NBSIR 82-2498

Solar Availability in Cities and Towns:

A Computer Model

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Washington, DC 20234

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Sponsored by
Passive and Hybrid Solar Energy Division
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Kalev Ruberg
Research Associate

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

An interactive computer program, SOLITE, has been written to determine the incident solar radiation on urban building surfaces, street surfaces and rooms facing urban street canyons. Hourly weather data and surface descriptors are interactively entered by the user. Solar radiation data are calculated with NOAA weather tape (TMY or TRY) cloud data using the Kimura/Stephenson cloud cover algorithm. SOLITE also calculates solar radiation transmission through user specified glazing assemblies. Shadows cast by surrounding buildings and overhangs are computed, as are the interreflection effects in street canyons. In addition, internal heat gains from occupants and lighting, and daylight availability on the workplane of a room are calculated. Output options include weather data summaries, incident insolation, occupant heat gain in rooms and useable hours of daylight in a room with a given occupancy. Either hourly or daily values may be specified as output.

Key words: solar access, glazing transmission, shading algorithms, daylighting, urban solar application, solar radiation data.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the many people who have aided in the realization of this computer model. Gary Gillette has kindly consented to the use of his daylighting algorithms in this model. Lawrence E. Flynn has done much of the solar algorithm support analysis. S. Robert Hastings , Dr. Edward A. Arens and Dr. Francis T. Ventre have been very helpful in guiding the research of this report. Frank Deserio is thanked for his far-sighted appreciation of the potential of urban passive solar design and for his sponsorship through the SOLAR CITIES program at the U.S. Department of Energy.

CONVERSION FACTORS FROM METRIC TO ENGLISH UNITS

Physical Characteristics	To Convert From	To	Multiply By
Length	m	ft	3.28
Area	m^2	ft^2	10.76
Velocity	ms^{-1}	mph	2.24
Temperature	^oC	^oF	$t_f=1.8t_c+32$
Temperature difference	^oC	^oF	1.8
Energy	J	BTU	0.948×10^{-3}
Power	W	BTU hr^{-1}	3.41
Power per unit area	W m^{-2}	BTU $hr^{-1}ft^{-2}$	0.317
U-value	W $m^{-2}{}^oC$	BTU $hr^{-1}ft^{-2}{}^oF^{-1}$	0.176
Thermal resistance	$m^2{}^oC$ W^{-1}	$hrft^2{}^oF$ BTU^{-1}	5.678
Pressure	kPa	in Hg	0.296

1 Gigajoule (GJ) = 10^9J = 0.948 BTU x 10^6

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INTRODUCTION

Computer models of solar availability are necessary for local solar access zoning, computer simulation of thermal behavior and analysis of building daylighting potential. An algorithm named SOLITE, developed at the Center for Building Technology, National Bureau of Standards, accesses hourly weather data from files created from the National Oceanic and Atmospheric Administration (NOAA) computer tapes. It calculates the solar access of and the solar radiation gain on a surface described by the program's user. Surface descriptions and position indicators are entered by the user in response to program generated queries. Although initially conceived for use by planners and designers for solar access assessment, the program has not seen sufficient use for confident application by computer neophytes. At present, SOLITE is suitable for use by research personnel for parametric studies of urban grid layouts, and the effect of these layouts on solar radiation gain and daylighting in rooms fronting on street canyons.

SOLITE is a program designed to provide solar gain and daylighting data for surfaces and rooms in an urban environment. "Surfaces" are building components with no associated occupants. Examples are windows, exterior walls, Trombe walls and solar collectors. "Rooms" on the other hand, are associated with occupants and internal gains from lights. Computations performed by SOLITE include calculations of internal gains and daylighting availability in the room, but do not include thermal performance calculations. Descriptors of the environment around a surface or room are simplified. Street canyons comprise a series of blocks around the area of analysis, with each block having a common height throughout. With proper answers to SOLITE's queries, the user may:

- create hourly solar radiation data files from weather files containing only cloud data.
- determine solar radiation on a window or street canyon surface.
- determine the absorbed radiation in a particular glazing assembly. The glazing assembly may comprise many materials and fluids and the user has the option of determining the solar gain in a particular layer of that assembly.
- determine the solar gain through a glazing assembly in a room facing the street canyon.
- calculate the internal gains in a specified room from lights, people and appliances (for thermal network analysis) .
- calculate the daylight levels in a room at three points on a workplane extending from the window to the rear of the room.
- find the number of useable daylight hours per day in the room based on the calculated daylight levels, simplified glare parameters, and occupancy hours.

As a planning tool for solar access, the computer model SOLITE was meant to interface with thermal analysis programs. With both solar availability analysis and thermal analysis, the solar use potential of an urban area may be estimated and scientifically based legal covenants may be described.

1. SOLAR ENERGY USE AND SOLAR AVAILABILITY IN CITIES

The prediction of solar radiation availability in urban areas is necessary for the future energy planning process in cities [1]. Solar availability data for specified surfaces in the urban geometry are required for zoning of solar access, for building energy use analysis, and for the analysis of daylighting potential in urban environments.

1.1 SOLAR ACCESS AND ZONING

Zoning ordinances in cities govern the location, bulk, height, shape, use, population density, and land coverage of structures within defined boundaries. The purposes of the zoning ordinance are to:

1. encourage appropriate land use,
2. prevent overcrowding of land,
3. conserve land value,
4. lessen traffic congestion,
5. prevent population concentrations,
6. **provide for light,**
7. reduce fire hazard and related dangers, and
8. assist in the provision of public services for health and sanitation.

These ordinances are prescribed to preserve a town's amenities and they affect the policies underlying the master plan [2]. The master plan further affects the physical shape of the city as well as the physical shape of buildings. Zoning ordinances may be used to protect solar access to buildings in order to allow implementation of solar heating devices or passive strategies, and to make use of insolation for daylighting. Although the zoning ordinance provides a suitable legal vehicle in urban areas for guaranteeing solar opportunities, for the practical application of the law [3] a firm, quantitative basis for evaluating solar access is required .

Optimum solar access zoning envelope configurations are a function of the applicability of solar technology to meet a zone's energy use requirement. A zone's energy use is the summation of the energy consumed by the buildings in that zone, and since segregated use zoning is prevalent in American cities, [4] a "typical" model building may be used to define the energy consumption of the zone [5]. However, due to changes in zoning codes, building codes and building technology, wide variations may occur within a zone over the lifetime of the city. It is therefore necessary to define a block or conglomerate of buildings that describe the variation [6]. An example of a zone with a single representative building is illustrated in the neighborhood commercial strip of Fig. 1.1. All of the buildings in the area shown by the map are triple story brick buildings with retail establishments on the ground floor and unheated stock rooms above. The energy requirements of a zone's buildings may be determined from thermal analysis computations using DOE-2 [7], BLAST [8] or DEROB [9].[1]

[1] SOLITE may be used to generate data for a node/network analysis program used for thermal analysis.

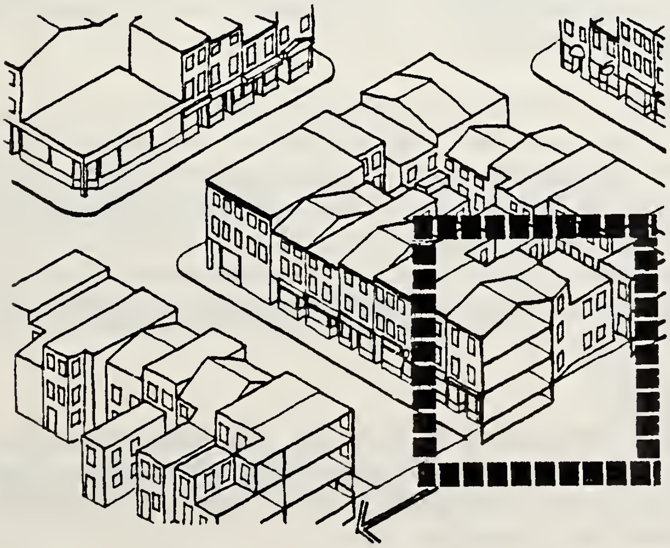


Fig. 1.1 A site plan of a commercial area in the Cross Street area of Baltimore MD. is shown in the top diagram. Buildings shaded in black represent similiar types of buildings. The homogeneous physical character of the neighborhood, permits the estimation of the urban zone's energy requirements and solar access characteristics by the analysis of the representative building shown in the outline. Building orientation and block lengths may be changed to accommodate the variety of building contexts found on the block.

Results from thermal analyses will indicate a prioritized list of solar requirements for a building. If a building or group of buildings requires more heating than cooling, maximum exposure is desired on the south zoned building plane. Parametric analysis of street widths, building heights, block lengths and cross street widths (assuming a grid-iron pattern) will produce a most significant variable. Multiple runs with the above parameters will yield a series of curves for solar availability at each building face. If cooling is the main concern, building facades should receive minimum radiation during the cooling months. Street widths should be reduced, and the color of building and street surfaces should be light. If daylighting is required, then light colored street canyon surfaces will increase the daylighting potential in rooms fronting the street (see Section 4.2).

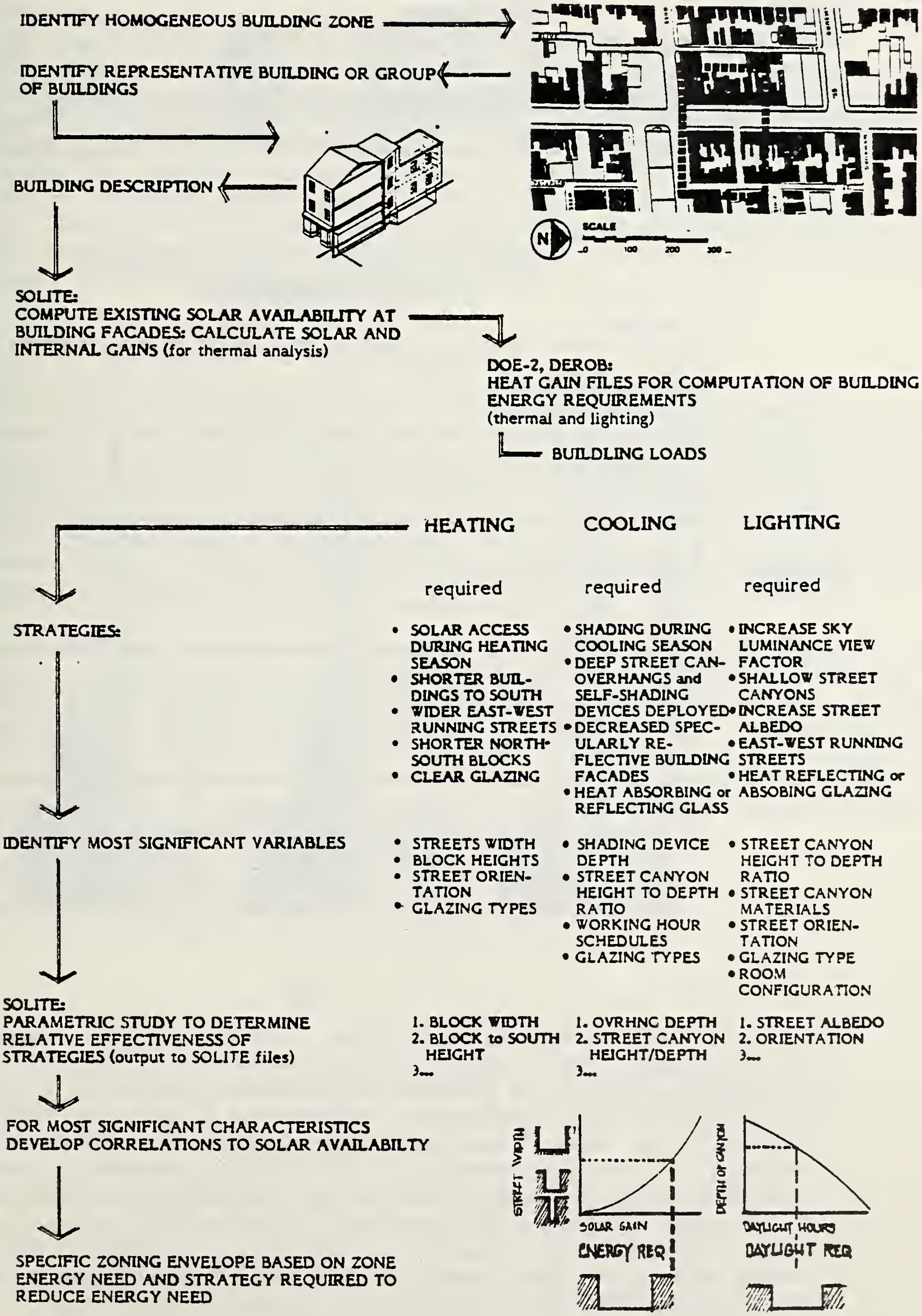
A strategy to delineate solar access envelopes includes:
1. identification of a typical building type (or types) for the zone,
2. **analysis of the solar availability and internal gains of the existing building in the existing environment,**
3. computation of the thermal energy requirements and lighting energy requirements for the typical building,
4. identification of major thermal and lighting loads that could be displaced by the application of solar technologies,
5. **parametric analysis of street widths, block heights and lengths, street canyon reflectances, and street orientations to determine significant physical characteristics,**
6. **analysis of daylighting and solar gain over a range of the significant physical charactersitics, and**
7. development of curves indicating the relationship between solar gain and the physical construct of the street canyon.

Bold items listed in the above strategy access SOLITE. The strategy is graphically illustrated in Fig. 1.2.

When a solar access envelope has been identified, the actual technological response for the building may be qualitatively determined from overlays of the solar availability and the building load during 24 hour periods. An example of this technique is shown in Fig. 1.3. A similiar technique using solar availability and building load has been proposed by Booze, Allen, Hamilton [10].

The quantity of solar radiation striking a building plane in an urban setting is a function of its physical surrounds as well as climate. Buildings cast shadows and reflect solar radiation. The urban atmosphere contains particulates and aerosols not typically found over suburban or rural solar measurement sites, and in urban areas relatively small distances cause large differences in microclimate [11]. Small local variations of solar radiation within a city are not determined by SOLITE [2] since the radiation data are calculated on the basis of hourly weather tapes for a particular

[2] Dr. Edward A. Arens is developing a code for the precise analysis of climatic variations over areas the size of city blocks. This algorithm is being developed at the University of California, Berkeley. Solar radiation is modified by changes of cloud cover calculated for a specific site.



IDENTIFY HOMOGENEOUS BUILDING ZONE

IDENTIFY REPRESENTATIVE BUILDING OR GROUP OF BUILDINGS

BUILDING DESCRIPTION

SOLITE:
COMPUTE EXISTING SOLAR AVAILABILITY AT BUILDING FACADES: CALCULATE SOLAR AND INTERNAL GAINS (for thermal analysis)

DOE-2, DEROB:
HEAT GAIN FILES FOR COMPUTATION OF BUILDING ENERGY REQUIREMENTS
(thermal and lighting)

BUILDLING LOADS

	HEATING	COOLING	LIGHTING
	required	required	required
STRATEGIES:	• SOLAR ACCESS DURING HEATING SEASON • SHORTER BUILDINGS TO SOUTH • WIDER EAST-WEST RUNNING STREETS • SHORTER NORTH-SOUTH BLOCKS • CLEAR GLAZING	• SHADING DURING COOLING SEASON • DEEP STREET CANYONS • OVERHANGS and SELF-SHADING DEVICES DEPLOYED • DECREASED SPECULARLY REFLECTIVE BUILDING FACADES • HEAT ABSORBING or REFLECTING GLASS	• INCREASE SKY LUMINANCE VIEW FACTOR • SHALLOW STREET CANYONS • INCREASE STREET ALBEDO • EAST-WEST RUNNING STREETS • HEAT REFLECTING or ABSOBING GLAZING
IDENTIFY MOST SIGNIFICANT VARIABLES	• STREETS WIDTH • BLOCK HEIGHTS • STREET ORIENTATION • GLAZING TYPES	• SHADING DEVICE DEPTH • STREET CANYON HEIGHT TO DEPTH RATIO • WORKING HOUR SCHEDULES • GLAZING TYPES	• STREET CANYON HEIGHT TO DEPTH RATIO • STREET CANYON MATERIALS • STREET ORIENTATION • GLAZING TYPE • ROOM CONFIGURATION
SOLITE: PARAMETRIC STUDY TO DETERMINE RELATIVE EFFECTIVENESS OF STRATEGIES (output to SOLITE files)	1. BLOCK WIDTH 2. BLOCK to SOUTH HEIGHT 3...	1. OVRHNG DEPTH 2. STREET CANYON HEIGHT/DEPTH 3...	1. STREET ALBEDO 2. ORIENTATION 3...

FOR MOST SIGNIFICANT CHARACTERISTICS DEVELOP CORRELATIONS TO SOLAR AVAILABILTY

SPECIFIC ZONING ENVELOPE BASED ON ZONE ENERGY NEED AND STRATEGY REQUIRED TO REDUCE ENERGY NEED

Fig. 1.2 Illustration of a process for developing zoning envelopes for existing urban areas using SOLITE to determine the solar availability characteristics at the representative building facades.

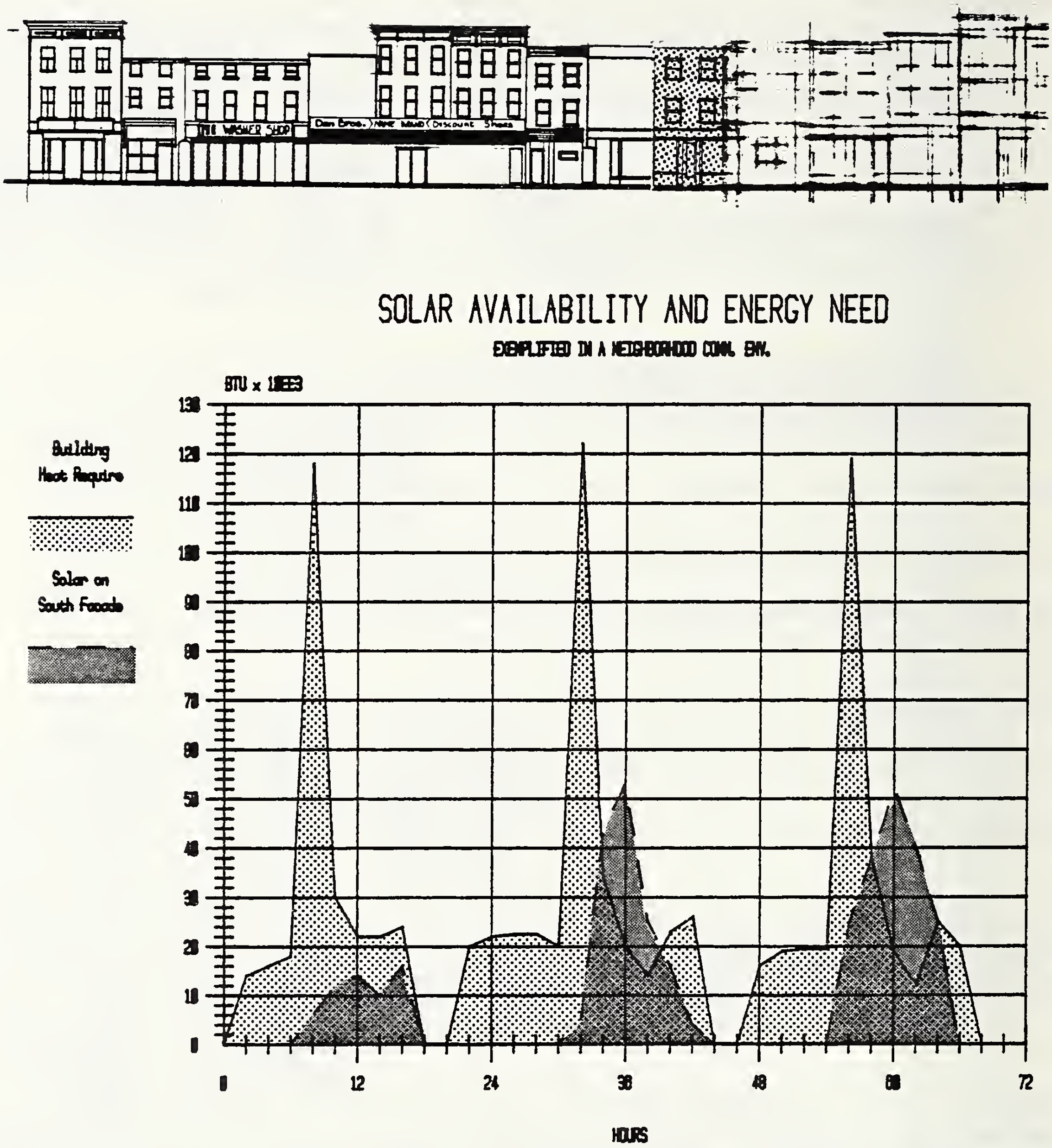


Fig. 1.3 A neighborhood commercial strip in Baltimore MD. exemplifies the use of SOLITE for the analysis of solar availability on building surfaces. The shaded portion of the indicated representative building is a potential wall collector. When the heating requirements of the small 75 m^2 (800 ft^2) building for three consecutive January days are compared to the solar availability on the south facade is is seen that the solar heating potential is negligible, except if directly applied to the daytime heating requirements of the store. Tempering the outer shell by the use of a canopy over the street might be a viable solution for this group of buildings. The large volume defined by a street canopy would provide thermal inertia as well as prevent undue infiltration losses from the facades of the buildings.

city. Based on this data, SOLITE can discriminate levels of gross solar radiation between cities, but not between city blocks. This latter level of accuracy may not be warranted for a solar access code, but distinctions of solar radiation availability in different cities may lead to variances from a national model code. For example, the national model code [12] might prescribe a building plane's exposure from 9 AM through 3 PM solar time each day. However, local cloud patterns may cause optimum exposure only in the afternoon from 11 AM-through 4 PM, thus contradicting the model code. Planning ramifications of the diurnally unsymmetrical cloud distribution would lead to north-west, south-east running streets and south-west facing building facades, contrary to national planning recommendations [13].

1.2 SOLAR ACCESS MODEL REQUIREMENTS

Solar access models ideally should be easily accessible to all city planners and city planning offices. This implies access to the software via remote terminals, or application of the software on affordable microcomputers. The use of desk-top computer terminals for solar access evaluation has been advocated by the City of Los Angeles [14]. Algorithms developed for such evaluations should be based on hourly solar position and local cloud cover data. A locale's planning agency would then be able to discern local cloud patterns and establish variations from the nationally proposed solar access zoning norms.

Master planning for solar access requires the analysis of energy end uses in typical buildings found in the zoned environments. Many computer algorithms exist for the analysis of building energy use, but some lack the ability to calculate heat gains due to internal sources and solar gain [15]. In order to provide the proper thermal energy use requirements, computer programs such as SINDA or MITAS [16] require data files with the building's specific heat gain information. Further, as daylighting represents up to 80 percent of the electrical use in offices [17], a thermal performance model must be augmented by a capability to analyze daylighting potential.

2. A SOLAR AVAILABILITY PROGRAM

In order to be an effective planning and analysis tool, a solar availability algorithm should be able to analyze:

1. solar availability on specific surfaces,
2. solar gain in buildings used to determine the thermal behaviour of existing structures, and
3. daylighting potential in buildings.

SOLITE calculates the solar availability on user-specified surfaces, the total heat gain in rooms, and the daylight available on the workplane of a room with a window. Program prompts are interactive, and question the user for descriptions of the city location, surface materials, glazing materials, room occupancy type and type of data output desired.

SOLITE is written in standard FORTRAN IV on the NBS UNIVAC machine. Changes to the code will be required for application on CYBER main-frames. The program comprises a MAIN program and a host of subroutines. Subroutines are accessed by the MAIN program in reponse to a user's requirements. Input and outputs are primarily from the MAIN program, as are the imbedded data for occupancy types. Subroutines are called by the MAIN program for calculation of solar radiation, glazing transmission, shading and daylighting. Outputs from the program include heat gain and daylighting data. These data are reported for all user-described enclosures or surfaces contiguous to an urban street canyon. In addition to files with heat gain or solar radiation data for specific user-defined surfaces, the algorithm also creates a new hourly weather data file with the addition of solar radiation data. Up to 10 surfaces or rooms may described during each run, and the program calculates hourly data for one year.

2.1 A SOLAR AVAILABILITY ALGORITHM

SOLITE is an interactive program for calculating incident insolation and daylighting. The range of computations is variable and depends on the user's requirements. If only a new weather data file with solar radiation is desired, a limited number of inputs are required, and run times are short. On the other hand if hourly heat gains are desired for thermal analysis and the daylight potential of rooms is calculated, all the subroutines are accessed and run times substanbtially increase. A chart of subroutines and functions contained in SOLITE is illustrated in Fig. 2.1.

The MAIN program provides the major access route to the subroutines. SOLITE's flowchart is illustrated in Fig. 2.2 and it indicates the rudimentary structure of the program. It also contains the data arrays for unit conversion, occupancy types and alphanumeric input/output. Subroutine SURFAC is called when surfaces and room descriptions are called for. SURFAC contains algorithms for structuring the input data for later computation by the transmission and shading subroutines.

Weather tapes are read in subroutines DAYC if only cloud data is available and from DAYRAC if solar radiation data already exists in the weather data files. Shading from adjacent buildings and solar transmission through glazing members are calculated in SHADOW and TRANS respectively. The program assumes that buildings on the same

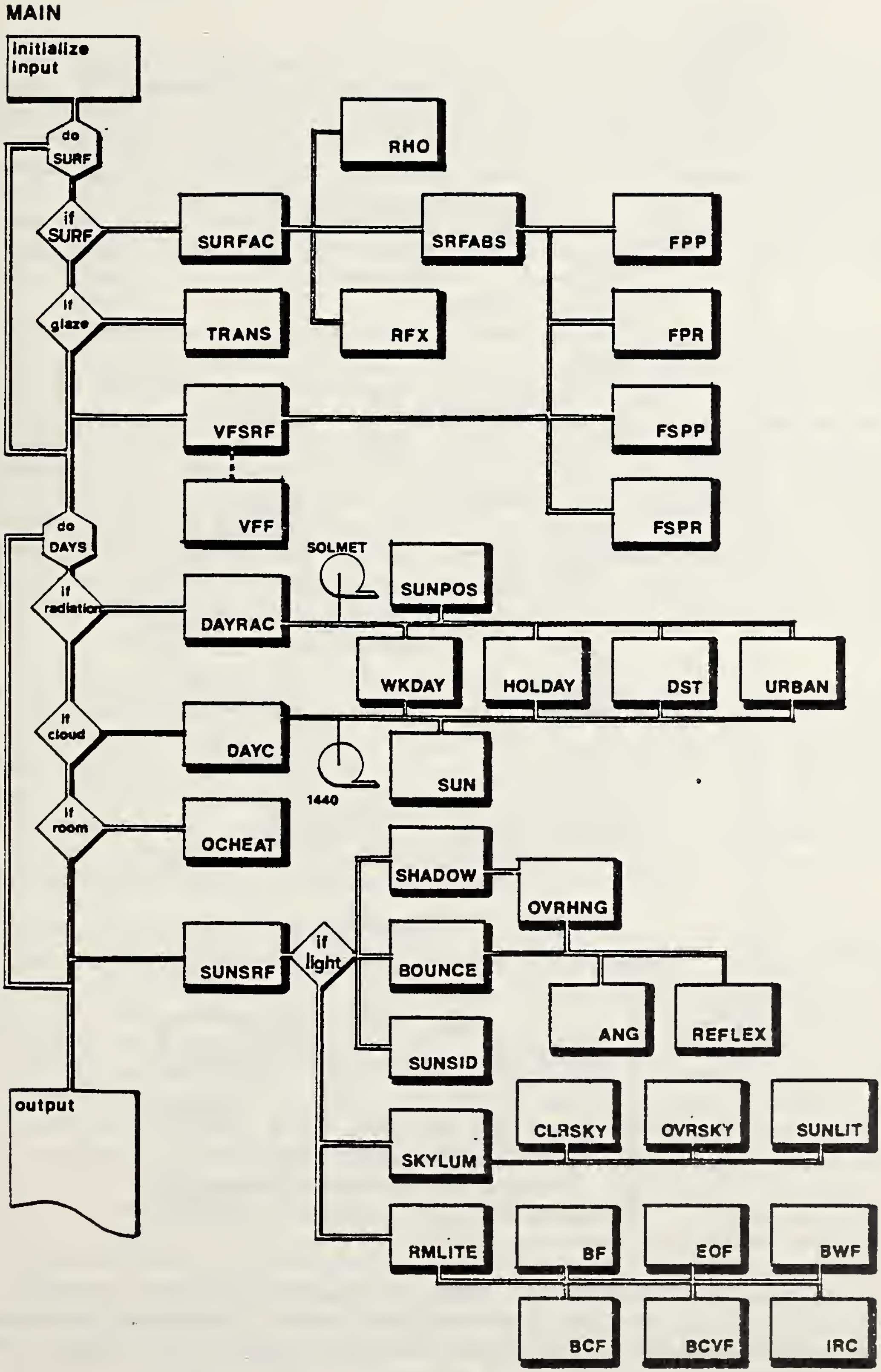


Fig. 2.1 Elements (functions and subroutines) of the solar availability program SOLITE are illustrated. The diagram shows relative association amongst the program's elements.

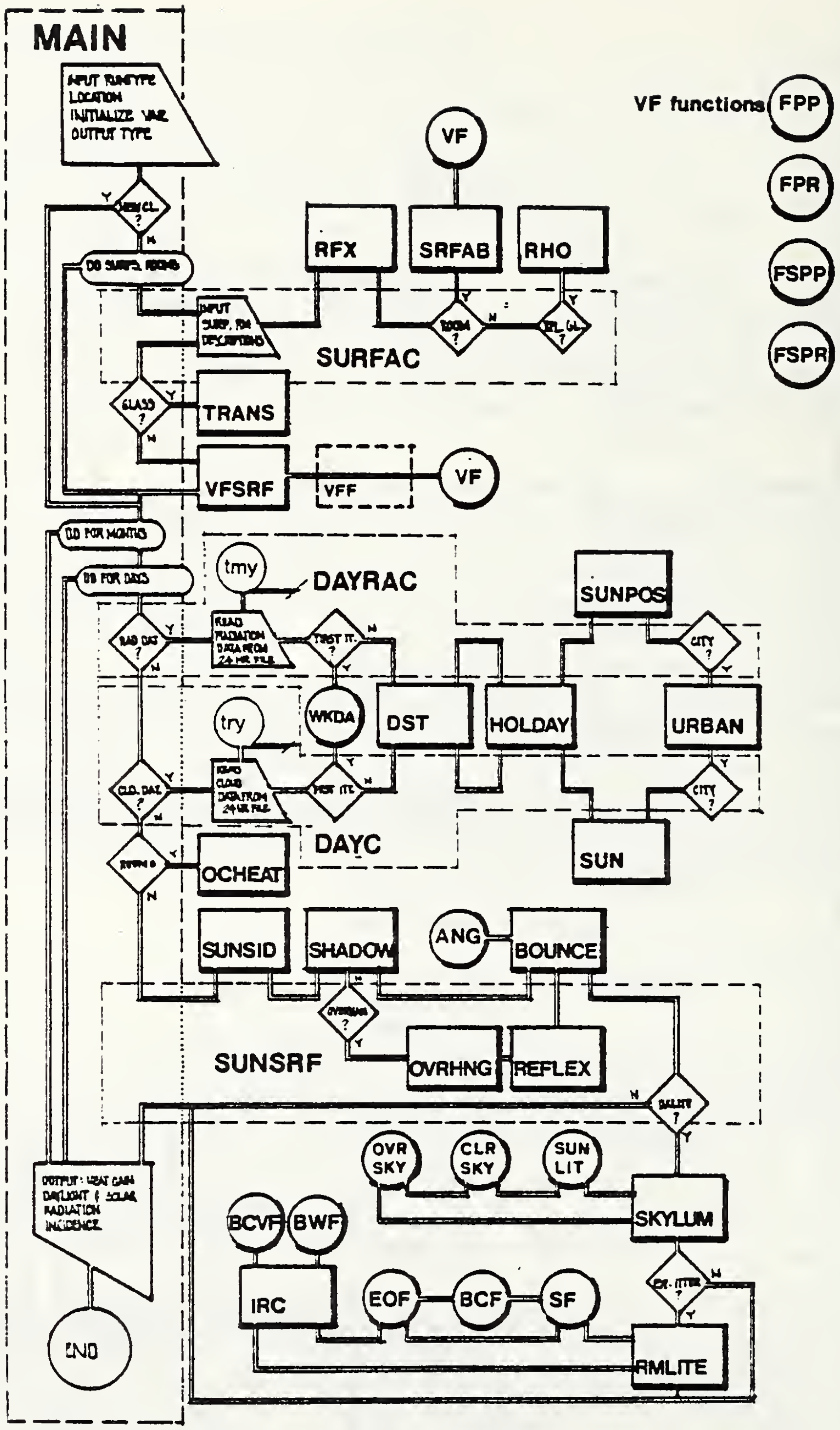


Fig. 2.2 Flowchart of solar availability program, SOLITE. Major subroutines are indicated by BOLD letters. Functions are indicated by circular elements and major branching points in the program are shown with a square.

side of the street form an equal building height line and that the cross streets are of equal width. These assumptions in the shading subroutine limit the complexity of the urban environment that can be modelled. Shading subroutines used in the algorithm may be substantially improved through the use of matrix calculation techniques. Transmission of solar radiation through the glazing is calculated using a finite solution to the sum of an infinite geometric series derived from the Stoke's equation [18]. Algorithms for shadowing and glazing transmission have not been rigorously verified with measurements, nor have the results been compared to results from existing algorithms [19].

Occupant and incidental heat gains are calculated in subroutine OCHEAT only if the user has specified the calculation of solar gain in rooms (as opposed to street-oriented surfaces). (If surfaces are specified, no incidental gains are calculated, as surfaces cannot be occupied.) Occupancy and electrical appliance heat gain schedules are a function of : (1) the building type, whether office, retail or residential, (entered in the MAIN program) (2) the type of day, (weekday, Saturday, Sunday calculated in WKDAY), or holiday, (calculated in HOLDAY) and (3) the designed power-to-area ratio of the room (entered in the MAIN program). The program user enters the maximum anticipated occupant and power load as a function of the building's square footage. The type of day as well as local standard time influence the internal gains schedule. Subroutines used to calculate weekdays and holidays were incorporated from NBSLD [20].

Daylighting analysis subroutines SKYWM and RMLITE come from DALITE II algorithms [21] developed by Gary Gillette (research associate at NBS). DALITE computes the sky luminance based on cloud cover data and RMLITE calculates the interreflections from the window to the workplane of the room. These algorithms have been verified by comparison with empirical measurements and other daylight analysis techniques [22]. Daylight subroutines are presently very loosely affiliated with other subroutines in SOLITE. These subroutines do not take advantage of the street canyon interreflection calculations in subroutine BOUNCE.

Solar intensity subroutines developed by Dr. T. Kusuda in NBSLD [23] were adapted for use in this program, but the basic ASHRAE solar intensity algorithm [24] is incorporated intact in subroutine SUN. In addition to the clear sky solar radiation data calculated by the subroutine, cloud cover factors are computed using the Kimura/Stephenson algorithm [25]. The Kimura/Stephenson clear sky radiation modifying coefficients are based on the correlation of cloud cover amount (measured in tenths) and solar altitude to direct and diffuse solar intensity. Results from the Kimura/Stephenson algorithm were compared with results from two other cloud based radiation modifiers: 1. the Boeing algorithm [26] used in DOE-2, and 2. the SOLMET [27] coefficients used by all thermal performance algorithms accessing Test Meteorological Year (TMY) [28] data. (SOLMET coefficients are also based on rain occurrence.) Although based on similiar surface observations of cloud and rain data, the three methods lead to differences as great as 158 Wm^{-2} for results derived from New York City January Test Reference Year (TRY) [29] cloud cover data. Since there are few measured radiation data bases available, the comparisons between these methods is only relative (see Appendix A.2). Given the large divergence between results from the methods, it was not possible to demonstrate the superiority of one method. The Kimura/Stephenson method was judged more reasonable than the Boeing due to the non-linear ratio between diffuse and beam solar radiation calculated as a function of cloud cover. SOLMET coefficients may still be used by the entry of TMY weather data rather than TRY.

Weather data files for radiation computation must be created and input to a file for SOLITE access. Climate data tapes must be decoded with the NBSLD (see Appendix F) weather tape reader from Test Reference Year (TRY) or 1440 tapes [30]. In order to use the data from these tapes, decoded weather data files must have the specific format described in the section titled "Use of SOLITE" in this report. A program used for decoding TMY or SOLMET weather tapes may be found in the the DOE-2 user's manual. A program that prepares a file from SOLMET tapes is listed in Appendix F.

3. SOLITE: PROGRAM DESCRIPTION

The amount of solar energy incident on a receiving surface is affected by shadows, cloud patterns, urban pollutants and turbidity, and the type of glazing system used in a solar application. This program calculates the effect of these variables on extraterrestrial radiation as it penetrates the atmosphere and is modified by the urban environment. Local hourly cloud cover data are the basis for solar radiation calculations. If the output from this program is to be used as input to a thermal network analysis program, internal gains from people and electrical appliances are also calculated.

SOLITE, the solar availability program, has limited interactive input prompting. Prompts are dependent on the path the user takes through the program. A **MAIN** program initiates the prompts and calls various subroutines in response to the user's requirements. These subroutines are listed below in the order of their execution. During a simple run for the addition of radiation data to a weather file, most of the subroutines are not called. If the user wishes to calculate daylighting or solar heat gain in a room, all of the subroutines are called. Subroutines include:

SURFAC	interactively prompts the user for building and glazing unit descriptors;
SRFAB	calculates the view factor of the interior room surfaces to the window;
RFX	asks for street canyon material descriptions;
RHO	determines type of glass in a glazing assembly;
VFSRF	characterizes the view factors of the surface to other street planes and to clear sky;
VFF	**future** subroutine calculates the inter-reflected street canyon diffuse radiation;
TRANS	calculates the transmission, absorption and reflection of a specified glazing assembly;
DAYC	reads weather data from cloud cover data bases (TRY, 1440) and sums data for averages;
DAYRAC	reads weather data with horizontal global radiation from files based on TMY or SOLMET data;
DST	calculates the daylight savings time indicator;
WKDAY	calculates the day of the week for determining occupancy;
HOLIDAY	calculates the holiday indicator for U.S. holidays;
URBAN	modifies the solar intensity at urban sites with a fit to simple measurement curves by Meinel and Meinel [31]. This subroutine must be accessed with caution due to correlation coefficients from a singular source;
SUN	calculates solar position and horizontal solar beam and diffuse radiation;
SUNPOS	calculates solar position and horizontal diffuse and beam radiation ratio if solar radiation data was input from a SOLMET data tape;
OCHEAT	calculates the heat gain due to occupants and electrical appliances for residential, commercial and retail room types;
SUNSURF	calculates diffuse, beam and reflected radiation on a user specified surface;
SUNSID	calculates the incident angles and solar radiation factors for the

	vertical and tilted street planes;
BOUNCE	analyzes the amount of beam radiation reflected onto a surface from the walls of a street canyon;
ANG	calculates the solar angle of incidence on a street plane surface for reflection calculations;
REFLEX	calculates the beam reflection coefficient as a function of the angle of incidence;
OVRHNG	calculates shadows cast by an overhang, and reflections from an integral window reflector.

The following subroutines are accessed by the subroutines requiring analysis of view factors:

FPP	calculates the view factor of the window surface to a parallel surface;
FPR	calculates the view factor of the window surface to a perpendicular surface;
FSPP	determines the view factor of the window to a surface, where the angle between the window normal and the surface normal is greater than 90° and less than 180°;
FSPR	determines the view factor of the window to a surface, where the angle between the window normal and the surface normal is less the 90° and greater than 180°.

Subroutines used for calculating daylight are accessed from subroutine **SUNSRF** and include:

SKYWM	calculates the average sky luminance as seen from a point of the workplane. Conditions between the clear and overcast sky luminance are determined by the cloud cover ratio;
SUNLIT	determines the direct solar luminance;
CLRSKY	calculates the average clear sky luminance;
IRC	calculates reflected light from internal wall surfaces;
RMLITE	computes the total daylight illumination at the workplane point;
BCFV	is the luminous view factor between a vertical window and a point on the opposing parallel vertical plane;
BCF	calculates the luminous view factor between the non-uniform overcast sky and a point on the workplane;
BWF	calculates the luminous view factor between a horizontal workplane and a vertical window;
SF	determines the sky view factor for the workplane points in a room;
EOF	computes the external reflection factor;
SCERL	determines the external reflected component of daylighting.

The solar availability program provides a user with a choice of three types of output. First, daily and monthly summaries of solar radiation on surfaces and coincident weather data tabulations may be printed. Second, hourly solar radiation data on surfaces and coincident weather data may be printed in a tabular format as input tables for simple thermal analysis algorithms. Third, hourly solar radiation and internal heat gain summations may be written to a file for a large scale thermal node/network analysis program (ie. SINDA or MITAS). In addition to these three types of output, hourly solar radiation data and hours of useable daylight per day are written to secondary files. Future versions of the program could contain a graphic output of the solar access as illustrated in Fig. 3.1. Graphic interaction with the presented software will result in a better grasp of the input and ouput data. The example is from a building shadow program written by Scott Wright at the Georgia Institute of Technology [32]. This software is scheduled to be included in the solar availability algorithm.

3.1 PREPARATION FOR RUNNING SOLITE

SOLITE was developed on the NBS UNIVAC 1108 and requires the assignment of "logical units" to specific files. On the CYBER system, the program will require a "PROGRAM" statement for the assignment of these logical units and files. SOLITE requires the assignment of eight logical units for input and output. An example of the assignments is illustrated in Fig. 3.2. and the descriptions of each logical unit and the required files are listed below:

1. **Unit 5:** the interactive user's input terminal. Interactive prompts are printed on this terminal and answers are rendered in free format. Since the program does not contain default values, all questions must be answered with a reasonable response;
2. **Unit 7:** the program user's input is written into this logical unit. After a first run with SOLITE, the interactive prompts may be eliminated, and this data file may be added directly to the program run with the Univac 1108 operating system command "@ADD filename" after the first program prompt;
3. **Unit 8:** the hourly weather data in the specified format is read from this logical unit;
4. **Unit 9:** the hourly weather data (with added radiation) is written to this unit;
5. **Unit 10:** output of incident solar and heat gain onto surfaces or into rooms is written to this file;
6. **Unit 11:** solar gain per unit metric of surface are output to the file;
7. **Unit 12:** daylight levels at three points on the workplane of the room are output to this unit;
8. **Unit 13:** useable daylight hours in the room are written to the file assigned to this unit.

Weather data assigned to unit 8 must be decoded from one of the NOAA type weather tapes using on of the decoding subroutines listed in Appendix F. The created weather file must be in on of the formats specified below. Each climate variable is read in blocks of 24 hours. The read statement is dependent on the type of weather data available. For weather data with only cloud cover values, subroutine DAYC is accessed and the read statement for the data is executed on a daily loop. For weather data with horizontal radiation, DAYRAC is used. The read statement follows:

Climate data with cloud cover only, decoded from TRY or 1440 tapes. Twenty-four hour periods:

```
DBT(24), DPT(24), WBT(24), WSP(24), BPR(24), CCT(24), TOC(24), WDR(24),
IYEAR, MON, DAY, IC
```

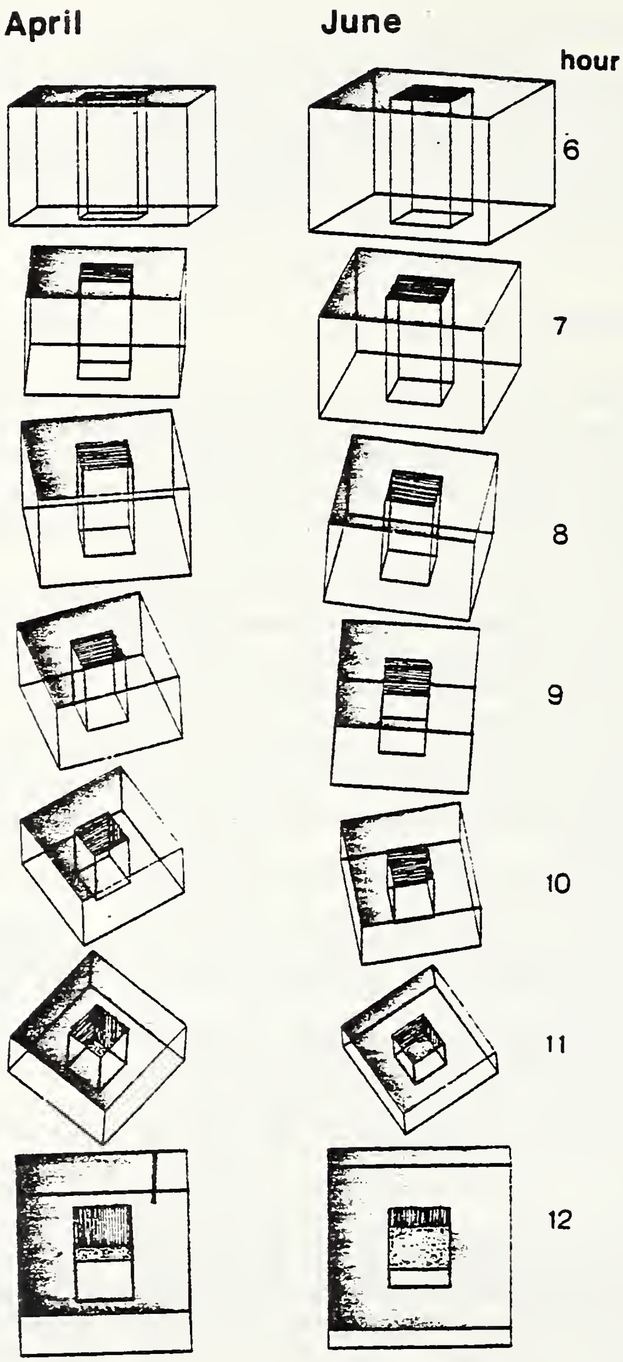


Fig. 3.1 A future subroutine of SOLITE will yield results from shading calculations using graphic output techniques. This will allow the type of graphic output of solar access illustrated. Presently no options exist for the use of graphic terminals with the algorithm. Here, the "sun's eye view", hour-by-hour in April and June of an atrium building in Atlanta is shown. In addition to qualitatively assessing the unshaded building areas, the addition of isopleths on the drawn surfaces may indicate quantitative radiation intensities.

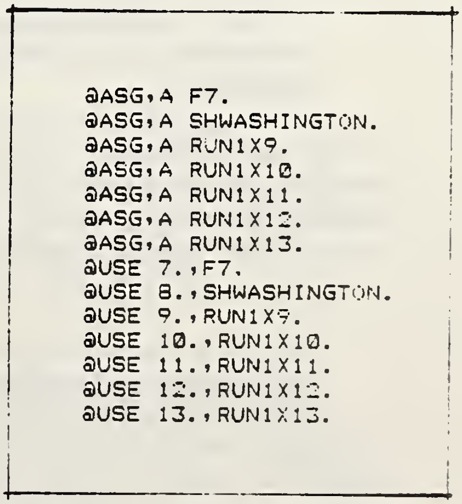
For climate data with horizontal radiation, decoded from TMY or SOLMET data. Twenty-four hour periods:

DBT(24), DPT(24), WBT(24), WSP(24), BPR(24), CCT(24),
TOC(24), WDR(24), RDT(24), RDR(24), IYEAR, MON, DAY, IC

Variable names are listed as they appear in the program so that the user may more easily identify these for any desired changes in the software. The hourly values may be in either SI or English units:

DBT	Dry-bulb temperature	(F° or C°)
DPT	Dew-point temperature	(F° or C°)
WBT	Wet-bulb temperature	(F° or C°)
WSP	Wind speed	(Knots Hr^{-1} or Ms^{-1})
BPR	Barometric pressure	(in HG or KPa)
CCT	Total cloud cover	(Tenths, reported in whole numbers from 0. through 10.)
TOC	Type of cloud	(0=cirrus, 1=stratus, 2=others)
WDR	Wind direction	(reported in degrees, 0°=north, measured clockwise)
RDT	Global radiation on a horizontal surface	(BTU Ft^{-2}Hr^{-1} or Wm^{-2})
RDR	Beam radiation on a horizontal surface	(BTU Ft^{-2}Hr^{-1} or Wm^{-2})

Included in the data file are values denoting the year (IYEAR), the month (MON), and the day (DAY) of the month. Each 24 hour period is also followed by a city code (IC). The above data files may be created from TRY tapes or TMY tapes using the decode file from NBSLD and DOE2 respectively. Source weather data years may be either



```
@ASG,A F7.
@ASG,A SHWASHINGTON.
@ASG,A RUN1X9.
@ASG,A RUN1X10.
@ASG,A RUN1X11.
@ASG,A RUN1X12.
@ASG,A RUN1X13.
@USE 7.,F7.
@USE 8.,SHWASHINGTON.
@USE 9.,RUN1X9.
@USE 10.,RUN1X10.
@USE 11.,RUN1X11.
@USE 12.,RUN1X12.
@USE 13.,RUN1X13.
```

Fig. 3.2 A runstream for assigning the appropriate files to a SOLITE run is shown as it would appear on a terminal connected to a UNIVAC 1108.

365 or 96 days long. This latter compressed year is a result of Dr. E. Arens' Shortyear algorithm [33]. Dr. Arens' program picks an 8 day interval representative of the monthly weather[3]. Data created by this algorithm assume the same daily block format as that for the full year data.

3.2 RUNNING SOLITE

Interactive prompts lead the user through the program but, due to the multiple capabilities of the program, runstreams may vary considerably. Information required from the user depends on the type of analysis desired. If only radiation data is to be added to a TRY or 1440 based weather file, only specifics regarding the city's location (latitude and longitude), and elevation are requested. If solar radiation gain data are desired for a surface, then the description of the surface, and its geometric location in the street canyon are requested (ie. distance from one end of a block). Finally, if solar gain and daylighting in a room are to be calculated, the user must input glazing descriptions and room surface descriptions in addition to the above data. The runstream depends on the user's inputs. Examples of three of many possible runs follow:

1. A runstream for finding solar radiation intensity on user defined surfaces is illustrated in Fig. 3.3. In this case, the user is asked for surface parameters. Surfaces located on walls or on streets are assumed to be proper rectangles on these urban canyon planes. Edges of the surface are parallel to the building and street edges. A rectangular surface on the roof must be further described by a tilt to the horizontal and azimuth, measured clockwise from south (south=0°).

