sun each hour. The radiation is projected onto glass surfaces, after taking into account the shading of exterior shading surfaces, and is transmitted, absorbed, and reflected in accordance with the properties of the glass in the window. As with the conduction through walls, the problem is presolved for a finite class of window properties.

Heat flow through interior walls and through surfaces in contact with the soil is treated as *steady state*, i.e., the capacitive effects of the walls are ignored in the hourly calculation, although they are taken into account in the calculation of the weighting factors (see below). For interior walls that are light and not load bearing, this is a reasonable assumption. Interior walls between a sunspace and an interior space, on the the other hand, can be massive and delayed conduction through such walls can be modeled.

The internal heat gains from people, lights, and equipment are basically fixed by the user's input of peak values multiplied by hourly values in the schedules for these gains.

In general, space heat gains are not equal to space cooling loads. An increase of radiant energy in a space does not immediately cause a rise in the space air temperature. The radiation must first be absorbed by the walls, cause a rise in the wall surface temperature, and then (by convective coupling between the wall and the air) cause an air temperature rise. This is handled in DOE-2 through *weighting factors*. The weighting factors are determined from a detailed heat balance which gives the response in time of a zone (with all its mass and walls and fenestration) to a unit pulse of each of the zone heat gains. The user can choose either to use precalculated ASHRAE weighting factors or to have the program calculate custom weighting factors for the space as input.

Special LOADS Features
In DOE-2 there are several features that greatly extend the usefulness of the program. In the LOADS program these include the ability to take advantage of credit for daylighting, the ability to model sunspaces and the transmission of solar radiation through interior windows, and a mechanism by which users can substitute their algorithms for those used by the program. Each of these features is described below.

Daylighting Credit. The daylighting simulation in DOE-2, coupled with the thermal loads and HVAC analysis, allows users to evaluate the energy- and cost-related consequences of daylighting strategies. The program takes into account the availability of daylight from sun and sky, window management in response to solar gain and glare, and various electric lighting control schemes.

The daylight illuminance calculation considers such factors as:

  window size and orientation
  glass transmittance
  inside surface reflectances of the space
  sun-control devices; blinds and overhangs
  luminance distribution of the sky
  discomfort glare

For each daylit space, a prepro-
cessor calculates and stores a set
of daylight factors for a series of
sun positions covering the annual
ranges of solar altitude and
azimuth at the specified building
latitude. These factors relate
interior illuminance and glare lev-
els to outdoor daylight levels.
The daylight factor calculation
takes into account the different
paths by which light can reach
the workplane (Fig. 2).

In the hourly daylighting calcula-
tion, the illuminance from each
window or skylight is found by
interpolating stored daylight fac-
tors using current-hour sun posi-
tion and cloud cover, then multi-
plying by current-hour exterior
horizontal illuminance. If the
glare-control option has been
specified, the program will
automatically close window blinds
or drapes in order to decrease
glare below a pre-defined comfort
level. Adding the illuminance
contributions from all the win-
dows then gives the total number
of footcandles at each reference
point.

The program then simulates the
lighting control system to deter-
mine the artificial lighting electri-
cal energy needed to make up the
difference, if any, between the
daylighting level and the required
illuminance. Finally, the lighting
electrical requirements are passed
to the thermal calculation, which
determines hourly heating and
cooling requirements for each
space.

Figure 2: Paths by which sunlight can
reach a workplane through a
transparent, unshaded
window.

An example building whose design involved extensive use of DOE-2 daylighting and ther-
mal analysis is shown in Fig. 3.

Figure 3: Interior view of the Great Gallery, Pacific Museum of Flight, Seattle, WA. The daylighting and thermal analysis of this heavily glazed building was done with DOE-2.1C (see V. Bazjanac and F. Winkelmann, "Daylighting Design of the Pacific Museum of Flight: Energy Impacts", in the BIBLIOGRAPHY).

Sunspace Model. DOE-2 allows the user to model the different forms of heat transfer that can occur between a sunspace (or atrium) and adjacent spaces, as shown in Fig. 4:
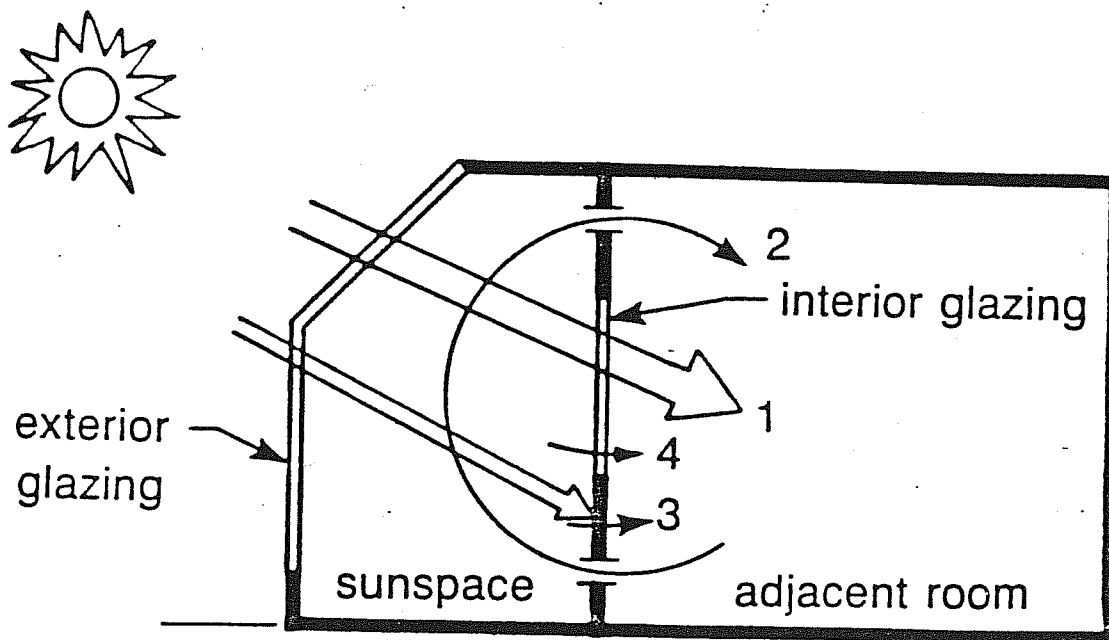
Figure 4: **Forms of heat transfer between a sunspace and an adjacent room (XBL 843-10187).**

1. **direct and diffuse solar gain through interior glazing,**
2. **forced or natural convection through vents or an open doorway,**
3. **delayed conduction through an interior wall, taking into account the solar radiation absorbed on the sunspace side of the wall,**
4. **conduction through interior glazing.**

In the SYSTEMS subprogram, the sunspace model also simulates venting of the sunspace with outside air to prevent overheating and, for residential applications, the use of a sunspace to preheat outside ventilation air.

Functional Input Approach. For advanced users, DOE-2 allows the user to modify the way that DOE-2 does its LOADS calculations without having to recompile the code. This "Functional Input Approach" involves writing FORTRAN-like functions in the LOADS input that compute the program variables desired by the user. The possibilities of this feature are many and include changing the value of the glass shading-coefficient depending on the amount of solar radiation on the windows, making the outside film coefficient dependent upon the wind direction, entering measured values of daylight factors, printing user designed reports, and changing schedules depending upon the thermal state of the building. A similar feature is available in SYSTEMS.

New LOADS Features in DOE-2.1D

Generalized Library. In the past it has only been possible to create DOE-2 libraries of materials, envelope constructions, and weighting factors. A new general library feature has been designed which will allow users of DOE-2.1D to create custom libraries containing descriptions of any building component or system of components. This will allow definition of libraries containing data which could consist of standard operation schedules for different zone types or of complex component descriptions. Even libraries of entire zone descriptions can be created.

Fenestration. Because heat gain and loss through windows has a large impact on energy performance of most buildings, the DOE-2 window thermal calculations have been improved, including:

- an automatic calculation of the shading of *diffuse* solar radiation by neighboring buildings and by architectural elements such as overhangs (previously only the shading of direct solar radiation was calculated);

- an improved calculation of infra-red radiation loss from the building envelope to the sky, taking into account atmospheric conditions (atmospheric moisture, cloud coverage) and blocking by architectural obstructions; and

- an improved calculation of the amount of sky diffuse radiation falling on windows and walls.

SYSTEMS

General Considerations

The SYSTEMS program simulates not only the equipment that provides heating, ventilating and/or air conditioning to the thermal zones, but also the interaction of this equipment with the building envelope.

This simulation comprises two major parts:

> Since the LOADS program calculates the "load" at constant space temperature, it is necessary to correct these calculations to account for equipment operation.

> Once the net sensible exchange between the thermal zones and the equipment is solved, the heat and moisture exchange between equipment, heat exchangers, and the heating and cooling coil loads can be passed to the primary energy conversion equipment or utility.

The dynamics of the interaction between the equipment and the envelope are calculated by the simultaneous solution of the room air-temperature weighting factor equation with the equipment controller relation. The former relates the "load" from LOADS and the heat extraction rate (the sensible coil load) to the zone temperature. The latter relates the heat extraction rate to the controlling zone temperature. Once the supply and thermal zone temperatures are known, the return air temperature can be calculated and the outside air system and other controls can be simulated. Thus the sensible exchange across all coils are calculated.

The moisture content of the air is calculated at three points in the system: the supply air leaving the coil, the return air and the mixed air. These values are calculated assuming that a steady state solution of the moisture balance equations each hour will closely approximate the real world. The return air humidity ratio is used as the input to the controller activating a humidifier in the supply airflow or resetting the cooling coil controller to maintain maximum space humidity set points. The moisture condensation on the cooling coils is simulated by characterizing the coils by a bypass factor and solving the coil leaving air temperature and humidity ratio simultaneously with the system moisture balance.

Once the above sequence is complete, all sensible and latent coil loads are known. These values are then either passed to the PLANT program as heating and cooling water circuit loads or, as in the case of direct-expansion equipment, the energy conversion is simulated in SYSTEMS.

System Types

The DOE-2 program provides the user with generic system types with many sizing and control options, depending upon the type chosen. The following table lists them with their familiar trade names.