2. A runstream where heat gain in rooms is reported, is illustrated in Fig. 3.4. In addition to the spatial locators of a window, glazing assembly descriptions, occupancy type, design occupant density, and design electrical power per unit floor area are requested information. For residential buildings, the family size determines internal gains. Daylight at the workplane is also calculated for rooms.

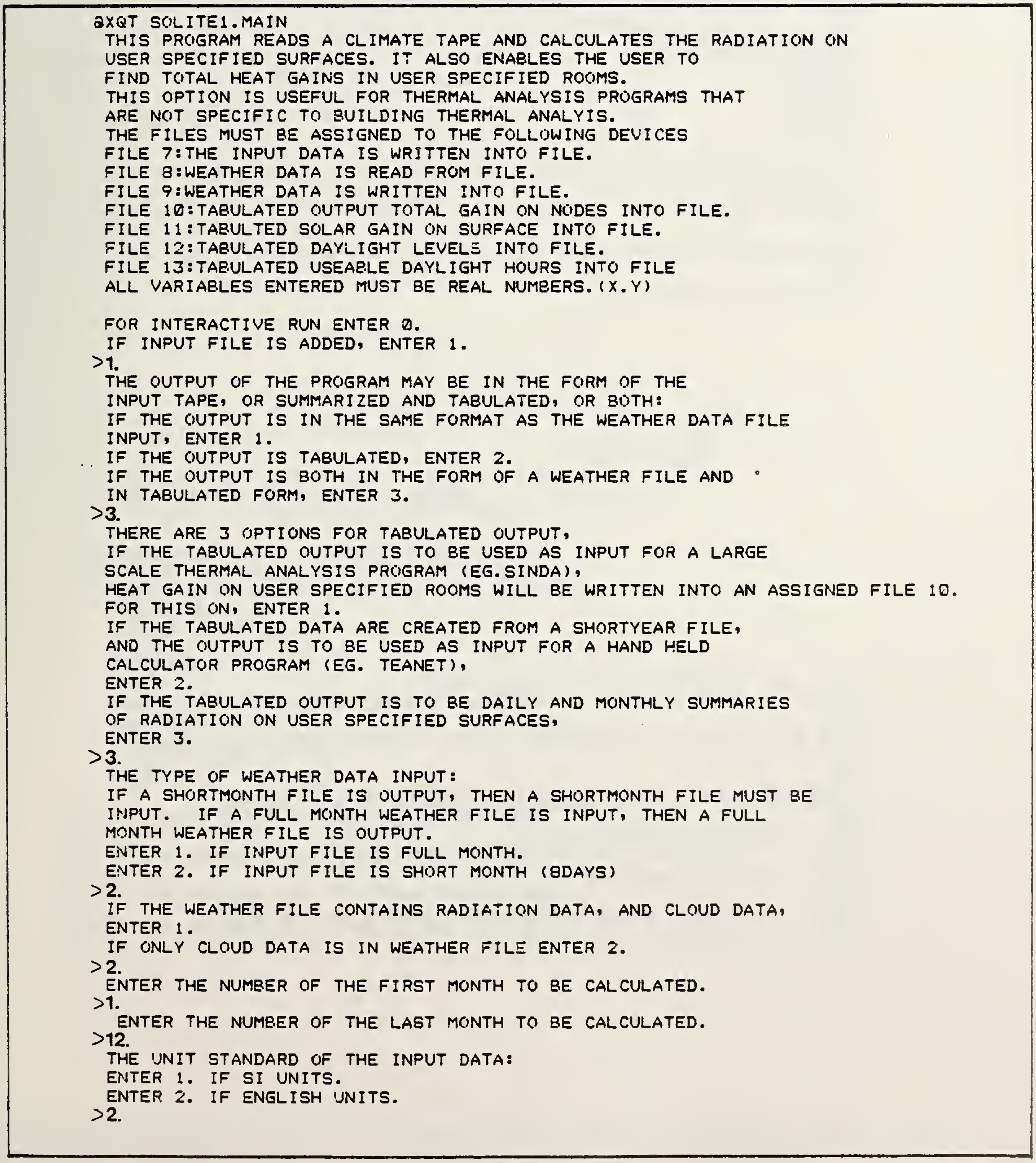
3. If only cloud data is available from NOAA data tapes, then a weather file containing solar radiation data may be created as the runstream of Fig. 3.5 illustrates.

As all paths through SOLITE have not been tested, the user must beware of possible abortive or erroneous input combinations. At this point, no potential exists for re-entering erroneous values. Errors may be replaced by editing the input file created by the program (logical unit 7) after the initial run. Examples of two files from logical

---

[3] Dr. E. A. Arens et. al. "Climate Data Abbreviation for Computerized Calculation of Heating and Cooling Requirements in Buildings", ENERGY and BUILDINGS 2, Ellsevier, Sequoia S.A., Lausanne, Switzerland, 1979, pp. 135-139.
Weighting coefficients for climatic variables were determined from parametric runs of NBSLD (a building energy loads program) on a residential dwelling. Caution must be exercised when using the compressed data for analysis of commercial building performance, as the weightings may differ, and the 8-day segment may not be the same as that chosen for residential buildings.

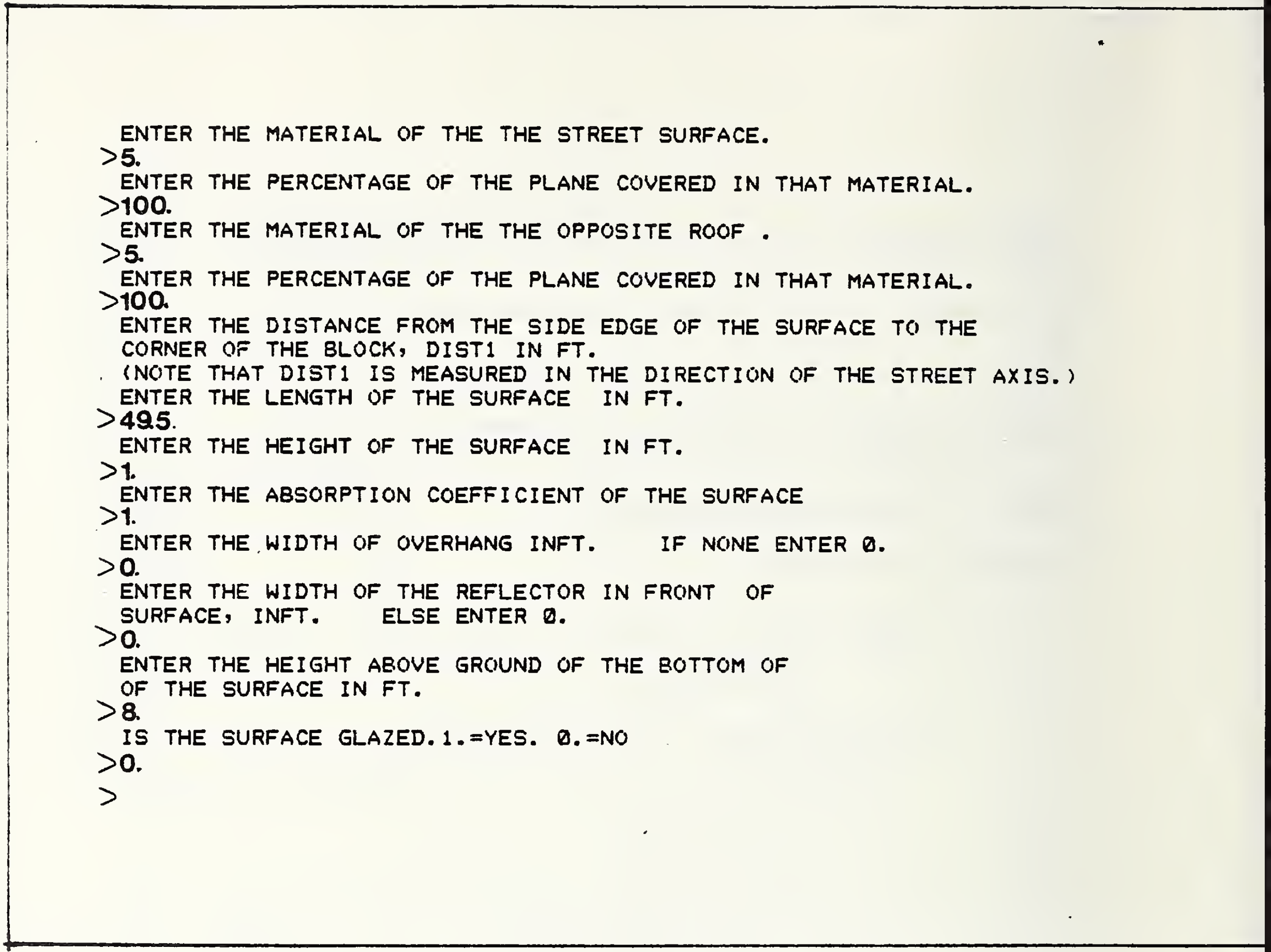
Fig. 3.3. An example of a run with interactive prompts from SOLITE. Responses in the runstream describe a surface in a street canyon. During data entry, SOLITE rewrites the inputs to an assigned FILE 7. Output files from the shown run will contain daily and monthly average solar gain on the specified surface. Note that before a run may begin, logical units 7 thru 13 must be assigned the appropriate files by the user.



```
@XQT SOLITE1.MAIN
 THIS PROGRAM READS A CLIMATE TAPE AND CALCULATES THE RADIATION ON
 USER SPECIFIED SURFACES. IT ALSO ENABLES THE USER TO
 FIND TOTAL HEAT GAINS IN USER SPECIFIED ROOMS.
 THIS OPTION IS USEFUL FOR THERMAL ANALYSIS PROGRAMS THAT
 ARE NOT SPECIFIC TO BUILDING THERMAL ANALYIS.
 THE FILES MUST BE ASSIGNED TO THE FOLLOWING DEVICES
 FILE 7:THE INPUT DATA IS WRITTEN INTO FILE.
 FILE 8:WEATHER DATA IS READ FROM FILE.
 FILE 9:WEATHER DATA IS WRITTEN INTO FILE.
 FILE 10:TABULATED OUTPUT TOTAL GAIN ON NODES INTO FILE.
 FILE 11:TABULTED SOLAR GAIN ON SURFACE INTO FILE.
 FILE 12:TABULATED DAYLIGHT LEVELS INTO FILE.
 FILE 13:TABULATED USEABLE DAYLIGHT HOURS INTO FILE
 ALL VARIABLES ENTERED MUST BE REAL NUMBERS.(X.Y)

 FOR INTERACTIVE RUN ENTER 0.
 IF INPUT FILE IS ADDED, ENTER 1.
>1.
 THE OUTPUT OF THE PROGRAM MAY BE IN THE FORM OF THE
 INPUT TAPE, OR SUMMARIZED AND TABULATED, OR BOTH:
 IF THE OUTPUT IS IN THE SAME FORMAT AS THE WEATHER DATA FILE
 INPUT, ENTER 1.
 IF THE OUTPUT IS TABULATED, ENTER 2.
 IF THE OUTPUT IS BOTH IN THE FORM OF A WEATHER FILE AND
 IN TABULATED FORM, ENTER 3.
>3.
 THERE ARE 3 OPTIONS FOR TABULATED OUTPUT,
 IF THE TABULATED OUTPUT IS TO BE USED AS INPUT FOR A LARGE
 SCALE THERMAL ANALYSIS PROGRAM (EG.SINDA),
 HEAT GAIN ON USER SPECIFIED ROOMS WILL BE WRITTEN INTO AN ASSIGNED FILE 10.
 FOR THIS ON, ENTER 1.
 IF THE TABULATED DATA ARE CREATED FROM A SHORTYEAR FILE,
 AND THE OUTPUT IS TO BE USED AS INPUT FOR A HAND HELD
 CALCULATOR PROGRAM (EG. TEANET),
 ENTER 2.
 IF THE TABULATED OUTPUT IS TO BE DAILY AND MONTHLY SUMMARIES
 OF RADIATION ON USER SPECIFIED SURFACES,
 ENTER 3.
>3.
 THE TYPE OF WEATHER DATA INPUT:
 IF A SHORTMONTH FILE IS OUTPUT, THEN A SHORTMONTH FILE MUST BE
 INPUT.  IF A FULL MONTH WEATHER FILE IS INPUT, THEN A FULL
 MONTH WEATHER FILE IS OUTPUT.
 ENTER 1. IF INPUT FILE IS FULL MONTH.
 ENTER 2. IF INPUT FILE IS SHORT MONTH (8DAYS)
>2.
 IF THE WEATHER FILE CONTAINS RADIATION DATA, AND CLOUD DATA,
 ENTER 1.
 IF ONLY CLOUD DATA IS IN WEATHER FILE ENTER 2.
>2.
 ENTER THE NUMBER OF THE FIRST MONTH TO BE CALCULATED.
>1.
  ENTER THE NUMBER OF THE LAST MONTH TO BE CALCULATED.
>12.
 THE UNIT STANDARD OF THE INPUT DATA:
 ENTER 1. IF SI UNITS.
 ENTER 2. IF ENGLISH UNITS.
>2.
```

```
 THE UNIT STANDARD OF THE OUTPUT DATA:
 ENTER 1. IF SI UNITS.
 ENTER 2. IF ENGLISH UNITS.
>2.
 ENTER 1. FOR DAYLIGHT CALCULATIONS. ELSE ENTER 0.
>0.
 THE LOCATION OF THE SITE:
 ENTER THE LATITUDE (IN DEGREES).
>39.
 ENTER THE LONGITUDE (IN DEGREES) .
>76.
 ENTER THE TIME ZONE;
 ATLANTIC TIME ZONE=4.
 EASTERN           =5.
 CENTRAL           =6.
 MOUNTAIN          =7.
 PACIFIC           =8.
>5.
 IS THE SITE IN AN URBAN AREA, AS OPPOSED TO A RURAL AREA:
 ENTER 1. FOR YES.
 ENTER 2. FOR NO.
>2.
 ENTER THE ELEVATION OF THE LOCALITY FT.    ABOVE SEA LEVEL
>100.
 ISOMTERIC OF URBAN SITE

      !    !   !                  !    !   !
      !    !   !                  !    !   !
  ....!    !   !..................!    !   !.....
     /     !  /                  /     !  /
    /      !HGT1                /      ! /
  ./       !/................../       !/........
   < STW2 ><   BLOCK LENGTH   >       *
               STREET AXIS  -->       *
                                    STW1
  .....        ....................   *    ......
      !       /!                  !   *   /!
      !   HGT2 !                  !   *  / !
      !     /  !                  !   * /  !
      !    !   !                  !    !   !
      !    !   !                  !    !   !


 FROM THE ISOMETRIC OF THE STREET ABOVE,
 ENTER THE STREET AXIS, IN DEGREES, MEASURED CLOCKWISE FROM SOUTH.
>270.
ENTER THE WIDTH OF THE STREET (STW1), CONTAINING THE SURFACES
 AND ROOMS, IN FT.
>150.
 ENTER THE WIDTH OF THE SECONDARY STREETS (STW2), IN FT.
>150.
 ENTER THE BLOCK LENGTH, IN FT.
>100.
 ENTER THE BLOCK WIDTH IN FT.
>100.
 ENTER THE HEIGHT OF THE BUILDINGS ON SIDE 1 OF THE BLOCK,
 (HGT1) IN FT.
>10.
```

```
 ENTER THE HEIGHT OF THE BUILDINGS ON SIDE 2 OF THE BLOCK,
 (HGT2) IN FT.
>10.
 ENTER HEIGHT OF BLDG. ON SIDE 1. OF CROSS STREET.
 IN FT.
>10.
 ENTER HEIGHT OF BLDG. ON SIDE 2. OF CROSS STREET
 IN FT.
 ENTER THE NUMBER OF SURFACES TO BE ANALYZED.
 THE MAXIMUM NUMBER OF SURFACES THAT MAY BE ENTERED IS   10
>1.
 ENTER 1. IF ROOM FACES PRIMARY STREET.
 ENTER 2. IF ROOM FACES CROSS STREET.
>1.
 ISOMETRIC OF URBAN SITE

     !    !   !                  !    !   !
     !    !   !        4.        !    !   !
 ....!    !   !..................!    !   !.....
    /     !  /       /SRF/-DST1>/     !  /
   /      ! /       1.         /      ! /
 ./       !/..................../      !/........

              STREET AXIS  -->   3.

 .....        ....................        ......
    /!       /!                 /!       /!
   / !      / !      2.        / !      / !
 ./  !     /..!. . . . . . .  /  !     /..!. . .
  :  !    !   !               :  !    !   !
  !  !    !   !         5.    !  !    !   !
  .  !    !   !               .  !    !   !

 DESCRIPTION OF THE SURFACE   1 ON THE PLANE
 A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
 THE SURFACE IS LOCATED. ENTER THAT NUMBER.
>1.
 THE SURFACES COMPRISING THE STREET CANYON
 MAY BE PICKED FROM THE FOLLOWING. ENTER THE
 APPROPRIATE REFRENCE NUMBER FOR EACH SURFACE.
    TREES (DECID)     1.
    TREES(CONIF)      2.
    GRASS             3.
    BITUMINOUS        4.
    BRICK             5.
    GLASS             6.
    CONCRETE          7.
    METAL             8.
    SNOW (SUMMER .2) 9.
    OTHER            10.

 ENTER THE MATERIAL OF THE THE WALL ITSELF    .
>5.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.
>100.
 ENTER THE MATERIAL OF THE THE OPPOSITE WALL .
>5.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.
>100.
```



```
 ENTER THE MATERIAL OF THE THE STREET SURFACE.
>5.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.
>100.
 ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .
>5.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.
>100.
 ENTER THE DISTANCE FROM THE SIDE EDGE OF THE SURFACE TO THE
 CORNER OF THE BLOCK, DIST1 IN FT.
 (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
 ENTER THE LENGTH OF THE SURFACE  IN FT.
>49.5.
 ENTER THE HEIGHT OF THE SURFACE  IN FT.
>1.
 ENTER THE ABSORPTION COEFFICIENT OF THE SURFACE
>1.
 ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.
>0.
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.
>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF
 OF THE SURFACE IN FT.
>8.
 IS THE SURFACE GLAZED.1.=YES. 0.=NO
>0.
>
```

Fig. 3.4 This runstream shows the entry of data for the analysis of four rooms of similiar type, but different orientations. For parametric studies requiring changes of single physical characteristic from run to run, the input data rewritten by SOLITE to logical Unit 7 may be edited after a run by accessing the data file with the computer's editor. With this procedure, the user may expedite runs, by-passing the interactive prompts.

```
 THIS PROGRAM READS A CLIMATE TAPE AND CALCULATES THE RADIATION ON
 USER SPECIFIED SURFACES. IT ALSO ENABLES THE USER TO
 FIND TOTAL HEAT GAINS IN USER SPECIFIED ROOMS.
 THIS OPTION IS USEFUL FOR THERMAL ANALYSIS PROGRAMS THAT
 ARE NOT SPECIFIC TO BUILDING THERMAL ANALYIS.
 THE FILES MUST BE ASSIGNED TO THE FOLLOWING DEVICES
 FILE 7:THE INPUT DATA IS WRITTEN INTO FILE.
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 FILE 9:WEATHER DATA IS WRITTEN INTO FILE.
 FILE 10:TABULATED OUTPUT TOTAL GAIN ON NODES INTO FILE.
 FILE 11:TABULTED SOLAR GAIN ON SURFACE INTO FILE.
 FILE 12:TABULATED DAYLIGHT LEVELS INTO FILE.
 FILE 13:TABULATED USEABLE DAYLIGHT HOURS INTO FILE
 ALL VARIABLES ENTERED MUST BE REAL NUMBERS.(X.Y)

 FOR INTERACTIVE RUN ENTER 0.
 IF INPUT FILE IS ADDED, ENTER 1.

>0.
 THE OUTPUT OF THE PROGRAM MAY BE IN THE FORM OF THE
 INPUT TAPE, OR SUMMARIZED AND TABULATED, OR BOTH:
 IF THE OUTPUT IS IN THE SAME FORMAT AS THE WEATHER DATA FILE
 INPUT, ENTER 1.
 IF THE OUTPUT IS TABULATED, ENTER 2.
 IF THE OUTPUT IS BOTH IN THE FORM OF A WEATHER FILE AND
 IN TABULATED FORM, ENTER 3.

>3.
 THERE ARE 3 OPTIONS FOR TABULATED OUTPUT,
 IF THE TABULATED OUTPUT IS TO BE USED AS INPUT FOR A LARGE
 SCALE THERMAL ANALYSIS PROGRAM (EG.SINDA),
 HEAT GAIN ON USER SPECIFIED ROOMS WILL BE WRITTEN INTO AN ASSIGNED FILE 10.
 FOR THIS OPTION, R 1.
 IF THE TABULATED DATA ARE CREATED FROM A SHORTYEAR FILE,
 AND THE OUTPUT IS TO BE USED AS INPUT FOR A HAND HELD
 CALCULATOR PROGRAM (EG. TEANET),
 ENTER 2.
 IF THE TABULATED OUTPUT IS TO BE DAILY AND MONTHLY SUMMARIES
 OF RADIATION ON USER SPECIFIED SURFACES,
 ENTER 3.

>1.
 THE INPUT WEATHER FILE MUST BE A IN THE SHORTMONTH FORMAT(8DAYS/MONTH)

 IF THE WEATHER FILE CONTAINS RADIATION DATA, AND CLOUD DATA,
 ENTER 1.
 IF ONLY CLOUD DATA IS IN WEATHER FILE ENTER 2.

>2.
 ENTER THE NUMBER OF THE FIRST MONTH TO BE CALCULATED.

>1.
  ENTER THE NUMBER OF THE LAST MONTH TO BE CALCULATED.

>2.
```
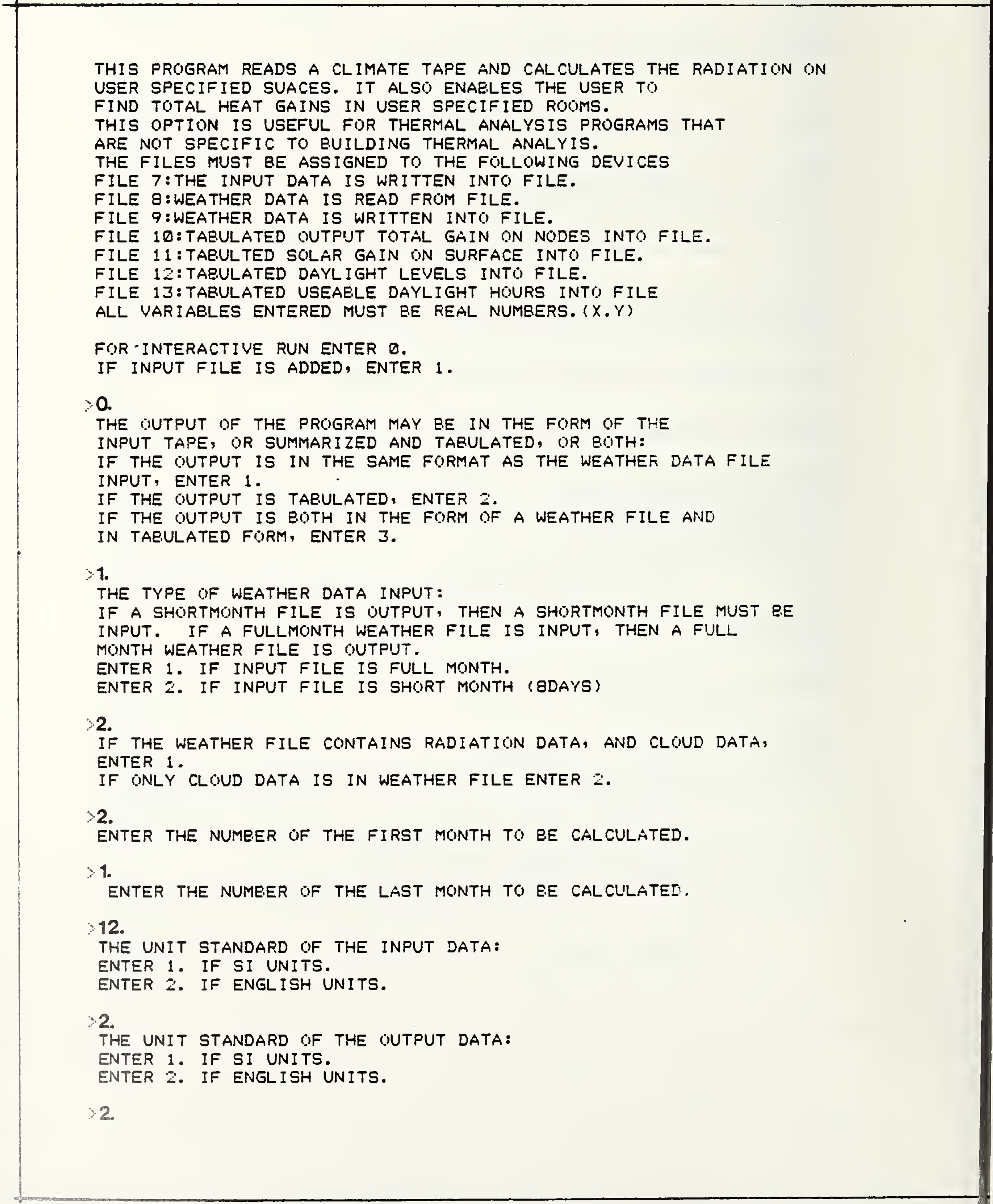

```
 ENTER THE OCCUPANCY TYPE OF THE BUILDING:
 IF RESIDENTIAL 1.
 IF RETAIL, 2.
 IF OFFICE, 3.

>3.
 ENTER 1. IF ROOM FACES PRIMARY STREET.
 ENTER 2. IF ROOM FACES CROSS STREET.

>1.
 ENTER THE FLOOR WIDTH, LENGTH AND HEIGHT
 INFT.

>12. 12. 8.5
 ENTER THE MAXIMUM EXPECTED OCCUPANCY OF THE ROOM IN F2/PRS

>100.
 ENTER THE MAXIMUM EXPECTED ELECTRICAL LOAD OF THE ROOM IN WAT/F2

>3.
 ENTER REFLECTANCE COEFFICIENTS OF:
 WALLS, CEILING AND FLOOR.(RATIO OF 1.)

>.8 .6 .2
 DESCRIPTION OF THE WINDOW    3 OF THE ROOM
 A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
 THE WINDOW  IS LOCATED. ENTER THAT NUMBER.

>1.
 ENTER THE MATERIAL OF THE THE WALL ITSELF   .

>6.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>40.
 ENTER THE MATERIAL OF THE THE WALL ITSELF   .

>7.
 ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>6.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>60.
 ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>5.
 ENTER THE MATERIAL OF THE THE STREET SURFACE.

>4.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .

>4.
```

```
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE DISTANCE FROM THE SIDE EDGE OF THE WINDOW  TO THE
 CORNER OF THE BLOCK, DIST1 IN FT.
 (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
>50.
 ENTER THE LENGTH OF THE WINDOW   IN FT.

>6.
 ENTER THE HEIGHT OF THE WINDOW   IN FT.

>4.
 ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.

>0.
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.

>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF
 OF THE WINDOW  IN FT.

>3.5
 ENTER THE HEIGHT OF BOTTOM SILL ABOVE FLOORFT.

>3.5
 ENTER THE DISTANCE FROM RIGHT PARTION WALL TO WINDOW LRHC
 LOOKING AT THE WINDOW FROM INSIDE ROOM INFT.

>3.
 IS THE WINDOW  GLAZED.1.=YES. 0.=NO

>1.
 DESCRIPTION OF THE GLAZING:
 ENTER THE NUMBER OF GLAZING LAYERS IN THE WINDOW

>1.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  1

>1.
 ENTER THE THICKNESS OF GLAZING LAYER  1 IN INCHES

>.25
 IF MEASURED TRANSMITTANCE, ENTER 0.
 IF ORDINARY GLASS, ENTER 1.
 IF WATER WHITE, ENTER 2.
 IF HEAT ABSORBING, ENTER 3.
 IF REFLECTING, ENTER 4.

>1.
 ENTER 1. IF LAYER 1 IS IN CONTACT WITH ABSORBING SURFACE.
 ELSE ENTER 0.

>0.
```

```
SPECIFIED GLAZING SECTION:

           I      I      I
LAYER      I  1   I  2   I
           I      I      I
MATERIAL   I GLASSI  AIR I
           I      I      I


ENTER THE OCCUPANCY TYPE OF THE BUILDING:
IF RESIDENTIAL 1.
IF RETAIL, 2.
IF OFFICE, 3.

>3.
ENTER 1. IF ROOM FACES PRIMARY STREET.
ENTER 2. IF ROOM FACES CROSS STREET.

>2.
ENTER THE FLOOR WIDTH, LENGTH AND HEIGHT
INFT.

>12.12. 8.5
ENTER THE MAXIMUM EXPECTED OCCUPANCY OF THE ROOM IN F2/PRS

>100.
ENTER THE MAXIMUM EXPECTED ELECTRICAL LOAD OF THE ROOM IN WAT/F2

>3.
ENTER REFLECTANCE COEFFICIENTS OF:
WALLS, CEILING AND FLOOR.(RATIO OF 1.)

>.8 .6 .2
DESCRIPTION OF THE WINDOW    4 OF THE ROOM
A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
THE WINDOW  IS LOCATED. ENTER THAT NUMBER.

>2.
ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .

>4.
ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
ENTER THE DISTANCE FROM THE SIDE EDGE OF THE WINDOW  TO THE
CORNER OF THE BLOCK, DIST1 IN FT.
(NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
>50.
ENTER THE LENGTH OF THE WINDOW   IN FT.

>6.
ENTER THE HEIGHT OF THE WINDOW   IN FT.

>4.
ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.

>0.
```

```
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.

>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF _ __ _
 OF THE WINDOW  IN FT.

>3.5
 ENTER THE HEIGHT OF BOTTOM SILL ABOVE FLOORFT.

>3.5
 ENTER THE DISTANCE FROM RIGHT PARTION WALL TO WINDOW LRHC
 LOOKING AT THE WINDOW FROM INSIDE ROOM INFT.

>3.
 IS THE WINDOW  GLAZED.1.=YES. 0.=NO

>1.
 DESCRIPTION OF THE GLAZING:
 ENTER THE NUMBER OF GLAZING LAYERS IN THE WINDOW

>1.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  1

>1.
 ENTER THE THICKNESS OF GLAZING LAYER  1 IN INCHES

>.25
 IF MEASURED TRANSMITTANCE, ENTER 0.
 IF ORDINARY GLASS, ENTER 1.
 IF WATER WHITE, ENTER 2.
 IF HEAT ABSORBING, ENTER 3.
 IF REFLECTING, ENTER 4.

>1.
 ENTER 1. IF LAYER 1 IS IN CONTACT WITH ABSORBING SURFACE.
 ELSE ENTER 0.

>0.
 SPECIFIED GLAZING SECTION:

           I       I       I
 LAYER     I  1    I  2    I
           I       I       I
 MATERIAL  I GLASSI  AIR   I
           I       I       I


 ENTER THE NUMBER OF SURFACES TO BE ANALYZED.
 THE MAXIMUM NUMBER OF SURFACES THAT MAY BE ENTERED IS    6
 0.
```

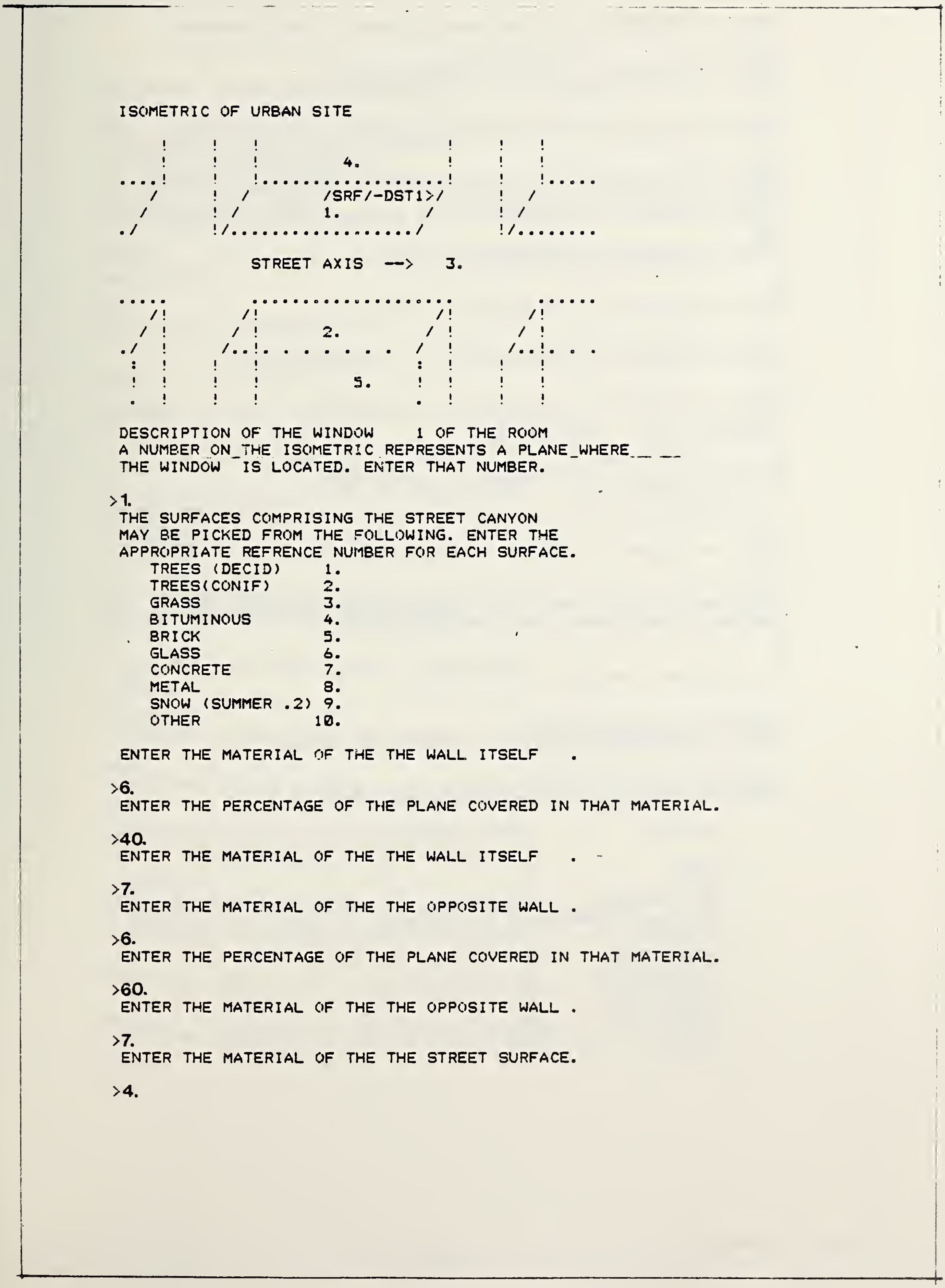
Fig. 3.5 Runtype below calculates solar radiation based on 1440 or TRY cloud data. A new weather file is created with the horizontal radiation components added to the file.



```
THIS PROGRAM READS A CLIMATE TAPE AND CALCULATES THE RADIATION ON
USER SPECIFIED SUACES. IT ALSO ENABLES THE USER TO
FIND TOTAL HEAT GAINS IN USER SPECIFIED ROOMS.
THIS OPTION IS USEFUL FOR THERMAL ANALYSIS PROGRAMS THAT
ARE NOT SPECIFIC TO BUILDING THERMAL ANALYIS.
THE FILES MUST BE ASSIGNED TO THE FOLLOWING DEVICES
FILE 7:THE INPUT DATA IS WRITTEN INTO FILE.
FILE 8:WEATHER DATA IS READ FROM FILE.
FILE 9:WEATHER DATA IS WRITTEN INTO FILE.
FILE 10:TABULATED OUTPUT TOTAL GAIN ON NODES INTO FILE.
FILE 11:TABULTED SOLAR GAIN ON SURFACE INTO FILE.
FILE 12:TABULATED DAYLIGHT LEVELS INTO FILE.
FILE 13:TABULATED USEABLE DAYLIGHT HOURS INTO FILE
ALL VARIABLES ENTERED MUST BE REAL NUMBERS.(X.Y)

FOR INTERACTIVE RUN ENTER 0.
IF INPUT FILE IS ADDED, ENTER 1.

>0.
THE OUTPUT OF THE PROGRAM MAY BE IN THE FORM OF THE
INPUT TAPE, OR SUMMARIZED AND TABULATED, OR BOTH:
IF THE OUTPUT IS IN THE SAME FORMAT AS THE WEATHER DATA FILE
INPUT, ENTER 1.
IF THE OUTPUT IS TABULATED, ENTER 2.
IF THE OUTPUT IS BOTH IN THE FORM OF A WEATHER FILE AND
IN TABULATED FORM, ENTER 3.

>1.
THE TYPE OF WEATHER DATA INPUT:
IF A SHORTMONTH FILE IS OUTPUT, THEN A SHORTMONTH FILE MUST BE
INPUT.  IF A FULLMONTH WEATHER FILE IS INPUT, THEN A FULL
MONTH WEATHER FILE IS OUTPUT.
ENTER 1. IF INPUT FILE IS FULL MONTH.
ENTER 2. IF INPUT FILE IS SHORT MONTH (8DAYS)

>2.
IF THE WEATHER FILE CONTAINS RADIATION DATA, AND CLOUD DATA,
ENTER 1.
IF ONLY CLOUD DATA IS IN WEATHER FILE ENTER 2.

>2.
ENTER THE NUMBER OF THE FIRST MONTH TO BE CALCULATED.

>1.
  ENTER THE NUMBER OF THE LAST MONTH TO BE CALCULATED.

>12.
THE UNIT STANDARD OF THE INPUT DATA:
ENTER 1. IF SI UNITS.
ENTER 2. IF ENGLISH UNITS.

>2.
THE UNIT STANDARD OF THE OUTPUT DATA:
ENTER 1. IF SI UNITS.
ENTER 2. IF ENGLISH UNITS.

>2.
```

```
 THE UNIT STANDARD OF THE INPUT DATA:
 ENTER 1. IF SI UNITS.
 ENTER 2. IF ENGLISH UNITS.

>2.
 THE UNIT STANDARD OF THE OUTPUT DATA:
 ENTER 1. IF SI UNITS.
 ENTER 2. IF ENGLISH UNITS.

>2.
 ENTER 1. FOR DAYLIGHT CALCULATIONS. ELSE ENTER 0.

>0.
 THE LOCATION OF THE SITE:
 ENTER THE LATITUDE (IN DEGREES).

>39.6
 ENTER THE LONGITUDE (IN DEGREES) .

>76.4
 ENTER THE TIME ZONE;
 ATLANTIC TIME ZONE=4.
 EASTERN           =5.
 CENTRAL           =6.
 MOUNTAIN          =7.
 PACIFIC           =8.

>5.
 IS THE SITE IN AN URBAN AREA, AS OPPOSED TO A RURAL AREA:
 ENTER 1. FOR YES.
 ENTER 2. FOR NO.

>2.
 ENTER THE ELEVATION OF THE LOCALITY FT.    ABOVE SEA LEVEL

>100.
 ISOMTERIC OF URBAN SITE

     !    !   !                  !    !   !
     !    !   !                  !    !   !
 ....!    !   !..................!    !   !.....
    /     !  /                  /     !  /
   /      !HGT1                /      ! /
 ./       !/................../       !/........
  < STW2 ><   BLOCK LENGTH   >       *
              STREET AXIS  -->       *
                                   STW1
 .....        ....................   *    ......
     !       /!                  !   *   /!
     !   HGT2 !                  !   *  / !
     !     /  !                  !   * /  !
     !    !   !                  !    !   !
     !    !   !                  !    !   !


 FROM THE ISOMETRIC OF THE STREET ABOVE,
 ENTER THE STREET AXIS, IN DEGREES, MEASURED CLOCKWISE FROM SOUTH,

>270.
 ENTER THE WIDTH OF THE STREET (STW1), CONTAINING THE SURFACES
 AND ROOMS, IN FT.

>110.
```

```
 ENTER THE WIDTH OF THE SECONDARY STREETS (STW2), IN FT.

>60.
 ENTER THE BLOCK LENGTH, IN FT.

>250.
 ENTER THE BLOCK WIDTH IN FT.

>100.
 ENTER THE HEIGHT OF THE BUILDINGS ON SIDE 1 OF THE BLOCK,
 (HGT1) IN FT.

>90.
 ENTER THE HEIGHT OF THE BUILDINGS ON SIDE 2 OF THE BLOCK,
 (HGT2) IN FT.

>150.
 ENTER HEIGHT OF BLDG. ON SIDE 1. OF CROSS STREET.
 IN FT.

>150.
 ENTER HEIGHT OF BLDG. ON SIDE 2. OF CROSS STREET
 IN FT.
>150.
 ENTER THE NUMBER OF ROOMS REQUIRING HEAT GAIN DATA
 A MAXIMUM OF 10 ROOMS MAY BE INPUT.

>4.
 FOR EACH ROOM;

 ENTER THE OCCUPANCY TYPE OF THE BUILDING:
 IF RESIDENTIAL 1.
 IF RETAIL, 2.
 IF OFFICE, 3.

>3.
 ENTER 1. IF ROOM FACES PRIMARY STREET.
 ENTER 2. IF ROOM FACES CROSS STREET.

>1.
 ENTER THE FLOOR WIDTH, LENGTH AND HEIGHT
 INFT.

>12. 12. 8.5
 ENTER THE MAXIMUM EXPECTED OCCUPANCY OF THE ROOM IN F2/PRS

>100.
 ENTER THE MAXIMUM EXPECTED ELECTRICAL LOAD OF THE ROOM IN WAT/F2

>30.
 ENTER REFLECTANCE COEFFICIENTS OF:
 WALLS, CEILING AND FLOOR.(RATIO OF 1.)

>.8 .6 .2
```



```
ISOMETRIC OF URBAN SITE

    !    !   !                  !    !   !
    !    !   !        4.        !    !   !
....!    !   !..................!    !   !.....
   /     !  /       /SRF/-DST1>/    !  /
  /      ! /        1.        /      ! /
./       !/................../       !/........

             STREET AXIS  -->    3.

.....        ....................        ......
   /!       /!                 /!       /!
  / !      / !      2.        / !      / !
./  !     /..!. . . . . . .  /  !     /..!. . .
 :  !    !   !               :  !    !   !
 !  !    !   !         5.    !  !    !   !
 .  !    !   !               .  !    !   !

DESCRIPTION OF THE WINDOW    1 OF THE ROOM
A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
THE WINDOW  IS LOCATED. ENTER THAT NUMBER.

>1.
THE SURFACES COMPRISING THE STREET CANYON
MAY BE PICKED FROM THE FOLLOWING. ENTER THE
APPROPRIATE REFRENCE NUMBER FOR EACH SURFACE.
   TREES (DECID)     1.
   TREES(CONIF)      2.
   GRASS             3.
   BITUMINOUS        4.
   BRICK             5.
   GLASS             6.
   CONCRETE          7.
   METAL             8.
   SNOW (SUMMER .2)  9.
   OTHER            10.

ENTER THE MATERIAL OF THE THE WALL ITSELF   .

>6.
ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>40.
ENTER THE MATERIAL OF THE THE WALL ITSELF   .

>7.
ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>6.
ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>60.
ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>7.
ENTER THE MATERIAL OF THE THE STREET SURFACE.

>4.
```

```
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .

>4.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE DISTANCE FROM THE SIDE EDGE OF THE WINDOW  TO THE
 CORNER OF THE BLOCK, DIST1 IN FT.
 (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
>50.
 ENTER THE LENGTH OF THE WINDOW   IN FT.

>6.
 ENTER THE HEIGHT OF THE WINDOW   IN FT.

>4.
 ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.

>0.
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.

>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF
 OF THE WINDOW  IN FT.

>3.5
 ENTER THE HEIGHT OF BOTTOM SILL ABOVE FLOORFT.

>3.5
 ENTER THE DISTANCE FROM RIGHT PARTION WALL TO WINDOW LRHC
 LOOKING AT THE WINDOW FROM INSIDE ROOM INFT.

>3.
 IS THE WINDOW  GLAZED.1.=YES. 0.=NO

>1.
 DESCRIPTION OF THE GLAZING:
 ENTER THE NUMBER OF GLAZING LAYERS IN THE WINDOW

>1.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  1

        MATERIAL           INDEX NUMBER

        GLASS              1.
        AIR                2.
        POLYCARBONATE      3.
        PLEXIGALSS(PMMA)   4.
        MYLR(PET)          5.
        TEDLAR(PVF)        6.
        TEFLON(FEP)        7.
        WATER-LIQUID       8.
        WATER-SOLID        9.
        QUARTZ            10.
        OTHER             11.

>1.
```

```
 ENTER THE THICKNESS OF GLAZING LAYER  1 IN INCHES

>.25
 IF MEASURED TRANSMITTANCE, ENTER 0.
 IF ORDINARY GLASS, ENTER 1.
 IF WATER WHITE, ENTER 2.
 IF HEAT ABSORBING, ENTER 3.
 IF REFLECTING, ENTER 4.

>1.
 ENTER 1. IF LAYER 1 IS IN CONTACT WITH ABSORBING SURFACE.
 ELSE ENTER 0.

>0.
 SPECIFIED GLAZING SECTION:

          I      I      I
 LAYER    I  1   I  2   I
          I      I      I
 MATERIAL I GLASSI  AIR I
          I      I      I



 ENTER THE OCCUPANCY TYPE OF THE BUILDING:
 IF RESIDENTIAL 1.
 IF RETAIL, 2.
 IF OFFICE, 3.

>3.
 ENTER 1. IF ROOM FACES PRIMARY STREET.
 ENTER 2. IF ROOM FACES CROSS STREET.

>1.
 ENTER THE FLOOR WIDTH, LENGTH AND HEIGHT
 INFT.

>12. 12. 8.5
 ENTER THE MAXIMUM EXPECTED OCCUPANCY OF THE ROOM IN F2/PRS

>100.
 ENTER THE MAXIMUM EXPECTED ELECTRICAL LOAD OF THE ROOM IN WAT/F2

>3.
 ENTER REFLECTANCE COEFFICIENTS OF:
 WALLS, CEILING AND FLOOR.(RATIO OF 1.)

>.8 .6 .2
 DESCRIPTION OF THE WINDOW    2 OF THE ROOM
 A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
 THE WINDOW  IS LOCATED. ENTER THAT NUMBER.

>2.
 ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .

>4.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
```

```
 ENTER THE DISTANCE FROM THE SIDE EDGE OF THE WINDOW  TO THE
 CORNER OF THE BLOCK, DIST1 IN FT.
 (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
>50.
 ENTER THE LENGTH OF THE WINDOW   IN FT.

>6.
 ENTER THE HEIGHT OF THE WINDOW   IN FT.

>4.
 ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.

>0.
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.

>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF
 OF THE WINDOW  IN FT.

>3.5
 ENTER THE HEIGHT OF BOTTOM SILL ABOVE FLOORFT.

>3.5
 ENTER THE DISTANCE FROM RIGHT PARTION·WALL TO WINDOW LRHC
 LOOKING AT THE WINDOW FROM INSIDE ROOM INFT.

>3.
 IS THE WINDOW  GLAZED.1.=YES. 0.=NO

>1.
 DESCRIPTION OF THE GLAZING:
 ENTER THE NUMBER OF GLAZING LAYERS IN THE WINDOW

>1.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  1

>1.
 ENTER THE THICKNESS OF GLAZING LAYER  1 IN INCHES

>.25
 IF MEASURED TRANSMITTANCE, ENTER 0.
 IF ORDINARY GLASS, ENTER 1.
 IF WATER WHITE, ENTER 2.
 IF HEAT ABSORBING, ENTER 3.
 IF REFLECTING, ENTER 4.

>1.
 ENTER 1. IF LAYER 1 IS IN CONTACT WITH ABSORBING SURFACE.
 ELSE ENTER 0.

>0.
 SPECIFIED GLAZING SECTION:

          I      I      I
 LAYER    I  1   I  2   I
          I      I      I
 MATERIAL I GLASSI  AIR I
          I      I      I
```

```
 ENTER 1. FOR DAYLIGHT CALCULATIONS. ELSE ENTER 0.

>0.
 THE LOCATION OF THE SITE:
 ENTER THE LATITUDE (IN DEGREES).

>39.
 ENTER THE LONGITUDE (IN DEGREES) .

>76.
 ENTER THE TIME ZONE;
 ATLANTIC TIME ZONE=4.
 EASTERN           =5.
 CENTRAL           =6.
 MOUNTAIN          =7.
 PACIFIC           =8.

>5.
 IS THE SITE IN AN URBAN AREA, AS OPPOSED TO A RURAL AREA:
 ENTER 1. FOR YES.
 ENTER 2. FOR NO.

>2.
 ENTER THE ELEVATION OF THE LOCALITY FT.    ABOVE SEA LEVEL

>100.
```

unit 7 are shown in Figs. 3.6 and 3.7. These files were created from a run analyzing four rooms facing a street canyon, and from the analysis of a single surface respectively.

3.3 OUTPUT FROM SOLITE RUNS

Four types of output files may be created by the solar availability program:

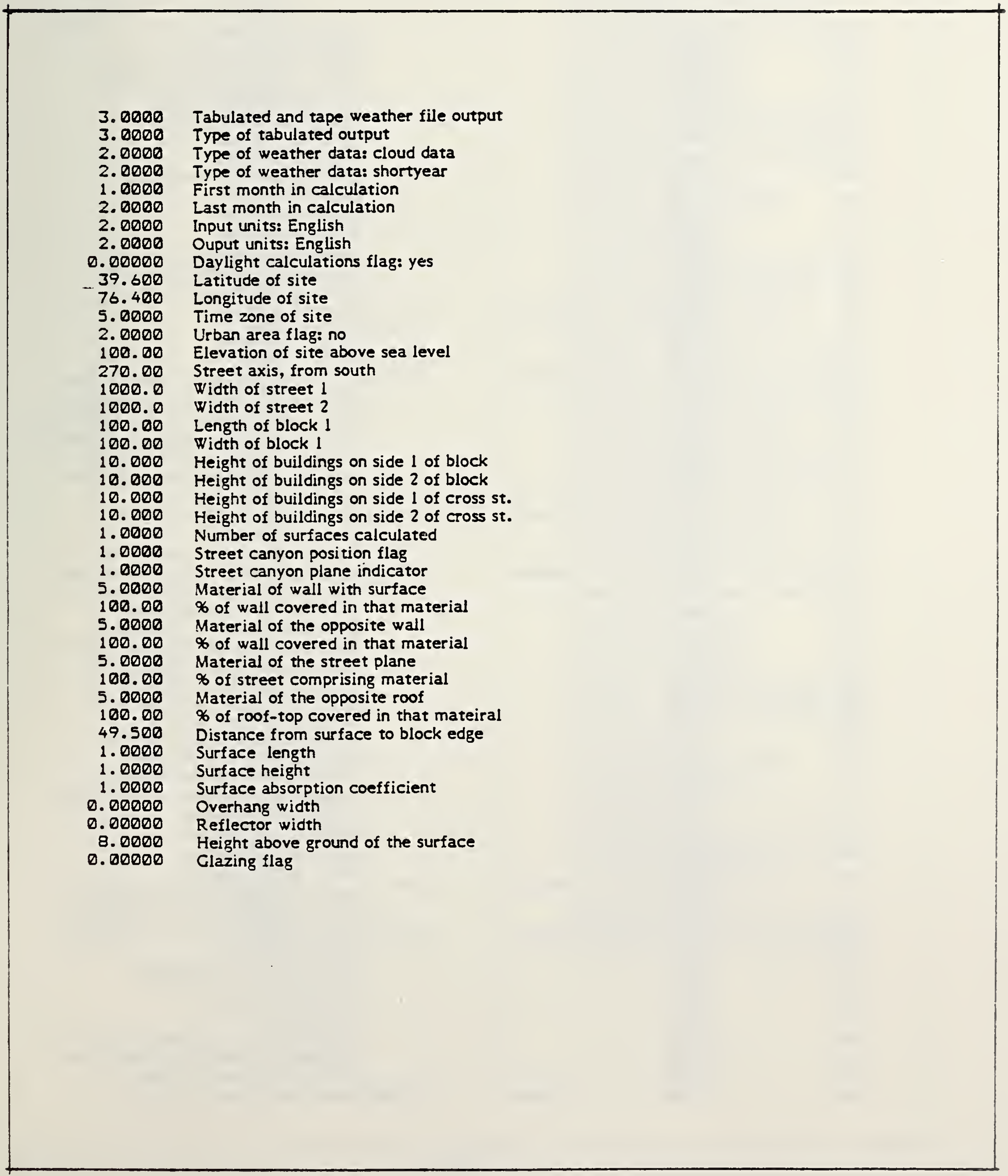
1. An expanded weather data file is created in the same format as the input weather data file, with the addition of horizontal total and direct solar radiation data to a 1440 type weather data file.
2. A tabulated report of hourly total radiation on surfaces or combined with occupancy heat gains in rooms is created. Hourly dry-bulb temperatures are also reported. Note that this reporting option is possible only with SHORTYEAR. It is the author's opinion that tabulation of hourly data for a complete year would be overwhelming. An example of the hourly tabulated shortmonth output is shown in Fig. 3.8.
3. An unlabelled file of hourly total radiation values for surfaces and total heat gain in rooms is created. This output option provides a file containing heat gains on a node for non-building specific thermal node/network analysis method. An example of this output and the format fields appears in Fig. 3.9.
4. A labelled daily summary of heat gain in rooms and on surfaces with a monthly reported average is created, as shown in Fig. 3.10.

These data are written to a file assigned to logical unit 10, and only one of the above ouput options may be chosen during a run. In addition to these four output options, if daylighting analysis is chosen, useable daylight hours, daylight quantity, and solar radiation per metric area are also written to the specified files (logical units 11, 12, and 13 respectively). Two daylight data files and one incident solar gain file are created:

1. The hours of available daylight on the workplane in a specific room are calculated. Illumination levels are calculated for three points along the midline of the room. At each point, the illumination level is compared to a lower limit of IES specified [34] footcandles, and an upper limit of 5.5 times the brightness at the workplane point nearest the window [35]. An example of this output file is illustrated in Fig. 3.11.
2. Depending on the output mode chosen, daily average or hourly illumination levels on the workplane of the room at three room depths are calculated, in footcandles. An example of this output is shown in Fig. 3.12.
3. Hourly solar radiation intensity per square metric is calculated for each of the surfaces described by the user. This file is created in a labelled, or unlabelled format depending on the user's ouput specification. Both modes are illustrated in Fig. 3.13 and Fig. 3.14 respectively.

A complete description of the structure of the program and the mathematical algorithms employed, is given in Appendices A through C. Program listings are found in Appendices D and E.

Fig. 3.6. Ouput file 7 written by SOLITE during the previous analysis of a surface (Fig. 3.3). This file could now be added to the run using the UNIVAC command "@ADD FILE 7." and the interactive prompts would be eliminated.



```
  3.0000   Tabulated and tape weather file output
  3.0000   Type of tabulated output
  2.0000   Type of weather data: cloud data
  2.0000   Type of weather data: shortyear
  1.0000   First month in calculation
  2.0000   Last month in calculation
  2.0000   Input units: English
  2.0000   Ouput units: English
0.00000    Daylight calculations flag: yes
  39.600   Latitude of site
  76.400   Longitude of site
  5.0000   Time zone of site
  2.0000   Urban area flag: no
  100.00   Elevation of site above sea level
  270.00   Street axis, from south
  1000.0   Width of street 1
  1000.0   Width of street 2
  100.00   Length of block 1
  100.00   Width of block 1
  10.000   Height of buildings on side 1 of block
  10.000   Height of buildings on side 2 of block
  10.000   Height of buildings on side 1 of cross st.
  10.000   Height of buildings on side 2 of cross st.
  1.0000   Number of surfaces calculated
  1.0000   Street canyon position flag
  1.0000   Street canyon plane indicator
  5.0000   Material of wall with surface
  100.00   % of wall covered in that material
  5.0000   Material of the opposite wall
  100.00   % of wall covered in that material
  5.0000   Material of the street plane
  100.00   % of street comprising material
  5.0000   Material of the opposite roof
  100.00   % of roof-top covered in that mateiral
  49.500   Distance from surface to block edge
  1.0000   Surface  length
  1.0000   Surface height
  1.0000   Surface absorption coefficient
0.00000    Overhang width
0.00000    Reflector width
  8.0000   Height above ground of the surface
0.00000    Glazing flag
```

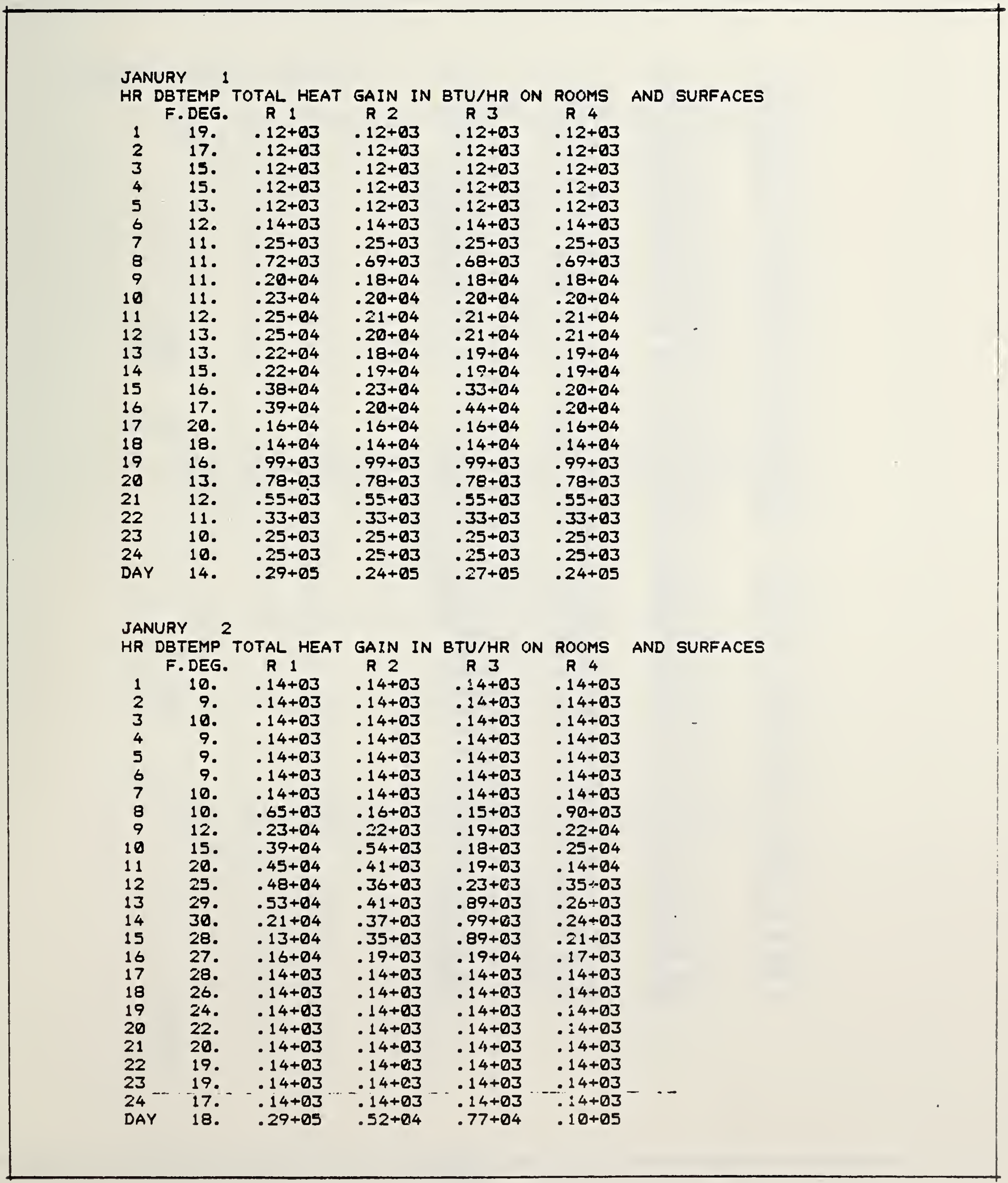
Fig. 3.7 Ouput file 7 written by SOLITE during execution of the previous runstream example (Fig. 3.4). A large difference may be seen between the two ouput files to 7 (of Fig. 3.6 and this listing). As the user's input determines the path through the program, the data file at logical unit 7 will vary from run to run.

```
 1:        3.0000                                  Tabulated and tape weather file output
 2:        1.0000                                  Type of tabulated output
 3:        2.0000                                  Type of weather data: cloud data
 4:        2.0000                                  Type of weather data: shortyear
 5:        1.0000                                  First month in calculation
 6:        2.0000                                  Last month in calculation
 7:        2.0000                                  Input units: English
 8:        2.0000                                  Ouput units: English
 9:        1.0000                                  Daylight calculations flag: yes
10:        39.600                                  Latitude of site
11:        76.400                                  Longitude of site
12:        5.0000                                  Time zone of site
13:        2.0000                                  Urban area flag: no
14:        100.00                                  Elevation of site above sea level
15:        270.00                                  Street axis, from south
16:        110.00                                  Width of street 1
17:        60.000                                  Width of street 2
18:        250.00                                  Length of block 1
19:        100.00                                  Width of block 1
20:        150.00                                  Height of buildings on side 1 of block
21:        90.000                                  Height of buildings on side 2 of block
22:        150.00                                  Height of buildings on side 1 of cross st.
23:        150.00                                  Height of buildings on side 2 of cross st.
24:        4.0000                                  Number of rooms to be analyzed
25:        3.0000                                  Occupancy indicator for room: office
26:        1.0000                                  Room faces primary street
27:        12.000         12.000          8.5000   Room width, length and height
28:        100.00                                  Occupancy of room
29:        3.0000                                  Maximum electrical gains in room
30:        .80000         .60000          .20000   Reflection coeff. walls, ceiling, floor
31:        1.0000                                  Position of window in street canyon
32:        6.0000                                  Material of wall with window
33:        40.000                                  % of wall faced with material
34:        7.0000                                  Second material of wall with window
35:        6.0000                                  Material of wall on opposite side
36:        60.000                                  % of wall faced with material
37:        7.0000                                  Second material of opposite wall
38:        4.0000                                  Material of street surface
39:        100.00                                  % of street comprising material
40:        4.0000                                  Material of the opposite roof
41:        100.00                                  % of roof covered with material
42:        50.000                                  Distance from window to block edge
43:        6.0000                                  Length of the window
44:        4.0000                                  Height of the window
45:        0.00000                                 Width of the overhang
46:        0.00000                                 Width of the reflector
47:        3.5000                                  Height of window sill above ground
48:        3.5000                                  Height of window sill above fin. floor
49:        3.0000                                  Distance of window from inside wall
50:        1.0000                                  Glazing flag
51:        1.0000                                  Number of layers of glazing
52:        1.0000                                  Glazing material of layer
53:        .25000                                  Thickness of glazing
54:        1.0000                                  Type of glass
55:        0.00000                                 Adjacency flag of glazing layer
56:        3.0000                                  Occupancy indicator for room: office
57:        1.0000                                  Room faces primary street
58:        12.000         12.000          8.5000   Room width, length and height
```

```
 59:              100.00                            Occupancy of room
 60:              3.0000                            Maximum electrical gains in room
 61:              .80000       .60000        .20000 Reflection coeff. walls, ceiling, floor
 62:              2.0000                            Position of window in street canyon
 63:              4.0000                            Material of the opposite roof
 64:              100.00                            % of roof covered with material
 65:              50.000                            Distance from window to block edge
 66:              4.0000                            Length of the window
 67:              4.0000                            Height of the window
 68:             0.00000                            Width of the overhang
 69:             0.00000                            Width of the reflector
 70:              3.5000                            Height of window sill above ground
 71:              3.5000                            Height of window sill above fin. floor
 72:              3.0000                            Distance of window from inside wall
 73:              1.0000                            Glazing flag
 74:              1.0000                            Number of layers of glazing
 75:              1.0000                            Glazing material of layer
 76:              .25000                            Thickness of glazing
 77:              1.0000                            Type of glass
 78:             0.00000                            Adjacency flag of glazing layer
 79:              3.0000                            Occupancy indicator for room: office
 80:              2.0000                            Room faces primary street
 81:              12.000       12.000        8.5000 Room width, length and height
 82:              100.00                            Occupancy of room
 83:              3.0000                            Maximum electrical gains in room
 84:              .80000       .60000        .20000 Reflection coeff. walls, ceiling, floor
 85:              1.0000                            Position of window in street canyon
 86:              6.0000                            Material of wall with window
 87:              40.000                            % of wall faced with material
 88:              7.0000                            Second material of wall with window
 89:              6.0000                            Material of wall on opposite side
 90:              50.000                            % of wall faced with material
 91:              7.0000                            Second material of opposite wall
 92:              4.0000                            Material of street surface
 93:              100.00                            % of street comprising material
 94:              4.0000                            Material of the opposite roof
 95:              100.00                            % of roof covered with material
 96:              50.000                            Distance from window to block edge
 97:              6.0000                            Length of the window
 98:              4.0000                            Height of the window
 99:             0.00000                            Width of the overhang
100:             0.00000                            Width of the reflector
101:              3.5000                            Height of window sill above ground
102:              3.5000                            Height of window sill above fin. floor
103:              3.0000                            Distance of window from inside wall
104:              1.0000                            Glazing flag
105:              1.0000                            Number of layers of glazing
106:              1.0000                            Glazing material of layer
107:              .25000                            Thickness of glazing
108:              1.0000                            Type of glass
109:             0.00000                            Adjacency flag of glazing layer
110:              3.0000                            Occupancy indicator for room: office
111:              2.0000                            Room faces primary street
112:              12.000       12.000        8.5000 Room width, length and height
113:              100.00                            Occupancy of room
114:              3.0000                            Maximum electrical gains in room
115:              .80000       .60000        .20000 Reflection coeff. walls, ceiling, floor
116:              2.0000                            Position of window in street canyon
```

117:	4.0000	Material of the opposite roof
118:	100.00	% of roof covered with material
119:	50.000	Distance from window to block edge
120:	6.0000	Length of the window
121:	4.0000	Height of the window
122:	0.00000	Width of the overhang
123:	0.00000	Width of the reflector
124:	3.5000	Height of window sill above ground
125:	3.5000	Height of window sill above fin. floor
126:	3.0000	Distance of window from inside wall
127:	1.0000	Glazing flag
128:	1.0000	Number of layers of glazing
129:	1.0000	Glazing material of layer
130:	.23000	Thickness of glazing
131:	1.0000	Type of glass
132:	0.00000	Adjacency flag of glazing layer
133:	0.00000	Number of surfaces calculated

Fig. 3.8 Tabulated hourly output from a run using SHORTYEAR weather file. The output shown was written by SOLITE to Unit 10.



```
JANURY    1
HR DBTEMP TOTAL HEAT GAIN IN BTU/HR ON ROOMS  AND SURFACES
    F.DEG.    R 1      R 2      R 3      R 4
 1    19.   .12+03   .12+03   .12+03   .12+03
 2    17.   .12+03   .12+03   .12+03   .12+03
 3    15.   .12+03   .12+03   .12+03   .12+03
 4    15.   .12+03   .12+03   .12+03   .12+03
 5    13.   .12+03   .12+03   .12+03   .12+03
 6    12.   .14+03   .14+03   .14+03   .14+03
 7    11.   .25+03   .25+03   .25+03   .25+03
 8    11.   .72+03   .69+03   .68+03   .69+03
 9    11.   .20+04   .18+04   .18+04   .18+04
10    11.   .23+04   .20+04   .20+04   .20+04
11    12.   .25+04   .21+04   .21+04   .21+04
12    13.   .25+04   .20+04   .21+04   .21+04
13    13.   .22+04   .18+04   .19+04   .19+04
14    15.   .22+04   .19+04   .19+04   .19+04
15    16.   .38+04   .23+04   .33+04   .20+04
16    17.   .39+04   .20+04   .44+04   .20+04
17    20.   .16+04   .16+04   .16+04   .16+04
18    18.   .14+04   .14+04   .14+04   .14+04
19    16.   .99+03   .99+03   .99+03   .99+03
20    13.   .78+03   .78+03   .78+03   .78+03
21    12.   .55+03   .55+03   .55+03   .55+03
22    11.   .33+03   .33+03   .33+03   .33+03
23    10.   .25+03   .25+03   .25+03   .25+03
24    10.   .25+03   .25+03   .25+03   .25+03
DAY   14.   .29+05   .24+05   .27+05   .24+05

JANURY    2
HR DBTEMP TOTAL HEAT GAIN IN BTU/HR ON ROOMS  AND SURFACES
    F.DEG.    R 1      R 2      R 3      R 4
 1    10.   .14+03   .14+03   .14+03   .14+03
 2     9.   .14+03   .14+03   .14+03   .14+03
 3    10.   .14+03   .14+03   .14+03   .14+03
 4     9.   .14+03   .14+03   .14+03   .14+03
 5     9.   .14+03   .14+03   .14+03   .14+03
 6     9.   .14+03   .14+03   .14+03   .14+03
 7    10.   .14+03   .14+03   .14+03   .14+03
 8    10.   .65+03   .16+03   .15+03   .90+03
 9    12.   .23+04   .22+03   .19+03   .22+04
10    15.   .39+04   .54+03   .18+03   .25+04
11    20.   .45+04   .41+03   .19+03   .14+04
12    25.   .48+04   .36+03   .23+03   .35+03
13    29.   .53+04   .41+03   .89+03   .26+03
14    30.   .21+04   .37+03   .99+03   .24+03
15    28.   .13+04   .35+03   .89+03   .21+03
16    27.   .16+04   .19+03   .19+04   .17+03
17    28.   .14+03   .14+03   .14+03   .14+03
18    26.   .14+03   .14+03   .14+03   .14+03
19    24.   .14+03   .14+03   .14+03   .14+03
20    22.   .14+03   .14+03   .14+03   .14+03
21    20.   .14+03   .14+03   .14+03   .14+03
22    19.   .14+03   .14+03   .14+03   .14+03
23    19.   .14+03   .14+03   .14+03   .14+03
24    17.   .14+03   .14+03   .14+03   .14+03
DAY   18.   .29+05   .52+04   .77+04   .10+05
```

Fig. 3.9 Unlabelled hourly ouput of heat gain in the user described rooms is for use with large-scale thermal analysis programs such as SINDA, or DEROB. The output format will have to be changed to match the requirements of the thermal analysis program READ formats. The SOLITE write formats are listed below.

```
1    1                                      FORMAT (1X,2I4,/,10E9.2)
.12+03   .12+03   .12+03   .12+03
.12+03   .12+03   .12+03   .12+03
.12+03   .12+03   .12+03   .12+03
.12+03   .12+03   .12+03   .12+03
.12+03   .12+03   .12+03   .12+03
.14+03   .14+03   .14+03   .14+03
.25+03   .25+03   .25+03   .25+03
.70+03   .68+03   .68+03   .69+03
.19+04   .18+04   .18+04   .18+04
.21+04   .20+04   .20+04   .20+04
.22+04   .21+04   .20+04   .21+04
.22+04   .20+04   .20+04   .20+04
.20+04   .18+04   .18+04   .18+04
.21+04   .19+04   .19+04   .19+04
.37+04   .22+04   .33+04   .20+04
.39+04   .20+04   .44+04   .20+04
.16+04   .16+04   .16+04   .16+04
.14+04   .14+04   .14+04   .14+04
.99+03   .99+03   .99+03   .99+03
.78+03   .78+03   .78+03   .78+03
.55+03   .55+03   .55+03   .55+03
.33+03   .33+03   .33+03   .33+03
.25+03   .25+03   .25+03   .25+03
.25+03   .25+03   .25+03   .25+03
1    2
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.63+03   .16+03   .15+03   .89+03
.22+04   .20+03   .20+03   .22+04
.39+04   .55+03   .21+03   .25+04
.45+04   .42+03   .23+03   .14+04
.48+04   .38+03   .25+03   .38+03
.52+04   .43+03   .91+03   .27+03
.19+04   .34+03   .93+03   .24+03
.11+04   .33+03   .85+03   .20+03
.15+04   .18+03   .19+04   .18+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
.14+03   .14+03   .14+03   .14+03
```

Fig. 3.10 Daily summaries, and monthly temperature and incident solar radiation averages are reported for surfaces (1 ft^2) oriented south (S1), north (S2), west (S3), and east (S4). A potential use of the program would be for the creation of solar radiation data tables for generic urban environments. In addition to the radiation data, average daily temperature summaries are also provided.

```
JANURY

 DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
      BULB  TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1     S 2     S 3     S 4
  1    14.   20.  10.   7.    507.    172.    489.    286.
  2    18.   30.   9.   9.   1658.    244.    550.    690.
  3    25.   38.  12.   7.   1923.    240.    726.    724.
  4    33.   43.  21.   7.    619.    197.    312.    486.
  5    40.   46.  34.   6.    442.    183.    315.    326.
  6    49.   63.  39.   7.    298.    162.    262.    279.
  7    49.   64.  27.  17.    856.    240.    584.    424.
  8    25.   29.  21.   8.   1167.    263.    406.    750.
 TOTAL
 MONTH  1.   64.   9.   0.    934.    213.    456.    495.


FEBRUY

 DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
      BULB  TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1     S 2     S 3     S 4
  1    40.   44.  37.   5.    397.    215.    348.    362.
  2    42.   45.  40.   6.    402.    218.    352.    366.
  3    44.   55.  38.   6.    407.    220.    356.    371.
  4    51.   56.  44.  13.   2199.    375.   1111.    965.
  5    36.   40.  32.  11.    442.    229.    368.    423.
  6    31.   37.  25.  10.   1985.    391.    975.   1138.
  7    37.   46.  31.   7.   1512.    367.   1027.    728.
  8    36.   44.  31.  11.    844.    294.    437.    700.
 TOTAL
 MONTH  2.   56.  25.   0.   1023.    289.    622.    632.


MARCH

 DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
      BULB  TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1     S 2     S 3     S 4
  1    40.   44.  34.  10.    547.    297.    463.    489.
  2    42.   45.  37.  16.    552.    300.    467.    494.
  3    41.   45.  37.  20.    756.    349.    638.    568.
  4    40.   46.  34.  15.   2177.    481.   1337.   1301.
  5    42.   55.  32.   8.   1163.    433.   1197.    738.
  6    54.   67.  41.   9.    814.    380.    761.    667.
  7    53.   67.  39.   9.   2036.    574.   1311.   1477.
  8    57.   73.  42.  10.   2138.    475.   1334.   1354.
 TOTAL
 MONTH  2.   73.  32.   1.   1273.    411.    939.    886.
```

```
APRIL

 DAY  DRY    MAX  MIN WIND   RADIATION ON SURFACE    BTU/F2
      BULB TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1      S 2     S 3     S 4
  1    43.   51.  37.  14.  1856.    713.  1705.   1528.
  2    45.   55.  34.  10.  1834.    602.  1570.   1573.
  3    51.   62.  39.  13.   990.    549.   688.   1188.
  4    58.   67.  51.   8.   722.    442.   579.    568.
  5    63.   74.  54.   7.   912.    571.   928.    671.
  6    61.   69.  56.  11.   964.    578.  1277.    662.
  7    63.   81.  51.   8.  1134.    627.  1141.    703.
  8    75.   88.  63.   8.  1801.    767.  1454.   1759.
 TOTAL
 MONTH  2.   88.  34.   0.  1277.    606.  1168.   1082.


MAY

 DAY  DRY    MAX  MIN WIND   RADIATION ON SURFACE    BTU/F2
      BULB TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1      S 2     S 3     S 4
  1    56.   65.  43.   7.  1351.    868.  1001.   1718.
  2    62.   70.  53.   9.  1636.   1029.  1832.   1478.
  3    65.   78.  48.   7.  1467.    855.  1765.   1679.
  4    70.   84.  54.   9.  1459.    861.  1767.   1681.
  5    73.   85.  59.  10.  1601.   1037.  1902.   1850.
  6    75.   87.  63.  11.  1270.    894.  1146.   1728.
  7    70.   74.  63.  10.   877.    703.   812.    676.
  8    68.   78.  58.   9.  1173.    846.  1647.    825.
 TOTAL
 MONTH  3.   87.  43.   0.  1354.    887.  1484.   1454.


JUNE

 DAY  DRY    MAX  MIN WIND   RADIATION ON SURFACE    BTU/F2
      BULB TEMP TEMP SPEED
      TEMP
          F.DEG.      MPH     S 1      S 2     S 3     S 4
  1    61.   70.  53.  14.  1002.    803.  1000.    727.
  2    68.   77.  59.  10.  1496.   1146.  1892.   1536.
  3    71.   81.  58.  12.  1468.   1090.  1382.   1892.
  4    80.   89.  70.  10.  1244.   1133.  1569.   1343.
  5    82.   90.  73.   7.  1490.   1180.  1874.   1921.
  6    81.   91.  72.   8.  1617.   1303.  1697.   1643.
  7    83.   96.  72.   6.  1512.   1177.  1653.   1946.
  8    84.   95.  76.   7.  1441.   1057.  1339.   1865.
 TOTAL
 MONTH  3.   96.  53.   0.  1409.   1111.  1551.   1609.
```

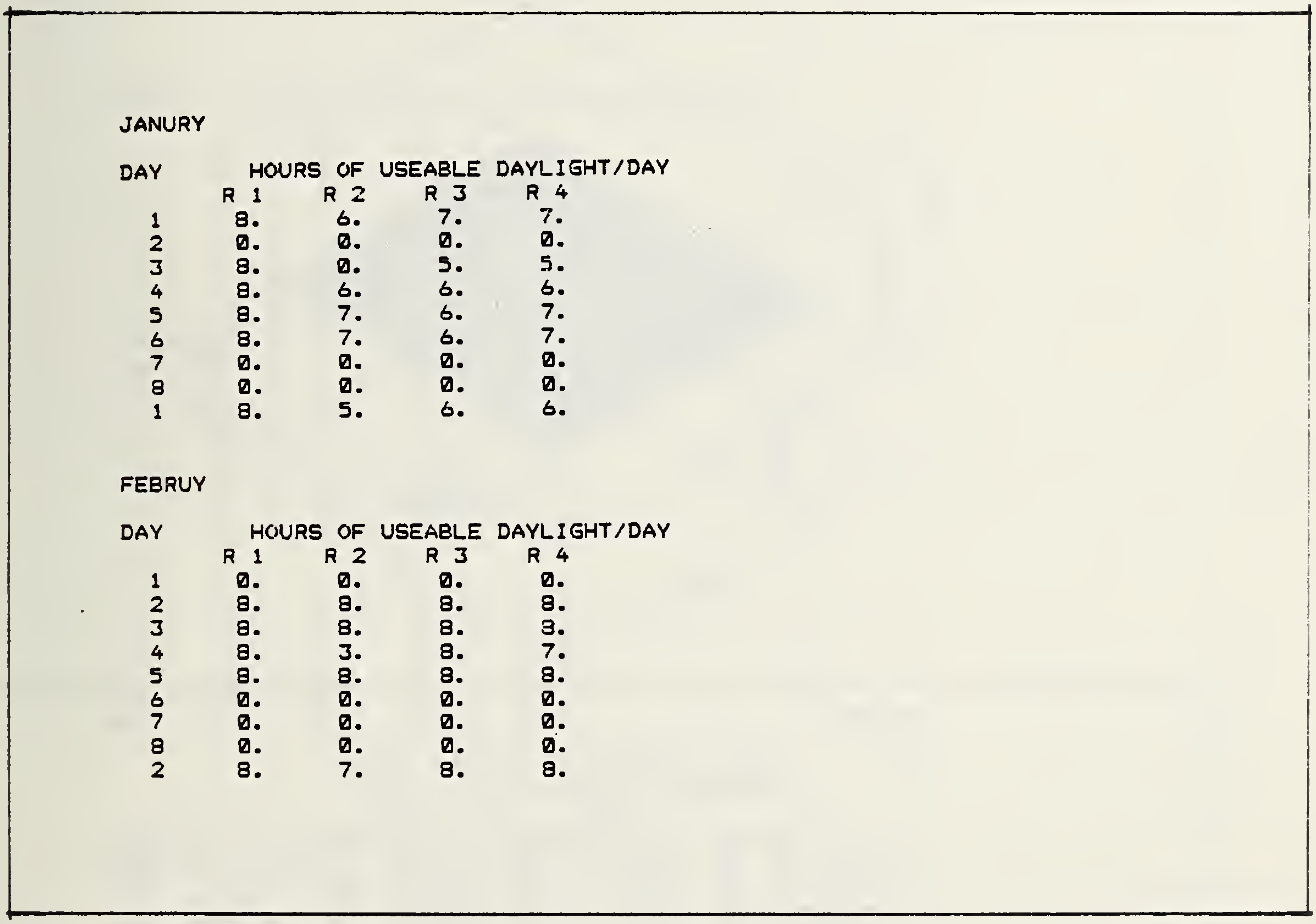
```
JULY

 DAY   DRY    MAX   MIN  WIND    RADIATION ON SURFACE    BTU/F2
       BULB  TEMP  TEMP  SPEED
       TEMP
           F.DEG.        MPH      S 1      S 2      S 3      S 4
  1     81.   92.   68.   11.   1363.     972.   1736.    1819.
  2     87.  100.   73.    8.   1394.     985.   1719.    1784.
  3     87.   99.   78.    9.   1488.    1086.   1327.    1550.
  4     77.   85.   70.    8.    727.     605.    550.     896.
  5     74.   81.   67.   15.   1501.    1099.   1626.    1329.
  6     74.   82.   63.    9.   1322.     910.   1049.    1902.
  7     74.   82.   65.   10.    793.     675.    825.     721.
  8     77.   86.   68.   11.   1395.    1012.   1222.    1607.
 TOTAL
 MONTH   3.  100.   63.    0.   1248.     918.   1257.    1451.


AUGUST

 DAY   DRY    MAX   MIN  WIND    RADIATION ON SURFACE    BTU/F2
       BULB  TEMP  TEMP  SPEED
       TEMP
           F.DEG.        MPH      S 1      S 2      S 3      S 4
  1     82.   92.   73.   11.   1560.     834.   1203.    1284.
  2     72.   82.   64.   13.   1713.     934.   1619.    1487.
  3     75.   86.   64.   12.   1653.     885.   1727.    1448.
  4     79.   89.   73.    9.    833.     548.    917.     668.
  5     82.   93.   72.   12.   1698.     860.   1522.    1647.
  6     74.   79.   69.   10.    895.     582.   1018.     695.
  7     72.   82.   64.   10.   1620.     857.   1525.    1599.
  8     65.   67.   64.   11.    524.     347.    414.     402.
 TOTAL
 MONTH   3.   93.   64.    0.   1312.     731.   1243.    1154.


SEPTEM

 DAY   DRY    MAX   MIN  WIND    RADIATION ON SURFACE    BTU/F2
       BULB  TEMP  TEMP  SPEED
       TEMP
           F.DEG.        MPH      S 1      S 2      S 3      S 4
  1     70.   74.   66.   12.    416.     225.    296.     332.
  2     71.   77.   66.    8.   1681.     584.   1410.     995.
  3     72.   77.   66.   10.    337.     198.    297.     280.
  4     78.   87.   71.   11.   1248.     491.   1188.     762.
  5     79.   88.   74.   12.   1422.     528.   1195.     838.
  6     69.   77.   63.   10.    353.     201.    270.     292.
  7     63.   69.   57.    9.   1977.     525.   1442.    1346.
  8     63.   75.   50.    6.   2022.     504.   1400.    1213.
 TOTAL
 MONTH   3.   88.   50.    0.   1182.     407.    937.     757.
```

```
OCTOBR

DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
     BULB  TEMP TEMP SPEED
     TEMP
         F.DEG.       MPH     S 1      S 2     S 3      S 4
 1    49.   58.  41.    8.   1977.    381.   1102.   1115.
 2    51.   65.  39.    2.   1980.    377.   1091.   1106.
 3    54.   67.  41.    2.   1956.    378.   1016.   1101.
 4    55.   67.  44.    4.   1489.    436.   1023.    855.
 5    57.   68.  48.    6.   1315.    418.    880.    786.
 6    61.   65.  56.    7.    235.    127.    191.    199.
 7    61.   63.  57.    9.    232.    125.    189.    196.
 8    53.   56.  49.   15.    732.    263.    472.    580.
TOTAL
MONTH  2.   68.  39.    0.   1240.    313.    746.    742.
```

```
NOVMBR

DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
     BULB  TEMP TEMP SPEED
     TEMP
         F.DEG.       MPH     S 1      S 2     S 3      S 4
 1    37.   45.  30.    8.   1994.    281.    864.    819.
 2    38.   50.  27.    5.   1765.    304.    727.    811.
 3    44.   56.  31.    3.    602.    197.    381.    354.
 4    56.   62.  47.   11.    220.    106.    179.    187.
 5    60.   69.  51.    6.   1441.    268.    480.    736.
 6    54.   61.  48.    3.    192.    100.    172.    152.
 7    55.   64.  49.    6.   1221.    295.    541.    661.
 8    52.   54.  49.    7.    189.     98.    170.    149.
TOTAL
MONTH  2.   69.  27.    0.    953.    206.    439.    484.
```

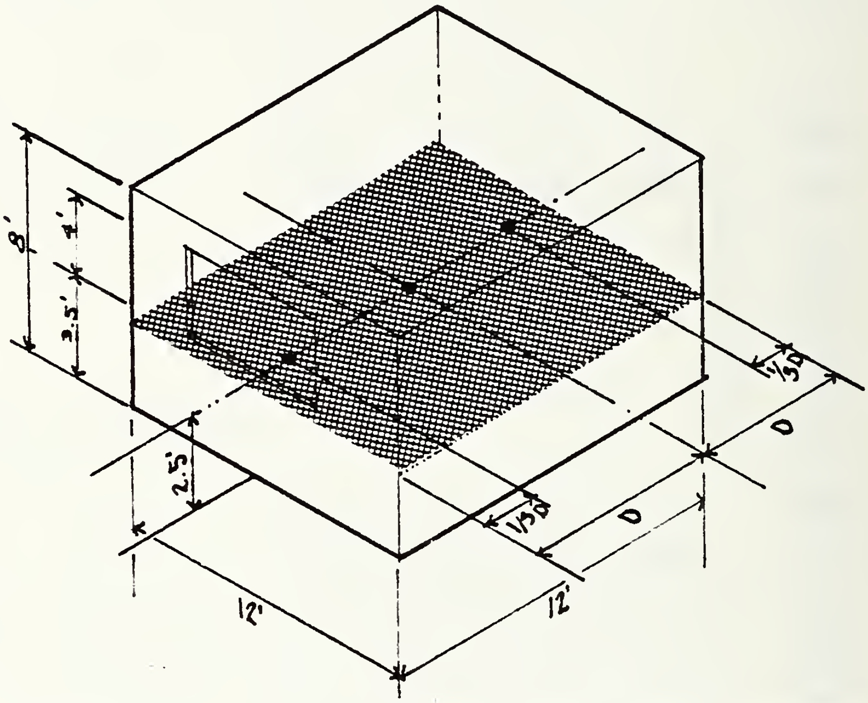
```
DECMBR

DAY  DRY    MAX  MIN  WIND    RADIATION ON SURFACE    BTU/F2
     BULB  TEMP TEMP SPEED
     TEMP
         F.DEG.       MPH     S 1      S 2     S 3      S 4
 1    51.   57.  42.   12.    342.    159.    266.    293.
 2    37.   42.  31.    9.    583.    187.    324.    429.
 3    44.   53.  38.   10.    288.    152.    259.    233.
 4    42.   47.  35.   11.   1943.    226.    709.    682.
 5    43.   50.  36.    9.    367.    161.    271.    293.
 6    40.   45.  32.   11.   2025.    243.    722.    709.
 7    38.   48.  32.    4.   1065.    218.    639.    345.
 8    40.   49.  31.    5.   1108.    222.    330.    658.
TOTAL
MONTH  2.   57.  31.    0.    965.    196.    440.    455.
```

Fig. 3.11 Hours of useable daylighting in a specified room are reported. Useable hours exclude hours when occupancy levels in a space are below 10%; for example, during holidays or weekends in offices.



```
JANURY

DAY       HOURS OF USEABLE DAYLIGHT/DAY
        R 1     R 2     R 3     R 4
  1      8.      6.      7.      7.
  2      0.      0.      0.      0.
  3      8.      0.      5.      5.
  4      8.      6.      6.      6.
  5      8.      7.      6.      7.
  6      8.      7.      6.      7.
  7      0.      0.      0.      0.
  8      0.      0.      0.      0.
  1      8.      5.      6.      6.

FEBRUY

DAY       HOURS OF USEABLE DAYLIGHT/DAY
        R 1     R 2     R 3     R 4
  1      0.      0.      0.      0.
  2      8.      8.      8.      8.
  3      8.      8.      8.      3.
  4      8.      3.      8.      7.
  5      8.      8.      8.      8.
  6      0.      0.      0.      0.
  7      0.      0.      0.      0.
  8      0.      0.      0.      0.
  2      8.      7.      8.      8.
```

Fig. 3.12 Average daily daylighting levels calculated for three points along the midline of a room. The position of the points is calculated in SOLITE and is reported on the output table in feet measured from the window towards the rear wall of a room.



```
JANURY

DAY          FOOT CANDLES ON WORKING PLANE
            DISTANCES FROM WINDOW IN FEET
        R 1             R 2              R 3              R 4
FT   2.   6.  10.    2.   6.  10.    2.   6.  10.    2.   6.  10.
 1 146.  36.  22.   50.   9.   7.   75.  14.  11.   49.  13.  10.
 2 605.249.  88.   27.   6.   6.   55.  13.  11.   78.  14.  13.
 3 769.271.103.   23.   6.   6.   88.  15.  14.   85.  16.  15.
 4   95.  31.  18.   47.   8.   6.   43.  11.   8.   46.  12.   9.
 5 124.  42.  21.   47.   8.   6.   43.  11.   8.   45.  12.   9.
 6   85.  29.  17.   51.   9.   6.   44.  11.   8.   46.  12.   9.
 7 229.  70.  33.   39.   7.   6.   59.  12.   9.   47.  12.   9.
 8 106.  33.  20.   43.   8.   6.   43.  11.   8.   56.  13.  10.
 1 270.  95.  40.   41.   8.   6.   56.  12.  10.   57.  13.  10.

FEBRUY

DAY          FOOT CANDLES ON WORKING PLANE
            DISTANCES FROM WINDOW IN FEET
        R 1             R 2              R 3              R 4
FT   2.   6.  10.    2.   6.  10.    2.   6.  10.    2.   6.  10.
 1 108.  37.  21.   64.  11.   8.   56.  14.  10.   59.  15.  11.
 2 109.  38.  22.   65.  11.   8.   57.  14.  10.   60.  16.  11.
 3 111.  38.  22.   66.  12.   8.   57.  14.  10.   61.  16.  11.
 4 704.142.  83.   33.   8.   7.  109.  19.  17.  107.  20.  17.
 5 114.  40.  23.   67.  12.   9.   59.  15.  11.   67.  18.  12.
 6 423.  92.  55.   42.   9.   7.   57.  16.  13.  151.  29.  20.
 7 407.  96.  56.   46.   9.   8.  109.  21.  16.   68.  21.  15.
 8 165.  47.  27.   63.  11.   8.   58.  15.  11.   76.  17.  13.
 2 268.  66.  39.   56.  10.   8.   70.  16.  12.   81.  19.  14.
```

Fig. 3.13 Labelled data file of solar radiation per square metric (as opposed to total gain on surface) is written to logical unit 11. The daily data are summed for a daily total, reported in the last row of each day.

```
JANURY   1 SOLAR B/HFT2 ON THE SURFACE AND ROOMS
IHR    R 1      R 2     R 3     R 4
  1      0.       0.      0.      0.
  2      0.       0.      0.      0.
  3      0.       0.      0.      0.
  4      0.       0.      0.      0.
  5      0.       0.      0.      0.
  6      0.       0.      0.      0.
  7      0.       0.      0.      0.
  8      2.       1.      0.      1.
  9      9.       3.      1.      3.
 10     15.       5.      2.      5.
 11     20.       7.      3.      6.
 12     22.       7.      9.      9.
 13     21.       7.      8.      9.
 14     18.       6.      5.      3.
 15     79.      20.     57.      3.
 16     84.       2.    105.      1.
 17      0.       0.      0.      0.
 18      0.       0.      0.      0.
 19      0.       0.      0.      0.
 20      0.       0.      0.      0.
 21      0.       0.      0.      0.
 22      0.       0.      0.      0.
 23      0.       0.      0.      0.
 24      0.       0.      0.      0.
DAY    270.      58.    191.     39.


JANURY   2 SOLAR B/HFT2 ON THE SURFACE AND ROOMS
IHR    R 1      R 2     R 3     R 4
  1      0.       0.      0.      0.
  2      0.       0.      0.      0.
  3      0.       0.      0.      0.
  4      0.       0.      0.      0.
  5      0.       0.      0.      0.
  6      0.       0.      0.      0.
  7      0.       0.      0.      0.
  8     21.       1.      0.     31.
  9     90.       5.      2.     86.
 10    156.      25.      2.     98.
 11    183.      16.      2.     51.
 12    195.      14.      3.      9.
 13    213.      17.     31.      5.
 14     83.      14.     35.      4.
 15     47.      13.     31.      3.
 16     61.       3.     72.      1.
 17      0.       0.      0.      0.
 18      0.       0.      0.      0.
 19      0.       0.      0.      0.
 20      0.       0.      0.      0.
 21      0.       0.      0.      0.
 22      0.       0.      0.      0.
 23      0.       0.      0.      0.
 24      0.       0.      0.      0.
DAY   1048.     106.    178.    287.
```

Fig. 3.14 Unlabelled version of the data file shown in Fig. 3.13 used for output to main-frame computer programs (eg. DEROB). The data file format description is listed below:

FORMAT(1X,I4,10F9.2)

```
   1       0.       0.       0.       0.
   2       0.       0.       0.       0.
   3       0.       0.       0.       0.
   4       0.       0.       0.       0.
   5       0.       0.       0.       0.
   6       0.       0.       0.       0.
   7       0.       0.       0.       0.
   8       0.       0.       0.       0.
   9       1.       1.       1.       2.
  10       1.       1.       2.       3.
  11       2.       1.       3.       3.
  12       2.       1.       5.       5.
  13       2.       1.       4.       5.
  14       2.       1.       3.       2.
  15      65.       1.      56.       3.
  16      80.       1.     105.       1.
  17       0.       0.       0.       0.
  18       0.       0.       0.       0.
  19       0.       0.       0.       0.
  20       0.       0.       0.       0.
  21       0.       0.       0.       0.
  22       0.       0.       0.       0.
  23       0.       0.       0.       0.
  24       0.       0.       0.       0.
         154.       9.     178.      23.
   1       0.       0.       0.       0.
   2       0.       0.       0.       0.
   3       0.       0.       0.       0.
   4       0.       0.       0.       0.
   5       0.       0.       0.       0.
   6       0.       0.       0.       0.
   7       0.       0.       0.       0.
   8      19.       0.       0.      31.
   9      80.       1.       2.      85.
  10     150.       2.       3.      99.
  11     176.       2.       4.      52.
  12     188.       2.       4.      10.
  13     204.       2.      32.       5.
  14      63.       2.      33.       4.
  15      33.       1.      29.       2.
  16      55.       1.      71.       1.
  17       0.       0.       0.       0.
  18       0.       0.       0.       0.
  19       0.       0.       0.       0.
  20       0.       0.       0.       0.
  21       0.       0.       0.       0.
  22       0.       0.       0.       0.
  23       0.       0.       0.       0.
  24       0.       0.       0.       0.
         967.      13.     179.     289.
```

4. IMPLEMENTATION OF SOLITE

SOLITE was written in standard Fortran IV on the UNIVAC 1108 computer at NBS. Changes in the code must be made in order for the program to compile on other computers.

4.1 USE OF THE PROGRAM FOR RESEARCH

In its present form, SOLITE may most effectively be used as a research tool. The limitations listed in the next chapter preclude its implementation as widely used software. It is best suited for:

1. conversion of cloud based weather data files to weather data files with radiation;
2. parametric analysis of window glazing unit transmission and light absorption;
3. parametric analysis of solar gain on surfaces in an urban environment;
4. analysis of daylighting options in rooms facing street canyons;
5. creation of hourly heat gain data files for thermal node network analysis algorithms. Both unformatted and tabulated forms are available, allowing the user to choose the format best suited to his needs. Large scale programs would require unformatted listings, while small scale thermal analysis programs on hand-held calculators may benefit from the tabulated SHORTYEAR files.

4.2 EXAMPLE OF ALGORITHM USE: Daylighting in an Urban Area

Daylighting potential of a typical office building in Baltimore Md. was computed using SOLITE. A series of room configurations, interior absorptances, and window reflector treatments were run and the resulting daylighting availability data in a hypothetical office were compared. In addition, the solar intensity on the windows and the resulting hours of daylighting on the workplane of this typical 12 ft. by 12 ft. office were determined for different street widths found in front of, and beside the modelled office structure. An area of Baltimore's Central Business District was chosen as a case study. From this area, a typical building condition was chosen. A randomly chosen area in Baltimore's Central Business District provides the environment for the analysis of daylighting potential. This area is illustrated in Fig. 4.1. SOLITE cannot reproduce the environment in any great detail. An example of a Central Business district and the simplification of the urban forms for SOLITE analysis is shown in Fig. 4.2.

A typical building in this environment is shown in Fig. 4.3. The analysis performed in this example is based on the building illustrated in the figure. Although regression analyses have not been performed, the figures illustrate a dependence of the daylighting amount on the height of the office in relation to the buildings around it, and the type of office interior finishes and street canyon surface reflectances. As the position of the hypothetical office was shifted from the bottom through the top floor of the structure, (Fig. 4.4) an increase in available daylighting was discerned. An office with darker interior surfaces suppressed available daylight (Fig. 4.5) as did deeper office plans. Daylighting in a 40 ft. deep, 40 ft. wide office is only possible in the first 12 ft. closest to the window (Fig. 4.6). However, in the case of both the typical small office and the larger office, an increase of overall street canyon

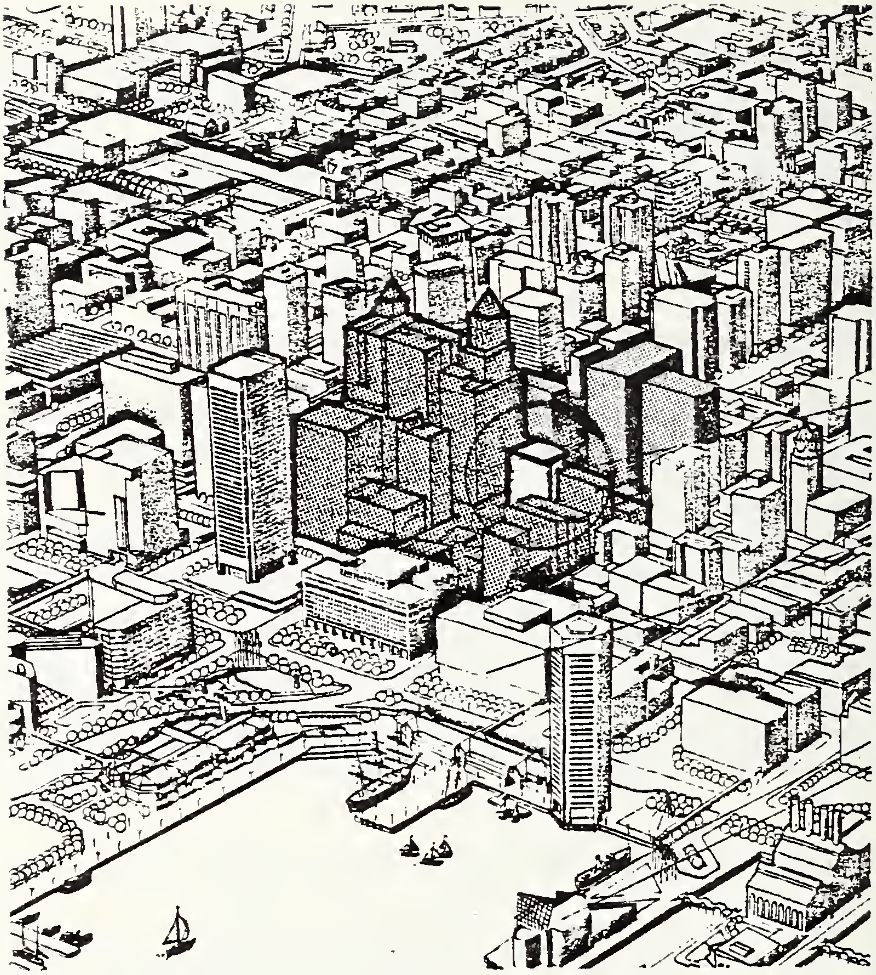
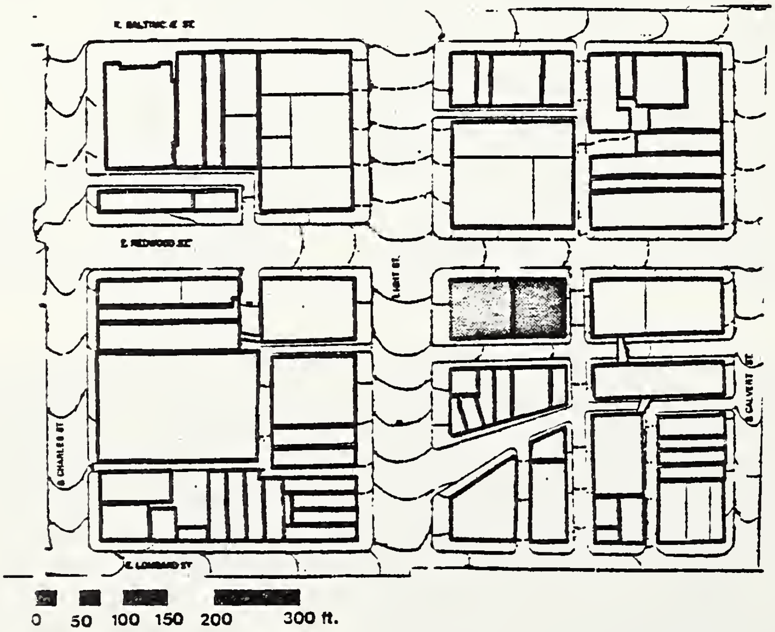


Fig. 4.1 Central Business District in Baltimore, Md. Sample building is chosen from the shaded area. Typical buldings in this limited survey could not be defined, thus two random sample buildings were chosen. These are shown shaded in the site plan illustrated below.



reflectances increased the daylighting available in the office. Conclusions drawn from this initial run of SOLITE must be tempered with the realization that the algorithm limiting "daylight hours" with respect to glare is simplistic. High albedos in the street canyon may lead to unacceptable glare conditions not indicated by the program.