Index of System Types	
Category	**Trade Name**
Single Supply Duct Types	Variable Temperature Packaged DX Variable Temperature Packaged Rooftop Desiccant Cooler Ceiling Induction Reheat Variable Air Volume Powered Induction Unit Packaged DX VAV Ceiling Bypass
Air Mixing Types	Multizone Packaged DX Multizone Dual Duct Two Pipe Fan Coil Four Pipe Fan Coil
Terminal Unit Types	Two Pipe Induction Four Pipe Induction Packaged Air Conditioner Water/Air Heat Pump
Residential	Furnace and Condensing Unit
Heating Only	Panel Heating Central Ventilation Unit Heater Classroom Unit Ventilator
Diagnostics	Sums Zone Loads

See Figure 5 on the next page for a drawing of a typical system.
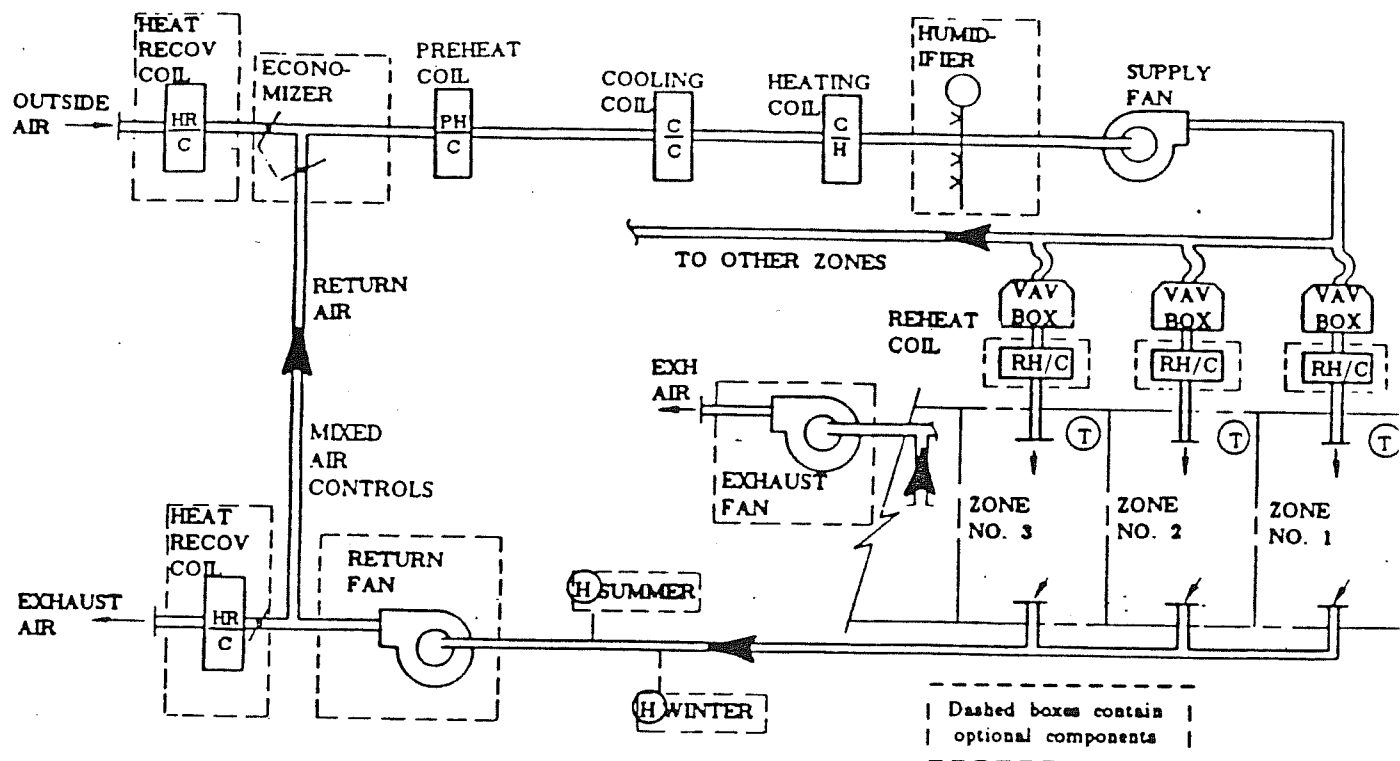
Figure 5: Variable-Air-Volume System

Special SYSTEMS Features

The DOE-2 program allows the user to attach many special features onto the generic system types. Some of the features only apply to one system type, but most features are compatible with all system types. Special features are as follows:

1. **Baseboard or Convection Heaters:**
    a) temperature control reset by outdoor air.
    b) temperature control by room temperature.

2. **Supply Air Temperature Reset:**
    a) controlled by outdoor air master/submaster.
    b) controlled by "warmest" zone.
    c) controlled by "coldest" zone (for dual duct and multi-zone hot decks).
    d) controlled by seasonal adjustments on predefined calendar dates.

3. **Return Air Humidity Controller** to either:
    a) reduce temperature of coil leaving air (and thus humidity content) to maintain a maximum relative humidity.

b)   add reheat using condenser waste heat or new energy to prevent overcooling of the space.

c)   inject moisture into the supply air stream to maintain a minimum relative humidity.

4.   **Outdoor Air Economizers** controlled by:

a)   mixed air temperature with a dry bulb high-limit temperature override.

b)   mixed air temperature with an enthalpy comparison of return and outside air plus a dry bulb high-limit temperature override.

c)   mixed air temperature with a dry bulb low-limit temperature override.

5.   **Air/Air Heat Pumps** for commercial unitary air-handling units with economizers as well as heat pumps for PTAC units and residential split systems. Supplemental heat using fossil fuels in lieu of electric resistance heaters is also feasible.

6.   **Air-Handling Unit Fans** may be defined either as draw-through or blow-through and the fan motor can be placed in or outside the air stream.

7.   **Air-Handling Unit Fans for VAV** systems can be controlled using:

a)   discharge dampers.

b)   inlet vanes.

c)   speed control.

d)   customized curve fit for special applications.

8.   **Natural Ventilation** for simulation of opening and closing windows in a residence.

9.   **Forced Ventilation** for simulating fabric roof system pressurization fans and/or ventilation for precooling buildings using cool night air.

10.   **Optimum Fan Start Control** to prevent fans from starting earlier than necessary to provide satisfactory space temperatures at time of occupancy.

11.   **Heat Recovery of Sensible Heat** in the return air stream and its exchange to the incoming outside ventilation air.

12.   **Night Temperature Setback** (and setup if required) with provision to maintain setback minimum temperature by:

a)   cycling main fans on.

b)   cycling powered induction unit fans on (with main fans off).

c)   modulating baseboard radiation.

13.   **Heat Recovery from Supermarket Refrigerated Casework** including provisions for defrost control, anti-sweat heaters, etc. This routine is also applicable to ice-rinks or cold storage applications.

System Design. Many equipment design parameters must be known before the hourly simulation can proceed. The user can specify these parameters in the description of the thermal zone or the HVAC system, or make use of a set of default procedures to calculate most of these parameters if the user does not provide the information. Before the simulation can start, all air flow rates, equipment capacities, and off-design performance functions must be known. Default curves for part-load operation are available for all the off-design performance functions; however, the user can replace one or more of these curves through a curve fitting command.

New SYSTEMS Features in DOE-2.1D

Functional Input Approach. The "Functional Input Approach" available in LOADS can also be used in SYSTEMS. This permits modeling of control strategies that are not simulated in the basic DOE-2 calculation. It also allows very advanced users to describe new system types.

Desiccant Cooling Several companies are developing desiccant cooling systems in which a hygroscopic material such as lithium chloride is used to remove moisture from the supply air stream. The desiccant is "regenerated" for further use by drying it with hot air from a gas-fired heater. Gas-fired desiccant systems of this type have the potential for being a replacement for, or a supplement to, conventional electric-driven cooling systems. A model for a packaged rooftop desiccant cooling system has been added to DOE-2.1D.

PLANT

The PLANT program simulates primary HVAC equipment, i.e., central boilers, chillers, cooling towers, electrical generators, pumps, heat exchangers, and storage tanks. In addition, it also simulates domestic or process water heaters, and residential furnaces. Its purpose is to supply the energy needed by the fans, heating coils, cooling coils, or baseboards (simulated in SYSTEMS), and the electricity needed by the building's lights and office equipment (simulated in LOADS). Building loads can be satisfied by using the user-defined plant equipment or by the use of utilities: electricity, purchased steam, and/or chilled water. Figure 6 shows the primary equipment components and energy flows that can be simulated by PLANT.

Plant Equipment

As in SYSTEMS, there are a number of generic plant equipment types whose characteristics and part-load performance curves can be defaulted or shaped by the the user:

Category	Trade Name
Heating Equipment	Fossil Fuel Steam Boiler Fossil Fuel Hot Water Boiler Electric Steam Boiler Electric Hot Water Boiler Residential Furnace Domestic Hot Water Heater Electric DHW Heater
Electricity Generators	Steam Turbine Diesel Generator Gas Turbine
Chillers	Open Centrifugal Open Reciprocal Hermetic Centrifugal Hermetic Reciprocal One Stage Absorption Two Stage Absorption Direct-Fired Absorption Chiller/Heater Double Bundle Gas-Engine Driven Reciprocating Chiller
Storage Tanks	Hot and Cold
Cooling Towers	Conventional and Ceramic
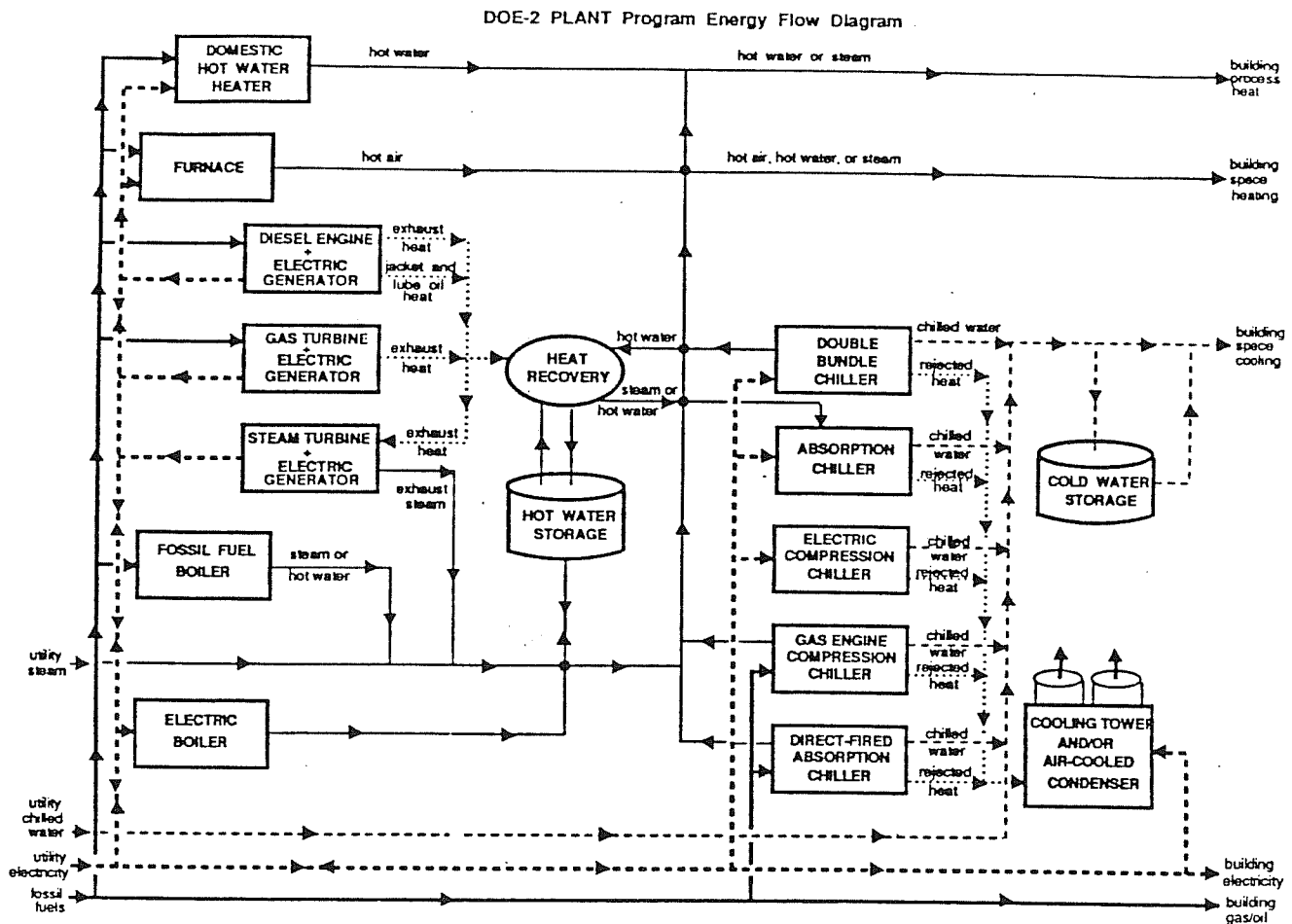
Figure 6: Possible DOE-2 PLANT components and energy flows. An actual plant would only have a subset of the components shown.