The run also indicated a significant difference between the daylighting potential with an east facing window as compared with that of a west facing window. Due to daylight savings time, the the workplane with a west facing window received considerably more light during office working hours than did the corresponding workplane with an east facing window. This may be interpreted from all Figs. 4.4 through 4.7.

Solar radiation available on a window qualitatively indicates the amount of daylighting received in a room. Solar radiation and useable hours of daylight per day for a typical building and street configuration (Fig. 4.8) are illustrated in Fig. 4.9. Strict correlation between available solar radiation and daylight potential has not been calculated but it appears that some scatter will result since SOLITE contains algorithms that allow beam interreflection within a street canyon which daylighting algorithms do not account for. An example of street interreflections leading to significantly increased solar gain on a building surface, and increased daylighting to the interior is illustrated by the scene in Fig. 4.10 of Atlanta, GA. where the Coastal States building reflects midday solar radiation onto the Hyat Regency's north-facing facade. In addition, the occupancy of the office affects the amount of "useful" daylight available. During lunch, when offices are deserted, useable daylight is reduced to zero as the occupants are not there to enjoy its benefits.

Both SOLITE based examples of CBD offices indicate the lower potential daylighting in the deep street canyons of the Central Business District. With further parametric studies of similiar zones in a city, and with the realization that a large portion of the commercial office building load is lighting, building envelopes conducive to daylight may be prescribed. Parametric studies of street surface and building facade surface colors will lead to codes allowing optimal daylighting provisions for offices in CBD areas.

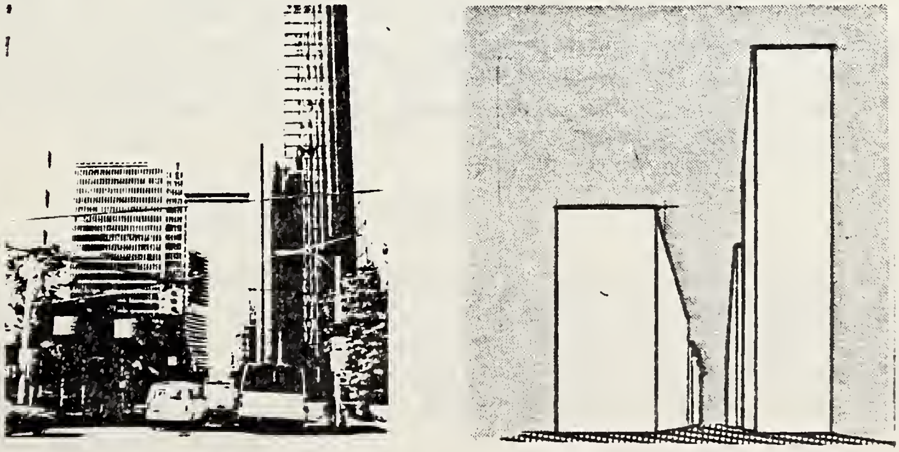


Fig. 4.2 SOLITE requires simplified descriptions of the environment as shown by the reduction of the CBD scene in the photograph into a series of similiar, regular blocks.

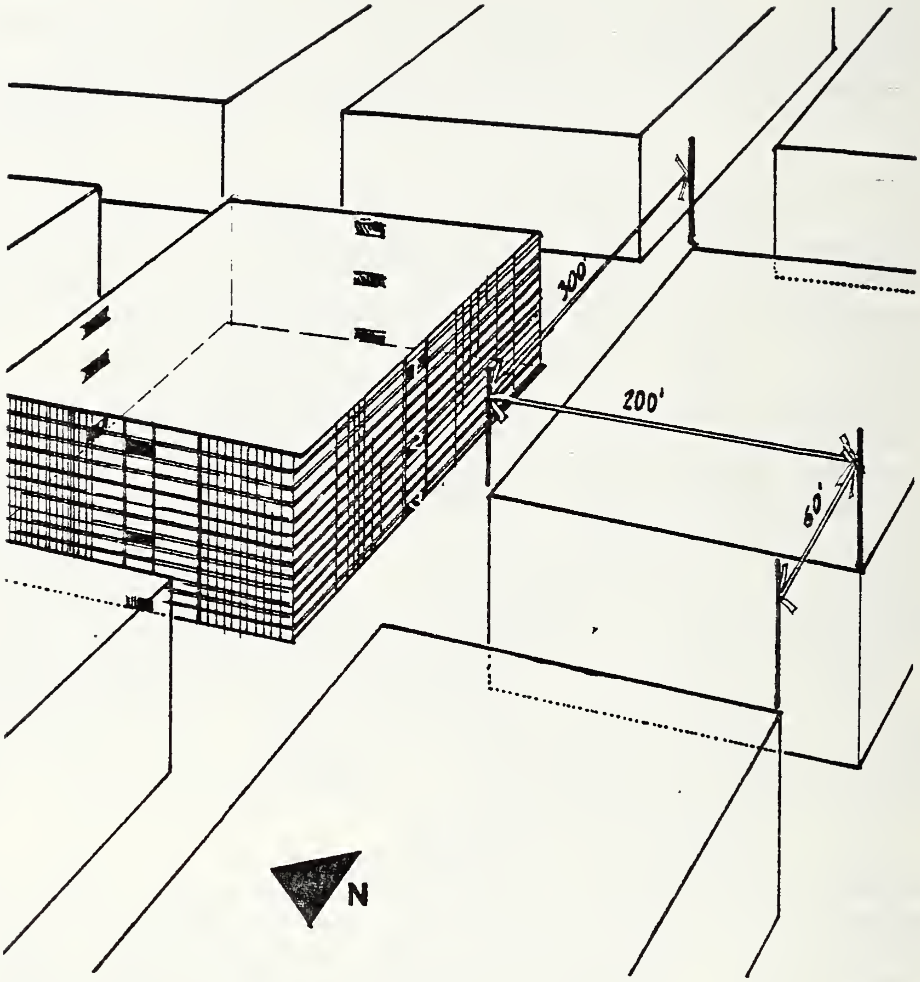


Fig. 4.3 A simplified description of the example building's environment. In a series of runs, the amount of useable daylight was determined for a typical office located on each face of the sample 13 storey building. The reflectances of the surrounding surfaces are: 0.2 for the street surface, and 0.4 for the building surfaces. Office locations on the first, sixth and twelfth floor levels were tested (at 10, 60, and 120 ft. levels above the street respectively).

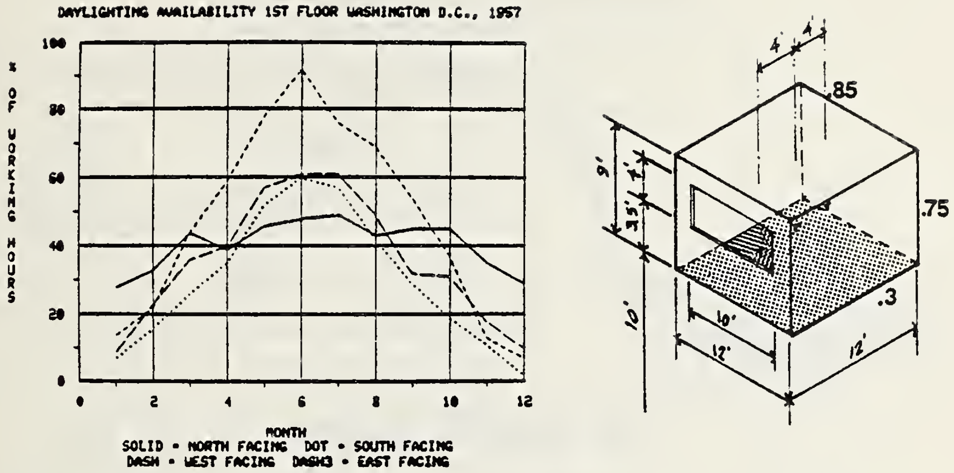


Fig. 4.4.a A typical office in the CBD example block at the first floor level is used as an example to calculate the available daylighting as a percentage of required daylighting. Dimensions of the office and window are indicated. The window is double glazed with the outside light's normal transmission assumed to be 0.74 and the inside light's normal transmission assumed to be 0.84. Reflectance ratios of the inside wall finishes are shown on the drawing.

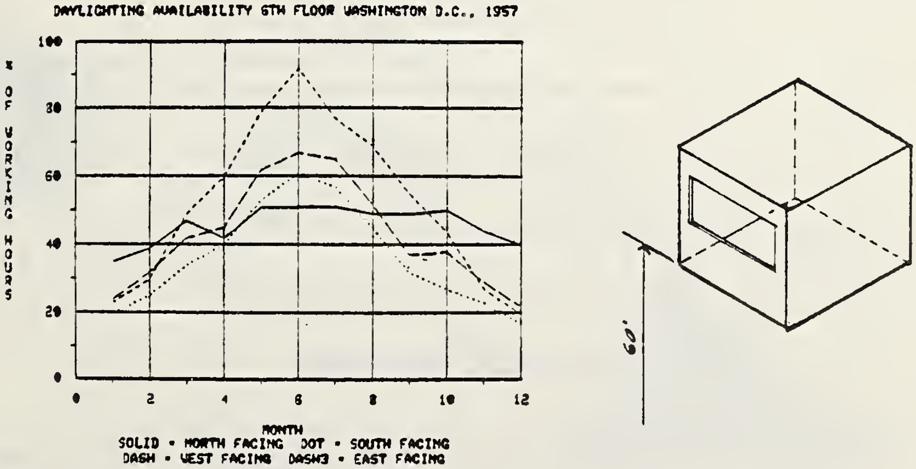


Fig. 4.4.b The available daylighting data for the typical office in the CBD example block on the 6th floor are shown for four principal window orientations. The southern exposure provides a constant light level whereas the western orientation has a relatively high summer lighting level peak (qualitatively indicating glare problems) and a low daylighting potential during winter.

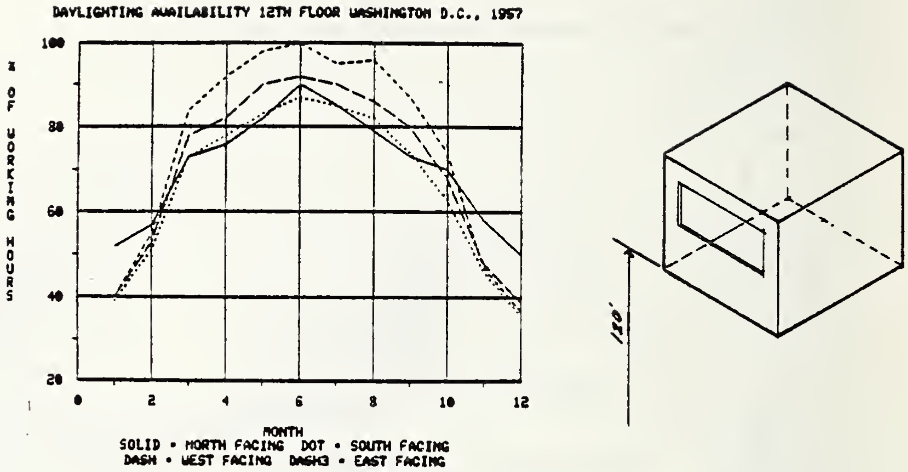


Fig. 4.4.c A typical office in the CBD example block , on the twelfth floor. All orientations have daylighting potential due to good exposure to sky luminance. Glare (only simplistically evaluated in SOLITE) will be problematic in this case.

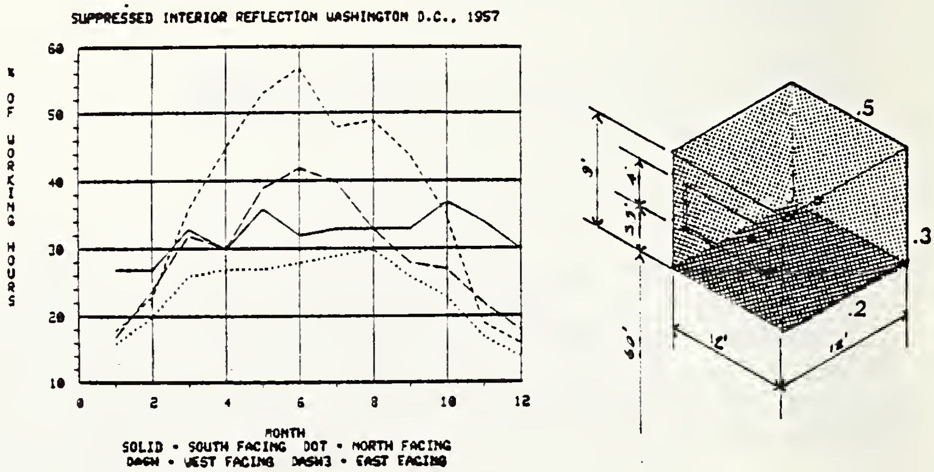


Fig. 4.5 A typical office in the CBD example block. Internal wall, ceiling and floor reflectances have been changed to the values indicated. The office is assumed to be on the sixth floor. A sharp reduction of available daylighting is indicated when compared with the base case shown in Fig. 4.4.b.

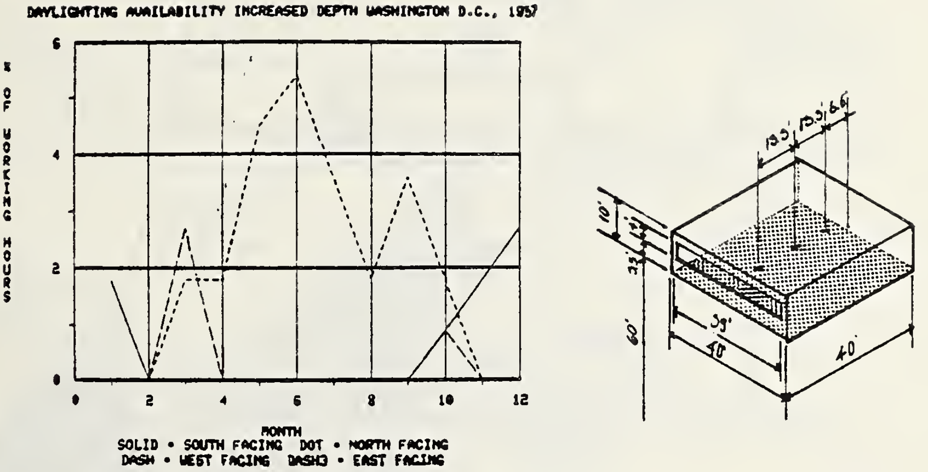


Fig. 4.6 An "open office" situation without partition walls or dividers, and with the same wall reflectances as shown for the office of Fig. 4.4.a. The light level calculations are an average of the three points shown on the drawing. Apart from the high light levels near the window in this case, the remaining two calculation points are deep within the room cavity and the calculated low light levels were expected.

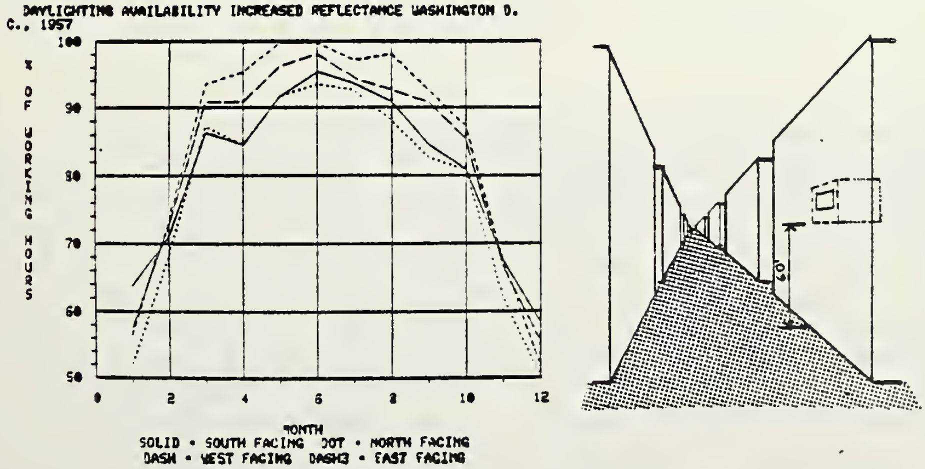


Fig. 4.7.a The typical office is shown fronting a street canyon with increased surface reflection coefficients. The curves illustrate the increase of daylightng potential for a sixth floor office. External street canyon reflectances are increased to 0.9.

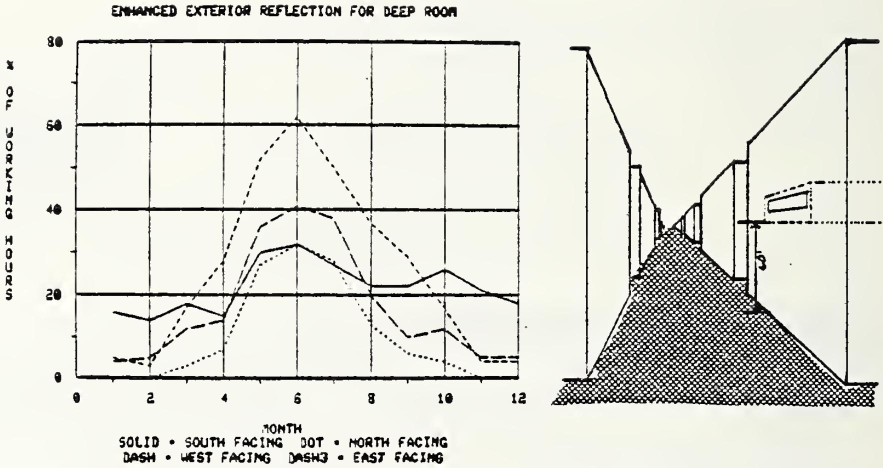


Fig. 4.7.b An increase of daylight potential is observed for the case of a deep office with increased external reflection coefficients. The relative position of the office in the street canyon has remained unchanged from the previous position in this example.

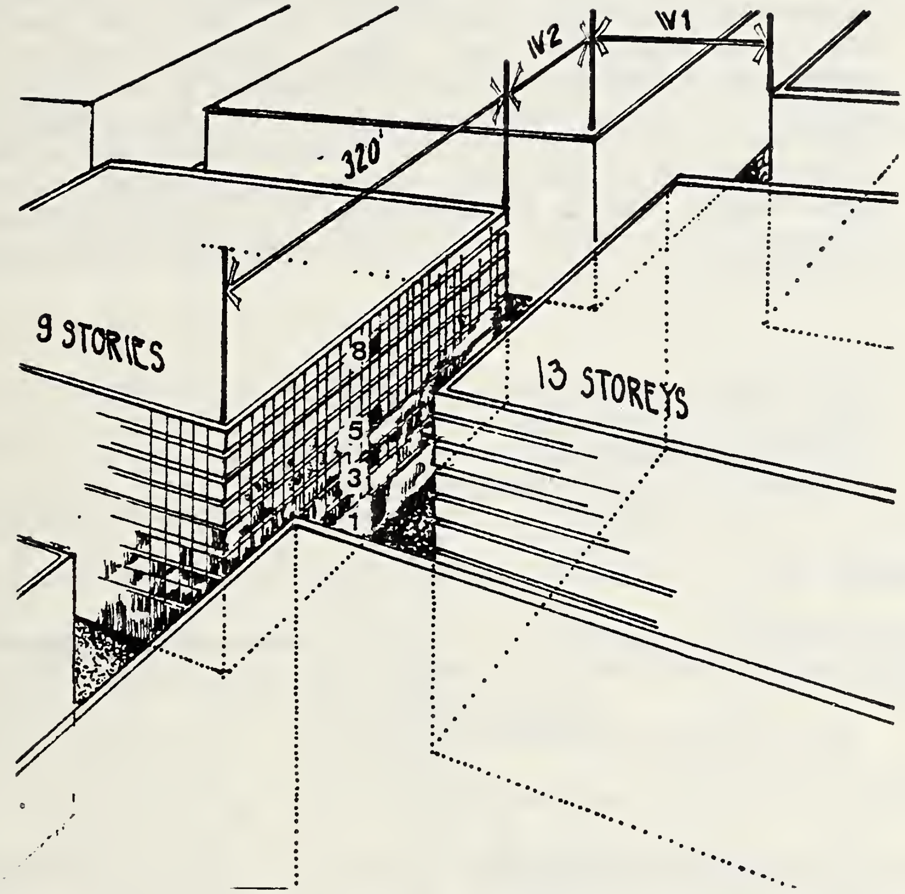
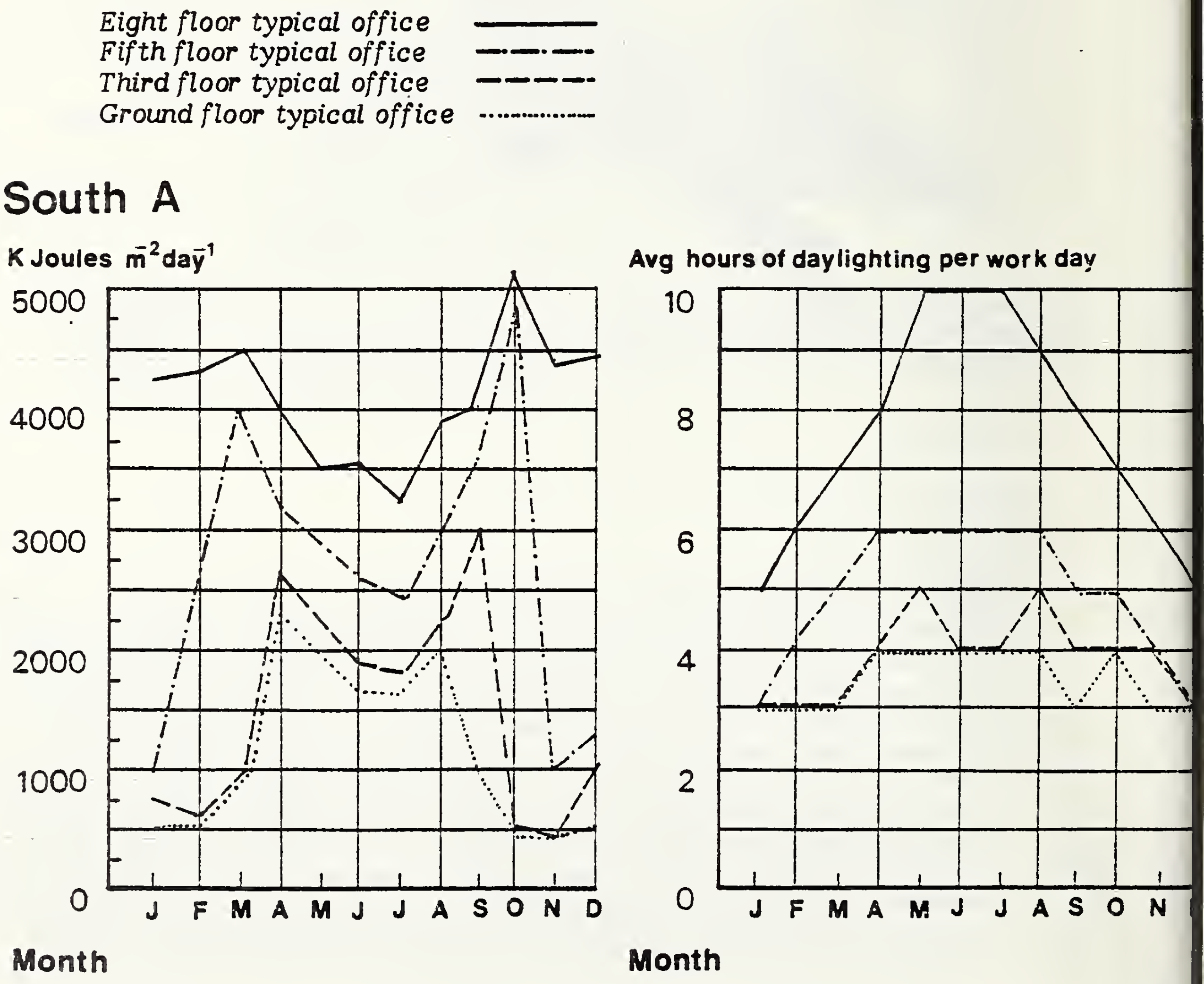
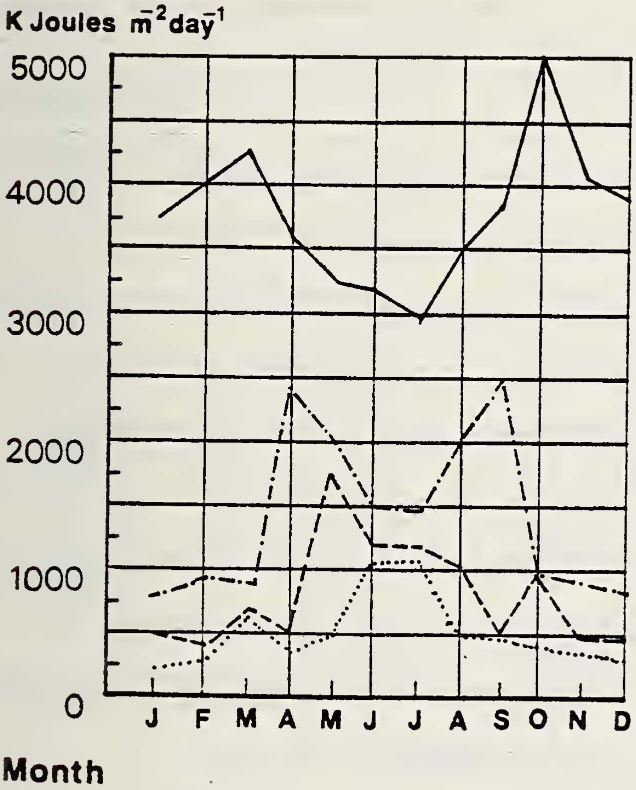


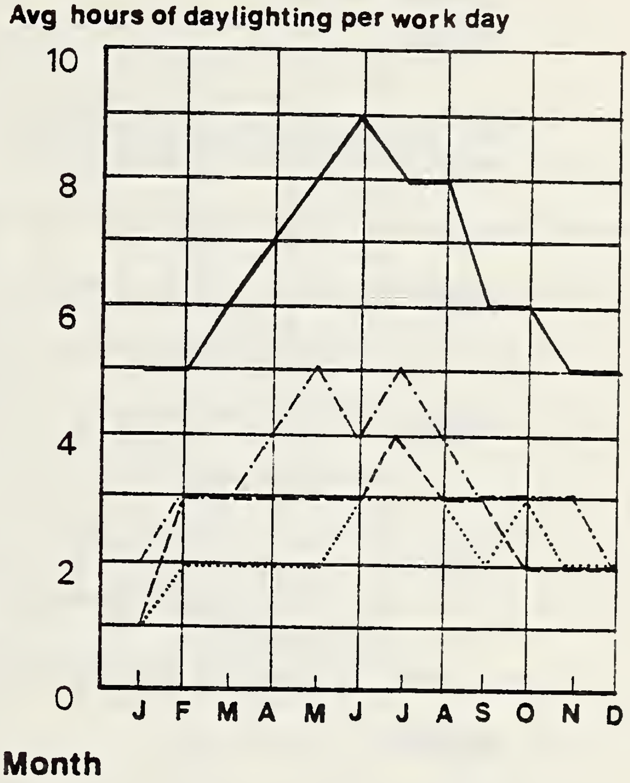
*Fig. 4.8 A second example CBD block illustrates a 9 storey sample building across from a 13 storey building. The following analysis includes the interreflection characteristics of the street. Solar radiation and daylight hours for four offices located at various heights were calculated (first floor,3.5 ft.,third floor, 33.5 ft.,fifth floor, 53.5 ft., and the eighth floor 83.5 ft.above street level), for all four facades of the illustrated building. Two conditions were examined: a wide street, and a narrow street condition. For the wide street, **W1=60 ft.** , and **W2=110 ft.** The narrow street is characterized by **W1=30 ft.** and **W2=20 ft.** In the following series of plots, results with wide streets are designated **A,** and plots of solar availability on windows with narrow streets are **B.** The street surface is bituminous, and the surrounding buildings comprise 60% glass and 40% concrete facades.*

Fig. 4.9 Data of solar availability and daylighting hours on average days per month on the described surfaces are indicated by the following plots. Facade orientations are indicated on the plots, and floor heights are indicated by keyed line types. ***Plot A*** *indicates surfaces facing* ***wide*** *streets,* ***plot B*** *indicates surfaces facing* ***narrow*** *street. Hours of available daylighting are daily averages per month from SHORTYEAR based data, and do not include times when the office occupancy was below 10% of the maximum expected occupancy. Output was converted to SI units from English inputs. One of the conclusions from these studies indicates that the width of the street on the north side does not influence daylight availability.*

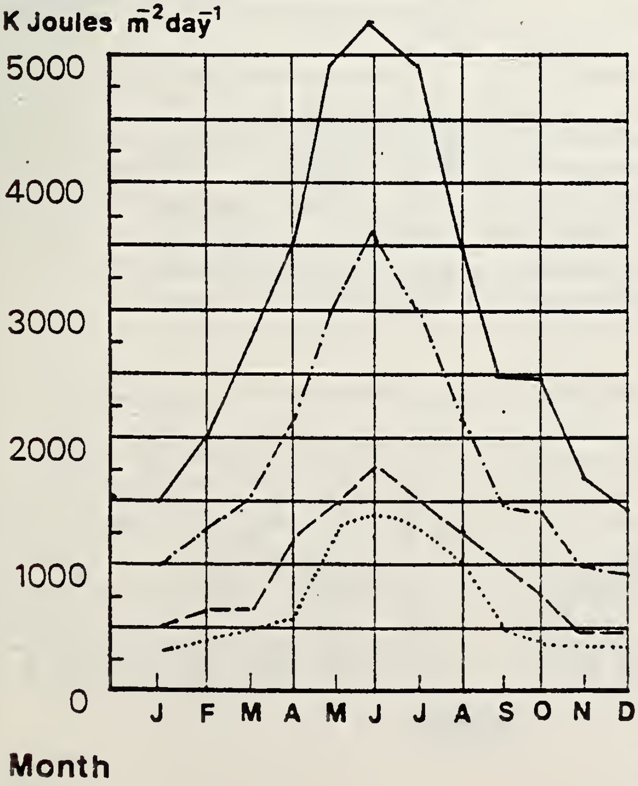


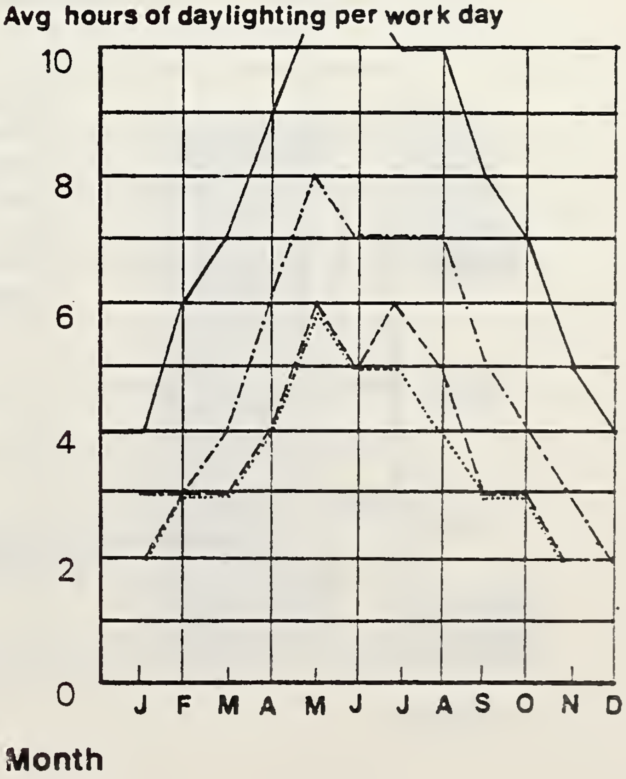
South B



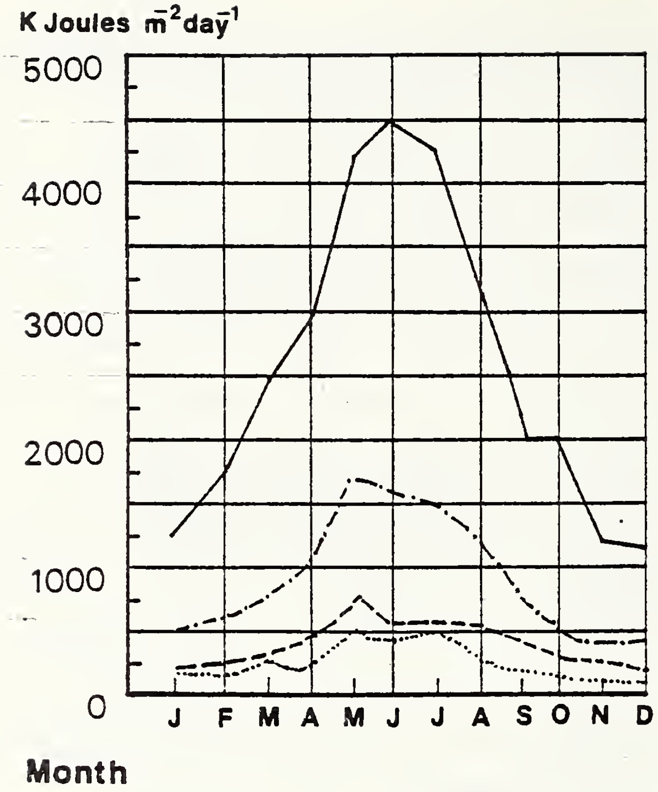


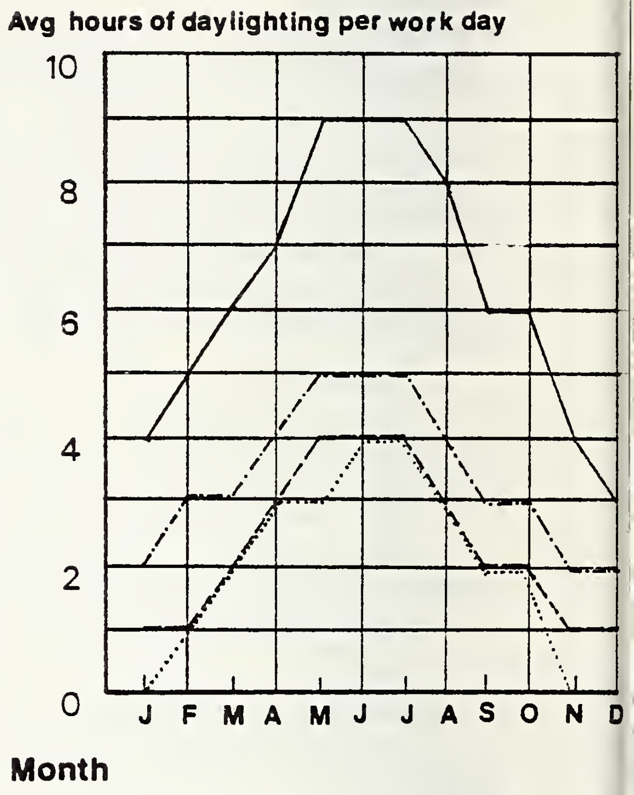
East A



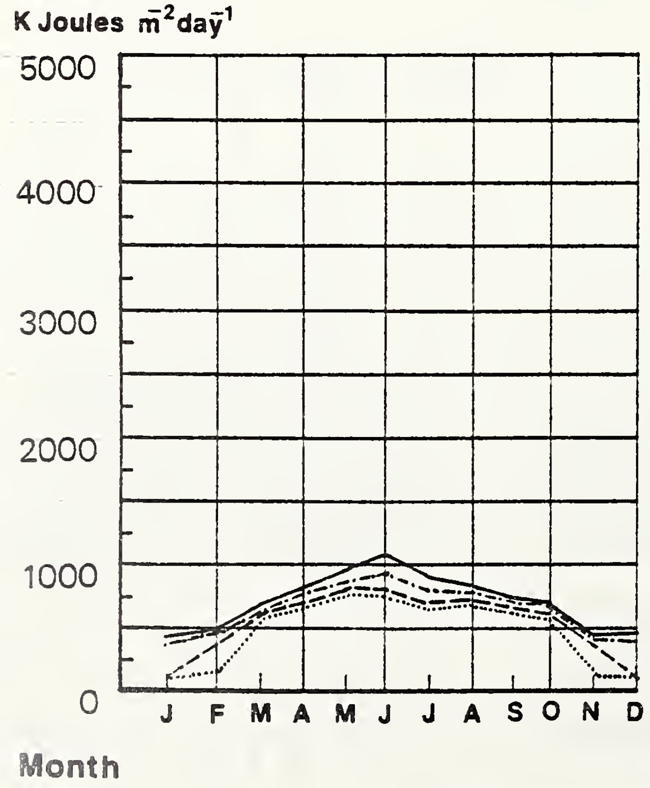


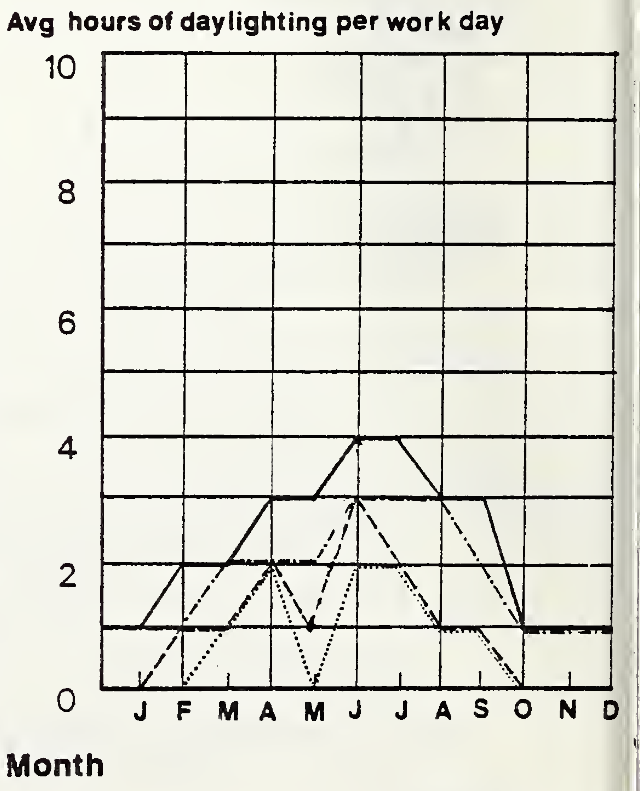
East B





North A





North B

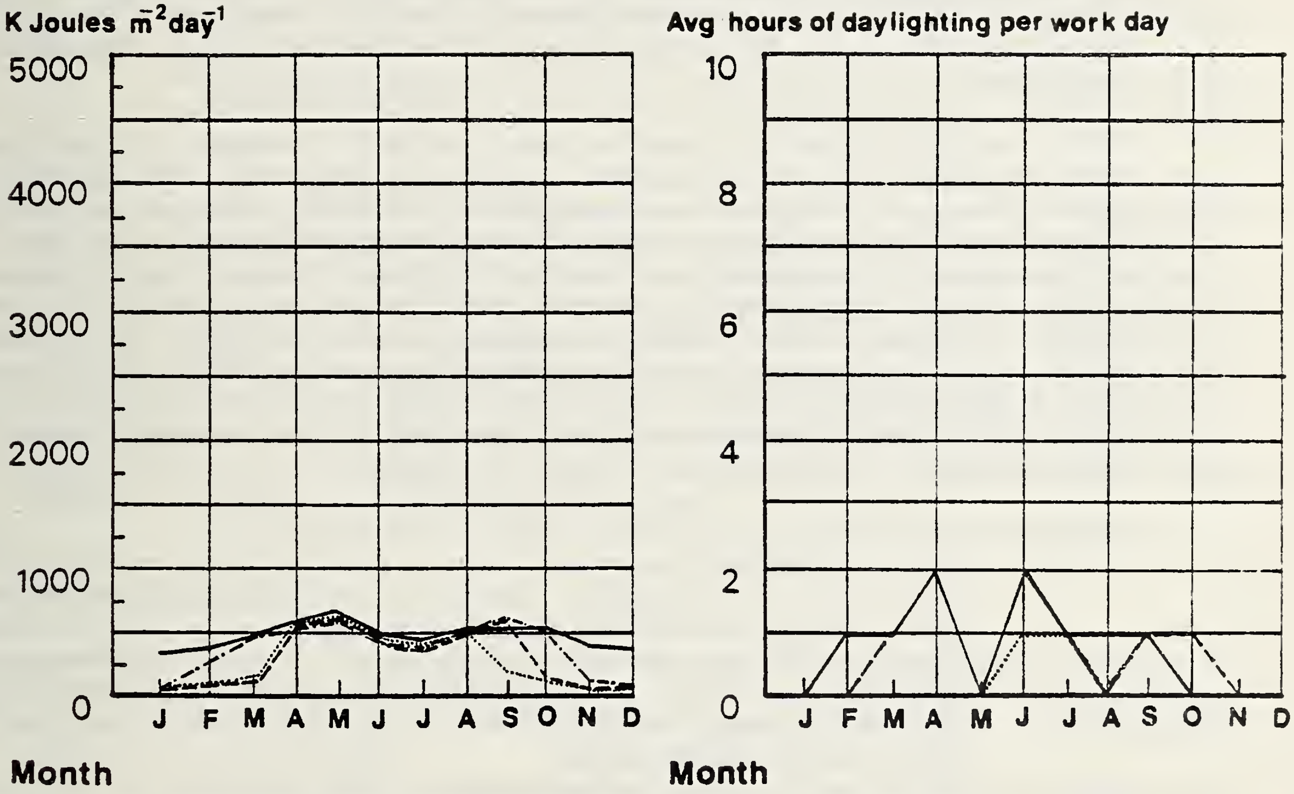
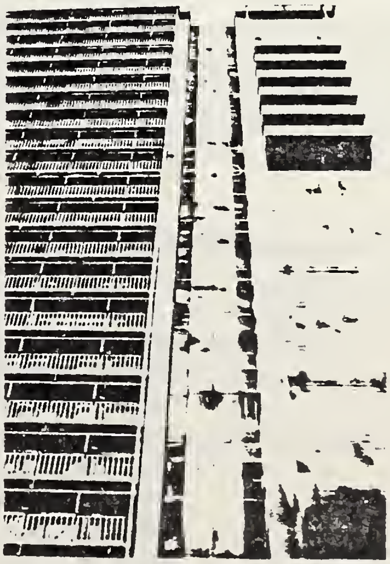


Fig. 4.10 Reflected radiation from the Coastal States building on the northwest facade of Hyatt Regency in Atlanta during early morning hours. Reflected radiation in urban environments may increase cooling loads or provide additional daylighting potential.



5. LIMITATIONS AND FUTURE WORK

As presented, SOLITE has a number of constraints. Further development of the program will allow its deployment by the intended user, the city planner. Future versions of SOLITE will incorporate "kinder" interactive interfaces, a more rigorous strategy for optimizing solar gain envelopes, and a larger selection of possible surface descriptions.

A solar availability algorithm should be able to optimally converge on a more complex zoning envelope than is allowed by this program. Although the edges describing the simple rectangular envelopes prescribed here could identify sloping shapes (with some help from the user), a different approach to the shading algorithm would allow more intricate opposing shapes, and more exact calculation of shadows. Ralph Knowles' [36] small scale solar access physical modelling procedure is an appropriate tool for the qualitative analysis of solar access in complex urban environments. But a need still exists for quantitative solar access modelling of geometries with similar complexity. Scott Wright's building shadow program is capable of analyzing shading on fairly complex shapes with a minimum amount of code. The program is listed in Appendix G, but has yet to be tied to the present version of SOLITE.

Additional constraints imposed by the program on the user include:

1. the irreversible entry of values. Once a value has been entered during the run, it may not be changed. Erroneous entries will cause run aborts. A "kinder" interaction that will allow default options to be chosen is required.
2. application of the program on a TTY terminal. Instead, a graphics package would greatly enhance the program's usefulness. Graphic interaction is necessary for input, output, and re-entry of required values by light-pen or graphic sketch-pad techniques.
3. the program's mainframe orientation. Although portions of the program may be used on mini or micro-computers, in its present form, the program is a mainframe computer based program. This limits SOLITE's applicability to users who have access to such facilities. In order for the software to be applied as envisioned, it should be applied on microcomputers, and thus be accessible to a large number of users.

SOLITE still requires a formal link to a thermal analysis program for realization of its initial goal. Presently, to achieve compatibility, output file formats must be changed to fit the format of the thermal analysis program's input files.

5.1 LIMITATIONS

SOLITE has seen only limited use during its development and its software contains a number of idiosyncracies of which the user should beware:

1. shadow and interreflected radiation subroutines assume a uniform building height opposite the surface being analyzed. Except for gaps created by cross-streets, the building line is assumed continuous.
2. cross street widths are assumed identical to each other.
3. only one window may be input per room. Thus solar gain and daylighting analysis for a room are confined to a single orientation. The program user must analyze multiple windows on one side as a single window.
4. radiation heat gains due to solar gain and room occupancy are spread

evenly within a room. In a thermal network analysis schedule, the heat gains and solar gains impact one node representing a room.

5. daylighting algorithms assume a spherical room configuration. Extreme deviations from a cubic room shape may cause errors in the interreflected daylighting portions of the program.
6. shading algorithms for the roof and overhangs simplify the surface by using geometric projection, and are not true representations of shading on the surface.
7. not all paths through the algorithm have been examined. Data from analysis have not been compared with other computer generated data bases. Care must be exercised when drawing conclusions from these data.
8. although the entry of variables for daylighting calculations is performed simultaneously with entry of solar gain descriptors, the two algorithms are separate. The daylighting algorithms do not access the BOUNCE and VFSRF subroutines that calculate the interreflection characteristics of the street. Daylighting algorithms must be tied to this portion of the analysis.

Algorithms in various reflection and shading subroutines (OVRHNG and VFF) are the newest additions to the program and have had limited use. Errors may occur when overhangs or reflectors are prescribed by the user.

5.2 FUTURE WORK

As an initial draft of solar availability software, SOLITE requires further development in order to eliminate the constraints and limitations described. The envisioned application of the software in planning offices by users with limited computing skills indicates two areas of need:

1. the development of solar availability software on micro/minicomputers for widespread distribution and use.
2. the development of computer graphic software to aid users with data entry and data analysis.

In addition to solar availability modelling, a formal link must be established with thermal analysis of environments where solar availability is being analyzed. This will lead to the development of solar potential zones in cities. In addition to these long-range goals, the algorithm is being improved by the use of a matrix calculation shading algorithm (Appendix G). Algorithms used in SOLITE are based on geometric analysis and use relatively large amounts of computing time.

In order to validate many of the calculation procedures used in SOLITE, measurements are required. The following list indicates the empirical data required for substantiation of assumptions incorporated in the program:

1. measurement of urban vs. rural radiation modifying coefficients.
2. measurement of cloud distribution on the sky vault and its influence on solar gain and daylighting.
3. measurement of the diffuse and spectral reflection characteristics of common building materials at various angles of incidence.

As this program has not been subjected to rigorous verification, a series of tests on the reliability of the major subroutines should be performed. These tests would encompass the shading, transmission, and view factor algorithms. Only after this is done can reliable conclusions be drawn.

APPENDIX A

ALGORITHM DESCRIPTIONS

The main program accesses a series of subroutines for the required calculations of solar gain and daylighting. The sequence of subroutines, and the parts of the program that are used, depend on the user's choice of run type. A number of tasks comprise the algorithm:

1. input data processing;
2. weather data input and manipulation;
3. solar radiation calculations including direct and diffuse radiation, as well as cloud modifier calculations;
4. surface orientation and street-canyon modified solar radiation calculations;
5. shading calculations;
6. surface transmission and absorption characteristics analysis, and
7. output data formatting.

Incidental gains in rooms and daylighting are also calculated by SOLITE, and the calculation procedures and internalized assumptions are presented in Appendices B and C respectively. Flowcharts in the appendices are all based on the master program flowchart shown in Fig. A.1. The flowcharts indicate the relative position and access points to the subroutines from the MAIN program.

A.1 INPUT DATA PROCESSING

The data input task is performed by a number of subroutines. A flow chart, shown in Fig. A.2, indicates the subroutine and program areas where the input data is processed. Required inputs include room type descriptors, general site descriptors, specific room and surface descriptors, and building occupancy descriptions. A distinction is drawn between "Surfaces" and "Windows" during the input prompting. A surface has no incidental internal heat gain characteristics and it is not associated with "occupancy" or daylight. A window, on the other hand, is an opening associated with a room. Occupant heat gains, and daylighting are calculated for rooms with windows. Surfaces require only position and glazing descriptors, (if glazing is present), whereas windows and their adjoining rooms require occupancy related information.

Input data are entered from logical unit 5 and the entered data are written to logical unit 7. A user may, subsequent to an initial interactive run and the creation of an input file at unit 7, add the created input file and suppress the computer generated input prompts. A datafile representing a hypothetical urban area is illustrated in section 3.3. The UNIVAC 1108 System Commands used to add the datafile is shown in Fig. A.3.

A.1.1 Input Data Processing

Format statements comprising the input data prompts are found at the end of both the MAIN program and subroutine SURFAC. (Listings of all programs and subroutines are

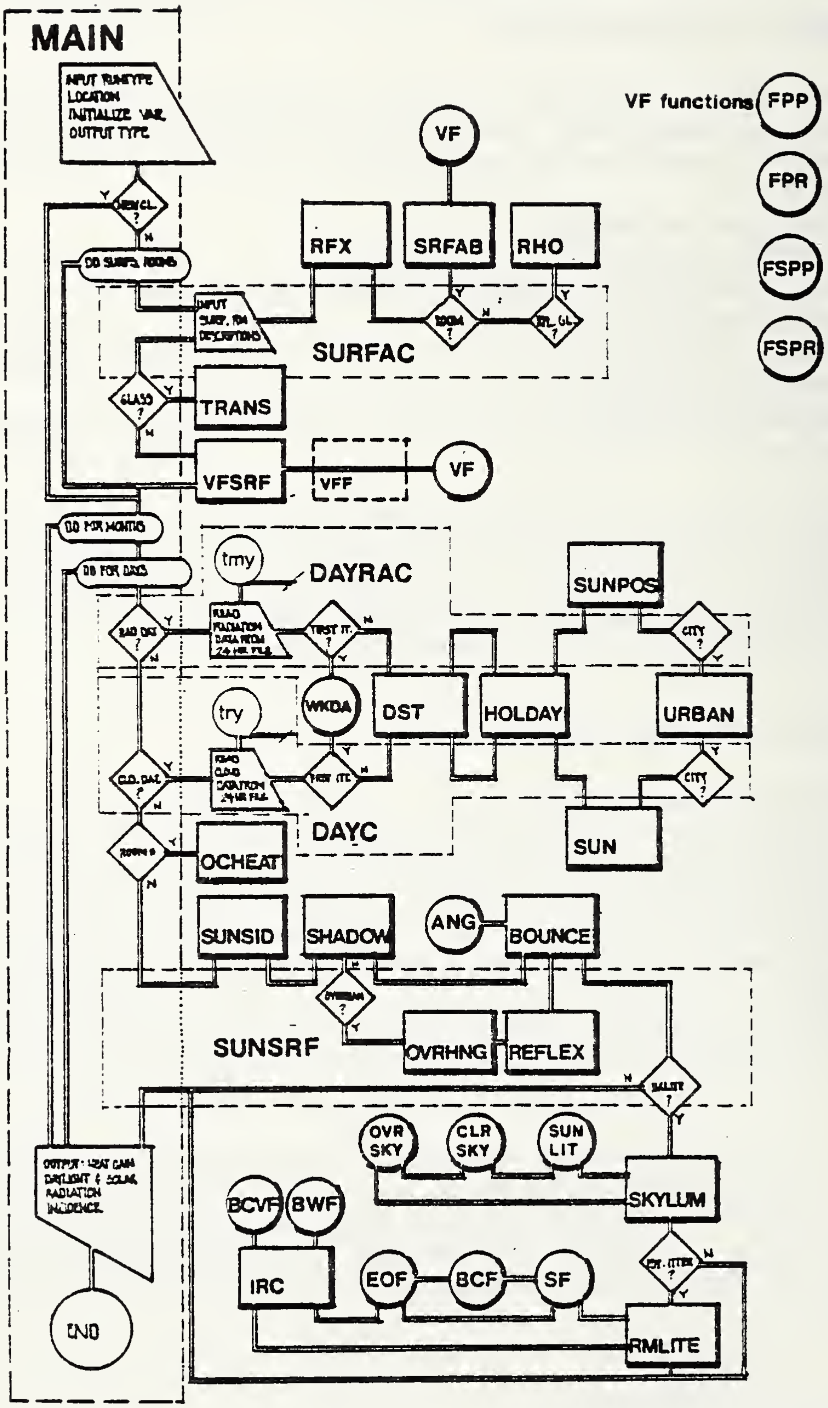


Fig. A.1 Flowchart of solar availability program SOLITE. Subroutines are indicated by **BOLD** type, and functions by circles. Note that returns from subroutines are not shown on this simplified flow chart. (Returns are to point of subroutine CALL statement.)

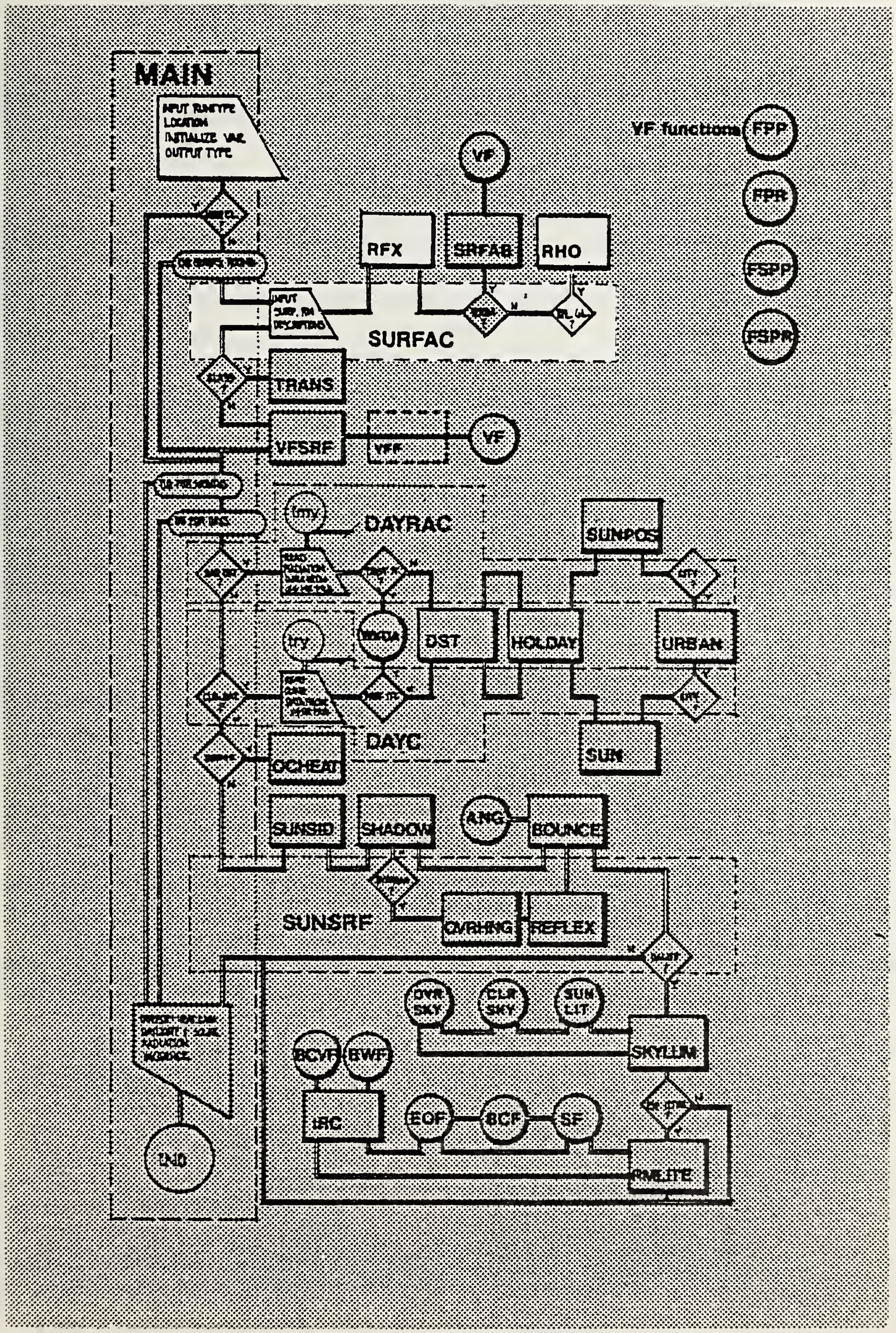
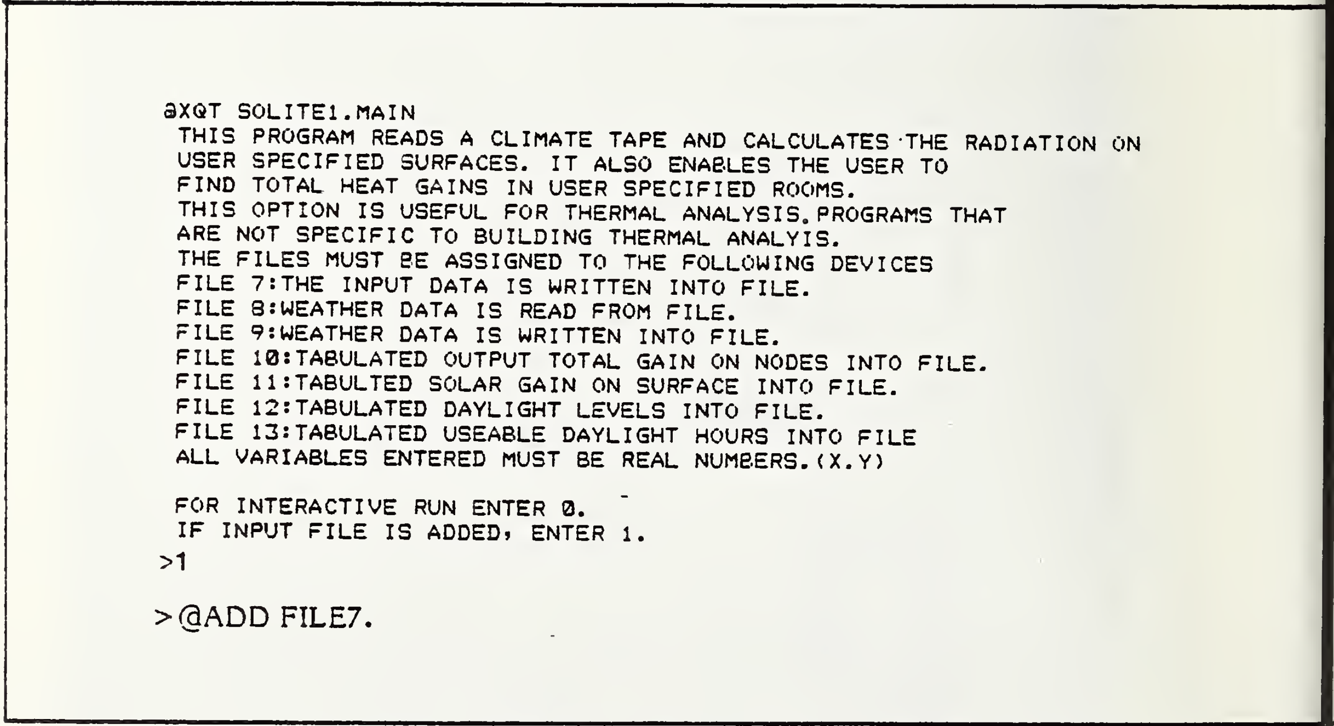


Fig. A.2 Flowchart of SOLITE indicating subroutines and areas in the program devoted to interactive input sequencing. These areas are highlighted.

found in Appendix D). Data are converted from SI units to English units (or visa versa) by reference to the specific conversion factors found in the CONV array of the MAIN program. The CONV array factors refer to the alphanumeric unit descriptors in array CON.

Input read by the main program includes:
1. run type descriptors (whether the run is for creating a new weather file or for calculating surface gains; whether the run uses a shortyear or long year; whether solar radiation exists in the weather data file or not, and whether the output is in the form of daily summaries or hourly files);
2. general site descriptors, (longitude and latitude, time zone, and elevation), and
3. room occupancy data (type of room classification as either retail, office commercial or residential; number of occupants, and designed electrical load).

Subroutine SURFAC prompts for specific information on window location and type:
1. the location of the window relative to the street canyon and the cross street;
2. the size of the window;
3. the types of materials comprising the street canyon for reflection calculations, and
4. the specifications of the window assembly.



```
@XQT SOLITE1.MAIN
 THIS PROGRAM READS A CLIMATE TAPE AND CALCULATES THE RADIATION ON
 USER SPECIFIED SURFACES. IT ALSO ENABLES THE USER TO
 FIND TOTAL HEAT GAINS IN USER SPECIFIED ROOMS.
 THIS OPTION IS USEFUL FOR THERMAL ANALYSIS.PROGRAMS THAT
 ARE NOT SPECIFIC TO BUILDING THERMAL ANALYIS.
 THE FILES MUST BE ASSIGNED TO THE FOLLOWING DEVICES
 FILE 7:THE INPUT DATA IS WRITTEN INTO FILE.
 FILE 8:WEATHER DATA IS READ FROM FILE.
 FILE 9:WEATHER DATA IS WRITTEN INTO FILE.
 FILE 10:TABULATED OUTPUT TOTAL GAIN ON NODES INTO FILE.
 FILE 11:TABULTED SOLAR GAIN ON SURFACE INTO FILE.
 FILE 12:TABULATED DAYLIGHT LEVELS INTO FILE.
 FILE 13:TABULATED USEABLE DAYLIGHT HOURS INTO FILE
 ALL VARIABLES ENTERED MUST BE REAL NUMBERS.(X.Y)

 FOR INTERACTIVE RUN ENTER 0.
 IF INPUT FILE IS ADDED, ENTER 1.
>1

>@ADD FILE7.
```

Fig. A.3 An example runstream using a previously created input data file (from logical unit 7) as an input file, and suppressing interactive prompts. Note the UNIVAC 1108 logical unit, and data file assignment sequence. This would be replaced by the PROGRAM statements on CYBER mainframes.

If glass surfaces are involved, subroutine RHO accesses parameters of the specified glazing types. Four types of glazing may be specified: reflective, heat absorbing, clear, and a glass of the user's own choice. In addition to glass, 10 other glazing materials may be chosen. Street canyon facade descriptors are input to RFX. Two materials may be input for each street canyon surface, for example, the facade opposite the room may comprise brick and glass. This subroutine keeps track of the street the user is describing (whether primary or secondary) and also keeps track of the surface materials and amounts of surface materials comprising a surface. Alphanumeric arrays found in subroutine RHO prompt the user for the proper street canyon plane.

A.1.2 Weather Data Input

Weather file formats are specified in section 3.1. Data are read from logical unit 8 by subroutines DAYC or DAYRAC depending on the type of weather data files created. In both cases, hourly weather data are necessary. DAYC is called if only cloud data are available (eg. TRY, 1440). DAYRAC is called when direct normal and total horizontal solar radiation data are available in the weather file. As SOLMET typically provides only direct normal radiation for the sites it covers, DAYRAC will calculate horizontal radiation and develop a diffuse to direct component ratio (using the Kimura/Stephenson algorithm) from the associated cloud data. A flowchart illustrating the position of the subroutines accessing weather files is shown in Fig. A.4. The following descriptions of algorithms use the variable names found in the program listings in order to allow the reader easier access for possible changes to the program.

The user must prepare a weather data file for the program to access NOAA data. The read statement for the datafile with only cloud data is:
READ(8) DBT, DPT, WBT, WSP, BPR, CCT, TOC, WDR, YY, IYEAR, IMON, IDAY, IC

The read statement for a file containing radiation data is:
READ(8) DBT, DPT, WBT, WSP, BPR, CCT, TOC, WDR, RDT, RDR, IYEAR, IMON, IC

Variable descriptions are given in section 3.1. Weather files for the user specified months of the year are re-written to logical unit 9 in the following format:

WRITE (9) DBT, DPT, WBT, WSP, BPR, CCT, TOC, WDR, RDT, ROR, IYEAR, MON, DAY, IC
where:

DBT	Dry Bulb Temperature	(F^{o} or C^{o})
DPT	Dew Point Temperature	(F^{o} or C^{o})
WBT	Wet Bulb Temperature	(F^{o} or C^{o})
WSP	Wind speed	(Knots, ms^{-1})
BPR	Barometric pressure	(in HG, KPa)
CCT	Cloud cover, total	(from 0. to 10. tenths)
TOC	Type of cloud:	0=cirrus 1=stratus 2=other (cumulus)
WDR	Wind direction in 16ths clockwise from the north	

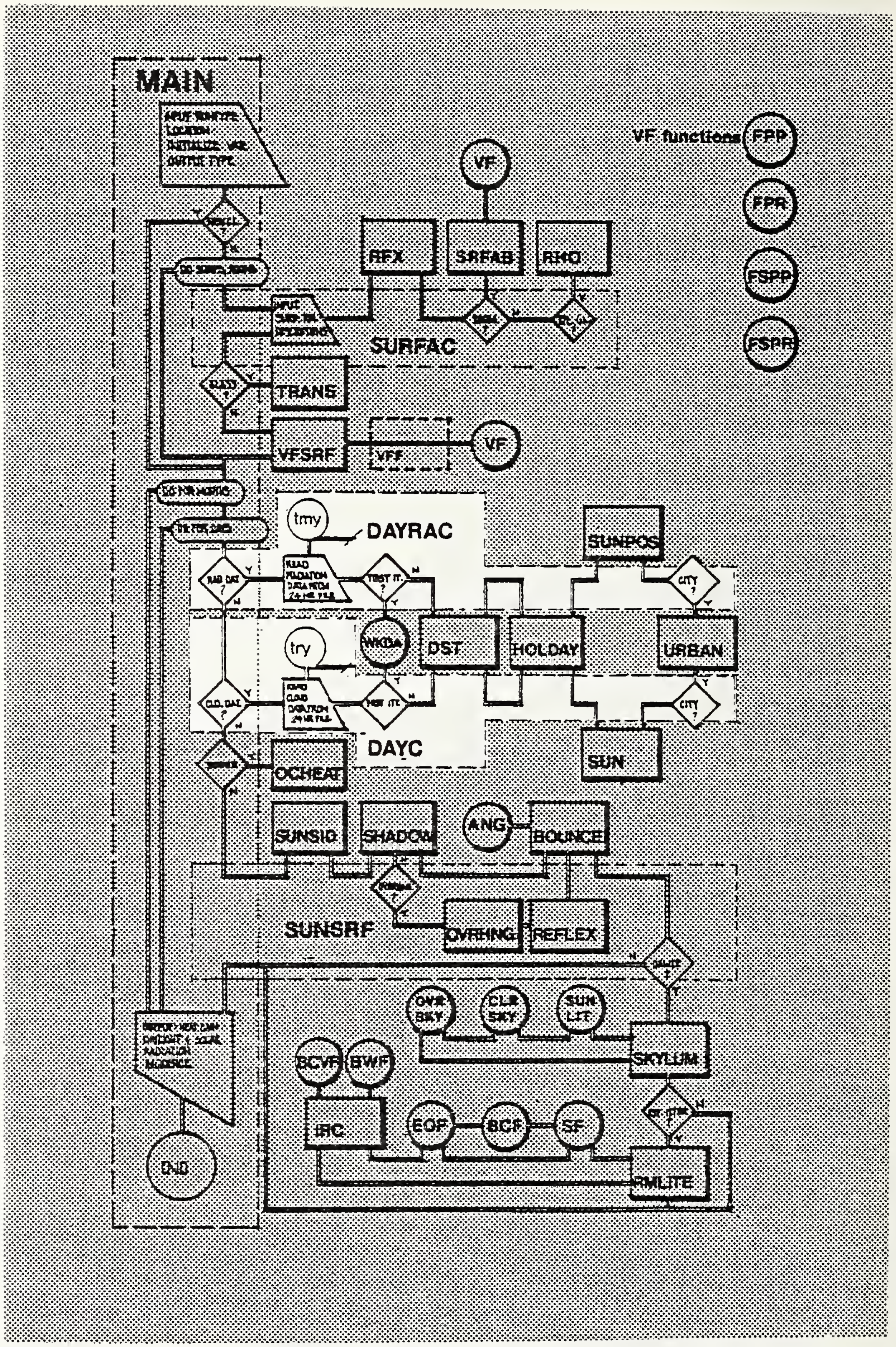


Fig. A.4 Weather data files (logical unit 8) are read by the subroutines highlighted in the flowchart above.

RDT	Total radiation on a horizontal surface	(BTU Ft^{-2} Hr^{-1}, Wm^{-2})
RDR	Direct radiation on a horizontal surface	(BTU $Ft^{-2}Hr^{-1}$, Wm^{-2})
IYEAR	Four digit integer signifying year	
MON	Two digit integer signifying month	
DAY	Two digit integer signifying day of month	
IC	Five digit integer city code (from TRY or TMY tapes)	

A.2 SOLAR RADIATION CALCULATIONS

SOLITE computes clear sky radiation in the absence of user supplied radiation data. A modifier is then applied to the clear sky figure to arrive at a cloud modified hourly radiation figure for a horizontal surface. Subroutines used for these calculations are illustrated in the flowchart of Fig. A.5.

A.2.1 Direct and Diffuse Clear Sky Solar Radiation

The intensity of clear sky radiation is calculated in subroutine SUN using ASHRAE algorithms outlined in NBSLD [37], the Building Energy Loads Calculation Program. In addition to the direct/diffuse split on a horizontal surface, SOLITE determines that same ratio for all the street canyon surfaces and user-specified surfaces. This requires the calculation of solar position. Solar position is also required for the computation of shadows. Subroutines SUN and SUNPOS calculate the position and the direct to diffuse radiation ratio for cloud cover data bases and SOLMET radiation data bases respectively. Descriptions of the variables are found in the appropriate listings in Appendix D. Both SUN and SUNPOS contain the following calculations:

1. The equation of time (EOT), declination angle (DEC), apparent solar irradiation with an air mass of 1 (A), atmospheric extinction coefficient (B), and the diffuse radiation factor (C). Extraterrestrial radiation values are stored in arrays located in subroutines SUN and SUNPOS. Values used in the calculations have been derived by ASHRAE [38]:
   SOLFAC(I)=A0(I)+A1(I)*C1+AZ(I)*CZ*A3(I)*C3+B1(I)*S1+BZ(I)*SZ+B3(I)*S3

where:

SOLFAC(I)	Solar position and intensity factor I=1 through 5: Solar declination angle, Equation of time, A,B,and C, respectively A0,A1,A2,A3,B1,B2, and B3 are listed in Table A.1
X	Angular position of earth each day around sun, January 1= (2*Pi/366)
C1	Cos(X)
C2	$C1^2$-$S1^2$
C3	C1*C2-S1*S2
S1	Sin (X)
S2	2*S1*C1
S3	C1*S2+S1*C2

This equation is a fit to the tabular values of A, B, C, EOT and extraterrestrial radiation found in the ASHRAE Handbook of Fundamentals (1977).

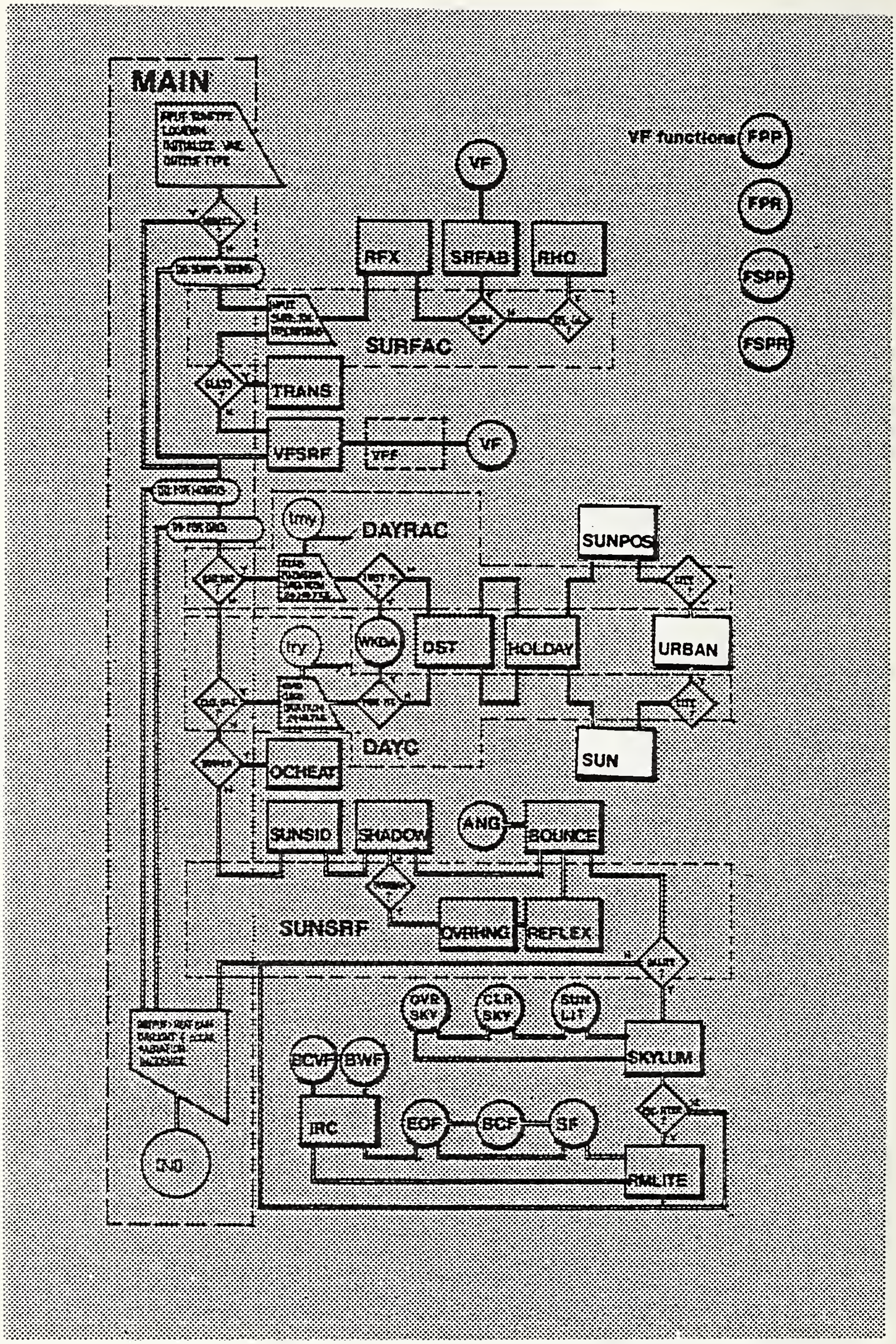


Fig. A.5 Clear day solar radiation, and cloud cover modifiers are calculated in subroutines highlighted in the flowchart.

2. For each hour, the hour angle is calculated:

$$HRANG=15*(IHR-12+TZN+EOT-IDST)-LONG$$

where:

IHR	Time of day (solar time)
HRANG	Angular position of sun with respect to true south (in degrees)
TZN	Time zone indicator
EOT	Equation of time (SOLFAC(2))
IDST	Daylight savings time indicator. IDST is calculated in DAYC or DAYRAC. It is 1 during daylight savings time and 0 during standard time.

3. The hour angle at sunrise:

$$HRPOS= -Sin(DEC)*(Cos(DEC))^{-1}*Tan(LATD)$$

where:

HRPOS	The sunrise angle
DEC	Solar declination: Sin(DEC)=SNDEC: Cos(DEC)=CSDEC
LATD	Site latitude, north positive: Tan (LATD)=TNLATD

4. Direction cosines of the sun's relative sky vault position. Refer to Fig. A.6 for illustration of variables:

$$Cos(Z)=Sin(LATD)*Sin(DEC)+Cos(LATD)*Cos(DEC)*Cos(HRANG)$$

where:

Z	Zenith angle
W	Hour angle to the east-west axis

$$Cos(W) =Cos(DEC)*Sin(HRANG)$$

TABLE A.1

VALUES OF COEFFICIENTS IN SOLFAC EQUATION

$$SOLFAC(I)=A0(I)+A1(I)*C1+A2(I)*C2+A3(I)*C3+B1(I)*S1+B2(I)*S2+B3(I)*S3$$

I	*A0*	*A1*	*A2*	*A3*	*B1*	*B2*	*B3*
1	*0.302*	*-22.9*	*-0.229*	*-0.243*	*3.851*	*0.002*	*-0.055*
2	*-0.0002*	*0.4197*	*-3.2265*	*-0.0903*	*-7.35*	*-9.39*	*-0.3361*
3	*368.4*	*24.52*	*-1.14*	*-1.09*	*0.58*	*-0.18*	*0.28*
4	*0.1717*	*-0.0344*	*0.0032*	*0.0024*	*-0.0043*	*0*	*-0.008*
5	*0.0905*	*-0.410*	*0.0073*	*0.0015*	*-0.0034*	*0.0004*	*-0.0006*

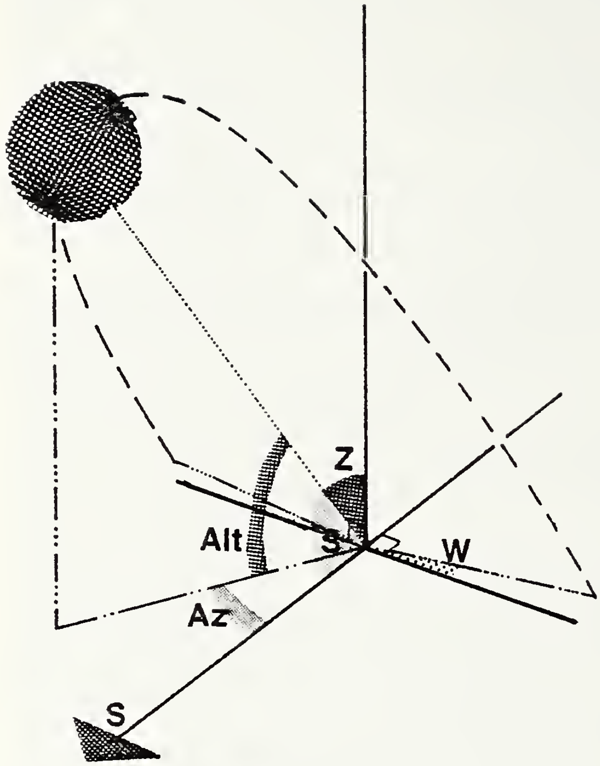


Fig. A.6 Variables used to determine sun's relative sky vault position: according to equations A.2.3-4.

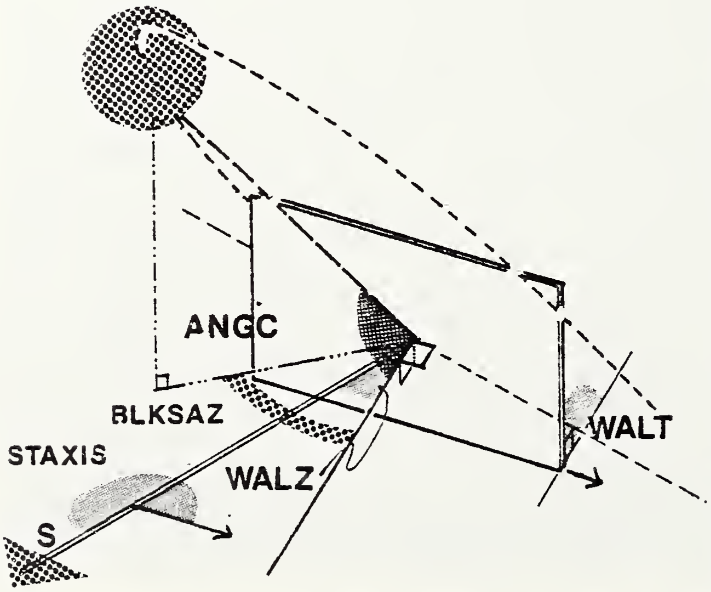


Fig. A.7 Variables used to determine the angle of incidence on a surface in the street canyon. Note that street canyon surfaces on walls, and the street are vertical and horizontal respectively. Roof surfaces may have a specified tilt. Refer to equation A.2.7 for application of variables. Street axis (STAXIS) and the azimuth of the face of the street canyon with respect to the sun's position (BLKSAZ) are used to determine the side of the street receiving radiation in subroutine SUNSID.

$$Cos(S) = (1-Cos(Z)^2-Cos(W)^2)^{0.5}$$

where:

S	Angle between the sun and the origin of the geometric calculation.

5. Clear sky hourly direct normal radiation intensity:

$$DNOIHR=(SOLFAC(3)*e^{(-SOLFAC(4)*(Cos(Z))^{-1})})$$

where:

DNOIHR	Direct normal radiation
SOLFAC(3)	Apparent solar irradiation at air mass =1: A
SOLFAC(4)	Atmospheric extinction coefficient: B
Cos(Z)	Cosine of the zenith angle.

6. Clear sky diffuse solar radiation on a horizontal surface:

$$RDFIHR=SOLFAC(5)*DNOIHR$$

where:

RDFIHR	Clear sky diffuse solar radiation
SOLFAC(5)	Diffuse radiation factor: C.

7. Angle of incidence and direct beam radiation are computed in subroutine SUNSURF, and for the street canyon planes in subroutine SUNSID. The variables are listed in Fig. A.7:

$$ANGINC=Cos^{-1}(Cos(WALT))*Cos(Z)+Sin(WALT)*Sin(WLAZ)*Cos(H)+Sin(WALT)*Cos(WLAZ)*Cos(S)$$

where:

ANGINC	Angle of direct beam incidence on a surface measured to surface normal
WALT	Surface tilt angle: Cos(WALT)=CSWALT(ISURF)
Z	Zenith angle: Cos(Z)=COSIH
WLAZ	Surface azimuth angle: Cos(Z)=COSIH
H	Solar azimuth to true south vector:Cos(H)=DRC2IH
S	Solar angle to true south vector:Cos(S)=DRC3IH.

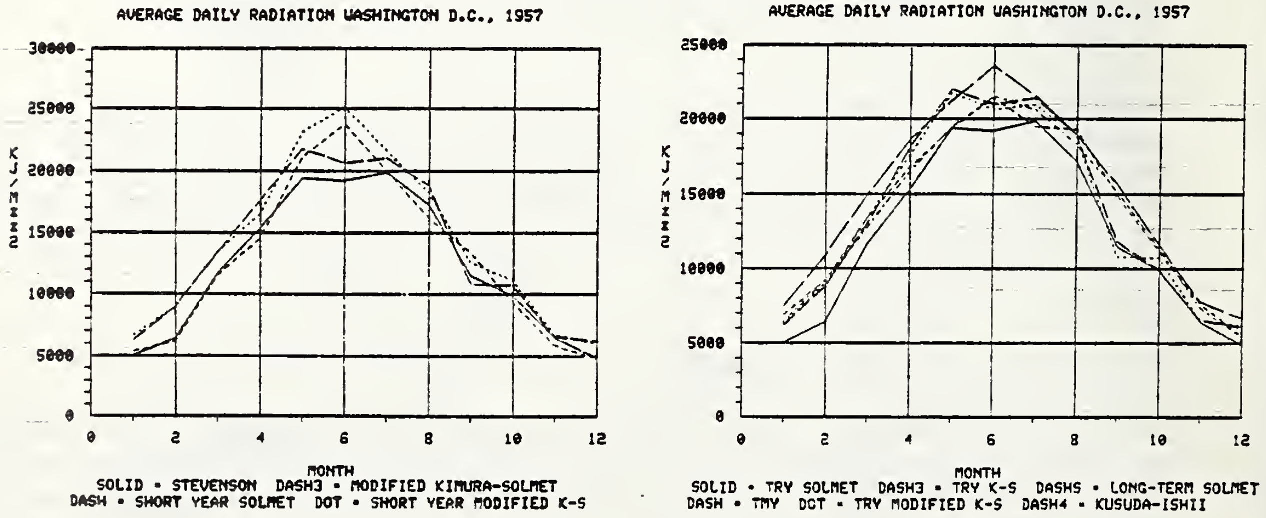
Although this algorithm employs the ASHRAE [39] method for determining clear day radiation, other methods such as that proposed by Atwater and Ball [40] and the NOAA developed coefficients for SOLMET radiation data [41] may also be tested in future applications. A more precise method for determining solar radiation which accounts for turbidity, aerosols and spectral distribution of the air mass may be found in reference [42].

A.2.2 Cloud Modified Solar Radiation

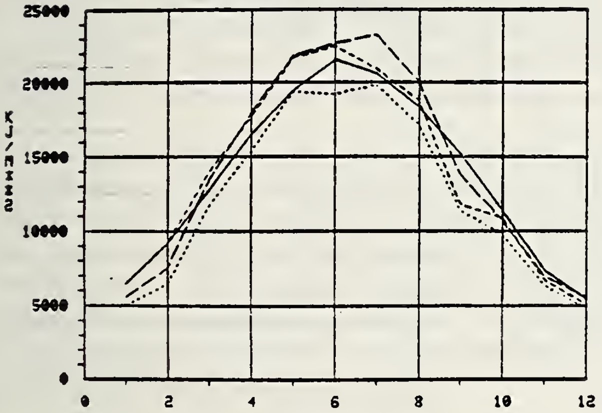
A series of methods have been devised to calculate direct and diffuse solar radiation as a function of cloud cover and cloud type. Building energy loads analysis computer algorithms, such as NBSLD, often include solar radiation generators for use with weather tapes like TRY and 1440. NBSLD employs the Kimura/Stephenson method [43] DoE2 uses the Boeing algorithm [44], and building energy performance algorithms accessing SOLMET or TMY data use the regression coefficients developed by the National Climatic Center [45]. A comparison has been made between these different solar radiation algorithms. Results of these comparisons will be reported in reference |46|.

The Kimura/Stephenson algorithm used in conjunction with TRY year data, predicts generally more insolation than long-term SOLMET, and less than Kusuda and Ishii [47] predicted with the Liu-Jordan [48] algorithms in a comparison of weather data from 8 cities. A synoptic comparison is illustrated in Fig. A.8. Selection of the best algorithm for insolation calculation from cloud cover data was not possible due to the inconsistent results from TRY based solar radiation calculations. Comparison with SOLMET indicated that Kimura/Stephenson data agreed in some cases, whereas the Boeing appeared to fit the SOLMET data better in others. A lack of long term consistent measurement of cloud cover, cloud type, direct solar insolation and horizontal insolation has made statistically rigorous comparisons and ratings of the different cloud modifier models impossible. Lack of this data has led to the correlation based functions and regression based coefficients found in all of the cloud cover algorithms and existing solar radiation data bases. Cloud cover based solar radiation modifying coefficients found in the three algorithms, Kimura/Stephenson, Boeing and SOLMET are shown in the curves of Fig. A.9. This program uses the

Fig. A.8 Radiation data from Kusuda/Ishii, long term SOLMET and TRY based Kimura/Stephenson calculations are compared. The solar radiation curves have been calculated with the various weather data bases illustrated. Although the Boeing algorithm predicts radiation in the Washington D.C. case within 10% of the other processors, the amount of direct normal radiation calculated exceeds both SOLMET and Kimura/Stephenson based calculations. The SHORTYEAR data base consistently predicts lower radiation totals for June and September. Little difference is perceived between the modified Kimura Stephenson (using only the lowest layer of cloud data for the radiation coefficient), and the original algorithm (using all four layers of cloud data) results.

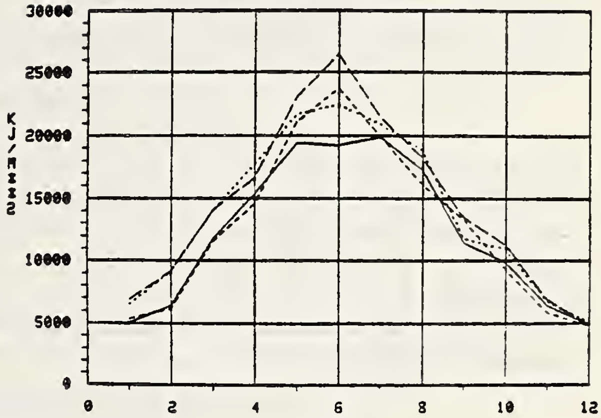


AVERAGE TOTAL DAILY RADIATION WASHINGTON D.C., 1957



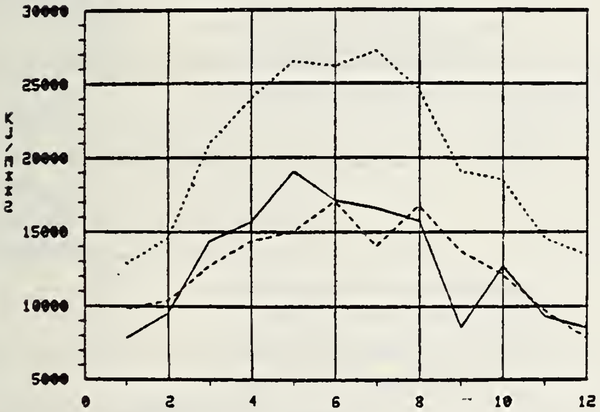
MONTH
SOLID • LONG TERM SOLMET DOT • SOLMET TRY
DASH • MODIFIED K-S TRY DASH3 • BOEING TRY

AVERAGE TOTAL DAILY RADIATION WASHINGTON D.C., 1957



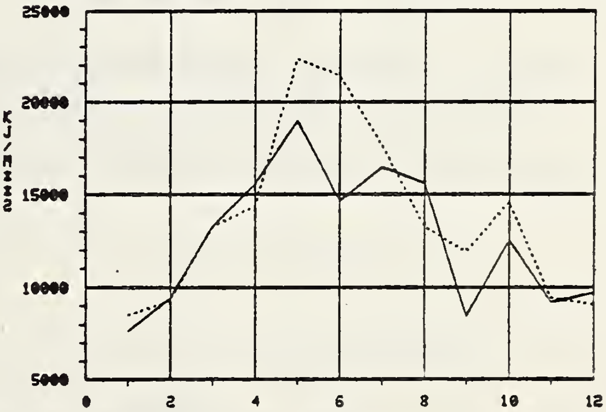
MONTH
SOLID • SOLMET TRY DASH • SOLMET SHORT TRY
DOT • MODIFIED K-S TRY DASH3 • MODIFIED K-S SHORT TRY

AVERAGE DIRECT NORMAL RADIATION WASHINGTON D.C., 1957



MONTH
SOLID • MODIFIED K-S TRY DOT • BOEING TRY
DASH • TMY

AVERAGE DAILY DIRECT NORMAL RADIATION WASHINGTON D.C., 1957



MONTH
SOLID • MODIFIED KIMURA-STEVENSON REAL YEAR.
DOT • MODIFIED KIMURA-STEVENSON SHORT YEAR.

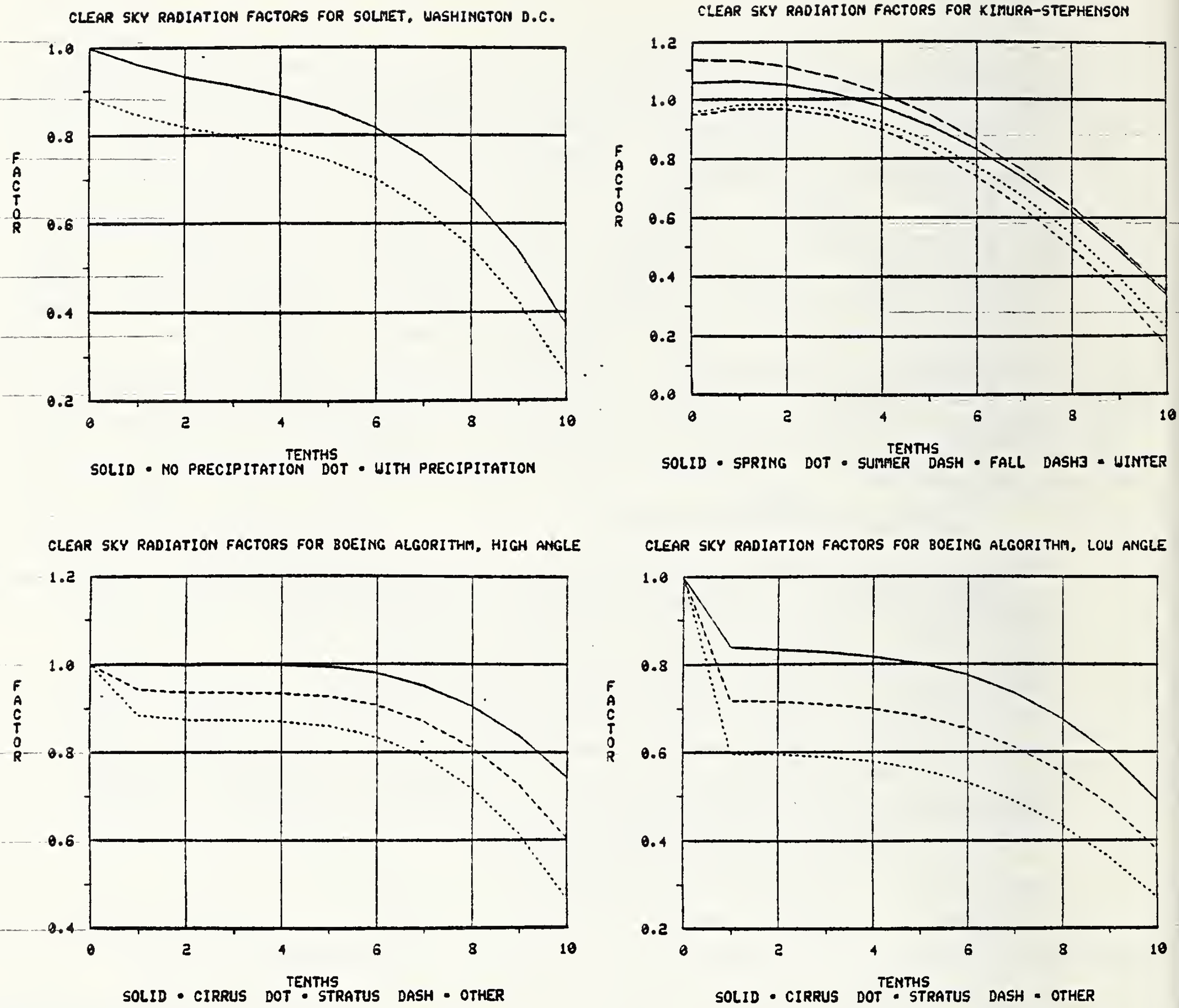


Fig. A.9 Cloud based radiation modifying coefficients from Boeing, SOLMET and Kimura/Stephenson are compared. In all cases, the factor is a modifying coefficient for clear day radiation values.

Kimura/Stephenson cloud cover algorithm, as it produces a non-linear ratio between diffuse and beam radiation with increasing cloud cover. The algorithm does deviate from the original Kimura Stephenson method by accessing only the lowest cloud layer of cloud cover data for the calculation of the modifying coefficient. Thus the amount and type of cloud used in the insolation calculation is from one layer, rather than the four layers specified in the original Kimura/Stephenson method.

SOLITE calculates both direct and diffuse radiation as a function of the cloud cover. The Boeing algorithm used in DoE2 computes both diffuse and direct solar radiation using a constant coefficient ratio. This results in a constant diffuse/direct ratio for all cloud cover types and amounts. SOLMET regressions may be used to calculate horizontal solar radiation data, but requires a second algorithm for computing the respective proportion of diffuse and direct insolation on vertical and tilted surfaces. The algorithm resident in subroutines SUN and SUNPOS calculates radiation intensity as a function of cloud cover:

1. Cloud cover amount is read from weather tape and is partially a function of the cloud type:

CC=CCT

where:

CC	Cloud cover amount
CCT	0.5*CC if TOC=0: ie. Type of cloud is cirrus. Thus cirrus reduces radiation only half as much as stratus or cumulus.

2. Cloud cover based radiation modifier is quadratic function from an empirical fit to data:

$CM=P+Q*CC*R*CC^2$

where:

CM	Cloud cover modifier
P	Cloudless sky factor
Q	First order coefficient
R	Second order coefficient

and P, Q, and R are listed in Table A.2 as a function of season.

TABLE A.2

COEFFICIENTS OF CLOUD COVER FUNCTION $CM=P+Q*CC+R*CC^2$

MONTH	*Sin(ALT)*	*P*	*Q*	*R*
March	*0.5-0.9*	*1.06*	*0.012*	*-0.0084*
June	*0.5-1.0*	*0.96*	*0.033*	*-0.0106*
September	*0.5-0.9*	*0.95*	*0.30*	*-0.0108*
December	*0.3-0.5*	*1.14*	*0.003*	*-0.0082*

3. A solar altitude dependent factor is determined:
$FACSLT=0.309*Cos(Z)+0.394*(Cos(Z))^2$
where:

FACSLT	Solar altitude dependent factor
Z	Zenith angle: Cos(Z)=COS1IH

4. From Kimura/Stephenson:
$EMPCST=Cos(Z)*(C+Cos(Z))^{-1}+(P-1)*(1-FACSLT)^{-1}$
where:

EMPCST	Ratio of direct to total horizontal radiation
C	Diffuse sky factor

5. Direct radiation on a horizontal surface, cloud modified:
$RDR=RDT*EMPCST*(1-CC*10^{-1})$
where:

RDR	Hourly direct radiation on a horizontal surface
RDT	Hourly total radiation on a horizontal surface, clear day

6. Diffuse radiation on a horizontal surface, cloud modified:
$RDF=RDT*(CM-EMPCST*(1-CC*10^{-1}))$
where:

RDT	Diffuse solar radiation on a horizontal surface,
CM	Cloud modifier factor

All solar radiation calculations are performed in English units (BTU $Ft^{-2}Hr^{-1}$) and results are converted to SI, if necessary, before final printing.

A.2.3 Urban Insolation

The lack of a large pool of measured urban, suburban and rural data from contiguous locations has led to the use of a simple fit to a sole data source curve (Fig. A.10) from Meinel and Meinel [49]. The coefficients used to modify solar diffuse and beam radiation are found in subroutine URBAN and are a function of the altitude. For every 15° change in the solar altitude, a new coefficient is applied to both the diffuse and direct radiation. Generally, the urban diffuse radiation increases and the direct beam decreases, while there is an overall reduction of about 10% in the urban measured radiation when compared with desert insolation data. The diffuse radiation comprises about 22% of the urban radiation, while in a desert environment, the diffuse component comprises only 8% of the total terrestrial solar radiation. The user calls these coefficients in the URBAN program by indicating an urban location during the input stage. If this simple fit is to be avoided, the flag is set to 0.