Plant Management

The user may establish the management of the plant equipment by setting up schedules and/or load ranges under which specified equipment will operate. In the absence of a user-defined plant management scheme, the equipment is simulated by default in the following order:

1. The hot and cold loop circulation pumps are simulated if they exist. The heating and cooling loads are adjusted for any losses that occur in the circulation loops and for the addition of pump heat.

2. The following equipment is modeled iteratively to minimize source energy consumption (see below for a fuller discussion):

   a. The chillers, cooling tower, and cold storage tanks.

   b. The electrical generators, operating under several tracking options.

c.   Heat recovery equipment and hot storage tanks are simulated to link the user-specified sources of waste heat to the user-specified heat demands.

3.   Following the heat recovery, the boilers are operated to satisfy any remaining heating loads.

4.   Finally, the program allocates any remaining heating, cooling, and electrical loads to the appropriate utility. If a utility has not been provided for, the remaining load is reported as an overload.

Early versions of the DOE-2 code assumed simply that, in the case of the electricity generators, only the electrical demands of a facility were important to decisions concerning the operation of a central plant. This reasoning stemmed from the fact that utility and regulatory attitudes toward the on-site generation of power often meant that a decision to generate power on-site was tantamount to leaving the electric grid entirely. The Public Utilities Regulatory Policy Act of 1978 mandated changes in those attitudes by requiring that utilities abandon discriminatory practices and offer fair prices to cogenerators and small power producers. The outcome of this change is that the actual electrical loads of a facility need not be the only consideration in determining the output of primary energy conversion equipment in a central plant.

The concept embodied in later versions of DOE-2 treats the diesel engine and gas turbine as energy conversion devices with two useful outputs: electricity and recoverable heat. Accordingly, the choice of which output to use in controlling the operation of these machines has been made an explicit option specifiable by the user. That is, the user can specify that the machines generate enough heat to meet thermal loads, irrespective of the amount of electricity produced and vice versa. The default allocation routines also ensure that the thermal and electrical output of the generators, when coupled with absorption and compression chillers, will be balanced when meeting heating and cooling loads.

Special PLANT Features

DOE-2 allows the user to address conventional chiller/boiler plants as well as many load management and energy saving techniques associated with energy conversion equipment. Special features are as follows:

Peak Electric Demand Shaving using:

    absorption chillers.

    diesel-driven generators.

    gas-driven generators.

    cold water storage, off-peak.

the operation of the above equipment may be set up for programmed charging at night and programmed release, based either on peak demand or a *time-of-day* period.

Electric Load Shifting and "Load Shedding" may be addressed by making parametric studies to determine advantageous system and equipment operating strategies based either on reductions in peak demand or *time-of-day* energy use.

Pumping Energy for Hot and Cold Water Circuits may be set up for either variable or constant flow rates.

Hot Water Storage of Recovered Heat may be analyzed, including programmed release of the stored media. An example might be an all-electric building with the stored heat released during the morning start-up period to reduce electric peaks caused by resistance heaters.

New PLANT Features in 2.1D

Gas-Engine Driven Chillers and Direct-Fired Absorption Chiller/Heater. Two new PLANT equipment simulations are available in DOE-2.1D: a direct fired, double effect absorption chiller-heater model, and an engine driven chiller model.

Direct-fired absorption chillers have enjoyed a strong market in Japan due to a national energy policy mandating gas cooling. Despite high first cost and COPs of only 1.0 to 1.1, the equipment has attained considerable popularity.

The engine driven chiller, on the other hand, is "new" to the market. Engine driven chillers were available in the 1960's, but for a variety of reasons the market for these units dried up in the 70's. The Gas Research Institute, in collaboration with some equipment manufacturers, is attempting to reintroduce this equipment to the market. These units offer good COPs, excellent part load performance, and the capability to overspeed to meet peak loads above the rated capacity. Hot water can be recovered from the engine exhaust and coolant to provide space heating or to run an absorption chiller for extra cooling and greater overall efficiency.

Ice-Storage Simulation. Off-peak production and storage of ice is attracting considerable interest as a way of reducing high daytime electricity costs. The PLANT program in DOE-2.1D contains a new, component-based ice-storage model called CBS/ICE, developed for ASHRAE by the University of Texas Center for Energy Studies. With CBS/ICE, users can configure a large variety of static (ice-on-coil) systems by linking together system components (evaporator, ice-tank, compressor, condenser, expansion value, controller, etc.). Because CBS/ICE is very computer intensive (it does an iterative solution each hour), it can generally only be used to simulate a few typical days of operation per year.

ECONOMICS

The ECONOMICS portion of the program computes the costs of energy for the various fuels or utilities used by the equipment. A wide variety of tariff schedules can be encompassed as well as computations that simulate the sale of electricity to the utility.

Rate Schedules. DOE-2 allows the following energy resources to be used: chilled water, steam, electricity, natural gas, fuel oil, coal, diesel oil, methanol, LPG, and biomass. For each of these resources used by a building the user may specify uniform cost rates, escalation rates, fixed monthly charges by season, various block charges by season, whether there are demand charges and how much, time-of-day charges, and, for electricity only, details about ratchet periods and types and conditions of sale to utilities. Not all of these apply to every fuel or resource, of course, and defaults exist for the simplest tariffs. On the other hand, most of the existing tariff structures can be simulated.

Investment Statistics. In addition to the possibility of treating the costs of energy, DOE-2 allows the user to simulate the life cycle costs of a building, from data provided and input by the user, and to compare the costs between two configurations of the building. Assuming one is the base case and the other is a retrofit or an alternative design, investment statistics such as pay back period, savings to investment ratio, etc., are computed over the life cycle of the building.

DOE-2 INPUT

Building Description Language

In order to simulate a building, the user must provide data on the building, its equipment and operating schedules, and the utility rate schedule. This is done in DOE-2 through a quasi-English description of the building using a specially designed input language called *Building Description Language* (BDL).

As with any language, BDL has a *vocabulary* and a *syntax*. The vocabulary in BDL consists of commands, keywords and code-words (all shown in upper case in the example that follows), in addition to user-defined names and numerical values. The syntax is a set of rules that regulate the relative position of the words and punctuation. In BDL this syntax is quite simple and consists, basically, of the sequence:

```
u-name = COMMAND      KEYWORD1 = value1
                      KEYWORD2 = value2
                                .
                                .
                                .
                      KEYWORDn = valuen ..
```

For example, the BDL input for a window might look like:

```
WIND-1 = WINDOW      HEIGHT = 4
                     WIDTH = 3
                     GLASS-TYPE = W-1
                     SETBACK = .5 ..
```

The symbol ".." is the command terminator. Some commands, like RUN-PERIOD or BUILDING-LOCATION, are required, while others, like DOOR or ENERGY-STORAGE, are optional and are entered only when the building being modeled has the feature being described or the modeler thinks they are thermodynamically important.

Similarly, the keywords within each command can be required or optional. So, even though DOOR is an optional command, once it has been used, the user must supply values for its HEIGHT, WIDTH, and CONSTRUCTION. On the other hand, the optional keywords within a command often have default values; i.e., if the user does not enter the keyword and a value, the program will assume that the keyword should take on a preassigned value. This is the case for the TILT of an EXTERIOR-WALL, which the program assumes is vertical unless told the contrary. Default values can considerably reduce the necessary input.

Because BDL ignores extra blank spaces in the input, the user can arrange the commands and keywords to provide the most clarity. As can be seen from the BDL sample input in the Appendix, an engineer or architect does not need to be a computer scientist to read the input and understand what has been done. This is important for two reasons. First, interested parties other than the author can read and evaluate the modeling with a minimum of effort. Second, the author can return to the input after several months or a year and quickly grasp what had been done earlier.

In addition to describing the building, the BDL portion of DOE-2 performs several other functions. From the user description of the layers of an exterior wall, BDL computes and stores the factors describing the delayed response of the wall to a temperature pulse. It also computes, for each space of the building, the weighting factors that describe the thermal response of the space to various heat gains. Since these calculations consume computer time and thus incur computer costs, a library feature exists that allows the user to store response factors and weighting factors permanently in a computer file.

Finally, BDL performs curve fitting to user input data that describes the performance characteristics of SYSTEMS and PLANT equipment.

DOE-2 OUTPUT

Although no one needs all of the results of the literally millions of calculations involved in a year's simulation of the energy performance of a building, everyone seems to want a different set of summary data. Successive versions of DOE-2 have seen an expansion in the number of the output reports, usually in response to the expressed needs of the user community. In DOE-2 there are three different types of reports that the user can choose to have printed: preformatted, hourly, and user-generated. For most purposes only a selection of the preformatted reports, the easiest to request, are of use.

Preformatted Reports

There are two kinds of preformatted reports in DOE-2: verification reports and summary reports. Verification reports, available in each of the subprograms, echo the user's input in a different form, allowing a check that the building being simulated has been properly described. These reports are especially helpful in catching input errors. The summary reports are the results of the simulation presented in various formats to stress different aspects of the building's performance. See the Appendix for some examples of summary and verification reports.

Hourly Reports

Many of the internal program variables in each of LOADS, SYSTEMS, and PLANT are accessible to the user for listing on an hour by hour basis. These variables, such as solar gain through a particular window or the temperature in a particular zone, can be listed according to a schedule defined by the user. It is also possible to report these variables by day or month, rather than hourly, to get summary statistics such as maximum and minimum values during the period as well as averages and sums.

User Designed Reports

With the ability to change program algorithms through the functional input approach, it is possible for the user to design an individualized report for the LOADS and SYSTEMS programs by writing a FORTRAN-like input function describing the output variables and the format for the report.

VALIDATION

Versions of DOE-2, up to the DOE-2.1C level, have been verified against manual calculations and against field measurements on existing buildings. The main verification project was sponsored by DOE and conducted at Los Alamos National Laboratory. Results are presented in *DOE-2 Verification Project, Phase I, Interim Report*, and *DOE-2 Verification Project, Phase I, Final Report* (see BIBLIOGRAPHY). Also, see *User-Effect Validation Tests of the DOE-2 Building Energy Analysis Program*, ASHRAE Transactions 1985, Vol. 91, Part II. Two representative results from this study are shown in Figs. 7 and 8.
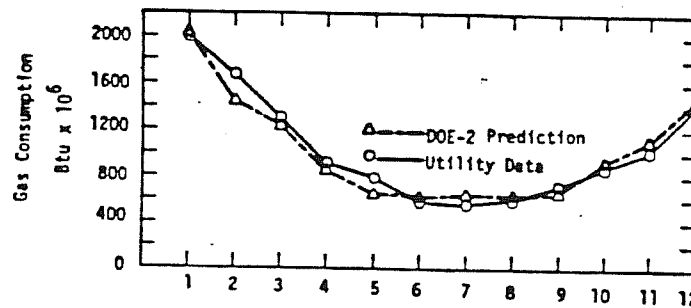
a: DOE-2 prediction vs gas utility data for restaurant
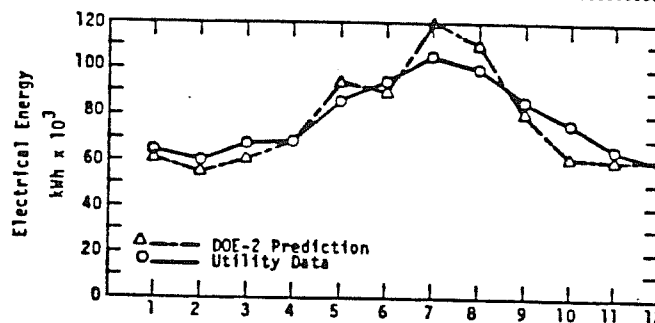
b: DOE-2 prediction vs electric utility data for restaurant
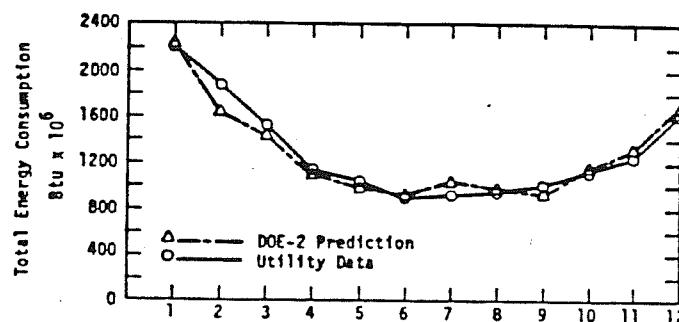
c: DOE-2 prediction vs total energy utility data for restaurant

Figure 7: Comparison of DOE-2.0A predictions to monthly utility data for gas consumption, electrical energy consumption, and total energy consumption for a restaurant near Chicago, IL. Numbers at the bottom of a-c are the months of the year (1977).
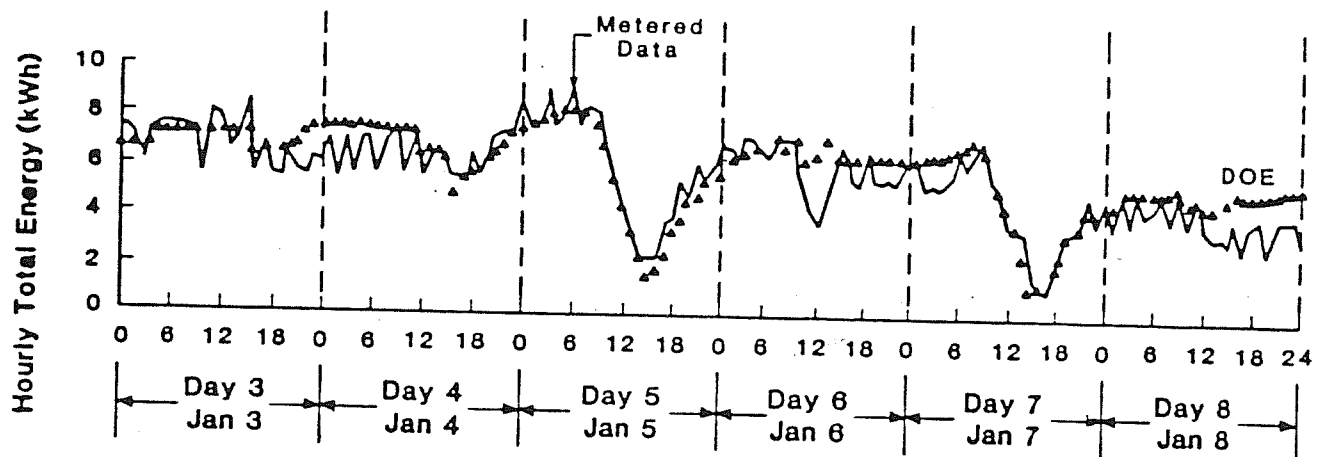
Figure 8: Comparison of DOE-2.1A predictions to metered hourly electrical energy consumption for a house in Columbus, OH. The house is heated (and cooled) by an electric heat pump.

A second study undertaken by LBL, *A Comparison of DOE-2.1C Prediction with Thermal Mass Test Cell Measurements*, compares DOE-2.1C results with test cells constructed in Tesuque Pueblo, NM, and in Gaithersburg, MD.

A third study, *A Comparative Validation Study of the BLAST-3.0, SERIRES-1.0, and DOE-2.1A Using the Canadian Direct Gain Test Building*, was conducted by the Solar Energy Research Institute.

Finally, the Tishman Research Corporation described a study of DOE-2.1B in *DOE-2: Comparison With Measured Data, Design and Operational Energy Studies in a New High-Rise Office Building, Vol. 5*; the report is available from NTIS.

These studies all show that, with few exceptions, the DOE-2 predictions agree well with ASHRAE calculation methods, manufacturers' data, and measured building energy consumption.

DOCUMENTATION

The following user documentation is available for DOE-2. It can be ordered from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; phone: (703)487-4650. Call NTIS to check prices before placing your order.

Document	NTIS Order Number	Description
DOE-2 Users Guide	LBL-8689, Rev.2.	[2.1A] introduction to building energy analysis and the DOE-2 input language.
DOE-2 Reference Manual	LBL-8706, Rev.2	[2.1A] detailed description of the input language and output reports; lists contents of the weather and materials libraries.
DOE-2 Supplement	DE-890-17728	[2.1D Update] a companion volume to the *Reference Manual*; how to use new 2.1B, 2.1C, and 2.1D features.
DOE-2 BDL Summary	DE-890-17726	[2.1D Update] a concise list of all commands and keywords used in the DOE-2 input language, along with minimums, maximums, and default values.
DOE-2 Sample Run Book	DE-890-17727	[2.1D Update] contains both input and output for 15 sample buildings and system and plant configurations.
2.1D Update Package	PB-901-43074	Updates documentation to the 2.1D version
Complete set of 2.1D Documentation	PB-852-11449	All documents listed above, including the Update Package PB-901-43074
Engineers Manual	DE-830-04575	Gives an engineering description and derivation of the calculations used in the program. [Not included with PB-852-11449]

The *DOE-2 User News* is also part of the documentation; it is a quarterly newsletter containing bug fixes, updates to user manuals and articles of interest to program users. The newsletter is distributed free of charge; to be put on the distribution list, to obtain back issues, or to submit an article, please write, FAX, or e-mail:

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BIBLIOGRAPHY

Validation Studies

Validation studies 1, 2, and 3 are available through the National Technical Information Service; write or call for price and availability. NTIS, 5285 Port Royal Road, Springfield, VA 22161; phone: (703)487-4650.

1. NTIS Order No. LA-8295-MS
    DOE-2 Verification Project, Phase 1, Interim Report,
    Los Alamos National Laboratory, 1981.

2. NTIS Order No. LA-10649-MS
    DOE-2 Verification Project, Phase 1, Final Report,
    Los Alamos National Laboratory, 1986.

3. NTIS Order No. DE-84010570/LA
    DOE-2: Comparison With Measured Data, Design and Operational Energy Studies in a New High-Rise Office Building, Vol. 5.

From ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329:

4. *User-Effect Validation Tests of the DOE-2 Building Energy Analysis Program,*
    ASHRAE Transactions 1985, Vol. 91, Part II.

From the Solar Energy Research Institute, 1617 Cole Boulevard, Golden, CO 80401:

5. SERI No. TR-253-2652, *A Comparative Validation Study of the BLAST-3.0, SERIRES-1.0, and DOE-2.1A Using the Canadian Direct Gain Test Building,* 1985.

From Lawrence Berkeley Laboratory:

6. LBL-18981, *A Comparison of DOE-2.1C Prediction with Thermal Mass Test Cell Measurements,* 1985.

Of related interest are the following publications, available from the Simulation Research Group at Lawrence Berkeley Laboratory:

7. LBL-23617, *Daylighting Design for the Pacific Museum of Flight: Energy Impacts,*
    V. Bazjanac and F. Winkelmann, 1988; Energy and Buildings, 13,187,1989.

8. LBL-18508, *Daylighting Simulation in the DOE-2 Building Energy Analysis Program,*
    F.C. Winkelmann and S. Selkowitz; Energy and Buildings, 8,271,1986.

9. LBL-14026, *Simulation of HVAC Equipment in the DOE-2 Program,* J.J. Hirsch.
    Proc. of the International Conference on Systems Simulation in Buildings, Liege, Belgium, 1982.

PROGRAM ACCESS AND STORAGE REQUIREMENTS

The source code for mainframe computer versions of DOE-2.1D is available on magnetic tape from Lawrence Berkeley Laboratory, from the National Energy Software Center at Argonne National Laboratory, and from NTIS. A version for IBM-PC/XT/AT and compatible microcomputers is also available from vendors in the private sector. Instructions for bringing up the program are included on the tape, and sample run inputs are provided for verification purposes. The following machine versions have been developed.

Machine Type	Operating System	Memory Required	Disk Required
DEC—VAX	VMS	1 MB	30 MB
SUN	UNIX	1 MB	30 MB
IBM-PC/XT/AT and compatibles	MS-DOS	640 KB	20 MB

The calculation time on 80386-based PC's with a math coprocessor is about 1 minute/zone for a full year simulation.

Again, contact the Simulation Research Group at Lawrence Berkeley Laboratory for help information on how to obtain the DOE-2 software and documentation.

APPENDIX

Simple Structure Run

The following example of a DOE-2 run describes a simple structure in Chicago with five zones, a return air plenum complete with an HVAC system and plant equipment, and a time-of-day electric rate structure. The user's input is echoed at the beginning of the program output. Comment lines *imbedded in the input* begin with a dollar sign ($). Comments on the sample run are indicated by italic type.