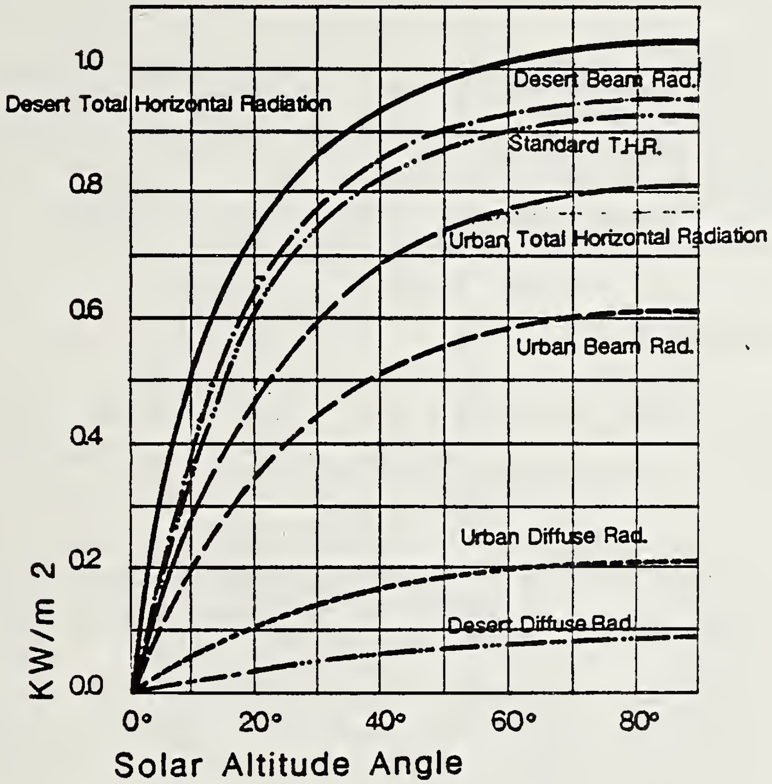


Fig. A.10 Defining curves for solar flux variation with solar altitude for desert and standard atmospheres. Curves for urban radiation are derived from observations on the eastern seaboard of the United States and are defined in subroutine URBAN. (After Meinel and Meinel 49 .)

A.3 SURFACE POSITION AND CONTEXT DEPENDENCY OF INSOLATION

Solar radiation incident on a surface is determined by the surrounding environment's shading and reflection characteristics. In urban environments, the surrounding context may increase the solar gain on the building by reflecting incoming radiation from other buildings, or reduce the amount of gain by shading a particular surface. SOLITE contains algorithms to compute both the diffuse and beam radiation behavior in the urban street canyon. Algorithms account for shading from nearby buildings, and for interreflections within the street canyon.

A.3.1 Diffuse Insolation

Calculations concerning radiation intensity on a surface are performed in subroutines VFSRF, VFF, SUNSID, and SUNSRF. The relative location of these subroutines in the overall program structure is shown in Fig. A.11.

Calculation of incident diffuse solar radiation on a surface includes:

1. calculation of view factors between the major street planes and clear sky,
2. calculation of view factors between overhangs, reflectors and street planes (simplified method applied in program),
3. calculation of view factors between window (or surface) and street planes, overhangs, and reflectors,
4. calculation of a total component from clear sky to surface, decremented by reflector view factor to surface, and
5. calculation of vertical (or tilted) diffuse insolation coefficients.

View factors between street planes and clear sky are calculated in subroutine VFSRF. This subroutine calls one of eight possible functions used to calculate view factors. Relationships between the street planes forming the street canyon and sky are shown in Fig. A.12.

View factors are calculated in the functions accessed by:
VFR(ISTS,O,OPP)=F(A,B,C,ANG)
where:

VFR	The view factor of a surface OPP from a surface O on a street named ISTS, (ISTS may equal either 1 or 2 depending on whether the street is primary or secondary)
F	One of five view factor functions dependent on the context of the surfaces
A,B,C	Descriptors of the dimensions of surface O and OPP, and distance between the two
ANG	Angular relationship between O and OPP

Five specific functions for (F), each called by subroutine VFSRF, are referenced for the view factors associated with the street canyon planes, as well as those defined for the windows and surfaces.

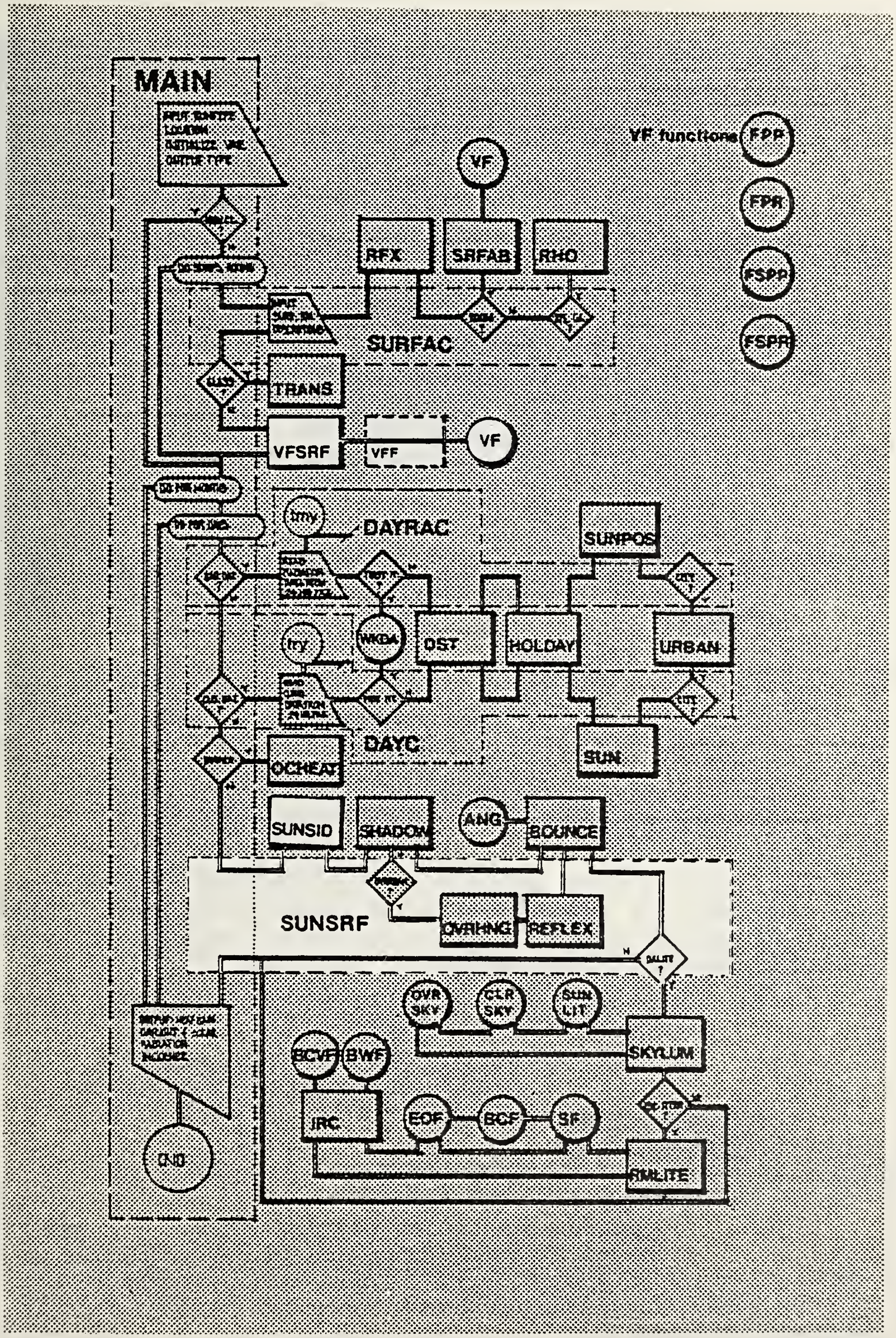


Fig. A.11 Highlighted portions of the flowchart contain subroutines used to calculate diffuse solar radiation factors in the street canyon and on the specified surfaces.

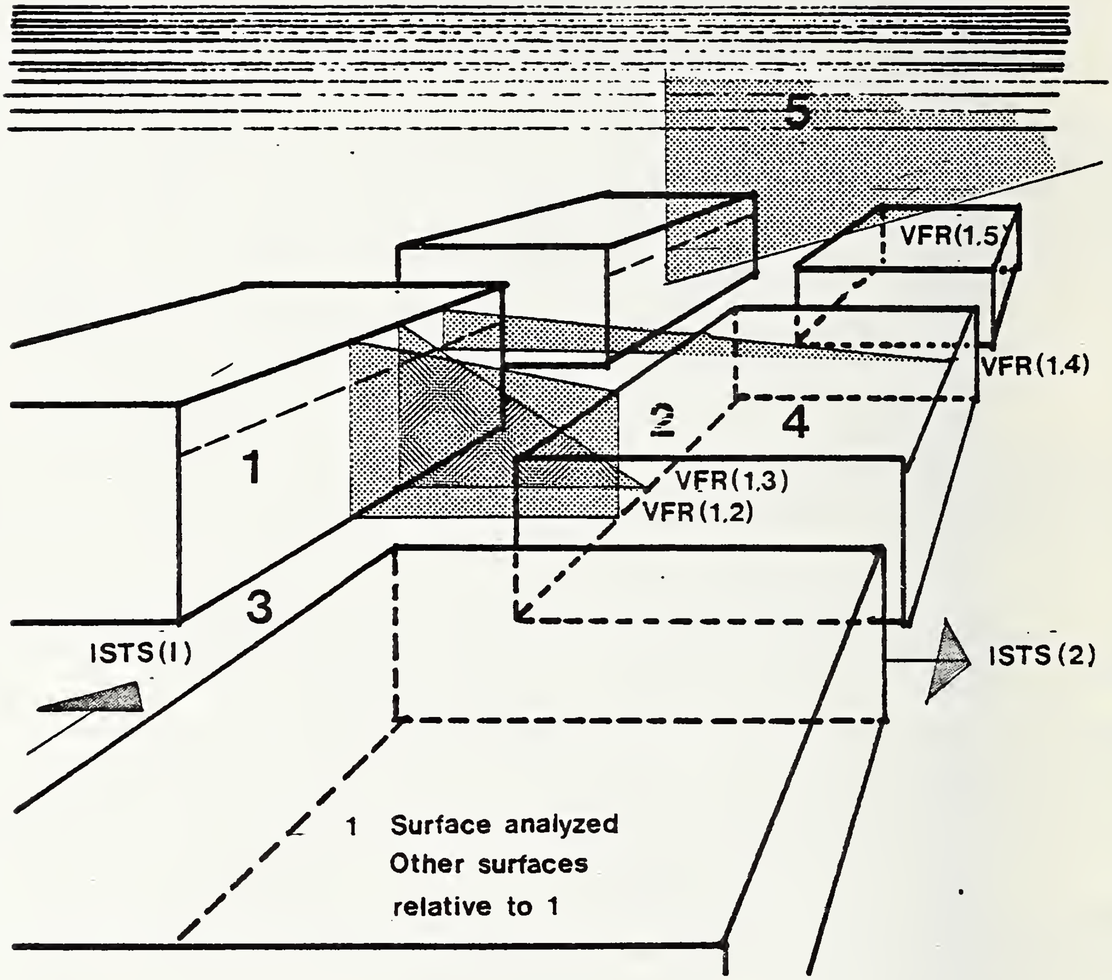


Fig. A.12 Diffuse insolation in a street canyon is determined by calculating the view factors to the viewed street canyon planes, and weighting the viewed plane's sky radiation exchange factor by the reflectance of the street surface.

1. For hemispherical sky radiation:

$VF=0.5*(1-Cos(ANG))$ [50]

where:

VF	View factor
ANG	Angle between horizon and obstruction. For street plane view surfaces, the angle is calculated from the midpoint of the surface.

2. For small surfaces perpendicular to a larger one: [51]

Function VF=FPR(A,B,C)

where:

$FPR=Atan(C*A^{-1})-A*((A^{2}+B^{2})^{-0.5})*(C*(A^{2}+B^{2})^{-0.5})$

A, B, C are illustrated in Fig. A.13

or alternately, in a subsequent version of this program, the following calculations will be performed for a more accurate calculation of interreflection between street canyon planes:
Function VF=FCPR(A,B,H)
where:

$$FCPR=0.5*Pi*(Atan(B*H^{-1})-H*(A^{2}+B^{2})^{-0.5}*Atan(B*(A^{2}+H^{2})^{-0.5}))$$

and A, B, and H are illustrated in Fig. A.14.

3. For a small surface parallel to a larger surface:
Function VF=FPP(A,B,C)
where:

$$\begin{aligned}&FPP=2*B/((A^{2}+B^{2})*Atan(C*(A^{2}+B^{2})^{-0.5})+2*C*(A^{2}+C^{2})^{-1}\\&\quad +Atan(B*(A^{2}+C^{2})^{-0.5}\end{aligned}$$

and A, B, and C are illustrated in Fig. A.15,
or in a future alternative:
Function VF=FCPP(A,B,H)
where:

$$\begin{aligned}&FCPP=0.5*Pi*(A*(A^{2}+H^{2})^{-1})*Atan(B*(A^{2}+H^{2})^{-1})\\&\quad +B*(B^{2}+H^{2})^{-1}+Atan(A*(B^{2}+H^{2})^{-1})\end{aligned}$$

and A, B, and H are illustrated in Fig. A.16.

4. For a small surface, not perpendicular to a larger surface where ANG is greater than 90° and less than 180°:
VF=FSPR(A,B,C,ANG)
where:

$$\begin{aligned}&FSPR=Atan(C*Cos(ANG)*(A)^{-1})-((A*Cos(ANG)\\&\quad +B*Sin(ANG))*(A^{2}+B^{2})^{-0.5}*Atan(C*(A^{2}+B^{2})^{-0.5})\\&\quad +(C*Sin(ANG)*(A^{2}+B^{2})^{-0.5})\\&\quad *Atan(A*Sin(ANG)*(A^{2}+C^{2})^{-0.5})\\&\quad -Atan(B*(A^{2}+C^{2})^{-0.5})\end{aligned}$$

and A, B, C and ANG are shown in Fig. A.17.

5. For a small surface not parallel to a larger surface, where ANG is greater than 0° and less than 90°:
VF=FSPP(A, B, C, ANG)
where:

$$\begin{aligned}&FSPP=-2*Sin(ANG)*(B*(A^{2}+B^{2})^{-0.5})*Atan(C*(A^{2}+B^{2})^{-0.5})\\&\quad +C*(A^{2}+C^{2})^{-0.5})*Atan(B*(A^{2}+C^{2})^{-0.5})\end{aligned}$$

and A, B, C, and ANG are illustrated in Fig. A.18.

The following functions will be integrated in future versions of SOLITE. The functions listed below will be used in conjunction with VFF or the diffuse interreflection subroutine:

1. For a surface similiar in size to the viewed surface and perpendicular to the viewed surface:
VF=FFPR (A,B,H)
where:

$$\begin{aligned}&FFPR=1*Pi^{-1}*(Atan(B*H^{-1})+A*H^{-1}*Atan(B*A^{-1})\\&\quad -(A^{2}+H^{2})^{0.5}*H^{-1}*Atan(B*(A^{2}+H^{2})^{-0.5})\\&\quad +H*(4*B)^{-1}*Ln((A^{2}+B^{2}*H^{2}\end{aligned}$$

$*((A^{2}+B^{2})*(B^{2}+H^{2}))^{-1}$
$+A^{2}*(4*B*H)^{-1}*Ln((A^{2}+B^{2}+H^{2})$
$*A^{2}*((A^{2}+B^{2})*(A^{2}+H^{2}))^{-1}$
$-B*(A*H)^{-1})*Ln((A^{2}+B^{2}*H^{2})*B^{2}$
$*((A^{2}+B^{2})*(H^{2}+B^{2})))$

and A, B, and H are illustrated in Fig. A.19.

2. For a surface similiar in size, and parallel to the viewed surface:

VF=FFPP(A,B,H)

where:

$FFPP=2*(A*B*Pi)^{1}*(B*(H^{2}+A^{2})^{0.5}*Atan(B*(A^{2}+H^{2})^{-0.5})$
$+A*(B^{2}+H^{2})^{0.5}-B*H*Atan(B*H^{-1})$
$-A*H*Atan(A*H^{-1})-0.5*H^{2}Ln((H^{2}+A^{2}+B^{2})*H^{2})$
$*(A^{2}+H^{2})*(B^{2}+H^{2}))^{-1})$

where A, b and H are shown in Fig. A.17.

View factors are calculated between the window and the surfaces viewed by the window. These same functions are used in the analysis of street view factors. Caveats of the view factor analysis for the windows and streets include:

1. the window width determines the width of the view factor function used in FFPR, when the view factors are calculated between the window and the overhang or reflector, and
2. width of the viewing surface is used in the FFPP calculation of view factors.

A new subroutine will be incorporated in the program to reduce the error in the calculation of diffuse radiation interreflection in a street canyon. Presently, the view factor calculated in VFSRF considers only the reflection from the opposite surface and the view factor of the sky from the window. In the next program issue, the view factor from the surface to clear sky is calculated in function VFF. This function calculates a partial sum of the infinite sum describing the effect of hemispherical diffuse solar reflection on a street canyon environment. A partial sum accounts for two series of reflections and view factor calculations beyond the window or surface being analyzed:

VFF=VF(1,2)*VF(2,sky)*RFF(2)+VF(1,2)*VF(2,N)*VF(N,SKY)*RFF(2)*RFF(N)...

where:

VFF	View factor sum function for diffuse radiation
VF(1,2)	View factor from window to a surface in the street canyon
VF(2,SKY)	View factor from surface in the street canyon to the sky
RFF(2)	Diffuse reflection coefficient of the street canyon surface.
VF(2,N)	View factor from street canyon surface to another street canyon surface (N)
VF(N,SKY)	View factor from street canyon surface to sky
RFF(N)	Diffuse reflection coefficient of the street canyon surface RFF=(ratio of material type 1 * diffuse reflection coefficient of material 1 + ratio of material 2 * diffuse reflection coefficient 2)

A given surface is not only influenced by the viewed planes surrounding it, but also by its tilt, the sector of the sky it views, and the sky's cloud distribution. A function, from Threlkeld [52], relates diffuse solar radiation on a vertical surface to that on a horizontal surface. The ratio is dependent on the cosine of the angle of beam incidence. This vertical wall factor is calculated in subroutine SUNSID for each street

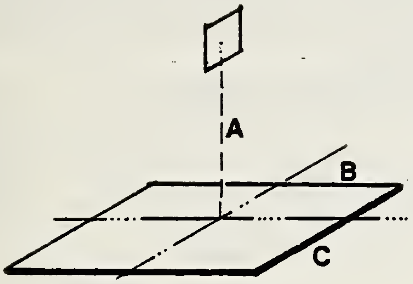


Fig. A.13 Variables A, B, and C for equation A.3.1.2a.

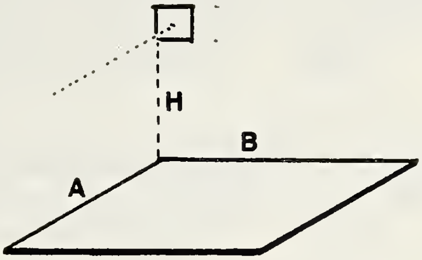


Fig. A.14 Variables A, B, and H for equation A.3.1.2b.

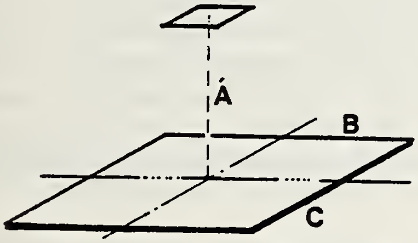


Fig. A.15 Variables A, B, and C for equation A.3.1.3a.

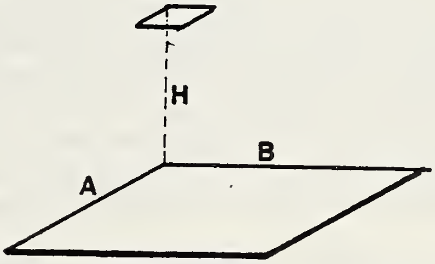


Fig. A.16 Variables A, B, and H for equation A.3.1.3b.

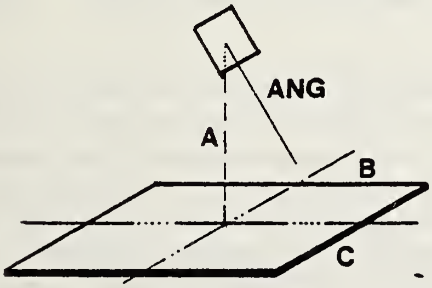


Fig. A.17 Variables A, B, C and ANG for equation A.3.1.4

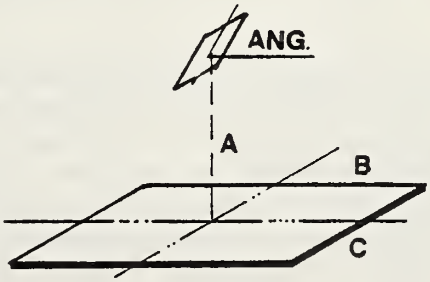


Fig. A.18 Variables A, B, C and ANG for equation A.3.1.5

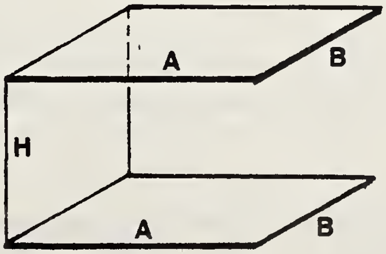


Fig. A.19 Variables A, B, and H for equation A.3.1.6.

canyon plane, and in subroutine SUNSRF for each user specified surface:

$$\mathrm{WALFAC=0.55+.437*COSINC+0.313*COSINC^2}$$

where:

WALFAC	Vertical wall radiation factor
COSINC	Cosine of the solar beam's incident angle

For a tilted surface:

$$\mathrm{WALFAC=Cos(WLALT)+WALFAC*(1-Cos(WLALT))}$$

where:

WLALT	Tilt of receiving surface from horizontal

Hypothetically, a similiar function may be used for both solar radiation and sky illuminance. In SOLITE, the algorithms used to compute the sky illuminance distribution could also be used to define the diffuse radiation. The diffuse radiation from the sky vault would be a function of the angle of view of the sky vault, and the sky condition. Three types of sky condition have been defined by Lim et. al. [53]: a clear sky, a cloudy sky, and an overcast sky. Clear sky radiation varies from a high around the sun to a low at the opposite reflex position on the sky vault, whereas an overcast sky has a more uniform radiation distribution. Various reports support the hypothesis of similiarities between the distribution of sky illuminance and diffuse radiation [54]. A link between the illuminance distribution function and the diffuse radiation processor remains to be made.

Total diffuse radiation on a surface is calculated in subroutine SUNSRF, and is a function of the diffuse sky radiation, the reflected diffuse radiation and the diffuse portion of the reflected beam radiation. Scattered, reflected beam solar radiation is calculated from total beam radiation by applying a 20% specular reflection factor to the beam and assuming hemispherical absorption and diffuse reflection for the remainder.

Each surface comprising the street canyon may comprise two materials. For example, walls may be of brick and glass, and streets, of asphalt and grass. Materials chosen by the program user have pre-stored normal incidence reflection coefficients defined in a data array RFMX in subroutine SURFAC. A normal angle of incidence is assumed for the stored reflectance values. A material's total reflection coefficient is coupled with a second value, the specular portion of the reflectance at normal incidence. This varies from 100% for glass to 0% for brick[4]. The amount of beam radiation specularly reflected increases with the angle of incidence. Coincident with the increase in specular reflection is a decrease of the diffuse reflection. Materials with very high specular reflection properties (close to 1.0) maintain this reflection coefficient through all angles.

---

[4] Discussions with Dr. J. Richmond, Spectrophotometry Group at the National Measurement Laboratory, NBS have led to the estimated specular/diffuse reflection properties of some common building materials. These material properties remains to be explored and documented.

Total diffuse radiation is calculated in SUNSRF. THe diffuse sky component is:
DIFF=WALFAC(1)*VF(5,1)*TRA(5,1)+WALFAC(N)*VF(N)*VF(N,1)*TRA(N,1)
where:

DIFF	Diffuse component factor
WALFAC	Vertical wall factor for diffuse solar gain
VF(5,1)	Sky view factor from window
VF(N,1)	View factor from window to street canyon plane
TRA	Transmission and room (or surface) absorption factor

The diffuse component of reflected beam radiation is:
DIFFB=RDB(N)*VF(1,N)*TRA(N,1)
where:

DIFFB	Diffused beam coefficient solar radiation factor
RDB	Scattered beam reflection coefficient for street canyon surface N, is arbitrarily set at 0.8 to indicate 80% of beam radiation reflection in street canyon is diffuse. Subroutine VFF will define the exact percentage.

Total diffuse radiation on a surface is:
RDFSRF=RDFH*(DIFF+DIFFB)*DIFC+RDRH*DIFF*DFBC
where:

RDFSRF	Diffuse solar radiation on a surface
RDFH	Hourly clear day diffuse radiation
DIFC	Ratio of calculated hourly cloud to clear sky radiation
RDRH	Hourly beam radiation
DFBC	Ratio of cloud to clear sky beam radiation

In addition to the calculating the beam and diffuse radiation absorbed beyond a glazing layer, SOLITE also computes the transmitted solar radiation (for daylighting analysis) and the incident solar radiation at the outer surface of the glazing. Variable TRA equals 1 for solar radiation on a window, and TRN replaces TRA for calculation of transmitted radiation. As daylighting on a workplane is a function of the transmitted radiatoin, TRN is used as the modifying coefficient for illumination. TRA equals 1 for calculation of incident energy on a perfect light-absorbing surface. The calculation of incident diffuse radiation in a street canyon is illustrated in Fig. A.20.

A.3.2 Direct Beam Insolation Calculation

Diffuse radiation calculations are accompanied by calculations of direct beam solar radiation in subroutine SUNSRF. Modifying factors (such as shading, reflections, and angle of incidence) are calculated in subroutines SUNSID, BOUNCE, REFLEX, ANG, SHADOW and OVRHNG. The relative context of these subroutines in SOLITE is illustrated in Fig. A.21.

Direct beam solar radiation incident on a window or surface is influenced by four factors:

1. the angle of incidence on the surface,
2. the shadows cast by the surrounding environment and window related overhangs,

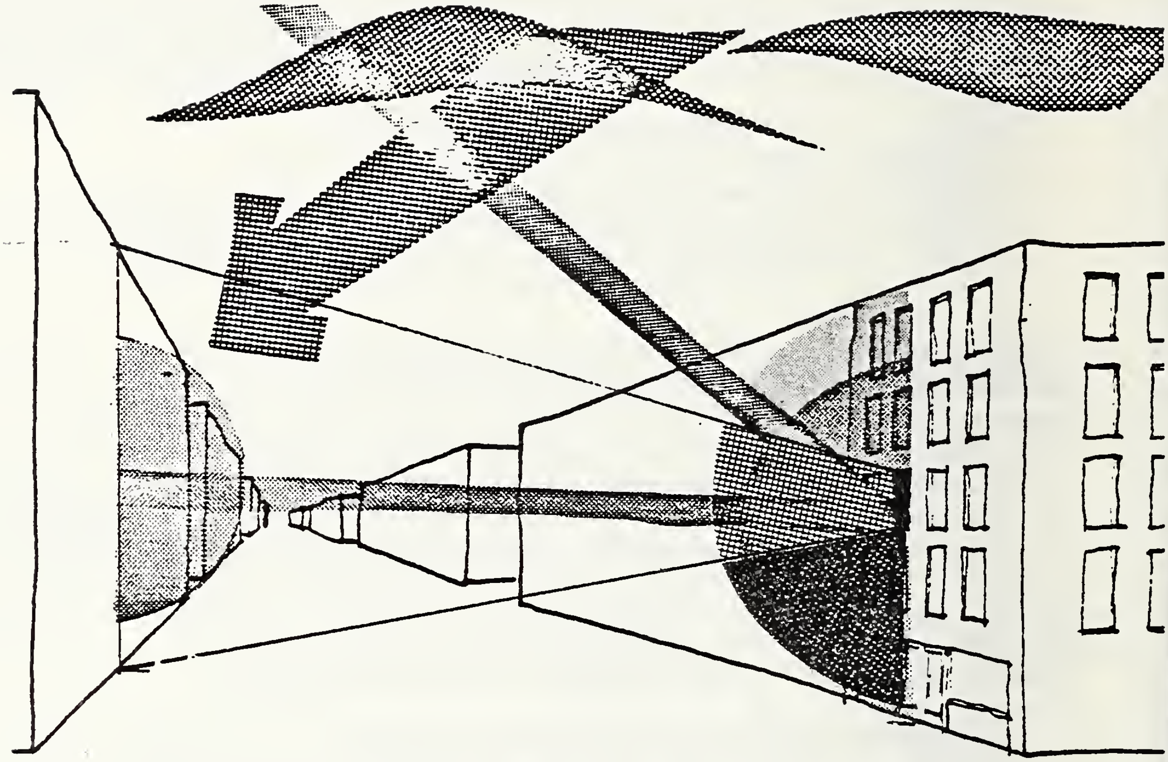


Fig. A.20 Diffuse insolation calculation comprises the diffuse radiation from the sky (5), the reflected diffuse radiation from the viewed street planes (1 thru 4), and the diffuse radiation component from the interreflected beam radiation component. VFR is the variable name used to denote the view factor coefficient from the surface to the surface being analyzed.

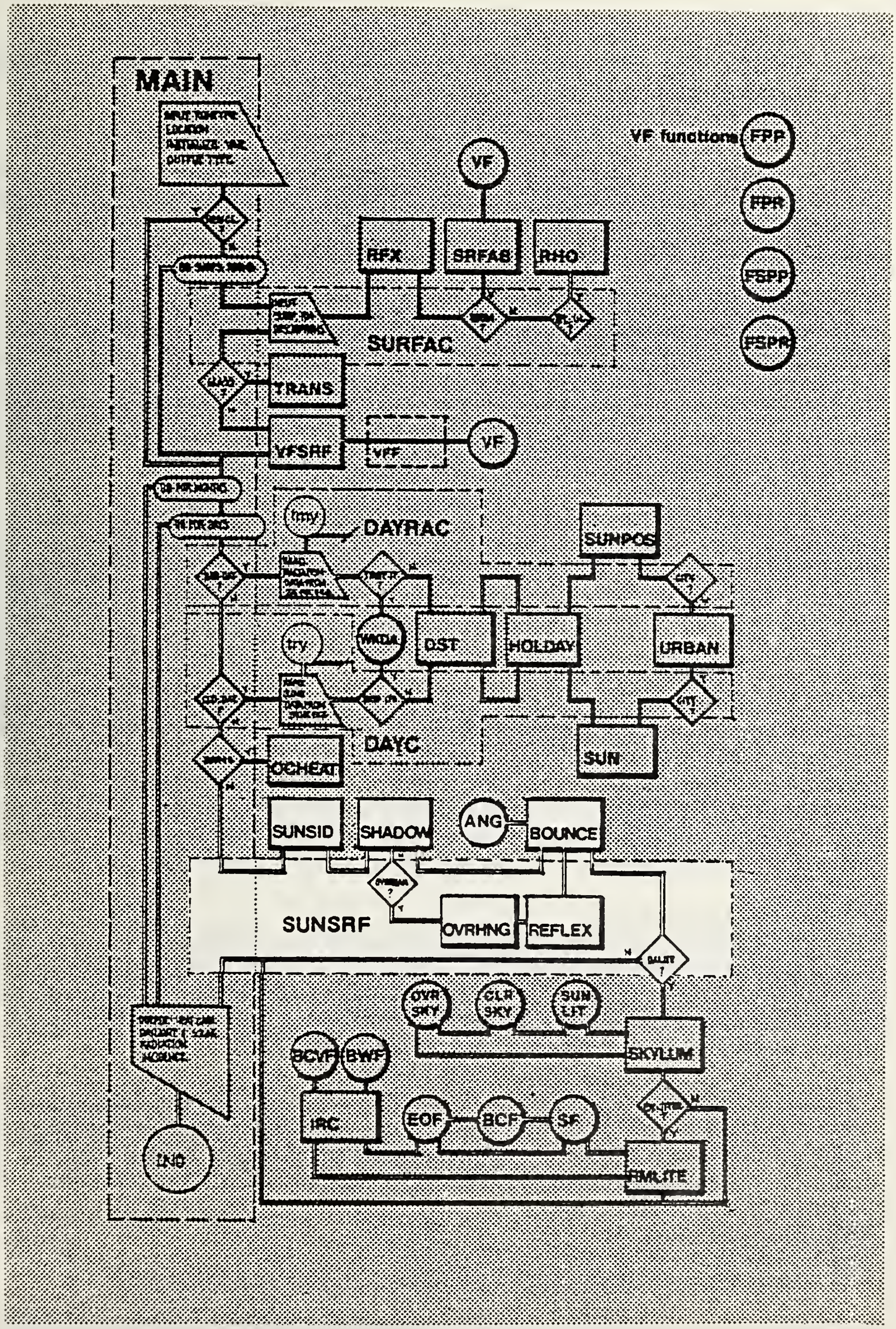


Fig. A.21 Flowchart indicates subroutines used for direct radiation component calculation.

3. the specular reflection from surrounding buildings, streets, roofs, and related window reflectors, and
4. the angle of incidence on the reflecting surfaces.

Shadow calculations for the block and the street are based on the assumption that buildings on the same side of the street are of equal height and that cross streets to the main street are of equal width. Computation of the shadow line on the surface is illustrated in Figs. A.22.

The analyses of roof aperture shadow configuration and the reflected beam radiation are different from the analysis methods used to calculate shadows on wall apertures. Roof apertures may be of any orientation, but the shadow analysis and the beam interreflection analysis assume that the roof surface is a horizontal plane with outlines of a horizontal projection of the actual plane. This may lead to gross errors for roof planes that have a vertical tilt. For vertical tilt surfaces on roofs, use the wall analysis method.

Shadows cast by the buildings opposite the surface onto associated overhangs or reflectors are calculated with simplified assumptions. Overhangs or reflectors are projected against the wall surface (using the profile angle of the solar beam as the angle of projection). The shadows on the projected outlines are calculated in a manner similiar to that used to calculate shadows cast by street canyon surfaces on the window. The shadow calculation algorithm is illustrated in Fig. A.23.

Computation of shadows cast by the overhang onto the surface or window includes side edge effects and do not assume an infinite overhang or reflector. Overhangs and reflectors may be shorter than the window itself. Calculations of side shading fin effects are not included in the program. Overhang shadows are calculated in subroutine OVRHNG. Overhang shadows cast upon a reflector are also calculated. The reflector shape is projected onto the wall and the overhang shadow cast on the projection is calculated in the manner used to calculate the shadow cast on the window or surface.

Specular reflections from surrounding buildings, streets, roof and reflectors are calculated in subroutines BOUNCE, REFLEX, and OVRHNG. Beam radiation entering an urban street canyon is reflected and re-reflected by the surfaces and is simultaneously decremented by the solar absorption and beam diffusing characteristics of the surfaces. This process is illustrated in Fig. A.24.

Specular reflection properties of the surface are calculated in subroutine REFLEX and are a function of the incident angle and the material surface properties. Although no tests have been performed on common building materials in their typical applications, a function was suggested by Dr. J. Richmond of the National Measurement Laboratory[5].

$$\mathrm{REFLEX}=R2+R3(1-e^{-x})$$

where:

REFLEX	Specular reflection coefficient of the material
R3	Difference between total and specular reflection at normal incidence
R2	Amount of specular reflection from the material at normal incidence
x	Angle of incidence indicator, (x) an arbitrary factor asumes values from 5 to 0 as the angle of incidence decreases from 90° to 0°.

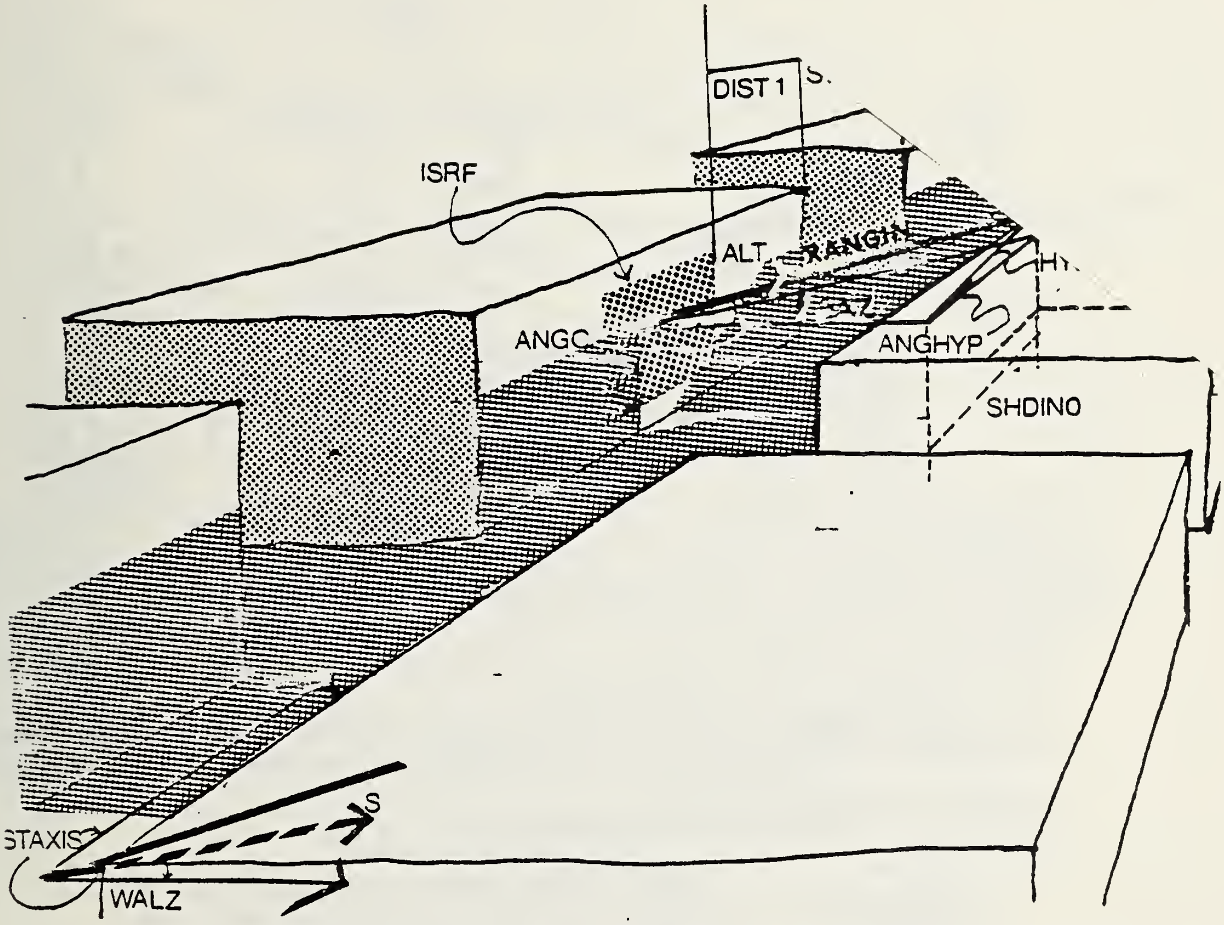


Fig. A22a Shadow calculation for a surface in the street canyon. The user specifies the location of the surface in the street canyon during entry of input data. Variables STAXIS (street axis), STW1(Primary street width), STW2 (Secondary or intersecting street width), and DIST1((Distance of surface edge from side of block in direction of STAXIS) are all input be the user. From the above diagram:

SAZ=SOLAZ-WALZ
RANGIN=STW1/CSAGIN
where:
- *CSAGIN Cosine of the angle of incidence (ANGC)*

HYP=RANGIN*SNAGIN
where:
- *SNAGIN Sine of ANGC*

ANGHYP=Asin(SNSALT/SNAGIN)
where:
- *SNSALT Sine of the solar altitude*

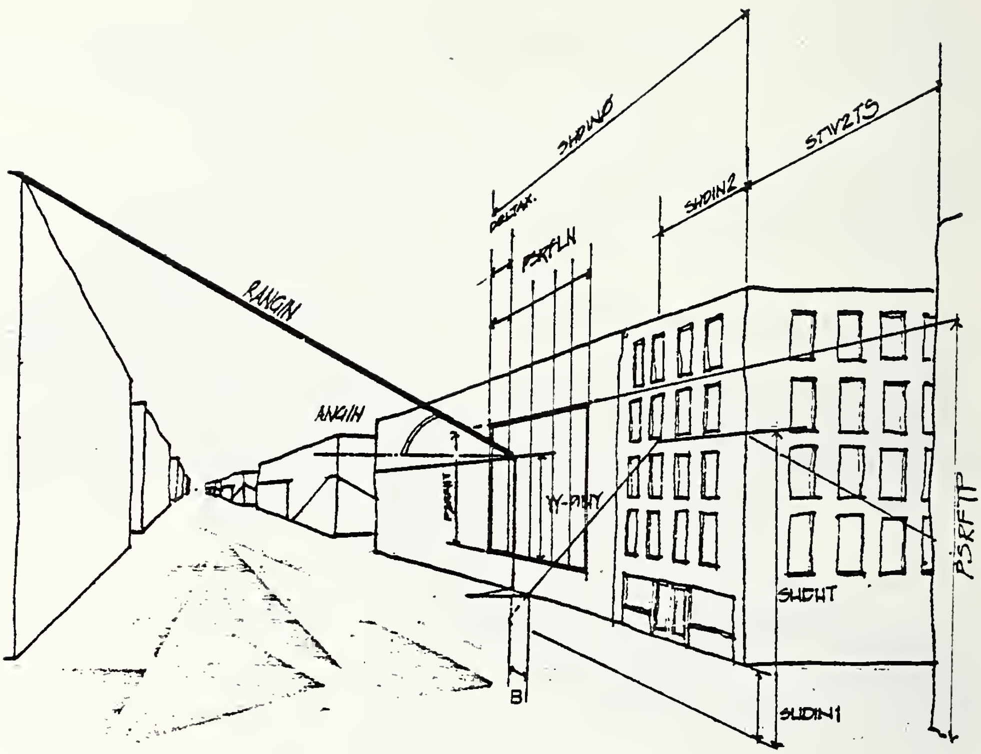


Fig. A.22b Shadow calculation in the street canyon, indicating the effect of the cross street intersection on the shadow. From the diagram above:

SHDHT=BLKHT(IWOP)-RANGIN*SNSALT

where:

SHDHT	*Height of cross street clear area on wall*
BLKHT(IWOP)	*Height of buildings on opposite side of street*
RANGIN	*Radius length of incident angle*
SNSALT	*Sine of solar altitude angle*

SHDIN1=SHDHT-STW2TS*TNAGHP

where:

SHDIN1	*Distance of cross street triangle apex from street level*
STW2TS	*Cross street width*
TNAGHP	*Tangent of ANGHYP*

B=SHDIN0*TNAGHP+SHDIN1

where:

B	*Slope of intersection projected shadow edge on street canyon surface plane*

SHADOW AREA=PSRFTP-SHDHT+SHDIN1+SHDIN

where:

SHDIN	*(YY-PINY)*DELTAX: The surface is divided into vertical strips and the position of the intersection line determines the area of the unshaded triangular projection*
DELTAX	*0.2*PSRFLN*

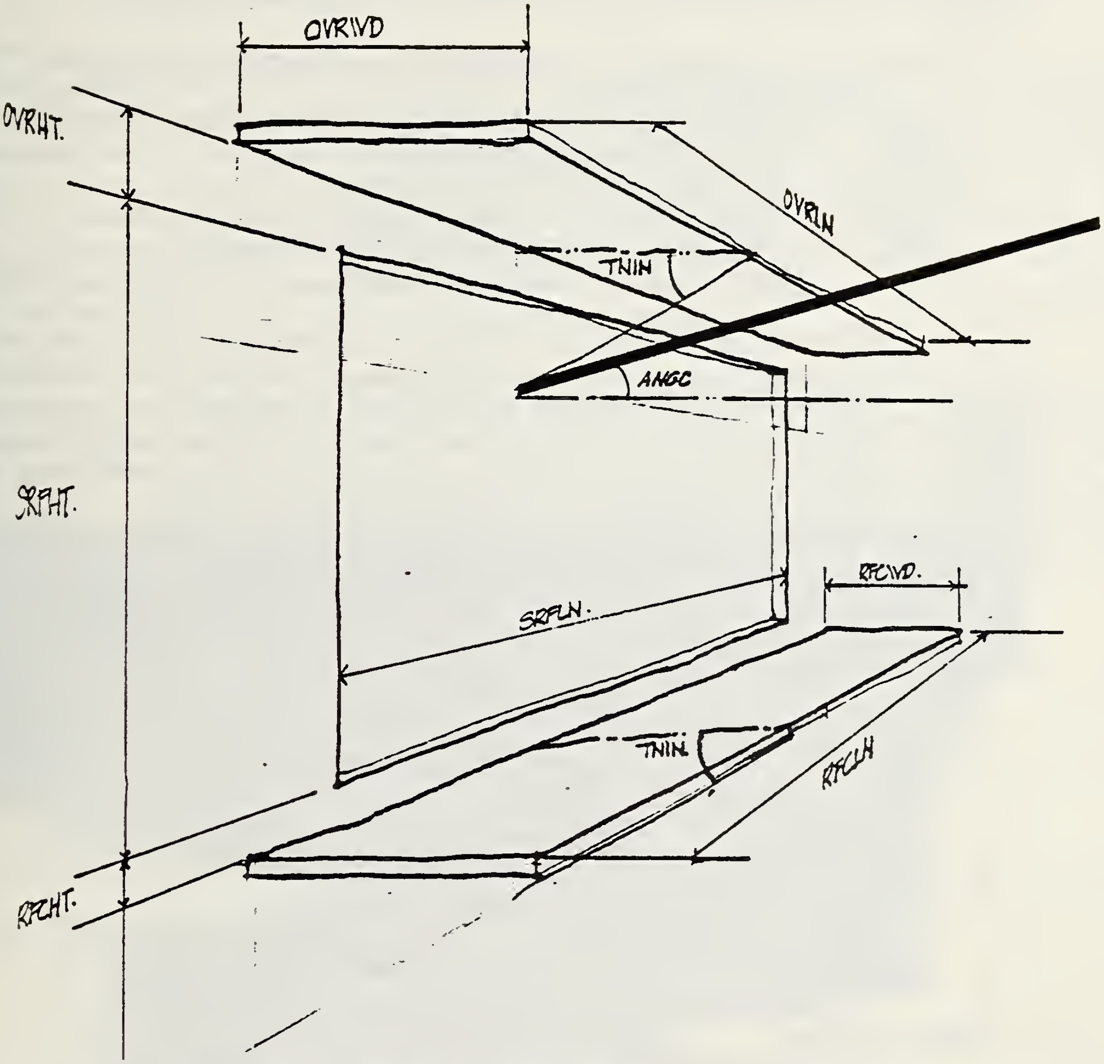


Fig. A.23 Overhang projection (and reversal of ANGC for reflection) calculation. The shadow area on the reflector is calculated as if the reflector were projected onto the plane of the wall:

PSRFHT=TNIN*OVRWD(n)
or:
PSRFHT=TNIN*RFCWD(n)

The shadow cast by an overhang onto the surface is geometrically calculated from the true position of the overhang relative to the window. The same algorithm is used here as is used for computing intersection projections, except that the window assumes a position analogous to the street position in an urban canyon.

Total beam energy incident on a surface is calculated in SUNSRF:

RDRSRF=(TRBH*RDRS*RDRSHD+RFXB*RDRRF*TRBRH)*DFBC

where:

RDRSRF	beam radiation on the surface (calculated in BTU $Hr^{-1}Ft^{-2}$ and later converted to Wm^{-2})
TRBH	transmission factor for beam energy incident on a surface
RDRS	beam radiation on a surface
RDRSHD	Ratio of unshaded surface area
RFXB	Amount of energy reflected onto a window surface
TRBRH	Transmission coefficient of reflected energy
DFBC	Hourly ratio of cloud modified radiation to clear day radiation

Both the reflected beam energy and the shadow calculations are performed only twice per month in order to shorten execution time. There is little penalty in accuracy. Absorbed, transmitted and incident energy are calculated for each surface. The absorption factor may be used in the thermal analysis node/network file, the transmitted energy is necessary for the room heat gains and daylighting analysis, and incident radiation is calculated for the solar radiation data file.

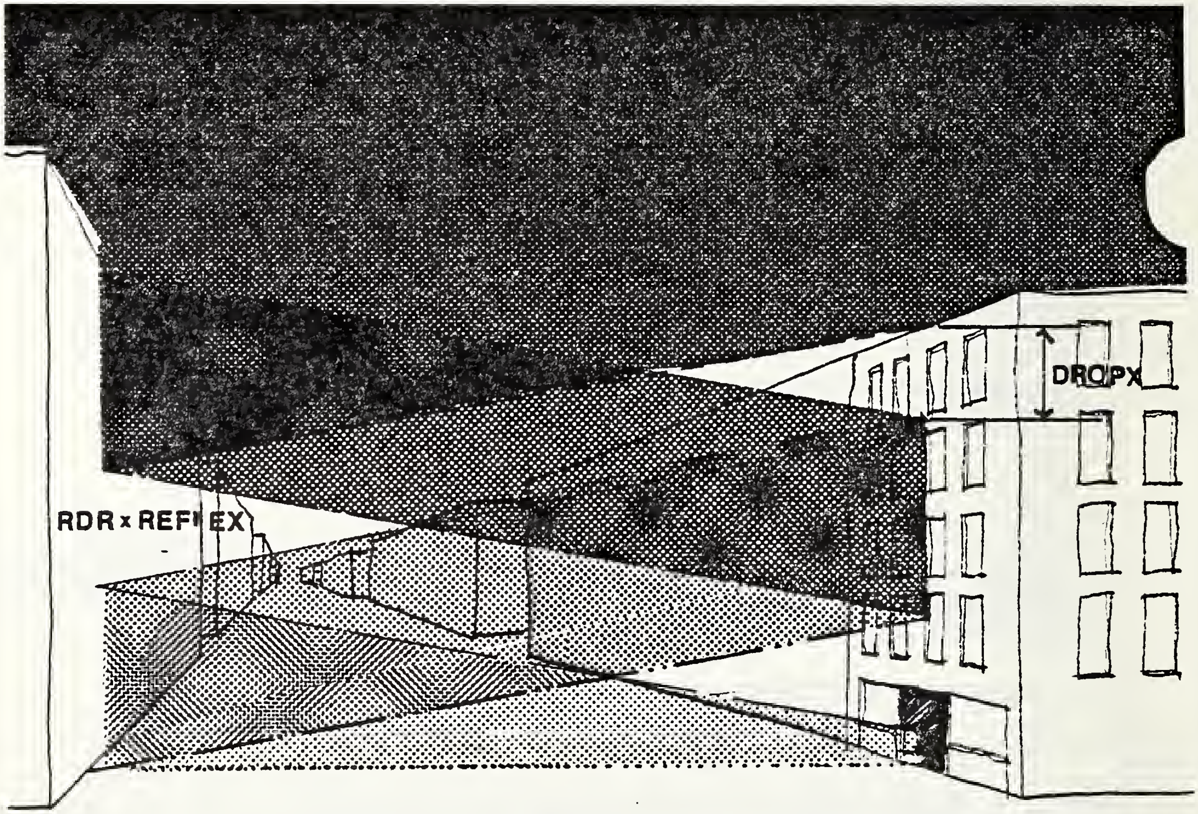


Fig. A.24 The direct beam radiation is decremented and bounced in an urban street canyon. In subroutine BOUNCE, the depth of beam penetration is calculated (DROPX) and the reflection factor decrements the beam bounce on each bounce.