Nine preformatted summary and verification reports have been chosen to demonstrate the reporting capability of DOE-2.
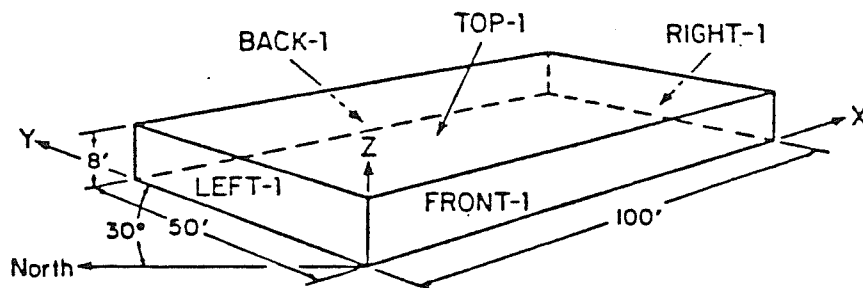
XBL 791-36

Figure 1A: Isometric view of basic building showing orientation. FRONT–1, RIGHT–1, etc., are u-names (user-defined names) for the front wall, right-hand wall, etc. The building coordinate axes (X, Y, and Z) are shown. The building is oriented 30° from true North.
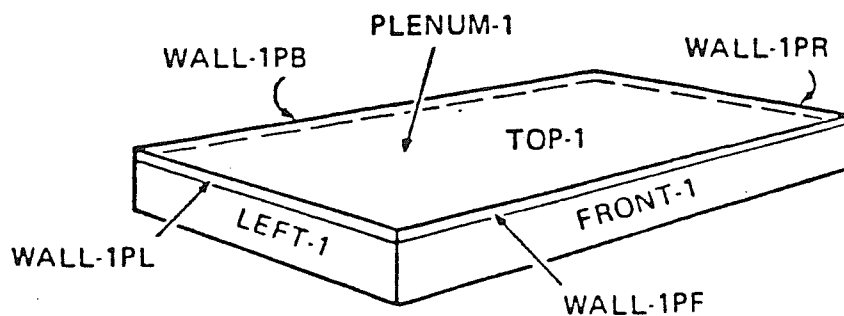
XBL 791-37A

Figure 2A: Basic building with plenum and its walls (u-named WALL–1PF, WALL–1PL, etc.).
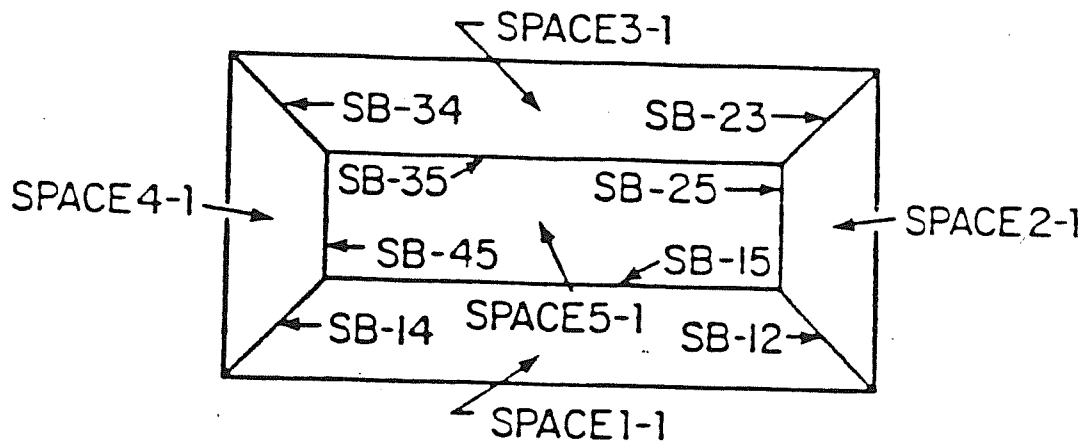
Figure 3A: Plan view showing zoning and u-names of spaces and interior walls.
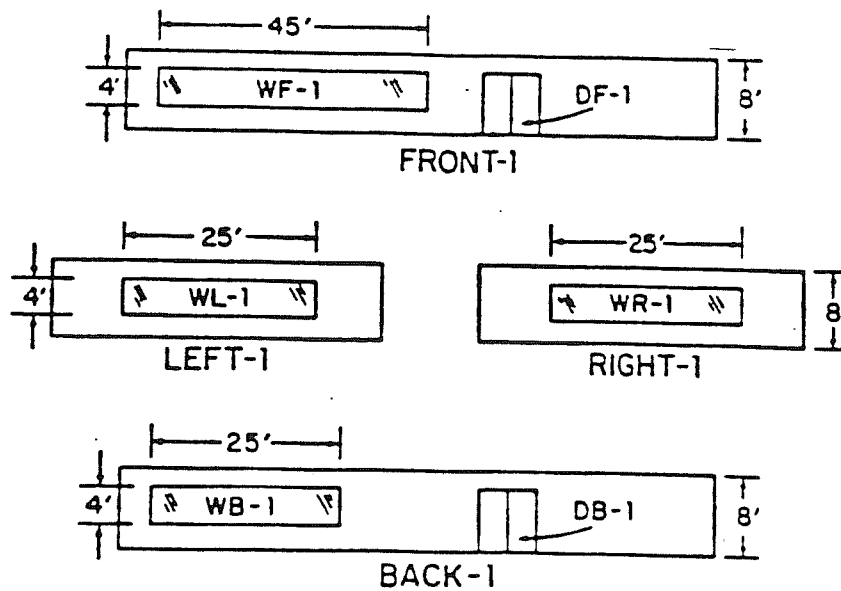
XBL 791-35

Figure 4A: Elevations showing placement of windows, doors, and their u-names.

Input and reports can be in metric units

The year of the weather tape used

The building is oriented 10° from true North

These code-words for building materials were selected from the stored DOE-2 library

A user-assigned name (u-name) for later reference

The daily profiles
Hours 1 to 8 at zero occupancy
hours 15 to 18 at full occupancy

```
INPUT LOADS  INPUT-UNITS  = ENGLISH
             OUTPUT-UNITS = ENGLISH ..

TITLE        LINE-1 *SIMPLE STRUCTURE RUN, CHICAGO *
             LINE-2 *EXAMPLE FOR DOE2.1D OVERVIEW* ..

ABORT            ERRORS ..
DIAGNOSTIC       WARNINGS ..

RUN-PERIOD       JAN 1 1974 THRU DEC 31 1974 ..
LOADS-REPORT     VERIFICATION = (LV-D)
                 SUMMARY      = (LS-C) ..
BUILDING-LOCATION  LATITUDE = 42.0    LONGITUDE = 88.0
                   ALTITUDE = 610     TIME-ZONE = 6
                   AZIMUTH  = 10 ..

$ CONSTRUCTION AND GLASS-TYPES

WAln2  = LAYERS       MATERIAL = (WD01,PW03,IN02,GP01) ..
RB-1-1 = LAYERS       MATERIAL = (RG01,BR01,IN22,WD01)
                      INSIDE-FILM-RES = .76 ..

WALL-1  = CONSTRUCTION LAYERS  = WAln2 ..
ROOF-1  = CONSTRUCTION LAYERS  = RB-1-1 ..
CLNG-1  = CONSTRUCTION U-VALUE = 0.27 ..
SB-U    = CONSTRUCTION U-VALUE = 1.5 ..
FLOOR-1 = CONSTRUCTION U-VALUE = 0.05 ..
W-1     = GLASS-TYPE   SHADING-COEF = .45  PANES = 2 ..

$ OCCUPANCY SCHEDULE

OCCUPY-1 = SCHEDULE THRU DEC 31
           (MON,FRI)(1,8)(0)(9,11)(1)
                    (12,14)(.8,.4,.8) (15,18)(1)
                    (19,21)(.5,.1,.1) (22,24)(0)
           (SAT,HOL)(1,24)(0) ..

$ LIGHTING SCHEDULE

LIGHTS-1 = SCHEDULE THRU DEC 31
           (WD)  (1,8)(.05)  (9,14)(.9,.95,1,.95,.8,.9)
                 (15,18)(1)  (19,21)(.6,.2,.2)
                 (22,24)(.05)
           (WEH) (1,24)(.05) ..

$ OFFICE EQUIPMENT SCHEDULE

EQUIP-1  = SCHEDULE THRU DEC 31
           (WD)  (1,8)(.2)  (9,14)(.8)
                 (15,20)(.8,.7,.5,.5,.3,.3)
                 (21,24)(.02)
           (WEH) (1,24)(.02) ..
```

```
$ INFILTRATION SCHEDULE
INFIL-SCH = SCHEDULE  THRU MAR 31  (ALL)  (1,24)  (1)
                      THRU OCT 31  (ALL)  (1,24)  (0)
                      THRU DEC 31  (ALL)  (1,24)  (1)  ..

$ SET DEFAULT VALUES
SET-DEFAULT FOR SPACE FLOOR-WEIGHT = 70 ..

SET-DEFAULT FOR WINDOW   HEIGHT     = 4.0
                         GLASS-TYPE = W-1  ..

$ GENERAL SPACE DEFINITION

OFFICE   = SPACE-CONDITIONS   PEOPLE-SCHEDULE    = OCCUPY-1
                              NUMBER-OF-PEOPLE   = 50
                              PEOPLE-HEAT-GAIN   = 400
                              LIGHTING-SCHEDULE  = LIGHTS-1
                              LIGHTING-TYPE      = REC-FLUOR-RV
                              LIGHT-TO-SPACE     = .80
                              LIGHTING-W/SQFT    = 3
                              EQUIP-SCHEDULE     = EQUIP-1
                              EQUIPMENT-W/SQFT   = 1
                              INF-METHOD         = AIR-CHANGE
                              AIR-CHANGES/HR     = .25
                              INF-SCHEDULE       = INFIL-SCH ..

$ SPECIFIC SPACE DETAILS

PLENUM-1 = SPACE    ZONE-TYPE    = PLENUM    VOLUME = 10000
                    FLOOR-WEIGHT = 5         AREA   = 5000 ..

WALL-1PF = EXTERIOR-WALL   HEIGHT = 2     WIDTH = 100
                           AZIMUTH = 180
                           CONSTRUCTION = WALL-1 ..

WALL-1PR = EXTERIOR-WALL   HEIGHT = 2     WIDTH = 50
                           AZIMUTH = 90
                           CONSTRUCTION = WALL-1 ..

WALL-1PB = EXTERIOR-WALL   HEIGHT = 2     WIDTH = 100
                           AZIMUTH = 0
                           CONSTRUCTION = WALL-1 ..

WALL-1PL = EXTERIOR-WALL   HEIGHT = 2     WIDTH = 50
                           AZIMUTH = 270
                           CONSTRUCTION = WALL-1 ..

TOP-1    = ROOF   HEIGHT = 50    WIDTH = 100
                  AZIMUTH = 180
                  TILT = 0       GND-REFLECTANCE = 0
                  CONSTRUCTION = ROOF-1 ..
```

Infiltration is "on" during winter months

Same as "SET MASTER DATA" in other programs

Maximum values that are multiplied by occupancy profiles

The infiltration schedule is referenced in the definition of space conditions

The first space definition, using the u-names of the plenum walls and roof, as shown in Figure 2 of the Appendix.

This assigns the general conditions (energy use and profiles) to the space

Input for an overhang over the South window

Notice the hierarchy of input. First is the space, then the exterior walls, then the windows within each wall

This is the input for the ceiling of SPACE2-1, which is shared by the plenum (as are the ceilings of the other four spaces)

```
SPACE1-1  = SPACE  SPACE-CONDITIONS = OFFICE  AREA = 1056  VOLUME = 8448
             NUMBER-OF-PEOPLE = 11  ..

FRONT-1   = EXTERIOR-WALL    HEIGHT = 8        WIDTH = 100
                             AZIMUTH = 180
                             CONSTRUCTION = WALL-1  ..

WF-1      = WINDOW           WIDTH      = 45
                             OVERHANG-A = 1    OVERHANG-B = .5
                             OVERHANG-W = 47   OVERHANG-D = 4  ..

C1-1      = INTERIOR-WALL    AREA = 1056        NEXT-TO  PLENUM-1
                             CONSTRUCTION = CLNG-1  ..

F1-1      = UNDERGROUND-FLOOR  AREA = 1056
                             CONSTRUCTION = FLOOR-1  ..

SB12      = INTERIOR-WALL    AREA = 135.76     NEXT-TO  SPACE2-1
                             CONSTRUCTION = SB-U  ..

SB14      = INTERIOR-WALL    LIKE SB12         NEXT-TO  SPACE4-1

SB15      = INTERIOR-WALL    AREA = 608         NEXT-TO  SPACE5-1
                             CONSTRUCTION = SB-U  ..

SPACE2-1  = SPACE  SPACE-CONDITIONS = OFFICE  AREA = 456  VOLUME = 3648
             NUMBER-OF-PEOPLE = 5  ..

RIGHT-1   = EXTERIOR-WALL    HEIGHT = 8        WIDTH = 50
                             AZIMUTH = 90
                             CONSTRUCTION = WALL-1  ..

WR-1      = WINDOW           WIDTH = 25  ..

C2-1      = INTERIOR-WALL    AREA = 456         NEXT-TO  PLENUM-1
                             CONSTRUCTION = CLNG-1  ..

F2-1      = UNDERGROUND-FLOOR  AREA = 456
                             CONSTRUCTION = FLOOR-1  ..

SB23      = INTERIOR-WALL    AREA = 135.76     NEXT-TO  SPACE3-1
                             CONSTRUCTION = SB-U  ..

SB25      = INTERIOR-WALL    AREA = 208         NEXT-TO  SPACE5-1
                             CONSTRUCTION = SB-U  ..
```

```
SPACE3-1  = SPACE      LIKE SPACE1-1   ..

          BACK-1       = EXTERIOR-WALL   HEIGHT  = 8            WIDTH = 100
                                         AZIMUTH = 0
                                         CONSTRUCTION = WALL-1   ..

          WB-1         = WINDOW          WIDTH = 45   ..

          C3-1         = INTERIOR-WALL   AREA = 1056    NEXT-TO  PLENUM-1
                                         CONSTRUCTION = CLNG-1    ..

          F3-1         = UNDERGROUND-FLOOR   AREA = 1056
                                         CONSTRUCTION = FLOOR-1   ..

          SB34         = INTERIOR-WALL   AREA = 135.8   NEXT-TO  SPACE4-1
                                         CONSTRUCTION = SB-U   ..

          SB35         = INTERIOR-WALL   AREA = 608     NEXT-TO  SPACE5-1
                                         CONSTRUCTION = SB-U   ..

SPACE4-1  = SPACE      LIKE SPACE2-1   ..

          LEFT-1       = EXTERIOR-WALL   HEIGHT  = 8            WIDTH = 50
                                         AZIMUTH = 270
                                         CONSTRUCTION = WALL-1   ..

          WL-1         = WINDOW          WIDTH = 25   ..

          C4-1         = INTERIOR-WALL   AREA = 456     NEXT-TO  PLENUM-1
                                         CONSTRUCTION = CLNG-1    ..

          F4-1         = UNDERGROUND-FLOOR   AREA = 456
                                         CONSTRUCTION = FLOOR-1   ..

          SB45         = INTERIOR-WALL   AREA = 208     NEXT-TO  SPACE5-1
                                         CONSTRUCTION = SB-U   ..

SPACE5-1  = SPACE      LIKE SPACE4-1   AREA = 1976   VOLUME = 15808
                       NUMBER-OF-PEOPLE = 20   ..

          C5-1         = INTERIOR-WALL   AREA = 1976    NEXT-TO  PLENUM-1
                                         CONSTRUCTION = CLNG-1    ..

          F5-1         = UNDERGROUND-FLOOR   AREA = 1976
                                         CONSTRUCTION = FLOOR-1   ..

END   ..
COMPUTE LOADS   ..
```

Making SPACE3-1 like SPACE1-1 copies the previous data

INPUT SYSTEMS   ..

SYSTEMS-REPORT SUMMARY = (SS-A) ..

$ SYSTEMS SCHEDULES

FAN-SCHED   = SCHEDULE   THRU DEC 31
                         (WD) (1,6)(0)(7,8)(-999)(9,18)(1) (19,24)(0)   *The fan profile has an optimum start period (-999) from 7 to 8 AM*
                         (WEH) (1,24)(0)

HEAT-SCHED = SCHEDULE   THRU DEC 31
                         (WD) (1,8)(55) (9,18)(70) (19,24)(55)   *The heating setpoint of the thermostat is 70°F during the day and 55°F at night*
                         (WEH) (1,24)(55) ..

COOL-SCHED = SCHEDULE   THRU DEC 31
                         (WD) (1,8)(99) (9,18)(78) (19,24)(99)   *Cooling setpoint is 78°F*
                         (WEH) (1,24)(99) ..

COOLOFF   = SCHEDULE   THRU DEC 31 (ALL) (1,24) (60) ..   *Cooling is available year around whenever the outside temperature goes above 60°F*
HEATOFF   = SCHEDULE   THRU DEC 31 (ALL) (1,24) (60) ..

R1   = DAY-RESET-SCH   SUPPLY-HI = 65   SUPPLY-LO = 60
                              OUTSIDE-LO = 30   OUTSIDE-HI = 75
SAT-RESET   = RESET-SCHEDULE   THRU DEC 31 (ALL) R1 ..

$ SYSTEM DESCRIPTION

CONTROL   = ZONE-CONTROL   DESIGN-HEAT-T   = 70
                             DESIGN-COOL-T   = 78
                             HEAT-TEMP-SCH   = HEAT-SCHED
                             COOL-TEMP-SCH   = COOL-SCHED
                             THERMOSTAT-TYPE   = REVERSE-ACTION

SPACE1-1   = ZONE   ZONE-CONTROL   = CONTROL
                     SIZING-OPTION = ADJUST-LOADS   *The minimum ventilation per person*
                     OA-CFM/PER   = 7 ..
SPACE2-1   = ZONE   LIKE SPACE1-1 ..
SPACE3-1   = ZONE   LIKE SPACE1-1 ..
SPACE4-1   = ZONE   LIKE SPACE1-1 ..
SPACE5-1   = ZONE   LIKE SPACE1-1

PLENUM-1   = ZONE   ZONE-TYPE   = PLENUM
                     SIZING-OPTION = ADJUST-LOADS   *The same u-names of spaces as input in the LOADS portion of the program*
                     DESIGN-HEAT-T = 50
                     DESIGN-COOL-T = 95 ..

S-CONT   = SYSTEM-CONTROL   COOLING-SCHEDULE = COOLOFF
                              HEATING-SCHEDULE = HEATOFF
                              HEAT-SET-T   = 65
                              COOL-CONTROL   = RESET
                              COOL-RESET-SCH   = SAT-RESET   *Another schedule being referenced*
                              MIN-SUPPLY-T   = 60 ..

```
SYST-1      =   SYSTEM

                SYSTEM-TYPE        =  VAVS
                SYSTEM-CONTROL     =  S-CONT
                FAN-SCHEDULE       =  FAN-SCHED
                FAN-CONTROL        =  SPEED
                SUPPLY-STATIC      =  5.5
                SUPPLY-EFF         =  .55
                NIGHT-CYCLE-CTRL   =  CYCLE-ON-ANY
                REHEAT-DELTA-T     =  58
                MIN-CFM-RATIO      =  .3
                ECONO-LIMIT-T      =  65
                RETURN-AIR-PATH    =  PLENUM-ZONES
                PLENUM-NAMES       =  (PLENUM-1)
                ZONE-NAMES         =  (SPACE5-1, SPACE1-1,
                                       SPACE2-1, SPACE3-1,
                                       SPACE4-1, PLENUM-1)  ..

END
COMPUTE SYSTEMS   ..

INPUT PLANT   ..

            PLANT-REPORT  SUMMARY=(BEPS)  ..

            $ EQUIPMENT DESCRIPTION

HWG     = PLANT-EQUIPMENT   TYPE = HW-BOILER
                            SIZE = .40  ..

CHIL1   = PLANT-EQUIPMENT   TYPE = HERM-REC-CHLR
                            SIZE = .18  ...  $ 15 TONS  ..

PLANT-PARAMETERS    BOILER-FUEL        = NATURAL-GAS
                    HERM-REC-COND-TYPE = AIR  ..

ENERGY-RESOURCE    RESOURCE = ELECTRICITY  ..
ENERGY-RESOURCE    RESOURCE = NATURAL-GAS  ..

END  ..
COMPUTE PLANT  ..
```

The system type selected is variable-air volume (VAVS)

The assignment of spaces (zones) to the VAVS system

400,000 Btu/hr peak output capacity

The code-word for a hermetic-reciprocating chiller with a condenser that normally defaults to water cooled. The PLANT-PARAMETERS changes it to air

ECONOMICS-REPORT   SUMMARY = (ES-D,ES-E)   ..

$ GAS ENERGY COSTS

ENERGY-COST   RESOURCE = NATURAL-GAS   UNIT = 100000
              UNIFORM-COST =.6   ESCALATION =.8 ..

A simple, uniform cost of 60¢ per therm for gas

$ ELECTRIC ENERGY COSTS

ENERGY-COST   RESOURCE = ELECTRICITY   ASSIGN-SCHEDULE = TIMEOFDAY
              ESCALATION = 7 ..

NIGHT = CHARGE-ASSIGNMENT   RESOURCE = ELECTRICITY   TYPE = ENERGY
              UNIFORM-CHARGE =.05 ..

SHD-P = CHARGE-ASSIGNMENT   RESOURCE = ELECTRICITY
              TYPE = ENERGY   UNIFORM-CHARGE =.06 ..

PEAK = CHARGE-ASSIGNMENT   RESOURCE = ELECTRICITY
              TYPE = ENERGY   UNIFORM-CHARGE =.07 ..

WD-RATE = DAY-CHARGE-SCH   (1,8) (NIGHT) (9,12) (SHD-P)
              (13,17) (PEAK) (18,22) (SHD-P)
              (23,24) (NIGHT) ..

SAT-RATE = DAY-CHARGE-SCH   (1,8) (NIGHT) (9,17) (SHD-P)
              (18,24) (NIGHT) ..

WEH-RATE = DAY-CHARGE-SCH   (1,24) (NIGHT) ..

TIMEOFDAY = SCHEDULE   THRU DEC 31 (WD) WD-RATE
                                   (SAT) SAT-RATE
                                   (SUN,HOL) WEH-RATE ..

END ..
COMPUTE ECONOMICS ..
STOP ..