5. Discussions with Dr. J. Richmond of NML, NBS have led to this general, simple formula. This function is not based on measurements and must be confirmed.

A.4 GLAZING TRANSMISSION

Passive and active solar systems are dependent on glazing systems for the transmission of solar radiation, and for the preservation of a thermal barrier between two thermally exclusive environments. Because passive solar (or active solar) thermal system design is dependent on the glazing assembly design, proper analysis of glazing transmission properties, and proper modelling of the thermal gains in various pieces of the assembly, are critical. This program provides an opportunity to analyze a variety of glazing materials and their interstitial space combinations. The user has a choice of reporting heat gain on a particular component in the assembly or he may choose to report the heat gain on the final absorbing (or room) surface.

An example of the analysis capability of SOLITE is illustrated in Fig. A.25 where the absorbed energy in a layer of FEP between a layer of glass and another layer of FEP is calculated. Although the program contains no thermal analysis capacity, the transmission program does permit the analysis of the absorbed energy in each of the layers of such an assembly. Heat gain in the user specified layers is output to logical unit 10. If no layers are specified, heat gain on the final absorbing layer is calculated by default.

Fig. A.25 The runstream that calculates solar radiation absorbed in a layer of FEP as part of a glazing assembly. The run is made with an absorbing surface reflection coefficient of 0.2. The initial part of this runstream is similiar to that illustrated in Fig. 3.3. Note the high transmission characteristics of 1 mil of FEP. (The heat gain per ft^2 resulted in only 1 BTUhr^{-1} being absorbed).

```
ISOMETRIC OF URBAN SITE

    !    !   !                  !    !   !
    !    !   !        4.        !    !   !
....!    !   !..................!    !   !.....
   /     !  /       /SRF/-DST1>/     !  /
  /      ! /        1.        /      ! /
./       !/................../      !/........

             STREET AXIS  -->   3.

.....        ....................        ......
   /!       /!                 /!       /!
  / !      / !      2.        / !      / !
./  !     /..!. . . . . . .  /  !     /..!. . .
 :  !    !   !               :  !    !   !
 !  !    !   !         5.    !  !    !   !
 .  !    !   !               .  !    !   !

DESCRIPTION OF THE SURFACE   1 ON THE PLANE
A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE
THE SURFACE IS LOCATED. ENTER THAT NUMBER.

>1.
```

```
 THE SURFACES COMPRISING THE STREET CANYON
 MAY BE PICKED FROM THE FOLLOWING. ENTER THE
 APPROPRIATE REFRENCE NUMBER FOR EACH SURFACE.
    TREES (DECID)     1.
    TREES(CONIF)      2.
    GRASS             3.
    BITUMINOUS        4.
    BRICK             5.
    GLASS             6.
    CONCRETE          7.
    METAL             8.
    SNOW (SUMMER .2)  9.
    OTHER            10.

 ENTER THE MATERIAL OF THE THE WALL ITSELF    .

>6.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>40.
 ENTER THE MATERIAL OF THE THE WALL ITSELF    .

>5.
 ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>6.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>60.
 ENTER THE MATERIAL OF THE THE OPPOSITE WALL .

>5.
 ENTER THE MATERIAL OF THE THE STREET SURFACE.

>4.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE MATERIAL OF THE THE OPPOSITE ROOF .

>4.
 ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT MATERIAL.

>100.
 ENTER THE DISTANCE FROM THE SIDE EDGE OF THE SURFACE TO THE
 CORNER OF THE BLOCK, DIST1 IN FT.
 (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE STREET AXIS.)
>49.5
 ENTER THE LENGTH OF THE SURFACE  IN FT.

>1.
 ENTER THE HEIGHT OF THE SURFACE  IN FT.

>1.
 ENTER THE ABSORPTION COEFFICIENT OF THE SURFACE

>0.8
```

```
 ENTER THE WIDTH OF OVERHANG INFT.    IF NONE ENTER 0.

>1.
 ENTER THE LENGTH, AND HEIGHT ABOVE TOP SILL IN,
>10.
>1.
 INDEX NUMBER FOR OVERHANG, REFLECTOR MATERIALS
       ALUMINIUM POLISHED   1.
       IRON WITH WHITE ENML 2.
       WHITE PAINT          3.
       GREY PANT            4.
       BLACK PAINT          5.
       BRICK                6.
       WOOD,LIGHT           7.
       WOOD,DARK            8.
       SNOW, ICE            9.
       CONCRETE            10.

 ENTER THE SURFACE MATERIAL OF THE OVERHANG

>10.
 ENTER PERCENTAGE OF OVERHANG     WITH THIS MATERIAL.

>100.
 ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF
 SURFACE, INFT.    ELSE ENTER 0.

>0.
 ENTER THE HEIGHT ABOVE GROUND OF THE BOTTOM OF
 OF THE SURFACE IN FT.

>10.
 IS THE SURFACE GLAZED.1.=YES. 0.=NO

>1.
 DESCRIPTION OF THE GLAZING:
 ENTER THE NUMBER OF GLAZING LAYERS IN THE SURFACE

>3.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  1

       MATERIAL          INDEX NUMBER

       GLASS             1.
       AIR               2.
       POLYCARBONATE     3.
       PLEXIGALSS(PMMA)  4.
       MYLR(PET)         5.
       TEDLAR(PVF)       6.
       TEFLON(FEP)       7.
       WATER-LIQUID      8.
       WATER-SOLID       9.
       QUARTZ           10.
       OTHER            11.

>1.
 ENTER THE THICKNESS OF GLAZING LAYER  1 IN INCHES

>.25
```

```
 IF MEASURED TRANSMITTANCE, ENTER 0.
 IF ORDINARY GLASS, ENTER 1.
 IF WATER WHITE, ENTER 2.
 IF HEAT ABSORBING, ENTER 3.
 IF REFLECTING, ENTER 4.

>3.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  2

>7.
 ENTER THE THICKNESS OF GLAZING LAYER  2 IN INCHES

>0.001
 ENTER 1. IF THIS LAYER,  2 IS IN CONTACT WITH LAYER  1
 ELSE ENTER 0.

>0.
 ENTER THE INDEX NO. OF THE MATERIAL OF LAYER  3

>7.
 ENTER THE THICKNESS OF GLAZING LAYER  3 IN INCHES

>0.002
 ENTER 1. IF THIS LAYER,  3 IS IN CONTACT WITH LAYER  2
 ELSE ENTER 0.

>0.
 ENTER 1. IF LAYER 3 IS IN CONTACT WITH ABSORBING SURFACE.
 ELSE ENTER 0.

>0.
 SPECIFIED GLAZING SECTION:

           I       I       I       I       I       I       I
 LAYER     I   1   I   2   I   3   I   4   I   5   I   6   I
           I       I       I       I       I       I       I
 MATERIAL  IHI  TRNI   AIR I   FEP I   AIR I   FEP I   AIR I
           I       I       I       I       I       I       I


 ENTER 0. FOR CALCULATION OF ENERGY ON ABSORBER SURFACE
 ELSE, ENTER THE LAYER NUMBER FOR ENERGY, ABSROBED THERE.

>3.
>file 10


  JANURY

   DAY   DRY    MAX   MIN  WIND    RADIATION ON SURFACE    BTU/F2
         BULB  TEMP  TEMP  SPEED
         TEMP
             F.DEG.        MPH     S 1
    1     14.   20.   10.    7.      0.
    2     18.   30.    9.    9.      1.
    3     25.   38.   12.    7.      1.
    4     33.   43.   21.    7.      0.
    5     40.   46.   34.    6.      0.
    6     49.   63.   39.    7.      0.
    7     49.   64.   27.   17.      0.
    8     25.   29.   21.    8.      1.
   TOTAL
   MONTH   1.   64.    9.    0.      0.
```

Description of the glazing layers, calculation of the properties of the layers and analysis of the transmission coefficients are performed in subroutines SURFAC, SRFAB, SUNSRF, and TRANS. Positions of these subroutines in the overall context of the program are illustrated in the flowchart of Fig. A.26. Glazing descriptions are input to subroutine SURFAC and RHO. Both the index of refraction and the extinction coefficient of the glazing assembly materials are defined in the subroutine. A user may choose from a menu of 10 materials and four types of glass, or he may input the glazing refraction and extinction coefficients himself. If the choice of materials is from the menu, the subroutine assigns the proper extinction coefficient and refractive index from arrays GLEX and GLREF respectively. The values in these arrays are defined by data statements found in subroutine SURFAC. A user may also define the transmission of the material at normal incidence, and the program will calculate the proper extinction coefficient. In addition to defining the extinction coefficient and the refractive index, subroutine SURFAC also defines the spatial relationship between the different layers. Congruity of the glazing layers is established by the setting of a number of flags.

In the example glazing assembly previously described, the user would set flags in the subroutine, in response to the program's queries concerning the congruity of the layer being described to the previous layer. Program prompts, inputs and responses are illustrated in the previously referenced Fig. A.25.

Glazing materials are assumed to be specular in nature. This assumption includes the final absorbing surface beyond the solar radiation transmitting materials. Absorption of the absorbing layer may be input as a single variable (as might be the case for a flat plate collector) otherwise, SOLITE will internally calculate a reflection coefficient for a room cavity in subroutine SRFABS. This is the case with a window of a room. The room cavity is not a "flat plate", but rather defines a cavity with a reflectance that is a function of the internal surface reflectances. However, in order for the transmission subroutine to calculate the absorptance of the layers, the final absorber must be a flat, specularly reflecting plate. For the case of the window, the room cavity is replaced by a hypothetical flat plate "mimicking" the absorption of the room. This final coefficient is internally calculated as a product of room surface interreflections, view factors to the window from the surfaces, and absorption characteristics of walls, ceiling and floor. Subroutine SRFABS calculates the view factors in a manner similiar to the view factor calculations for diffuse radiation distribution in the street canyon:

SRFABS=SVFW*RSRF*WVFS

where:

SRFABS	Total absorption of the window opening
SVFW	Surface view factor of window
WVFS	Window view factor to surface
RSRF	Surface reflection coefficient

View factors to the window are calculated using the same functions referenced by subroutine VFSRF. These include the function FPP, FPR, FSPR, and FSPP. See section A.3.1 for a description of the functions.

The calculation procedure defining the substitute surface absorption of a room cavity behind a window is a simplified algorithm. A more rigorous approach would use an

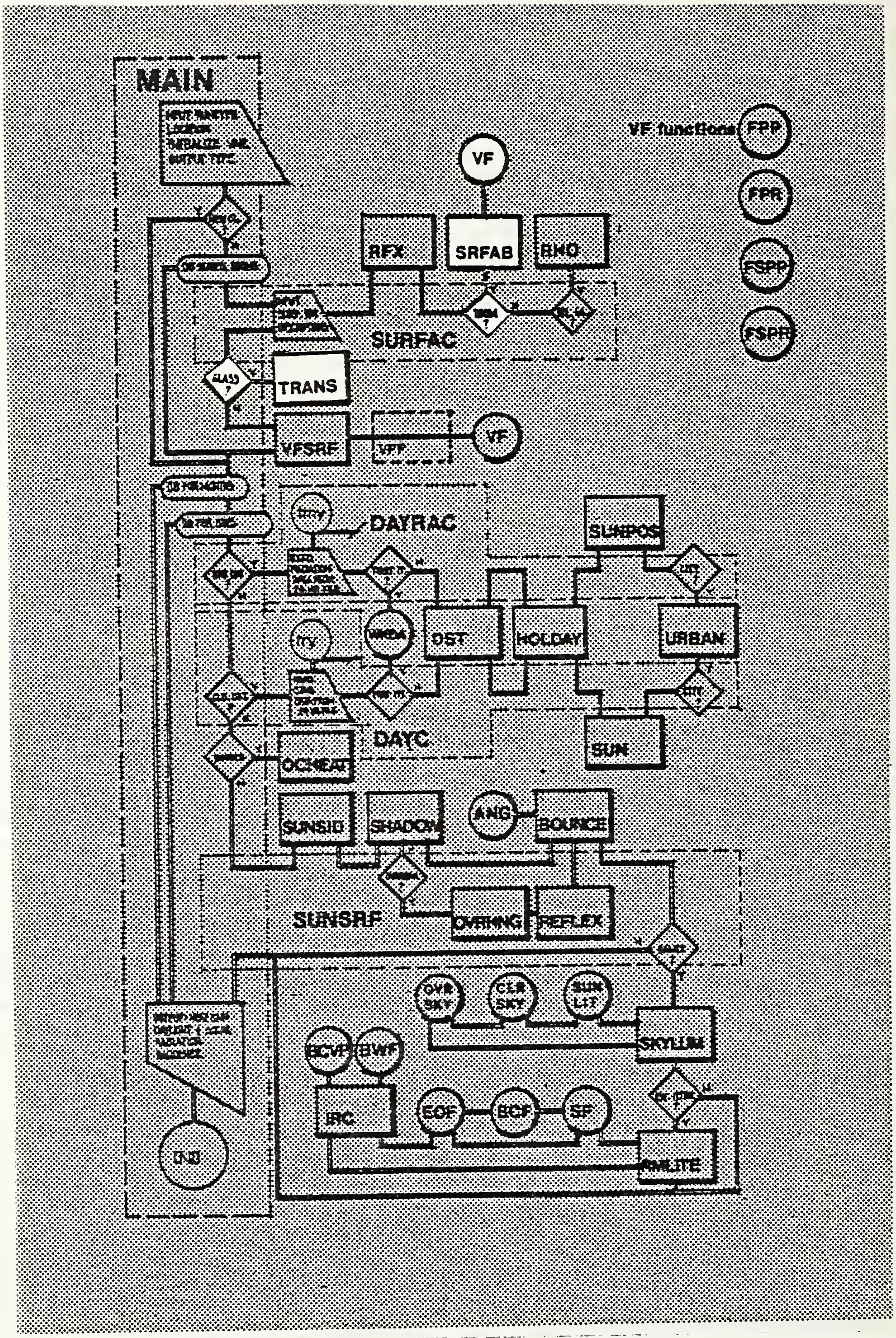


Fig. A.26 Subroutines used to determine the transmission and absorbing properties of a glazing assembly are highlighted in the flowchart above.

algorithm similiar to that of Dr. N. Arumi [55]. This rigorous effects of the beam interreflections within the room and traces the room geometry. A matrix based approach to this problem would be than the one presented here. Subroutine TRANS calculates the coefficient of the glazing assembly and defines the absorption in any partic Reflection and transmission of a material are dependent on the refractive in the extinction coefficient. Snell's law describes the refractive index as:

$\mathbf{GLAREF=Sin(ANGINC)*(Sin(THETA))^{-1}}$

where:

GLAREF	Index of refraction
ANGINC	Angle of incidence on the surface of the material
THETA	Angle of refraction in the material

At least two axes of polarization must be accounted for in computing the reflectance of a glazing surface and the transmission through a defined layer [56]. Errors of 11-13 percent may otherwise result. The reflection in each plane of polarization may be described by:

$\mathbf{R(1)=Sin(ANGINC-THETA)^{2}*(Sin(ANGINC+THETA))^{-2}}$ A.4.1

$\mathbf{R(2)=Tan(INC-THETA)^{2}*(Tan(INC+THETA))^{-2}}$ A.4.2

where:

R(1)	Perpendicular polarized component of reflection
R(2)	$Tan(ANGINC-THETA)^{2}*(Tan(ANGINC+THETA))^{-2}$

where:

R(1)	Perpendicular polarized component of reflection
R(2)	Parallel polarized component of reflection
ANGINC	Angle of incidence with the surface
THETA	Angle of refraction

Specific properties of glazing materials are derived from Bouger's law:

$\mathbf{-dI_g(x)=I_g(x)K_g dx}$

where:

K	Monochromatic extinction coefficient
I	Intensity at x for the specific wavelength g.

Transmittance is the ratio between I(0) and I(x'), where x' is the optical thickness of the material. It is assumed that transmission is fairly constant over the visible range of wavelengths for the materials listed in the glazing menu (0.5-3 micron range of radiation):

$\mathbf{T=e^{(-K*L)}}$

where:

T	Transmittance of the material (range from 0 to 1)
L	Actual travel distance of the beam through the material: $L=Thickness*(Cos(THETA))^{-1}$.

It has been assumed that the extinction coefficient calculated in subroutine SURFAC is constant in the wavelengths from 500 nm to 3000 nm were 90 percent of the extraterrestrial radiation is found. It is also assumed that the refractive index does not change as a function of wavelength. This is a valid assumption [57], given the materials that the user may choose from listed in array GLAS.

The extinction coefficient (K) may be expressed as:

$K=-Ln(T)*L^{-1}$

If the user enters a transmission coefficient for normal beam incidence, then K is calculated in subroutine SURFAC.

With multiple layers of specular transmitting materials, the reflectance calculation follows Stoke's equation. For each polarization component:
$RHO=R(n)+R(n)*T(n)^2*(1-R(n))^2*(1+R(n)^2*T(n)^2+...)$
Similiarly for transmittance:
$TAU=(1-R(n))^2+T(n)*(1+R(n)^2*T(n)^2+R(n)^4*T(n)^4...)$
where:

RHO	Reflection coefficient for parallel surfaces
TAU	Transmittance for parallel specular reflecting and transmitting surfaces
R	Reflection coefficient of the individual surfaces (n)
T	Transmittance of the material defined by the surfaces

The above relationships may be simplified and solved as an infinite geometric series for reflection and transmission respectively by the layers:

$$RHO=R(1+(T^2*(1-R^2)*(1-R^2*T^2)^{-1}) \qquad \text{A.4.3}$$

and:

$$TAU=T(1-R)^2*(1-R^2*T^2)) \qquad \text{A.4.4}$$

User defined glazing assemblies are redefined in subroutine TRANS. Each surface pair is defined as a double layer. These double layers are then substituted as single layers and the reflection/transmission calculation is performed again by the substitution of the layers. A final layer, or absorber, is assumed to be a specular reflector in order to maintain the integrity of the solution. This calculation sequence is listed below and illustrated in Figs. A.27. The transmission algorithm comprises three steps:

1. calculation of the reflection of each surface and the transmission through each pair of surfaces,
2. calculation of the reflection and transmission through a series of surfaces and layers, substituting the previous double pair in each subsequent solution, and

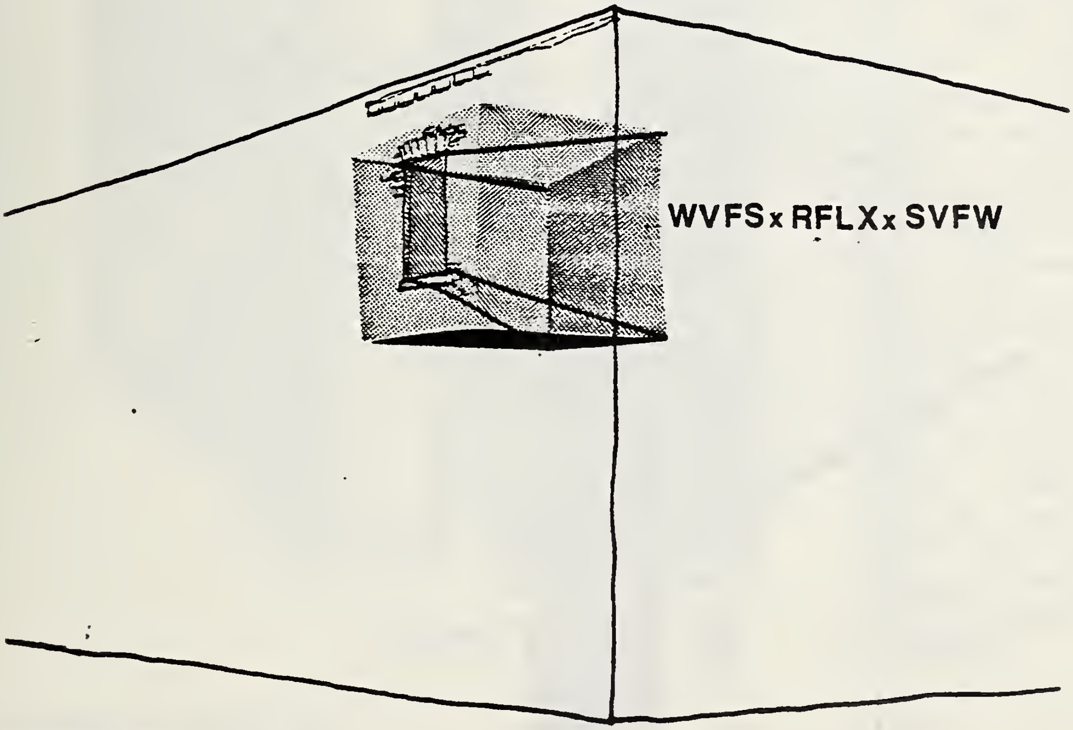


Fig. A.27a View factors of the interior room surfaces to the window and the reflection coefficients of the interior room finishes determine the resulting "surrogate" specular absoption surface.

3. calculation of the absorption in the layer chosen by the user, or calculation of the total transmission of the glazing assembly.

Array sizes in the transmission subroutines must be increased if the material's properties do not correspond to the above assumptions or if more than 10 layers are desired. If the glazing does not have constant transmission and reflection properties over the visible range, the transmission subroutine would have to be called for all of the desired wavelengths. Coefficients for transmission and reflection are continuous over the hemisphere subtending the glazing surface, but SOLITE calculates transmission only for consecutive 6° arcs. Beam radiation angles of incidence and hemispherical diffuse solar angles of incidence are converted to an array address for the appropriate transmission coefficient calculated for each 6° arc.

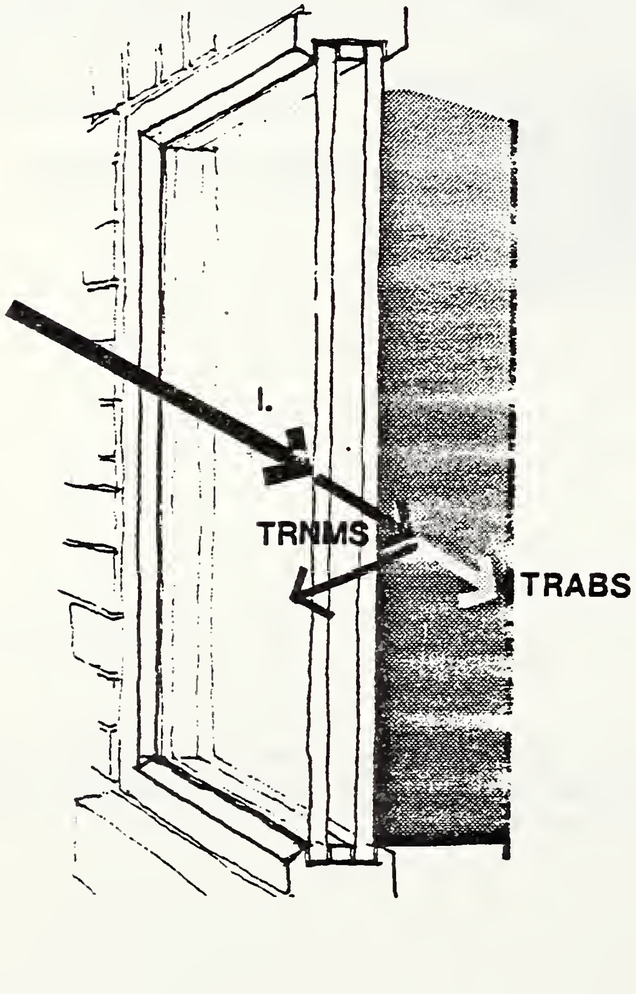


Fig. A.27b Variables used to describe the transmission (TRNMS) of the glazing for daylighting analysis and the absorption of the room or surface (TRABS) in the heat gain calculations.

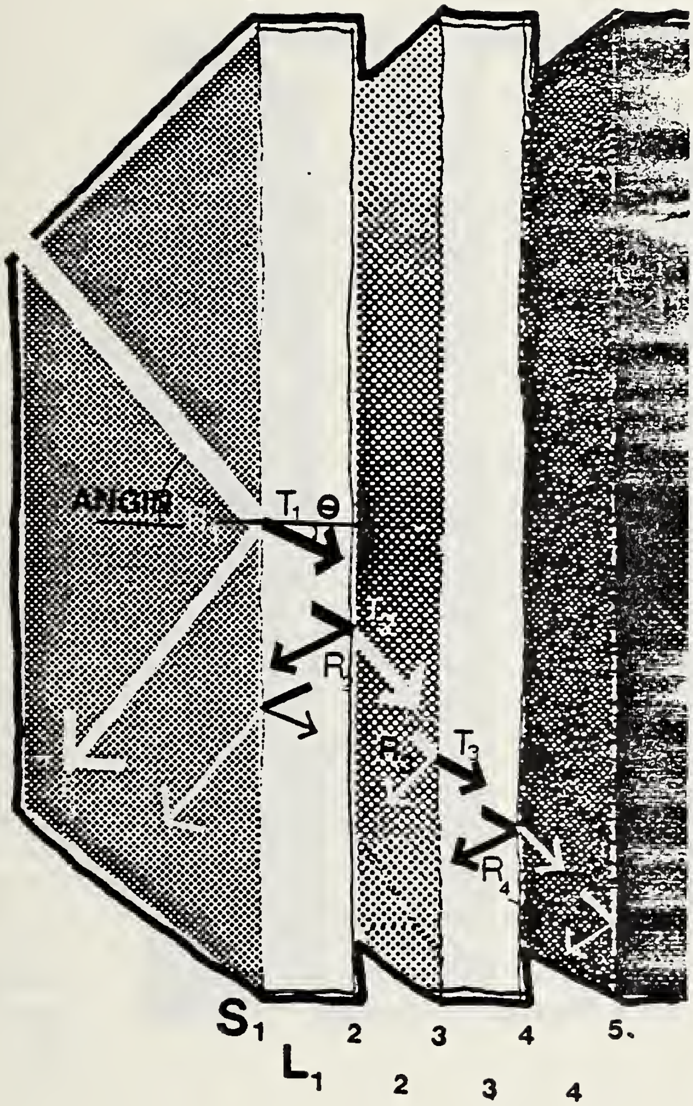


Fig. A.27c Variables used in the transmission subroutine:
For the two layers of glazing shown, the subroutine creates four material layers (in this example glass, air, glass, and air) and five surfaces shown above. Each surface has a reflection coefficient (R) determined by the angle of incidence (ANGIN) and the angle of refraction (O), and each layer has a transmission coefficient (T) determined by the length of travel through the specific material.

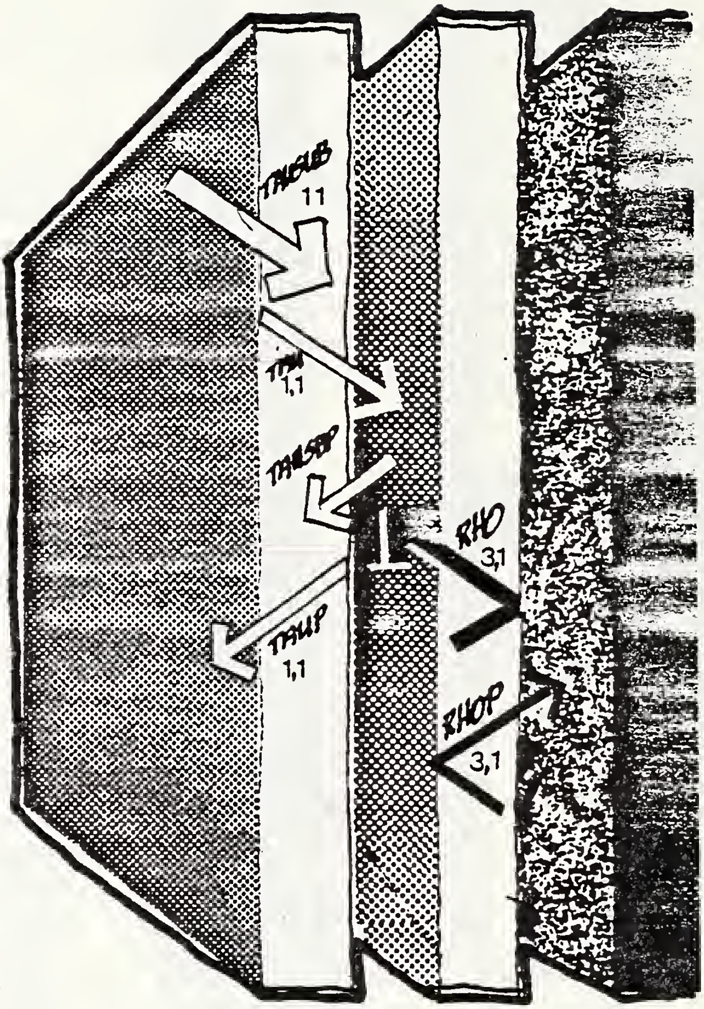


Fig. A.27d From equations A.4.3 the total reflection of each layer (and its boundary surfaces) and the total transmission through a surface and a layer are calculated both in the direction of the incident beam and in the direction of the reflected beam (indicated in the variable names by rrrrP).

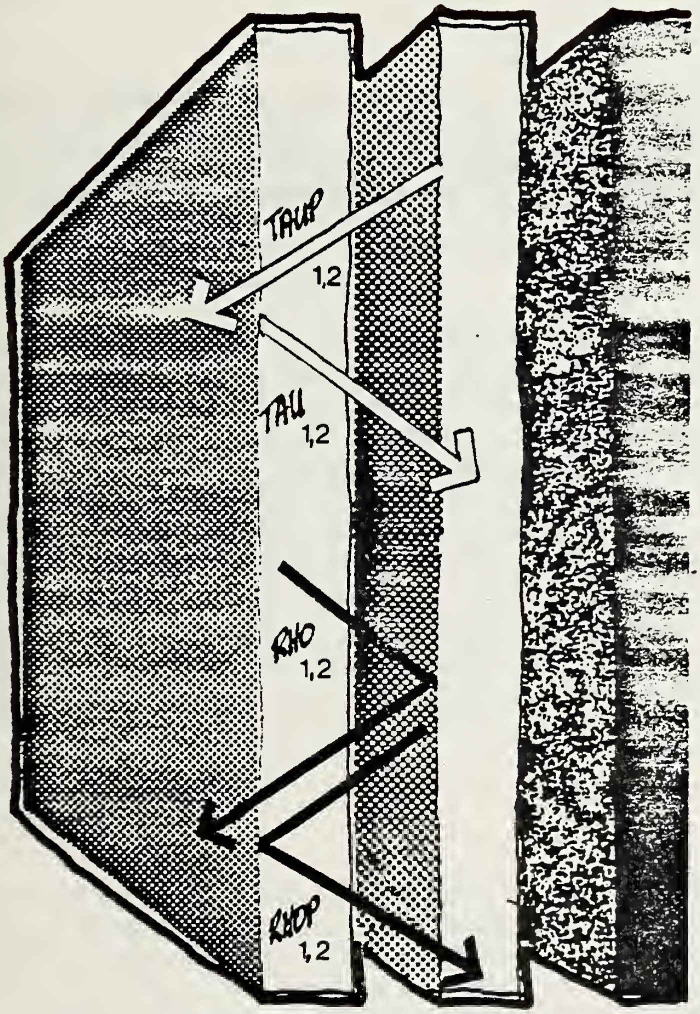


Fig. A.27e The forward and backward reflections and transmission are calculated for a series of surfaces and layers. This itteration is performed until all the surfaces and layers have been successively included in the calculation.

A.5 OUTPUT

The output format statements are found in the MAIN program. Output format type is dependent on the user specified output flags. The tests for these occur at the end of the main program. Before total surface or room heat gains are output to file 10, the solar heat gain, heat gain from occupants and electrical heat gain are summed in the MAIN program.

APPENDIX B

INCIDENTAL GAINS

A function of this program is the preparation of a data file of sensible heat gains in a given space for thermal loads analysis. These heat gains include heat generated by occupants, electrical lights, and appliances. Finite difference programs such as SINDA, MITAS or DEROB require internal gain calculations in order to properly model the thermal behaviour of a building .

Incidental gains are a function of the building type. The type in turn determines the occupancy schedules, type of daily use, and intensity of hourly use. Other parameters that affect the heat gain in a room are the area of the occupied room, and the designed electrical and occupant loads. Although average internal incidental gain profiles my be generated for an office or retail space on a square-foot basis, a similiar generalization is less meaningful in a residence, as residential heat gains are not uniformly distributed in a house |58|. Electrical appliance gains are heaviest in kitchens and living rooms, while night-time occupancy heat gains are heaviest in bedrooms. This program does not make these distinctions. Residential heat gain is applied uniformly throughout the entire house, and is based on the family size and the square footage of the space being analyzed relative to the house square footage. Future refinement will provide a functional relationship between residential heat gain and room type.

B.1 HOURLY PROFILES

Incidental gains are a function of both time of day and type of day. SOLITE contains the hourly profiles, but the user must apply the maximum occupant and electrical design loads to these profiles. These maxima are provided only for the commercial, office and retail space. For residential analysis the user provides the family size and room size. Daily heat gain profiles have been reported in numerous sources [59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69] but these data differ amongst each other. For SOLITE, the hourly energy profiles from these sources were averaged and this average profile was applied to a maximum daily value. Calculations for internal gains are performed in the MAIN program, subroutines OCHEAT, WKDAY, and HOLDAY. The relative position of these calculations in SOLITE is illustrated in Fig. B.1.

The greatest variation of daily internal gain profiles is found amongst residential gains. A comparison between several sources for residential occupant gains profiles and residential electrical use profiles is illustrated in Fig. B.2. Residential occupant heat gains is close to 100% of the maximum through the evening and early morning hours, and drops to approximately 40% in the morning, to 20% at noon, and then returns to 100% in the evenings. The residential occupancy gains used in this program are shown in Fig. B.2 as a solid line. The profile used in the program is an average of all the listed profile references and is shown by the solid lines in the figures. Incidental occupant heat gain profiles for commercial and retail buildings show agreement in the profiles found in the myriad sources as illustrated in Figs. B.3 and B.4 respectively. Occupant heat gains are stored in array HGOCC, and may be found in the MAIN program.

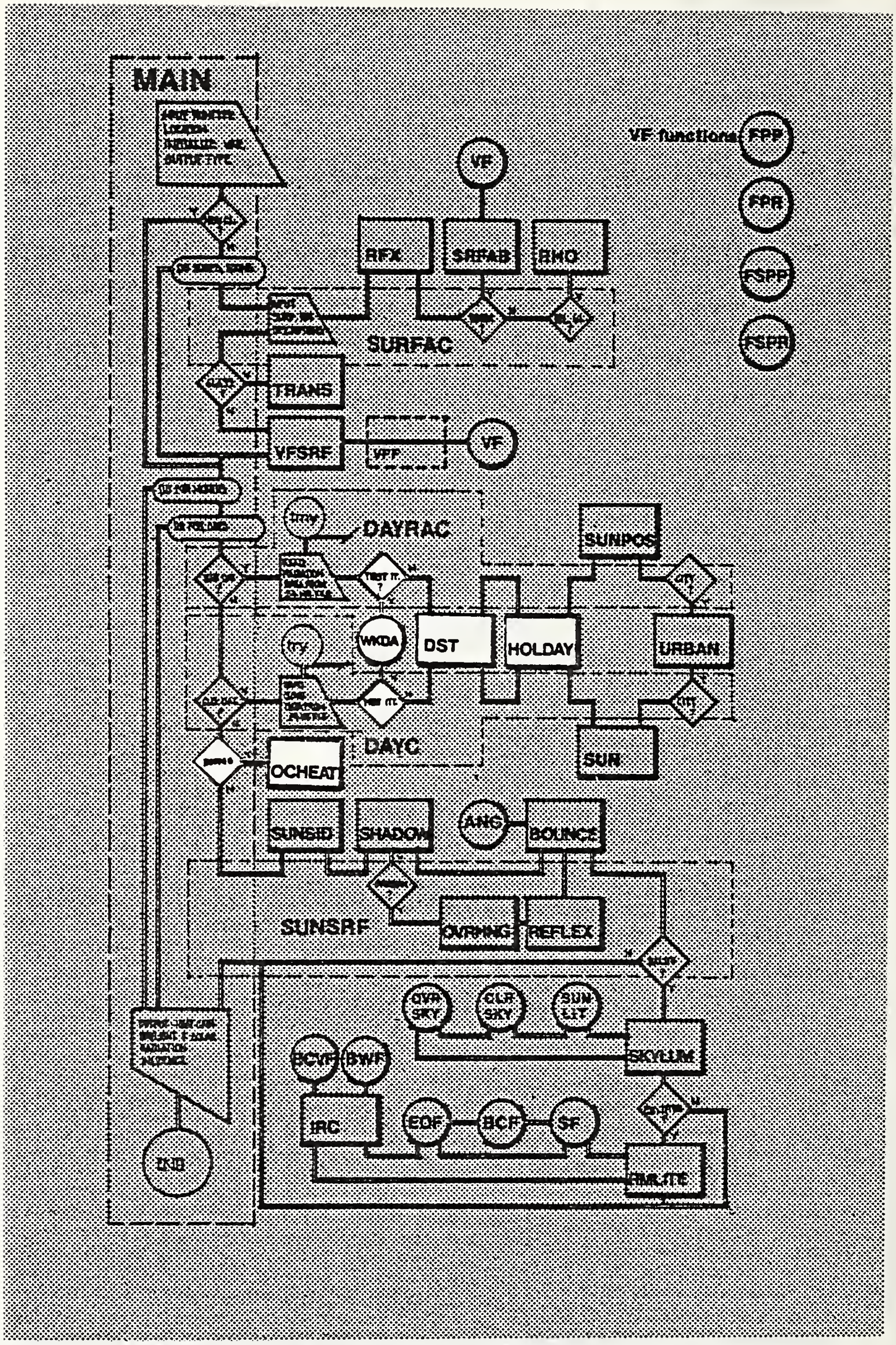


Fig. B.1 Highlighted subroutines and functions comprise flowchart of occupant gains subroutines

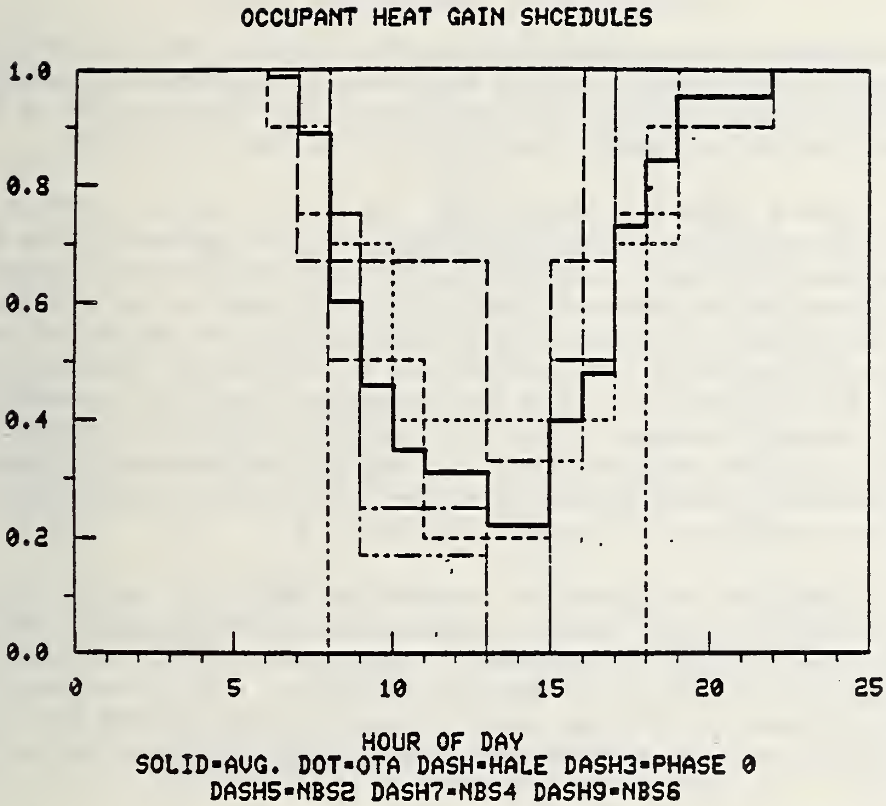


Fig. B.2 Residential hourly heat gain profiles as a ratio of the hourly maximum for all days of the week. Solid line profile is used in SOLITE to generate internal gains. (NBS references refer to Ref. 71 .)

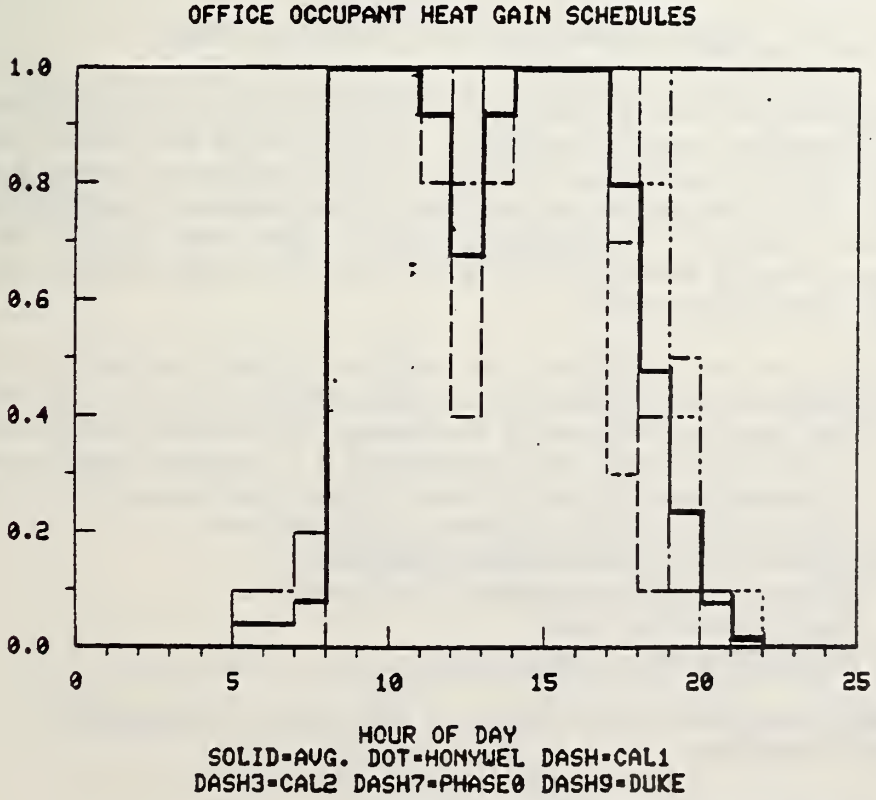


Fig. B.3 Hourly occupant heat gain profiles for an office, as a ratio of the daily hour maximum, for weekdays. (Refer to list of references 59 thru 69 for sources of other curves.)

Although no substantial difference could be discerned between residential weekday and weekend use data, several sources indicate that these differences may be significant 69 . For both commercial buildings and retail spaces, the difference due to occupant gains is significant for the various day types, as shown in Figs. B.3 and B.4.

Appliance and lighting heat gain data from the above sources showed similiar disagreement in the case of the residential profiles, but more agreement (due to fewer sources) was shown by the commercial building heat gain profile data. The solid black line in Fig. B.5 illustrates the residential electrical profile used in this program, and is an average of the profiles surveyed. Heat gain from lights and appliances comprises the total residential electrical load contributing to the room's internal heat gain. Gains to a room due to losses from water heating are assumed to be isolated from the living space. If residential analysis is specified, gains from lights are segregated from appliance gains for future incorporation of a "daylight displacement" algorithm. A closer correlation exists among profiles of residential electrical lighting than among electrical appliance use profiles all shown in Fig. B.5.

Heat gain from lights and equipment in commercial and retail spaces follows the respective occupancy schedules closely. Profiles for electrical gains in offices and retail spaces are illustrated in Figs. B.6 and B.7 respectively. There are fewer sources of data for commercial building types than for residences. For a weekend or holiday profile, the data is based on only one source 70 . Electrical lighting and equipment gains in commercial buildings are characterized by heavy daytime use and reduced evening use.

B.2 MAXIMUM HEAT GAINS

Profiles for daily heat gains for different day types provide only the ratio of the hourly heat gain to the maximum possible heat gain. For both retail and office space, this maximum is input by the program user as a power rating per square metric of the area (Wft^{-2} or Wm^{-2}). Default values are not provided by the program. Typical values that may be used are 3.25 Wft^{-2} in commercial office space, and $10Wft^{-2}$ for retail spaces. Maximum occupant load is entered by the user as a design density figure (eg. 100 ft^2 per person in an office space).

Residential maxima are less definitive. In addition to hourly variation of internal residential gain profiles, the heat gain may be characterized by the size of the family, and the size of the room in relation to the house. Since most of the residential profiles assume a 4 member family, the relationship is a function based on the four member family. A discontinuity occurs if there are only two people in the family, as it is assumed that the house will not be occupied during the day:

$$\mathbf{NODOCC=(4-2*NODOCC)*0.25*(NODRMA*NODFLA^{-1})}$$

NODOCC	Maximum number of people in the household
NODFLA	Floor area of the house
NODRMA	Area of the room under scrutiny.

Electrical appliance use is not linearly related to the number of occupants: 71

$$\mathbf{NODELC=(NODOCC-4)*0.5+4}$$

where:

NODELC	The electrical heat gain multiplier
NODOCC	The number of occupants in a house

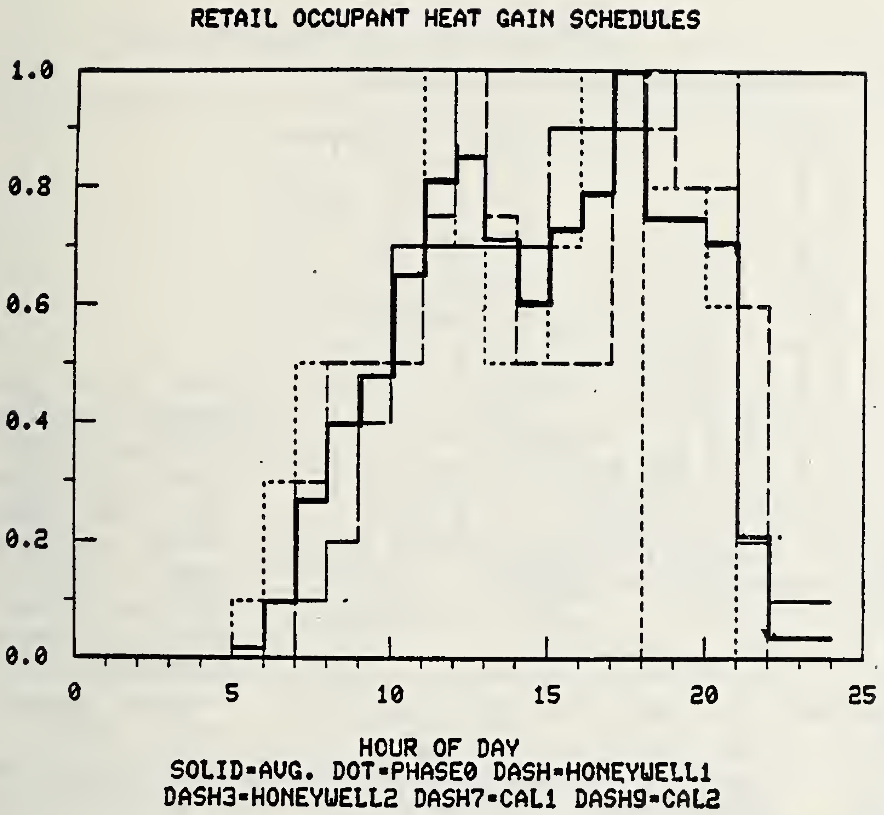


Fig. B.4a Hourly occupant heat gain profiles for weekdays in a retail space, as a ratio of the daily hour maximum

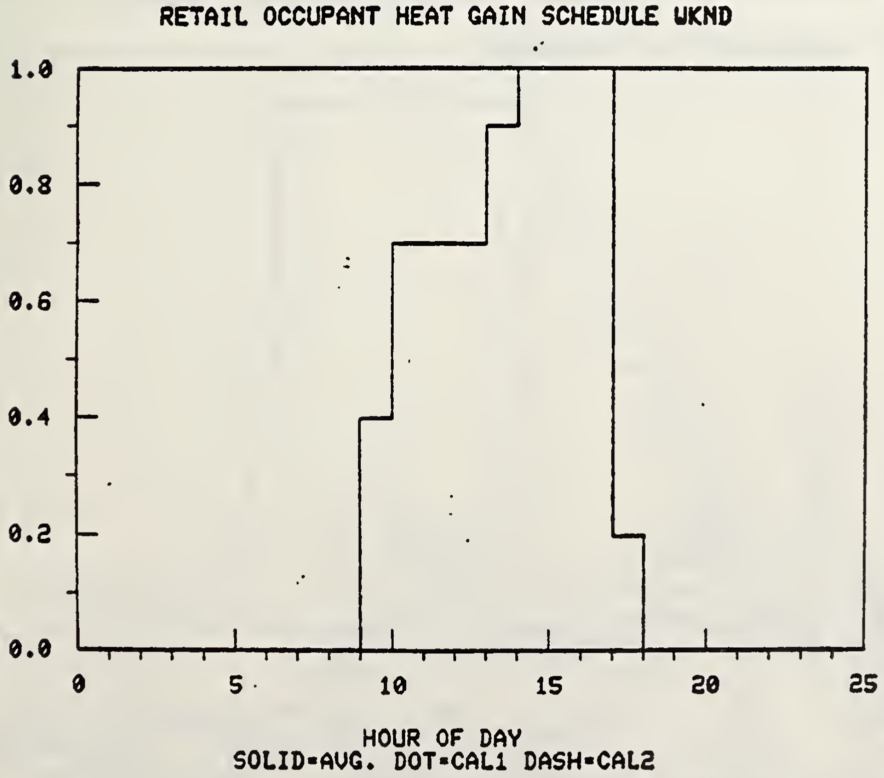


Fig. B.4b Hourly occupant heat gain profiles for a retail space on a weekend. The California model buildings study is the only source of information for the data.