A simple time-of-day rate for electricity during the weekdays:

5¢/kwh at night (11 PM to 8 AM)
6¢/kwh shoulder (9 AM to 12 noon)
7¢/kwh at peak (1 PM to 5 PM)

There are no demand charges

B U I L D I N G   E N E R G Y   A N A L Y S I S   P R O G R A M

DEVELOPED BY

LAWRENCE BERKELEY LABORATORY/UNIVERSITY OF CALIFORNIA

WITH MAJOR SUPPORT FROM

UNITED STATES DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY
OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS
BUILDING SYSTEMS DIVISION

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- LV-D DETAILS OF EXTERIOR SURFACES IN THE PROJECT   WEATHER FILE- CHICAGO   WYEC

NUMBER OF EXTERIOR SURFACES   9   RECTANGULAR   9   OTHER   0
(U-VALUE INCLUDES INSIDE AIR FILM PLUS OUTSIDE AIR FILM AT 7.5 MPH WINDSPEED)

SURFACE	SPACE	- - - GLASS - - - U-VALUE (BTU/HR-SQFT-F)	AREA (SQFT)	- - - WALL - - - U-VALUE (BTU/HR-SQFT-F)	AREA (SQFT)	- WALL + GLASS - U-VALUE (BTU/HR-SQFT-F)	AREA (SQFT)	AZIMUTH
WALL-1PB	PLENUM-1	0.000	0.00	0.068	200.00	0.068	200.00	NORTH
BACK-1	SPACE3-1	0.490	180.00	0.068	620.00	0.163	800.00	NORTH
RIGHT-1	SPACE2-1	0.490	100.00	0.068	300.00	0.173	400.00	EAST
WALL-1PR	PLENUM-1	0.000	0.00	0.068	100.00	0.068	100.00	EAST
WALL-1PF	PLENUM-1	0.000	0.00	0.068	200.00	0.068	200.00	SOUTH
FRONT-1	SPACE1-1	0.490	180.00	0.068	620.00	0.163	800.00	SOUTH
WALL-1PL	PLENUM-1	0.000	0.00	0.068	100.00	0.068	100.00	WEST
LEFT-1	SPACE4-1	0.490	100.00	0.068	300.00	0.173	400.00	WEST
TOP-1	PLENUM-1	0.000	0.00	0.173	5000.00	0.173	5000.00	ROOF
F1-1	SPACE1-1	0.000	0.00	0.050	1056.00	0.050	1056.00	UNDERGRND
F2-1	SPACE2-1	0.000	0.00	0.050	456.00	0.050	456.00	UNDERGRND
F3-1	SPACE3-1	0.000	0.00	0.050	1056.00	0.050	1056.00	UNDERGRND
F4-1	SPACE4-1	0.000	0.00	0.050	456.00	0.050	456.00	UNDERGRND
F5-1	SPACE5-1	0.000	0.00	0.050	1976.00	0.050	1976.00	UNDERGRND

An echo of your input

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- LS-C BUILDING PEAK LOAD COMPONENTS   WEATHER FILE- CHICAGO   WYEC

*** BUILDING ***

FLOOR AREA   5000 SQFT   465 SQMT
VOLUME   50000 CUFT 1416 CUMT

	COOLING LOAD AUG 23 4PM				HEATING LOAD FEB 3 5AM	
	SENSIBLE		LATENT		SENSIBLE	
TIME	(KBTU/H)	(KW)	(KBTU/H)	(KW)	(KBTU/H)	(KW)
DRY-BULB TEMP	94F 34C				-3F -19C	
WET-BULB TEMP	75F 24C				-4F -20C	
WALLS	3.181	0.932	0.000	0.000	-8.997	-2.635
ROOFS	0.000	0.000	0.000	0.000	0.000	0.000
GLASS CONDUCTION	5.015	1.469	0.000	0.000	-21.250	-6.224
GLASS SOLAR	9.365	2.743	0.000	0.000	2.516	0.737
DOOR	0.000	0.000	0.000	0.000	0.000	0.000
INTERNAL SURFACES	-1.675	-0.491	0.000	0.000	0.000	0.000
UNDERGROUND SURFACES	13.334	3.905	0.000	0.000	-8.000	-2.343
OCCUPANTS TO SPACE	3.905	1.145	4.824	1.413	0.036	0.010
LIGHT TO SPACE	34.965	10.240	0.000	0.000	2.174	0.637
EQUIPMENT TO SPACE	11.325	3.317	0.000	0.000	0.372	0.109
PROCESS TO SPACE	0.000	0.000	0.000	0.000	0.000	0.000
INFILTRATION	0.000	0.000	0.000	0.000	-15.016	-4.398
TOTAL	75.510	22.115	4.824	1.413	-48.165	-14.106

TOTAL LOAD   80.334 KBTU/H   23.528 KW   -48.165 KBTU/H   -14.106 KW

TOTAL LOAD / AREA   16.07 BTU/H.SQFT   50.650 W /SQMT   9.633 BTU/H.SQFT   30.368 W /SQMT

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*****************************************************
*                                                   *
*  NOTE  1)THE ABOVE LOADS EXCLUDE OUTSIDE VENTILATION AIR  *
*  ----    LOADS                                     *
*        2)TIMES GIVEN IN STANDARD TIME FOR THE LOCATION  *
*          IN CONSIDERATION                          *
*                                                   *
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Building peak sensible load → (75.510)

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- LV-D DETAILS OF EXTERIOR SURFACES IN THE PROJECT   WEATHER FILE- CHICAGO WYEC
---(CONTINUED)-------

	AVERAGE U-VALUE/GLASS (BTU/HR-SQFT-F)	AVERAGE U-VALUE/WALLS (BTU/HR-SQFT-F)	AVERAGE U-VALUE WALLS+GLASS (BTU/HR-SQFT-F)	GLASS AREA (SQFT)	OPAQUE AREA (SQFT)	GLASS+OPAQUE AREA (SQFT)
NORTH	0.490	0.068	0.144	180.00	820.00	1000.00
EAST	0.490	0.068	0.152	100.00	400.00	500.00
SOUTH	0.490	0.068	0.144	180.00	820.00	1000.00
WEST	0.490	0.068	0.152	100.00	400.00	500.00
ROOF	0.000	0.173	0.173	0.00	5000.00	5000.00
ALL WALLS	0.490	0.068	0.147	560.00	2440.00	3000.00
WALLS+ROOFS	0.490	0.139	0.163	560.00	7440.00	8000.00
UNDERGRND	0.000	0.050	0.050	0.00	5000.00	5000.00
BUILDING	0.490	0.103	0.120	560.00	12440.00	13000.00

-43.App-

This report checks wall and glass U-factors (and overall U-factors) plus the areas of wall, roof, and floor surfaces resulting from the inputs

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- SS-A SYSTEM MONTHLY LOADS SUMMARY FOR   SYST-1   WEATHER FILE- CHICAGO   WYEC

MONTH	COOLING ENERGY (MBTU)	TIME OF MAX DY	HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM COOLING LOAD (KBTU/HR)	HEATING ENERGY (MBTU)	TIME OF MAX DY	HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM HEATING LOAD (KBTU/HR)	ELECTRICAL ENERGY (KWH)	MAXIMUM ELEC LOAD (KW)
JAN	0.00000					0.000	-22.164	2	8	11.F	11.F	-351.844	5127.	20.420
FEB	0.00000					0.000	-18.694	25	8	11.F	11.F	-349.570	4449.	20.005
MAR	0.08105	19	16	65.F	51.F	17.681	-12.257	18	8	27.F	24.F	-331.389	4877.	19.631
APR	2.34182	26	16	88.F	62.F	100.846	-3.567	15	8	34.F	32.F	-280.639	5045.	22.042
MAY	7.13346	22	18	78.F	72.F	103.004	-0.311	20	8	48.F	46.F	-105.861	5182.	21.970
JUN	14.59762	12	16	92.F	71.F	134.866	0.000					0.000	4986.	23.463
JUL	23.13407	10	18	89.F	68.F	142.970	0.000					0.000	5726.	23.908
AUG	21.63276	28	17	90.F	77.F	145.266	0.000					0.000	5641.	23.670
SEP	10.53538	9	16	91.F	73.F	145.503	-0.071	30	8	47.F	46.F	-64.792	4942.	24.140
OCT	3.22776	18	17	78.F	65.F	94.483	-0.484	28	8	37.F	32.F	-150.165	5100.	21.975
NOV	0.02701	1	13	62.F	54.F	6.335	-7.388	25	8	30.F	25.F	-333.272	4438.	19.604
DEC	0.00000					0.000	-19.119	16	8	8.F	7.F	-375.627	4912.	19.878
TOTAL	82.711						-84.056						60429.	
MAX						145.503						-375.627		24.140

Total cooling coil load passed to the chiller → 82.711

Maximum cooling load → 145.503

-44.App-

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- SV-A SYSTEM DESIGN PARAMETERS   SYST-1   WEATHER FILE- CHICAGO WYEC

SYST-1

SYSTEM NAME	ALTITUDE MULTIPLIER
SYST-1	1.020

SUPPLY FAN (CFM)	ELEC (KW)	DELTA-T (F)	RETURN FAN (CFM)	ELEC (KW)	DELTA-T (F)	OUTSIDE AIR RATIO	COOLING CAPACITY (KBTU/HR)	SENSIBLE (SHR)	HEATING CAPACITY (KBTU/HR)	COOLING EIR (BTU/BTU)	HEATING EIR (BTU/BTU)
5182.	5.962	-3.6	0.	0.000	0.0	0.075	155.800	0.783	-9.470	0.00	0.00

ZONE NAME	SUPPLY FLOW	EXHAUST FLOW	FAN (KW)	MINIMUM FLOW RATIO	OUTSIDE AIR FLOW	COOLING CAPACITY (KBTU/HR)	SENSIBLE (SHR)	EXTRACTION RATE (KBTU/HR)	HEATING CAPACITY (KBTU/HR)	ADDITION RATE (KBTU/HR)	MULTIPLIER
SPACE5-1	1673.	0.	0.000	0.300	143.	0.00	0.00	32.52	-104.78	-86.72	1.0
SPACE1-1	1112.	0.	0.000	0.300	82.	0.00	0.00	21.61	-69.64	-57.64	1.0
SPACE2-1	622.	0.	0.000	0.300	41.	0.00	0.00	12.10	-38.97	-32.25	1.0
SPACE3-1	1091.	0.	0.000	0.300	82	0.00	0.00	21.22	-60.37	-56.58	1.0
SPACE4-1	683.	0.	0.000	0.300	41.	0.00	0.00	13.29	-42.01	-35.43	1.0
PLENUM-1	0.	0.	0.000	0.000	0.	0.00	0.00	0.00	0.00	0.00	1.0

System design air flow (pointing to 5182.)

Zone space design air flow (pointing to SUPPLY FLOW column)

Air handling unit cooling coil capacity (pointing to COOLING CAPACITY 155.800)

Heating capacity of zone reheat coils (pointing to HEATING CAPACITY column)

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- PS-B MONTHLY PEAK AND TOTAL ENERGY USE   WEATHER FILE- CHICAGO   WYEC

MO	UTILITY-	ELECTRICITY	NATURAL-GAS
JAN	TOTAL(MBTU)	19.547	35.296
	PEAK(KBTU)	79.914	451.659
	DY/HR	7/ 9	2/ 8
FEB	TOTAL(MBTU)	16.941	29.940
	PEAK(KBTU)	78.500	449.224
	DY/HR	25/ 9	25/ 8
MAR	TOTAL(MBTU)	17.945	19.864
	PEAK(KBTU)	77.226	429.664
	DY/HR	19/15	18/ 8
APR	TOTAL(MBTU)	18.802	5.967
	PEAK(KBTU)	114.789	374.198
	DY/HR	26/16	15/ 8
MAY	TOTAL(MBTU)	20.984	0.550
	PEAK(KBTU)	111.376	173.402
	DY/HR	22/16	20/ 8
JUN	TOTAL(MBTU)	23.008	0.000
	PEAK(KBTU)	130.010	0.000
	DY/HR	12/15	30/ 1
JUL	TOTAL(MBTU)	28.196	0.000
	PEAK(KBTU)	129.371	0.000
	DY/HR	22/15	31/ 1
AUG	TOTAL(MBTU)	27.554	0.000
	PEAK(KBTU)	132.463	0.000
	DY/HR	20/15	31/ 1
SEP	TOTAL(MBTU)	21.248	0.129
	PEAK(KBTU)	133.951	109.968
	DY/HR	9/15	30/ 8
OCT	TOTAL(MBTU)	19.071	0.869
	PEAK(KBTU)	110.274	225.735
	DY/HR	18/15	28/ 8
NOV	TOTAL(MBTU)	15.986	12.117
	PEAK(KBTU)	77.130	431.697
	DY/HR	25/11	25/ 8
DEC	TOTAL(MBTU)	18.577	30.603
	PEAK(KBTU)	78.065	476.971
	DY/HR	16/11	16/ 8
	ONE YEAR	247.858	135.335
	USE/PEAK	133.951	476.971

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- PV-A EQUIPMENT SIZES   WEATHER FILE- CHICAGO   WYEC

E Q U I P M E N T	SIZE (MBTU/H)	NUMBER INSTD	AVAIL	SIZE (MBTU/H)	NUMBER INSTD	AVAIL	SIZE (MBTU/H)	NUMBER INSTD	AVAIL	SIZE (MBTU/H)	NUMBER INSTD	AVAIL	SIZE (MBTU/H)	NUMBER INSTD	AVAIL	SIZE (MBTU/H)	NUMBER INSTD	AVAIL
HW-BOILER	0.400	1	1															
HERM-REC-CHLR	0.180	1	1															

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- PS-D PLANT LOADS SATISFIED

WEATHER FILE- CHICAGO   WYEC

HEATING LOADS

	MBTU SUPPLIED	PCT OF TOTAL LOAD
HW-BOILER	87.5	100.0
LOAD SATISFIED	87.5	
TOTAL LOAD ON PLANT	87.5	

COOLING LOADS

	MBTU SUPPLIED	PCT OF TOTAL LOAD
HERM-REC-CHLR	86.1	100.0
LOAD SATISFIED	86.1	
TOTAL LOAD ON PLANT	86.1	

ELECTRICAL LOADS

	MBTU SUPPLIED	PCT OF TOTAL LOAD
ELECTRICITY	247.9	100.0
LOAD SATISFIED	247.9	
TOTAL LOAD ON PLANT	247.8	

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- PS-D PLANT LOADS SATISFIED   .WEATHER FILE- CHICAGO WYEC
--(CONTINUED)---------

SUMMARY OF LOADS MET

TYPE OF LOAD	TOTAL LOAD (MBTU)	LOAD SATISFIED (MBTU)	TOTAL OVERLOAD (MBTU)	PEAK OVERLOAD (MBTU)	HOURS OVERLOADED
HEATING LOADS	87.5	87.5	0.000	0.000	0
COOLING LOADS	86.1	86.1	0.000	0.000	0
ELECTRICAL LOADS	247.8	247.9	0.000	0.000	0

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- BEPS ESTIMATED BUILDING ENERGY PERFORMANCE

WEATHER FILE- CHICAGO   WYEC

ENERGY TYPE IN SITE MBTU -	ELECTRICITY	NATURAL-GAS
CATEGORY OF USE		
SPACE HEAT	6.27	135.33
SPACE COOL	31.47	0.00
HVAC AUX	18.49	0.00
DOM HOT WTR	0.00	0.00
AUX SOLAR	0.00	0.00
LIGHTS	149.50	0.00
VERT TRANS	0.00	0.00
MISC EQUIP	42.12	0.00
TOTAL	247.86	135.33

TOTAL SITE ENERGY   383.19 MBTU   76.6 KBTU/SQFT-YR GROSS-AREA   76.6 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY.   879.65 MBTU   175.9 KBTU/SQFT-YR GROSS-AREA   175.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =   0.8
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED   =   0.0

NOTE   ELECTRICITY AND/OR FUEL USED TO GENERATE ELECTRICITY IS APPORTIONED BASED
       ON THE YEARLY DEMAND. ALL OTHER ENERGY TYPES ARE APPORTIONED HOURLY.

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- ES-D SUMMARY OF FUEL AND UTILITY USE AND COSTS

Btu/kwH · *Btu/therm* · *therms* · *kwh* · *kw*

MONTH		ELECTRIC ....UNIT... 3412.97	NTRL-GAS ...UNIT... 100000.00
JAN	ENERGY CONSUMPTION (UNIT/MO)		353.
	PEAK DEMAND (UNIT/HR)		
	TOTAL COST ($)	357.16	211.78
FEB	ENERGY CONSUMPTION (UNIT/MO)	4964.	299.
	PEAK DEMAND (UNIT/HR)	23.	4.
	TOTAL COST ($)	308.88	179.64
MAR	ENERGY CONSUMPTION (UNIT/MO)	5258.	199.
	PEAK DEMAND (UNIT/HR)	23.	4.
	TOTAL COST ($)	328.87	119.18
APR	ENERGY CONSUMPTION (UNIT/MO)	5509.	60.
	PEAK DEMAND (UNIT/HR)	34.	4.
	TOTAL COST ($)	347.80	35.80
MAY	ENERGY CONSUMPTION (UNIT/MO)	6148.	5.
	PEAK DEMAND (UNIT/HR)	33.	3.
	TOTAL COST ($)	390.28	3.30
JUN	ENERGY CONSUMPTION (UNIT/MO)	6741.	0.
	PEAK DEMAND (UNIT/HR)	38.	0.
	TOTAL COST ($)	429.60	0.00
JUL	ENERGY CONSUMPTION (UNIT/MO)	8261.	0.
	PEAK DEMAND (UNIT/HR)	38.	0.
	TOTAL COST ($)	525.47	0.00
AUG	ENERGY CONSUMPTION (UNIT/MO)	8073.	0.
	PEAK DEMAND (UNIT/HR)	39.	0.
	TOTAL COST ($)	513.89	0.00
SEP	ENERGY CONSUMPTION (UNIT/MO)	6226.	1.
	PEAK DEMAND (UNIT/HR)	39.	1.
	TOTAL COST ($)	395.54	0.77
OCT	ENERGY CONSUMPTION (UNIT/MO)	5588.	9.
	PEAK DEMAND (UNIT/HR)	32.	2.
	TOTAL COST ($)	353.90	5.22
NOV	ENERGY CONSUMPTION (UNIT/MO)	4684.	121.
	PEAK DEMAND (UNIT/HR)	23.	4.
	TOTAL COST ($)	292.89	72.70
DEC	ENERGY CONSUMPTION (UNIT/MO)	5443.	306.
	PEAK DEMAND (UNIT/HR)	23.	5.
	TOTAL COST ($)	339.50	183.62
TOTAL	ENERGY CONSUMPTION (UNIT/YR)	72622.	1353.
	PEAK DEMAND (UNIT/HR)	39.	5.

TOTAL COST ($)   4583.78   812.01

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- ES-E SUMMARY OF ELECTRICITY CHARGES
---CONTINUED-----

MONTH	CHARGE-ASSIGNMENT (U-NAME)	LENGTH (HR/MO)	CONSUMPTION BY C-A (KWH)	ENERGY CHARGE ($)	MEASURED DEMAND (KW)	BILLING DEMAND (KW)	DEMAND CHARGE ($)	TOTAL CHARGES ($)
NOV	NIGHT	409	610.	30.52	10.	10.	0.00	
	SHD-P	216	2279.	136.72	23.	23.	0.00	
	PEAK	95	1795.	125.64	21.	21.	0.00	292.89
DEC	NIGHT	414	770.	38.49	10.	10.	0.00	
	SHD-P	225	2611.	156.67	23.	23.	0.00	
	PEAK	105	2062.	144.34	22.	22.	0.00	339.50
TOTAL			72622.	4583.78			0.00	4583.78

SIMPLE STRUCTURE RUN, CHICAGO

REPORT- ES-E   SUMMARY OF ELECTRICITY CHARGES

MONTH	CHARGE-ASSIGNMENT (U-NAME)	LENGTH (HR/MO)	CONSUMPTION BY C-A (KWH)	ENERGY CHARGE ($)	MEASURED DEMAND (KW)	BILLING DEMAND (KW)	DEMAND CHARGE ($)	TOTAL CHARGES ($)
JAN	NIGHT	400	812.	40.62	10.	10.	0.00	
	SHD-P	234	2749.	164.92	23.	23.	0.00	357.16
	PEAK	110	2166.	151.62	22.	22.	0.00	
FEB	NIGHT	370	740.	37.01	10.	10.	0.00	
	SHD-P	207	2376.	142.59	23.	23.	0.00	308.88
	PEAK	95	1847.	129.29	22.	22.	0.00	
MAR	NIGHT	405	677.	33.86	10.	10.	0.00	
	SHD-P	234	2564.	153.84	23.	23.	0.00	328.87
	PEAK	105	2017.	141.17	23.	23.	0.00	
APR	NIGHT	376	532.	26.61	8.	8.	0.00	
	SHD-P	234	2719.	163.14	32.	32.	0.00	347.80
	PEAK	110	2250.	158.05	34.	34.	0.00	
MAY	NIGHT	400	508.	25.40	5.	5.	0.00	
	SHD-P	234	2994.	179.64	31.	31.	0.00	390.28
	PEAK	110	2646.	185.24	33.	33.	0.00	
JUN	NIGHT	395	519.	25.93	14.	14.	0.00	
	SHD-P	225	3192.	191.51	36.	36.	0.00	429.60
	PEAK	100	3031.	212.16	38.	38.	0.00	
JUL	NIGHT	400	672.	33.61	16.	16.	0.00	
	SHD-P	234	3938.	236.26	37.	37.	0.00	525.47
	PEAK	110	3651.	255.60	38.	38.	0.00	
AUG	NIGHT	391	642.	32.12	13.	13.	0.00	
	SHD-P	243	3839.	230.35	37.	37.	0.00	513.89
	PEAK	110	3592.	251.42	39.	39.	0.00	
SEP	NIGHT	404	528.	26.38	14.	14.	0.00	
	SHD-P	216	2971.	178.25	37.	37.	0.00	395.54
	PEAK	100	2727.	190.91	39.	39.	0.00	
OCT	NIGHT	400	508.	25.41	6.	6.	0.00	
	SHD-P	234	2788.	162.45	38.	38.	0.00	353.90
	PEAK	110	2372.	166.04	32.	32.	0.00	