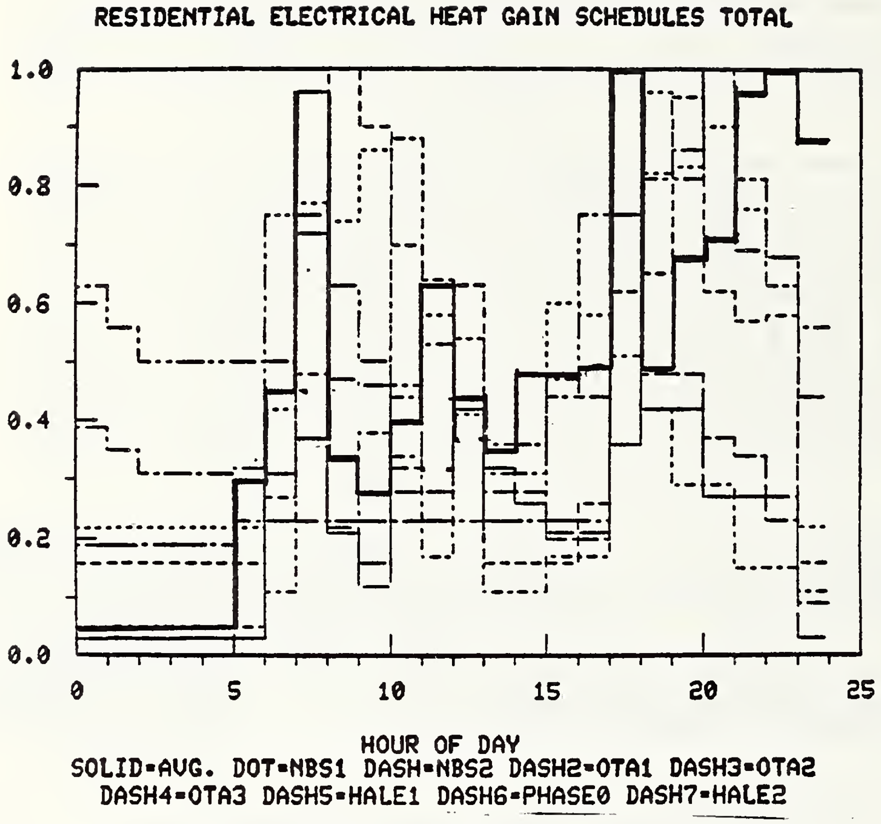


Fig. B.5a Residential electrical heat gain profiles, total of appliances and lights. (Note references such as OTA1 or OTA2 are from a series of different residential building types — from single family through apartments reported in the OTA study. Ref. 60.)

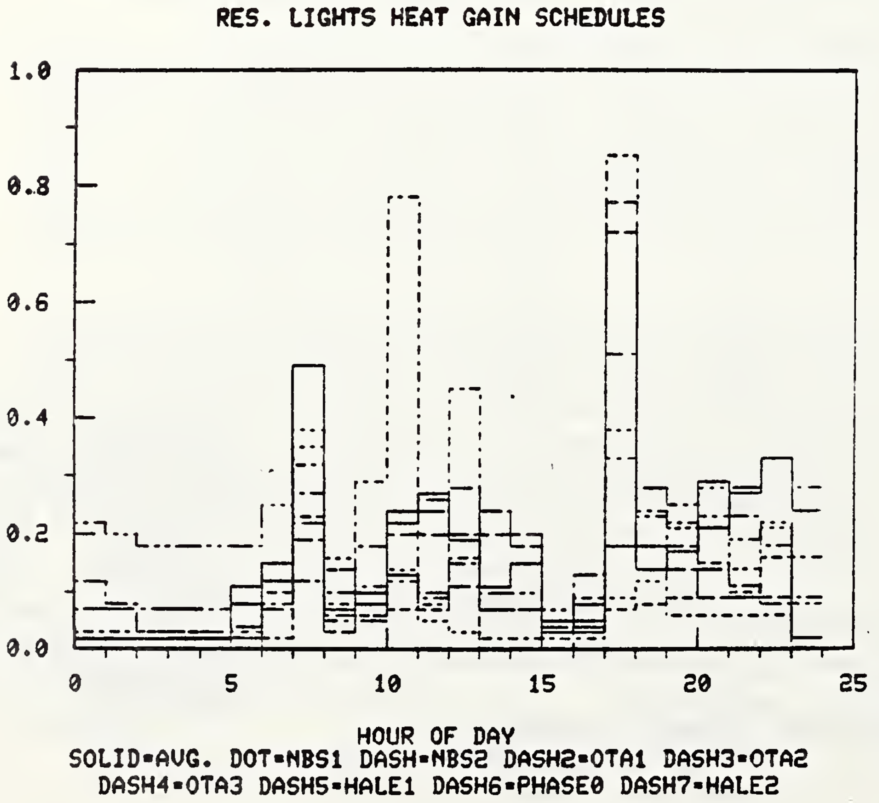


Fig. B.5b Profiles of residential heat gain from electrical lights.

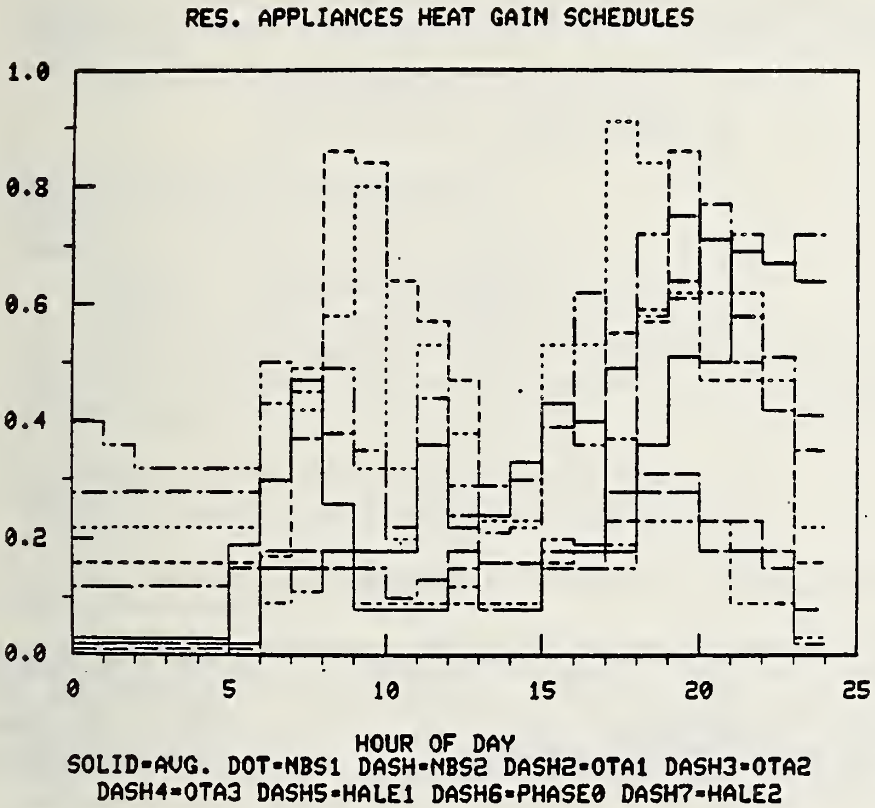


Fig. B.5c Profiles of heat gain from residential electrical appliances.

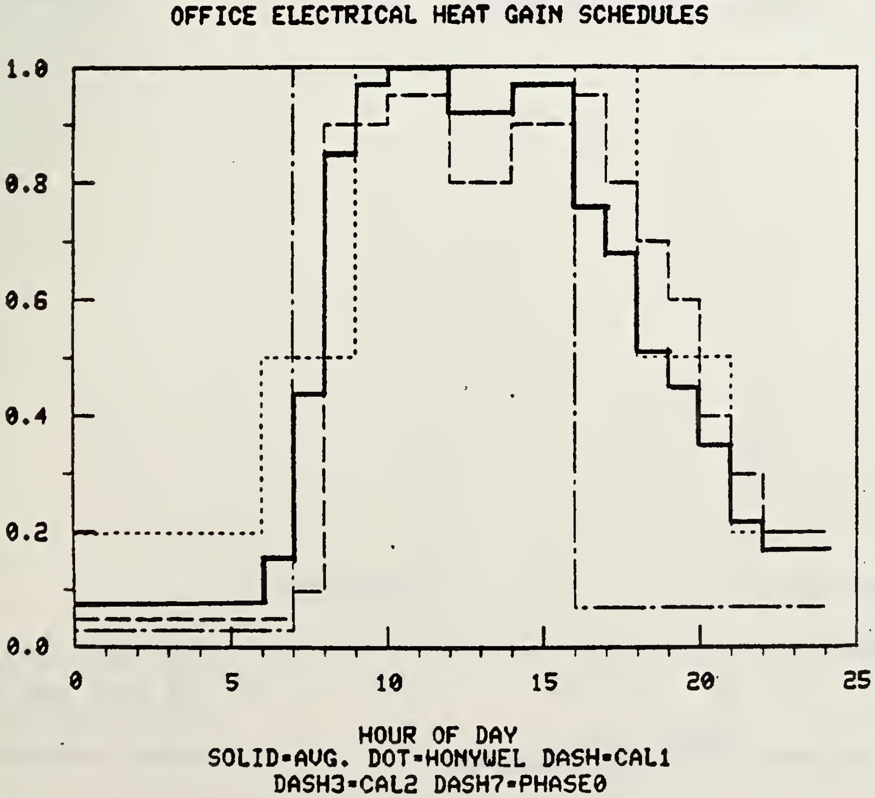


Fig. B.6 Electrical heat gain profiles for office spaces. Weekend heat gains for offices are 0.1.

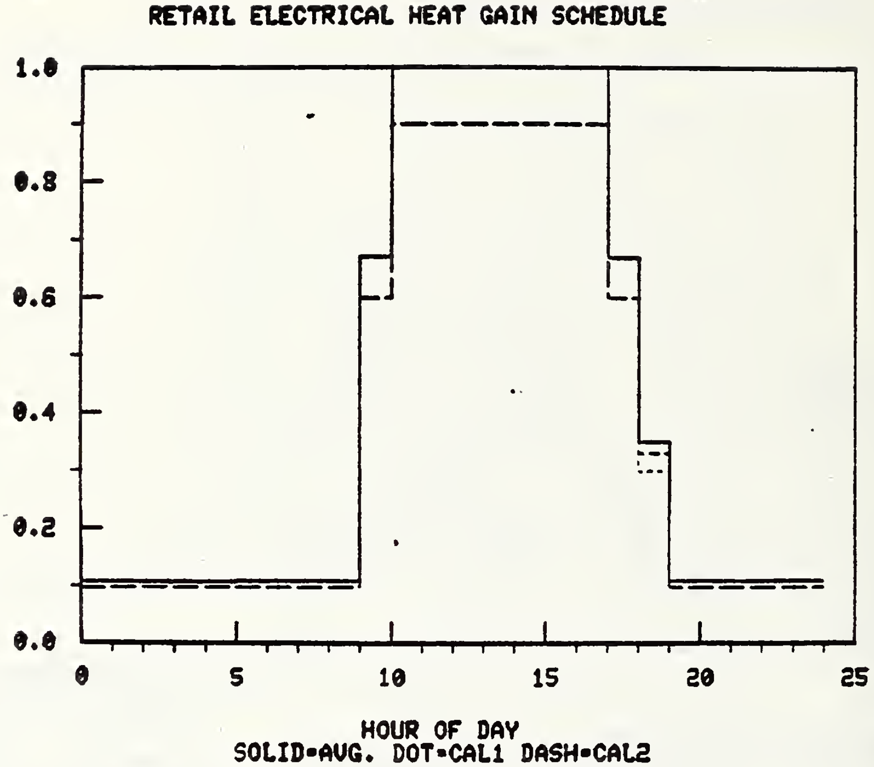


Fig. B.7a Electrical heat gain profiles for retail space, weekdays.

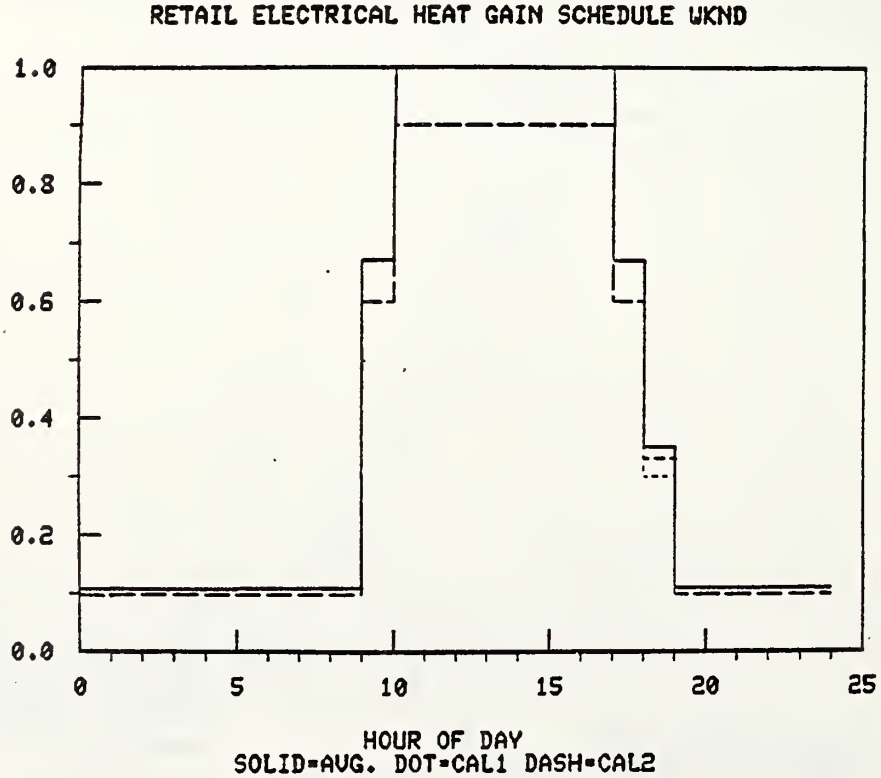


Fig. B.7b Electrical heat gain profiles for retail space, weekends.

Finally, total heat gain on a node, both residential and commercial is:
NODELC=NODELC*ELEMAX
where:

ELEMAX	1180.0 BTU Hr^{-1} in the summer and [72] 1291.3 BTU Hr^{-1} in the winter

Sensible gains from occupants are:
NODOCT=NODOCC*255 BTU Hr^{-1} [73]
where:

NODOCT	Occupant heat input to the node
NODOCC	Number of occupants in a house

All of the above calculations occur in the MAIN program. As incidental gains are a function of day type, three subroutines are used to determine this factor: WKDAY, HLDAY and OCHEAT.

Subroutine WKDAY calculates days of the week:
KKDAY=1 though 7 where 1=Sunday and 7=Saturday

HLDAY calculates legal holidays in the United States:
IHOL=1 for holidays.

Subroutine OCHEAT determines the profile type used as a function of the day type through a series of tests. Residential occupancy remains unchanged over day type. Retail occupancy has long days during weekdays and holidays, and short days during weekends. Offices are opened during weekdays only. As a distinction is made between surfaces and rooms, occupancy gains are not calculated for surfaces, only for occupied spaces.

APPENDIX C

DAYLIGHTING CALCULATIONS

At present, the daylighting calculations are only loosely affiliated with the calculations for solar gain. Algorithms incorporated in this program were developed by Research Associate Gary Gillette at the National Bureau of Standards, and have been compared to empirical data. Basic assumptions of the program include the following:

1. the daylighting calculations are based on a spherical room configuration. Aspect ratios deviating from a cubic shape may lead to reduced accuracy of the predictions,
2. only one window may be analyzed at a time, and
3. the estimation of glare is too simplistic. In order to determine a "useable" hour of daylight, the daylight level at the calculation point closest to the window may not exceed the brightness of the window by more than a 5.5 ratio [74].

Calculation procedures used in the programs (named DALITE) are presented by Gary Gillette in reference [21]. These analysis programs are linked to SOLITE through subroutine SUNSRF and the input data is shared by both programs. Array ZSLITE contains the values used in the daylighting analysis. All inputs to SOLITE are converted to English units before being passed on to DALITE. All values output from the DALITE programs (shown in Fig. C.1) are in English units.

Two branches comprise the daylighting programs: SKYLUM and RMLITE. These major algorithm branches calculate the sky brightness and the room lighting factors respectively. Before calling the DALITE algorithms, three points are described in the user defined room. These points form the calculation points for daylight levels in the room. The points occur along the midline of the room, drawn from the window to the rear wall of the room. A central point is located at the equidistant point from the window and the rear wall. The first calculation point is a third of the distance from the window to the central point, and the last point is a third of the distance from the rear wall to the central part of the room as illustrated in Fig. 3.12.

Calculated daylight levels at these three points are returned to subroutine SUNSRF where they are tested against:

1. allowable daylight levels for the three types of occupancies, (set in subroutine SUNSRF)
2. glare levels, and
3. usefulness of the light. If the occupancy is less than 10% of the maximum, no daylight hours are ouput.

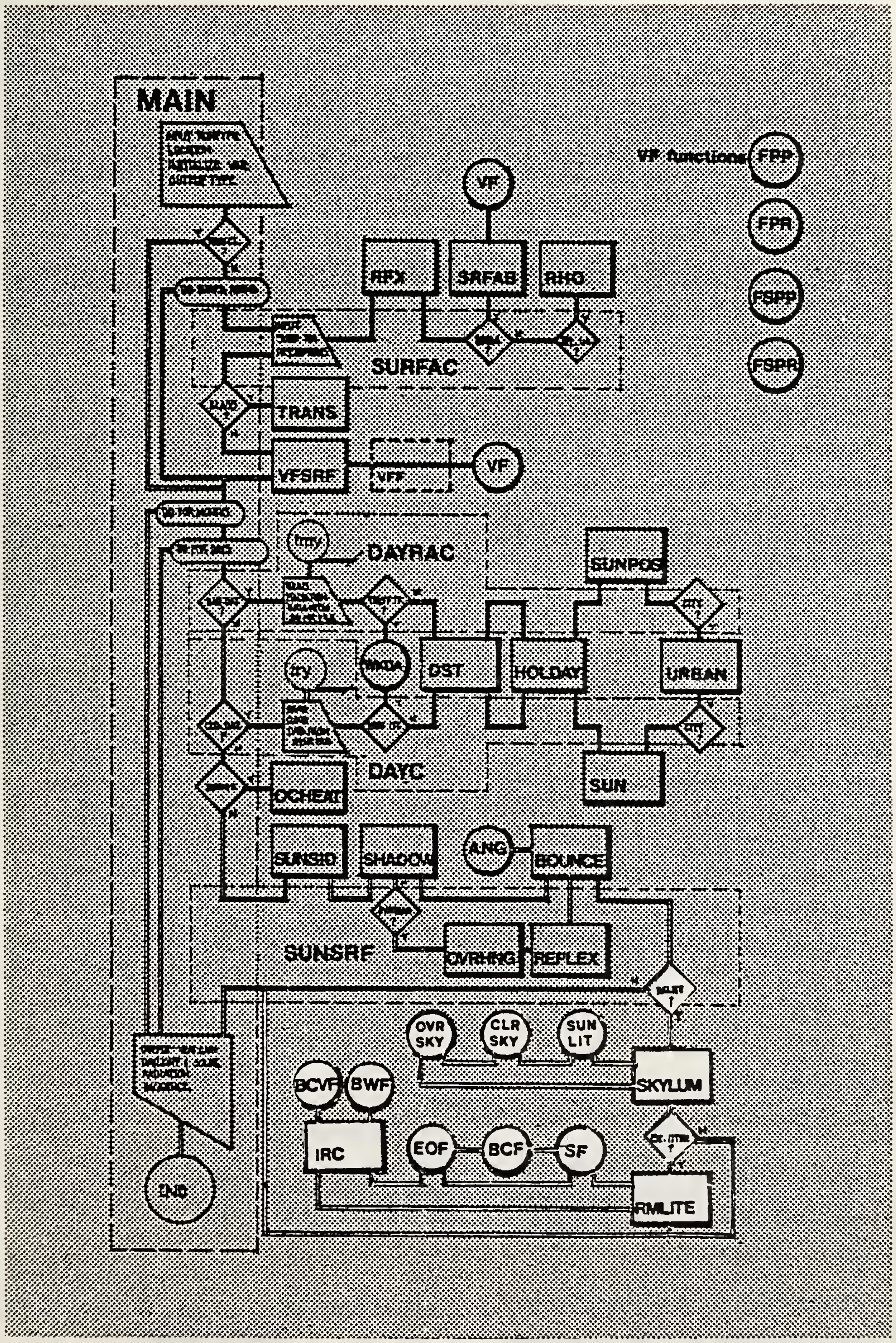


Fig. C.1 Subroutines used for the calculation of daylighting in rooms are accessed from subroutine SUNSURF and are highlighted in the above flowchart.

APPENDIX D

LISTING OF SOLITE

The programs are found listed in the following order:

ERRATA

Description	**Page**	**Replace with**
"INFT.".. Found in listings of SOLITE runs (pp.19-35) are caused by the lack of a space in a data array of the program	128	Line 225: replace 6HFT. / with 6H FT. /
"PARTION"...found in listings of SOLITE runs (p. 35) may be replaced by "PARTITION" in data arrays.	147	Line 303: replace "PARTION" with "PARTITION"

```
SUNACT*SOLITE1(1).MAIN(0)
      COMPILER (DIAG=3)
C
C
C *********************** SOLITE1 ***********************************
C
C
C     ******************************************************************
C
C MAIN PROGRAM: INITIALIZES VARIABLES AND CALLS SUBROUTINES FOR CALCU-
C LATION OF SOLAR GAIN AND DAYLIGHTING ON SURFACES AND IN ROOMS.  THIS
C PROGRAM ALSO CALCULATES THE INTERNAL GAINS IN ROOMS AND CREATES A DATA
C FILE FOR OTHER BUILDING ENRGY ANALYSIS COMPUTER PROGRAMS.
C
C     ******************************************************************
C
C A      ALPHA ARRAY FOR UNITS OUTPUT
C ABSL   ABSORPTION COEFFICIENT OF SURFACE FROM TRANS SUBROUTINE
C AINC   ANGLE OF INCIDENCE PASSED TO TRANS SUBROUTINE
C ALR    ALPHA ARRAY OF 'ROOM' INDICATORS
C ALS    ALPHA ARRAY FOR 'SURFACE' INDICATORS
C ALU    ALPHA ARRAY FOR COMPOSITE TITLING OF TABULATED DATA
C AMON   ALPHA ARRAY FOR MONTH NAMES
C ANC    INCREMENTAL ANGLE OF INCIDENCE PASSED TO TRANS
C ANGIN  ANGLE OF INCIDENCE ON 5 SURFACE COMPOSING STREET CANYON
C ANGINC ANGLE OF INCIDENCE (DIRECT BEEM) ON SURFACE
C ANOD   ALPHA ARRAY FOR OUPUT NODES
C AREA   CONVERSION FACTOR FOR AREA
C BLKHT  BLOCK HEIGHT OF SIDES OF STREET CANYON
C BLKLEN LENGTH OF BLOCKS COMPRISING STREET CANYON
C BPR    ATMOSPHERIC PRESSURE
C CCT    CLOUD COVER 1-10
C CONV   CONVERSION FACTOR ARRAYS
C COSINC COSINE OF INCIDENCE ANGLE
C CSLATD COSINE OF SITE LATITUDE
C CSWALT COSINE OF SURFACE TILT FROM HORIZONTAL, DEGREES.
C CSWLAZ COSINE OF WALL AZIMUTH, CLOCKWISE FROM SOUTH
C DAMXXX DAILY MEAN OF CLIMATE INDICATER (EG. TEMPERATURE)
C DAY    DAY COUNTER
C DBT    DRY BULB TEMPERATURE
C DIRCS2 DIRECTION COSINE FROM SUN SUBROUTINE, INDICATES SOLAR
C        POSITION
C DIST   DISTANCE FROM EDGES OF SURFACE TO ENDS OF BLOCK
C DLTDL  LEVEL OF DAYLIGHT ON WORKPLANE AT ONE OF 3 POINTS IN
C        THE ROOM, AVERAGE FOR DAYLIGHT HOURS, FOOTCANDLES.
C DLTHL  HOURLY DAYLIGHT LEVEL AT THE 3 POINTS.
C DNORAD DIRECT NORMAL RADIATION(CLOUDLESS SKY)
C DDPT   DEW POINT TEMPERATURE
C DLLMIN ARRAY FOR MINIMUM DAYLIGHT LEVELS
C ELEMAX MAXIMUM ELCTRICAL RATING OF THE ROOM
C ENERGY CONVERSION FACTOR FOR ENERGY
C FINMN  LAST MONTH OF ANALYSIS
C FLGDLT DAYLIGHT FLAG, 1=DAYLIGHTING ANALYSIS
C FLGFIL WEATHER FILE FLAG, 1=RADIATION,2=CLOUDS ONLY
C FLGGL  GLAZING FLAG, 1=GLAZED  SURFACE,WINDOW
C FLGGLL NUMBER OF LAYER IN GLAZING LAYER BEING ANALYZED
C FLGIN  INPUT UNITS TYPE FLAG, 1=SI, 2=ENGLISH
C FLGINA PROMPT FLAG, 1=SUPPRESS PROMPTS
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C FLGOT  OUTPUT UNITS FLAG
C FLGOUT TYPE OF OUTPUT FLAG,1=ONLY TAPE, ONLY TABULATED FILES, 3=
C        BOTH
C FLGRAD TYPE OF WEATHER DATA AVAILABLE, 1=SOLAR DATA, 2=CLOUD DATA ONLY
C FLGSRF THE STREET CANYON PLANE WHERE SURFACE IS LOCATED
C FLGST  STREET FLAG, INDICATES WHETHER PRIMARY OR CROSS STREET FRONTED
C FLGTAB TYPE OF TABULATED OUTPUT, 2=SHORTYEAR OUTPUT HOURLY, 3=
C        DAILY SUMMARIES
C FLGURB IF SITE IS IN URBAN AREA, CALL URBAN SUBROUTINE, SIMPLE
C        FIT TO REPORTED DATA, MEINEL, MEINEL
C FLHT   HEIGHT OF ROOM
C FLNGTH FLOOR LENGTH
C FLWID  WIDTH OF ROOM
C GLAEXT GLAZING EXTINCTION COEFFICIENT
C GLAREF GLAZING REFRACTION COEFFICIENT
C GLATHK GLAZING THICKNESS
C HEAT   CONVERSION FACTOR FOR HEAT
C HCELE  ARRAY FOR RATIO OF MAXIMUM ELECTRICAL USE
C HCOCC  ARRAY FOR RATIO OF MAXIMUM OCCUPANCY
C HLDY   HOLIDAY INDICATOR
C HRSLID DAILY HOURS OF USEABLE DAYLIGHTING
C HRSLIT MONTHLY HOURS OF USEABLE DAYLIGHTING
C IAZZ   ARRAY OF SUN POSITION RELATIVE TO AXIS OF STREET.
C ICNT   TYPE OF SURFACE  1=WINDOW  2=COLLECTOR
C IEST
C IHEN
C IDYOYR DAY OF YEAR
C IFINMN LAST DAY OF ANALYSIS
C INDAY  DAY OF MONTH USED TO CALCULATE TYPE OF DAY (WKDY ARRAY
C IOST   OPPOSITE SIDE OF STREET TO SUNNY SIDE
C IR     ROOF PLANE ON SMAE SIDE OF STREET AS SURFACE
C IROP   ROOF PLANE ON OPPOSITE SIDE
C IS     SEASON INDEX
C ISRT   SUN RISE HOUR
C ISS    ARRAY FOR SUNNY STREET SIDE
C ISST   SUN SET TIME
C IST    ISS FROM SUBROUTINE SURFAC
C ISTFLG MAXIMUM NUMBER OF STREETS THAT SURFACES FRONT
C ISTRMN STARTING MONTH
C ISTS   STREET INDICATOR, 1=PRIMARY, 2=CROSS STREET
C ITER   NUMBER OF ITERATIONS THE PROGRAM HAS MADE
C IVFD   ANGLE INDICATORS OF DIFFUSE VIEW FACTORS
C IW     WALL SURFACE ON SAME SIDE AS SURFACE
C IWOP   WALL SURFACE OPPOSITE THE SURFACE SIDE
C IYRDA  FIRST DAY OF MONTH
C KKDAY  DAY TYPE, 1=SUNDAY, 7=SATURDAY
C MIDDAY MIDDLE DAY OF MONTH, START OF SHORT YEAR DAYS
C NMXXXX MONTHLY MEANS OF CLIMATIC INDICATORS
C MONDA  NUMBER OF DAYSIN THE ANALYSIS
C NNODES NUMBER OF ROOMS ANALYZED
C NNSURF NUMBER OF SURFACES ANALYZED
C NN2    TOTAL NUMBER OF SURFACES ANLYZED
C NODELT TOTAL ELECTRICAL LOADS, PER ROOM, HOURLY
C NODFLA FLOOR AREA OF ROOM
C NODHRT HOURLY INTERNAL HEAT GAINS IN ROOM
C NODMNT MONTHLY INTERNAL HEAT GAINS
C NODOCC OCCUPANT GAINS, HOURLY RATIO OF MAXIMUM
C NODOCT  HOURLY OCCUPANT GAINS
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C NODTYP TYPE OF RESIDENCY, 1=RESIDENCE, 2=RETAIL, AND 3=OFFICE
C P      SOLAR RADIATION COEFFICIENT
C POWER  CONVERSION FACTOR, POWER
C Q      SOLAR RADIATION COEFFICIENT
C R      SOLAR RADIATION COEFFICIENT
C RADLAT LATITUDE OF SITE, RADIANS
C RDF    DIFFUSE RADIATION, HORIZONTAL SURFACES, INCLUDING CLOUDS
C RDFSRF DIFFUSE RADIATION ON SURFACE
C RDR    DIRECT RADIATION, HORIZONTAL SURFACES, CLOUD MODIFIED
C RDRSHD SHADOW FACTOR, RATIO OF SURFACE IN SHADOW
C RDRSRF RADIATION RECEIVED BY SURFACE
C RDT    TOTAL RADIATION ON HORIZONTAL SURFACE
C RDTSRF TOTAL RADIATION RECEIVED ON SURFACE
C RFM    MATERIAL INDICATOR FOR SURFACES COMPRISING STREET CANYON
C RFMX   MATEIAL REFLECTION COEFFICIENTS OF STREET CANYON MATERIALS
C RLATD  LATITUDE OF SITE
C RLN    LENGTH CONVERSION FACTOR
C RLNZ   CONVERSION FACTOR FOR DAYLIGHTING ANALYSIS (ALL UNITS ENGLISH)
C RLONG  LONGITUDE OF SITE
C SNLATD SINE OF LATITUDE
C SNWALT SINE OF WALL TILT FROM HORIZONTAL
C SNWLAZ SINE OF AZIMUTH OF WALL MEASURED FROM SOUTH
C SOLALT SOLAR ALTITUDE
C SOLAZ  SOLAR AZIMUTH, CLOCKWISE FROM SOUTH
C SOLFAC SOLAR COEFFICIENTS
C SRFABS ABSORTION COEFICIENT OF SURFACE
C SRFAR  AREA OF SURFACE
C SRFDAT TOTAL SOLAR RADIATION ON SURFACE, DAILY
C SRFHAG HEIGHT ABOVE GROUND OF SURFACE'S BOTTOM EDGE
C SRFHRT HOURLY TOTAL OF SOLAR RADIATION ON SURFACE
C SRFHT  HEIGHT OF THE SURFACE
C SRFLN  LENGTH OF SURFACE
C SRFMNT AVERAGE SOLAR RADIATION (DAILY)ON SURFACE PER MONTH
C STAXIS AXIS OF STREET MEASURED FROM TRUE SOUTH
C STRMN  STARTING MONTH OF ANLYSIS
C STW1   PRIMARY STREET WIDTH
C STW2   SECONDARY STREET WIDTH
C TEMP1  TEMPERATURE CONVERSION FACTOR
C TNLATD TANGENT OF SITE LATITUDE
C TOC    TYPE OF CLOUD
C TRA    DIFFUSE RADIATION ABSORPTION FACTOR
C TRABS  TRANSMISSION ARRAY FOR SURFACES WITH 15 DIFFERENT ANGLES OF
C        INCIDENCE
C TRANL  TRANSMISSION COEFFICIENT (NO ABOSRPTION) FO RGLAZING, 15 ANGLES
C        OF INCIDENCE
C TRN    DIFFUSE RADIATION TRANSMISSION
C TZN    TIME ZONE
C VF     VIEW FACTOR OF SURFACE TO SURROUNDINGS
C WALALT TILT OF SURFACE TO HORIZONTAL
C WALAZ  AZIMUTH OF SURFACE TO TRUE SOUTH
C WALFAC THRELKELD'S FACTOR FOR DIFFUSE RADIATION ON A VERTICAL SURFACE
C WALZ   WALL AZIMUTHS OF STREET FACING CANYONS
C WATT   CONVERSION FACTORS, POWER
C WBT    WET BULB TEMPERATURE
C WDT    WIND DIRECTION
C WIND   WIND SPEED CONVERSION FACTOR
C WKDY   WEEKDAY ARRAY
C WSP    WIND SPEED
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C
C
C DIMENSION ARRAYS AND CREATE COMMON BLOCKS FOR DATA TRANSFER TO
C SUBROUTINES
C ***************************************************************************
C
C
C ZSLITE DAYLIGHT ANALYSIS PARAMETERS ARRAY (DEFINED IN SKYLUM,RMLIT
C
C
      DIMENSION DLTML(10,3),HRSLIT(10),HRSLID(10),RR(4),PP(4),QQ(4),
     2 ANOD(3),AMON(12),MIDDAY(12),LASTDA(12),CONV(3,8),ALU(10),
     3 SRFHRT(10),SRFDAT(10),SRFMNT(10),ALR(9),ALS(9),MOCCDA(10)
      REAL NODHRT(10),NODAT(10),NODMNT(10)
      COMMON /DLL/ DLLMIN(10),IHST(10),IHEN(10)
      COMMON /RX/ RFM(2,5,2,2),RFMX(10,2),RFT(2,5)
      COMMON /ST/ ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
     2 ISS(2,24),WALFAC(2.2,24),ANGIN(2,5,24)
      COMMON /CLD/ CCT(24),TCC(24)
      COMMON /DIF/ IVFD(5,10,2),VF(5,10),TRA(5,10),TRN(5,10)
      COMMON /LATITU/ CSLATD,SNLATD,TNLATD
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDIL(10,3),
     2 DLTDEG(10,3)
      COMMON /WKD/ IYRDA(12),WKDY(12,31),HLDY(12,31)
      COMMON /WAL/ WALAZ(10),WALALT(10),STAXIS(2),STW1(2),STW2(2),
     2 BLKLEN(2),BLKHT(2,2),FLGST(10),CSWALT(10),SNWALT(10),CSWLAZ(10),
     3 SNWLAZ(10)
      COMMON /WHT/ DBT(24),DPT(24),WBT(24),WSP(24),BPR(24),WDR(24),
     2 YY(24)
      COMMON /OCC/ NODES,NODTYP(10),NODFLA(10),NODOCC(10),NODELC(10),
     2 NODELT(10,24),NODOCT(10,24).HGELE(3,24,3).HGOCC(3,24.3)
      COMMON /SRF/ DIST(2,10),SRFHAG(10),SRFLN(10),SRFHT(10),SRFAR(10),
     2 SRFABS(10),A(2,13),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
     3 FLGGLL(10)
      COMMON /TRA/ GLAREF(15,10),GLAEXT(15,10),GLATHK(15,10),NLAY(12),
     2 NSURF(15)
C
C SEASONAL COEFFICIENTS FOR SOLAR RADIATION CALCULATION
C
      DATA PP /1.06,.96,.95,1.14/ QQ /.012,.033,.03,.003/ RR /-.0084,
     2 -.0106,-.0108,-.0082/
C
C ALPHANUMERIC DATA FOR OUTPUT TITLING
C
      DATA (AMON(N),N=1,12) /6HJANURY,6HFEBRUY.6HMARCH ,6HAPRIL ,
     2 6HMAY   ,6HJUNE  ,6HJULY  ,6HAUGUST,6HSEPTEM,6HOCTOBR,6HNOVMBR,
     3 6HDECMBR/
      DATA (ANOD(N),N=1,3) /6HROOMS ,6HSURFAC,6HES    /
C
C ALPHANUMERIC DATA FOR INTERACTIVE PROMPTING OF PROPER UNITS
C
      DATA (A(2,I),I=1,13) /6HFT.   ,6HF2/PRS,6HWAT/F2.6HFT2   ,6HF.DEG.
     2,6HMPH   ,6HB/HFT2,6HBTU/HR,6HBTU/DA,6HBTU/MN,6HBTU/YR,6HINCHES,
     3 6HBTU/F2/
      DATA (A(1,I),I=1,13) /6HMETERS.6HM2/PRS,6HWAT/M2.6HM2    ,6HC.DEG.
     2,6HM/SEC ,6HW/M2  ,6HWATTS ,6HWH/DAY,6HWH/MON,6HWH/YR ,6HCM    .
     3 6HW/M2  /
      INTEGER DAY,WKDY,HLDY
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      REAL NNODES,NODTYP,NODFLA,NODOCC,NODELC,NNSURF,NODELT,NODOCT,
     2 NODRMA
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(3),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24),ISRT,ISST
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /ANS/ RDFSRF(10,24),RDRSRF(10,24),RDTSRF(10,24),N2,
     2 ANGINC(10.24),RDRSHD(10,24),TRABS(10,15),TRNMS(10,15)
      COMMON /DAM/ DAMDBT,DAMWBT,DAMWSP,DAMCCT,DAMTOC,DAMRDR,DAMRDF,
     2 DAMRDT,DAMWDR,DAMMAX,DAMMIN
      COMMON /MNM/ MNMDBT(12).MNMWBT(12),MNMWSP(12),MNMCCT(12),
     2 MNMTOC(12),MNMWDR(12),MNMRDR(12),MNMRDF(12),MNMRDT(12),MNMMAX(12)
     3,MNMMIN(12)
      REAL MNMDBT,MNMWBT,MNMWSP,MNMCCT,MNMTOC,MNMWDR,MNMRDR,MNMRDF,
     2 MNMRDT,MNMMAX,MNMMIN
      COMMON /CON/ TEMP1,TEMP2,WIND,POWER,AREA,RLN,ENERGY,HEAT,RLNZ
C
C DATA FOR CONVERSION OF ENGLISH TO SI UNITS
C
      DATA (CONV(1,I),I=1,8) /.5555,17.78,.514,3.152,.0929,.3048,.2928,
     2 1055.9/
C
C DATA FOR CONVERSION OF SI TO ENGLISH UNITS
C
      DATA (CONV(2,I),I=1,8) /1.8,32.,1.94,.3173,10.764,3.28,3.3467,
     2 .000947/
C
C DATA FOR NO DATA CONVERSION
C
      DATA (CONV(3,I),I=1,8) /1.0,0.0,6*1.0/
C
C ELECTRICAL AND OCCUPANT HEAT GAINS FOR RESIDENTIAL
C
      DATA ((HGELE(ID,IHR,1),ID=1,3),IHR=1,24) /13*.04,3*.31,3*.4,3*.25,
     2 3*.18,3*.33,3*.31,3*.44,3*.28,3*.27,3*.21,3*.22,3*1.,3*.49,3*.5,
     3 3*.38,3*.33,3*.27.3*.1/
      DATA ((HGOCC(ID,IHR,1),ID=1.3),IHR=1,24) /18*1.,3*.99,3*.89,3*.6,
     2 3*.46,3*.35,6*.31,6*.22,3*.4,3*.48,3*.73,3*.34.9*.95,6*1./
C
C ELECTRICAL AND OCCUPANT HEAT GAINS FOR RETAIL
C
      DATA ((HGELE(ID,IHR,2),ID=1,2),IHR=1,24) /4*.22,2*.2,6*.22,2*.26,
     2 2*.32,2*.64,2*.84.14*1.,8*.8,2*.49,2*.41,2*.30/
      DATA ((HGOCC(ID,IHR,2),ID=1,2),IHR=1,24) /10*0..2*.02,2*.1,2*.27,
     2 2*.4,2*.48,2*.65,2*.81,2*.85,2*.71,2*.6,2*.73,2*.79,2*1.,4*.75,
     3 2*.71,2*.21,4*.04/
      DATA (HGELE(3,IHR,2).IHR=1,24) /9*.11,.67.7*1.,.67,.33,5*.11/
      DATA (HGOCC(3,IHR,2),IHR=1,24) /9*0.,.4,3*.7,.9,3*1.,.2,6*0./
C
C ELECTRICAL AND OCCUPANT HEAT GAIN RATIOS FOR OFFICE SPACE
C
      DATA (HGELE(1,IHR,3),IHR=1,24) /6*.08,.16,.44,.85,.97,2*1.,2*.92,
     2 2*.97,.76,.68,.51,.45,.35,.22,2*.17/
      DATA (HGOCC(1,IHR,3),IHR=1,24) /5*0.,2*.04,.08,3*1.,.92,.68,.92.
     2 3*1.,.8,.48,.24,.08,.02,2*0./
      DATA ((HGELE(ID,IHR,3),ID=2,3),IHR=1,24) /48*.1/
      DATA ((HGOCC(ID,IHR,3),ID=2,3),IHR=1,24) /48*0./
      DATA (LASTDA(MON),MON=1,12) /31,28.31,30,31.30,31,31,30,31.30,31/
      DATA (MIDDAY(MON),MON=1,12) /12,41,71,101,131,168,198,228,255,284,
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     2 315,346/
      DATA (IYRDA(MON),MON=1,12) /0,31,59,90,120,151,181,212,243,273,304
     2,334/
      DATA (ALR(I),I=1,9) /3HR 1,3HR 2,3HR 3,3HR 4,3HR 5,3HR 6,3HR 7,
     2 3HR 8,3HR 9/
      DATA (ALS(I),I=1,9) /3HS 1,3HS 2,3HS 3,3HS 4,3HS 5,3HS 6,3HS 7,
     2 3HS 8,3HS 9/
C
C
C ALGORITHM BEGINS WITH RUNTYPE SPECIFICATIONS
C
C ******************************************************
C
      PRINT 640
      PRINT 10
10    FORMAT (29H FOR INTERACTIVE RUN ENTER 0.,/,
     2 33H IF INPUT FILE IS ADDED, ENTER 1.,/)
      READ (5,670) FLGINA
      IF (FLGINA.EQ.0.) PRINT 660
C
C
C TYPE OF OUTPUT DESIRED: 1=TAPE  2=TABULAR  3=BOTH
C
      READ (5,670) FLGOUT
      WRITE (7,670) FLGOUT
      IF (FLGOUT.GT.1..AND.FLGINA.EQ.0.) PRINT 680
C
C TYPE OF TABULAR OUTPUT DESIRED
C
      IF (FLGOUT.GT.1.) READ (5,670) FLGTAB
      IF (FLGOUT.GT.1.) WRITE (7,670) FLGTAB
      IF (FLGTAB.EQ.2..AND.FLGINA.EQ.0.) PRINT 690
      FLGFIL=0.
      IF (FLGTAB.EQ.2.) FLGFIL=2.
      IF ((FLGTAB.LT.1..OR.FLGTAB.EQ.3.).AND.FLGINA.EQ.0.) PRINT 700
      IF (FLGTAB.LT.1..OR.FLGTAB.EQ.3.) READ (5,670) FLGFIL
      IF (FLGTAB.LT.1.OR.FLGTAB.EQ.3.) WRITE (7,670) FLGFIL
      IF (FLGINA.EQ.0.) PRINT 710
      READ (5,670) FLGRAD
      WRITE (7,670) FLGRAD
      IF (FLGFIL.NE.2.) GO TO 30
C
C  SHORTYEAR HAS WARMUP PERIOD THAT IS DISCARDED BY THIS PROGRAM
C
      DO 20 I=1,8
          IF (FLGRAD.EQ.2.) READ (8) DBT,DPT,WBT,WSP,BPR,CCT,TOC,WDR,YY,
     2IYEAR,IMON,IDAY,ICITY
          IF (FLGRAD.EQ.1.) READ (8) DBT,DPT,WBT,WSP,BPR,CCT,TOC,RDT,RDR
     2,IEAR,IMON,IDAY,IC
20        CONTINUE
30    IF (FLGINA.EQ.0.) PRINT 720
      READ (5,670) STRMN
      WRITE (7,670) STRMN
      IF (FLGINA.EQ.0.) PRINT 730
      READ (5,670) FINMN
      WRITE (7,670) FINMN
      ISTRMN=STRMN
      IFINMN=FINMN
```

```
C
C READ TYPE OF INPUT AND OUTPUT UNITS
C
      IF (FLGINA.EQ.0.) PRINT 740
      READ (5,670) FLGIN
      WRITE (7,670) FLGIN
      IF (FLGINA.EQ.0.) PRINT 750
      READ (5,670) FLGOT
      WRITE (7,670) FLGOT
      IN=FLGIN
      IOUT=FLGOT
C
C DEFINE CONVERSION FACTORS FROM CONVERSION ARRAY
C
      IF (IN.EQ.IOUT) ICON=3
      IF (IN.EQ.1.AND.IOUT.EQ.2) ICON=2
      IF (IN.EQ.2.AND.IOUT.EQ.1) ICON=1
      TEMP1=CONV(ICON,1)
      TEMP2=CONV(ICON,2)
      WIND=CONV(ICON,3)
      POWER=CONV(ICON,4)
      RLN=CONV(ICON,6)
      RLNZ=1.
      IF (IOUT.EQ.1) RLNZ=CONV(1,6)
      AREA=CONV(ICON.5)
      ENERGY=CONV(ICON,7)
      HEAT=CONV(ICON.8)
      IF (FLGINA.EQ.0.) PRINT 40
40    FORMAT (47H ENTER 1. FOR DAYLIGHT CALCULATIONS. ELSE ENTER,8H 0.,/
     2)
      READ (5,670) FLGDLT
      WRITE (7.670) FLGDLT
      IF (FLGINA.EQ.0.) PRINT 760
C
C READ THE LATITUDE AND LONGITUDE OF THE SITE
C
      READ (5,670) RLATD
      WRITE (7,670) RLATD
      RADLAT=RLATD*.0174532925
      CSLATD=COS(RADLAT)
      SNLATD=SIN(RADLAT)
      TNLATD=SNLATD/CSLATD
      IF (FLGINA.EQ.0.) PRINT 770
      READ (5,670) RLONG
      WRITE (7,670) RLONG
      IF (FLGINA.EQ.0.) PRINT 780
      READ (5,670) TZN
      WRITE (7.670) TZN
      IF (FLGINA.EQ.0.) PRINT 790
      READ (5.670) FLGURB
      WRITE (7,670) FLGURB
      IF (FLGINA.EQ.0.) PRINT 50, A(IN,1)
50    FORMAT (27H ENTER THE ELEVATION OF THE LOCALITY ,A6,
     2 16H ABOVE SEA LEVEL,/)
C
C ALL DAYLIGHT CALCULATION VARIABLES (ZSLITE) ARE IN
C ENGLISH UNITS.
C
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```
      READ (5,670) ZSLITE(1,23)
      WRITE (7,670) ZSLITE(1,23)
      ZSLITE(1,23)=ZSLITE(1,23)*RLN/RLNZ
C
C TRANSFER BEYOND ALL SURFACE AND WINDOW INPUT IF ONLY
C RADIATION TAPE DESIRED
C
      IF (FLGOUT.LE.1.) GO TO 270
      IF (FLGINA.EQ.0.) PRINT 800
      IF (FLGINA.EQ.0.) PRINT 810
C
C READ AXIS OF STREET
C SECONDARY STREET AXIS SET PERPENDICULAR TO FIRST
C
      READ (5,670) STAXIS(1)
      WRITE (7,670) STAXIS(1)
      IF (FLGINA.EQ.0.) PRINT 820, A(IN,1)
      READ (5,670) STW1(1)
      STAXIS(2)=STAXIS(1)+90.
      IF (STAXIS(2).GT.360.) STAXIS(2)=STAXIS(2)-360.
      WRITE (7,670) STW1(1)
      IF (FLGINA.EQ.0.) PRINT 830, A(IN,1)
      READ (5,670) STW2(1)
      STW1(2)=STW2(1)
      STW2(2)=STW1(1)
      WRITE (7,670) STW2(1)
      IF (FLGINA.EQ.0.) PRINT 840, A(IN,1)
C
C BLOCK LENGTH AND WIDTH ARE SET
C
      READ (5,670) BLKLEN(1)
      IF (FLGINA.EQ.0.) PRINT 850, A(IN,1)
      READ (5,670) BLKLEN(2)
      WRITE (7,670) BLKLEN(1)
      WRITE (7,670) BLKLEN(2)
      IF (FLGINA.EQ.0.) PRINT 860, A(IN,1)
      READ (5,670) BLKHT(1,1)
      WRITE (7,670) BLKHT(1,1)
      IF (FLGINA.EQ.0.) PRINT 870, A(IN,1)
      READ (5,670) BLKHT(1,2)
      WRITE (7,670) BLKHT(1,2)
      IF (FLGINA.EQ.0.) PRINT 60, A(IN,1)
      READ (5,670) BLKHT(2,1)
      WRITE (7,670) BLKHT(2,1)
      IF (FLGINA.EQ.0.) PRINT 70, A(IN,1)
      READ (5,670) BLKHT(2,2)
      WRITE (7,670) BLKHT(2,2)
60    FORMAT (50H ENTER HEIGHT OF BLDG. ON SIDE 1. OF CROSS STREET.,/,
     2 4H IN ,A6,/)
70    FORMAT (49H ENTER HEIGHT OF BLDG. ON SIDE 2. OF CROSS STREET,/,
     2 4H IN ,A6)
C
C CONVERT DEGREES TO RADIANS
C
      STAXIS(1)=STAXIS(1)*3.14159/180.
      STAXIS(2)=STAXIS(2)*3.14159/180.
C
C WALL AZIMUTHS SET PERPENDICULAR TO STREET AXES
```

```
C
      WALZ(1,1)=STAXIS(2)
      WALZ(1,2)=WALZ(1,1)-3.14159
      IF (WALZ(1.2).LT.0.) WALZ(1,2)=WALZ(1,2)+6.283
      WALZ(2,2)=STAXIS(1)
      WALZ(2,1)=WALZ(2,2)-3.14159
      IF (WALZ(2,1).LT.0.) WALZ(2,1)=WALZ(2,1)+6.283
C
C CONVERT BLOCK PHYSICAL PARAMETERS TO RADIANS
C
      STW1(1)=STW1(1)*RLN
      STW1(2)=STW1(2)*RLN
      STW2(1)=STW2(1)*RLN
      STW2(2)=STW2(2)*RLN
      BLKLEN(1)=BLKLEN(1)*RLN
      BLKLEN(2)=BLKLEN(2)*RLN
      BLKHT(1,1)=BLKHT(1,1)*RLN
      BLKHT(1,2)=BLKHT(1,2)*RLN
      BLKHT(2,1)=BLKHT(2,1)*RLN
      BLKHT(2,2)=BLKHT(2,2)*RLN
C
C SET MAXIMUM NUMBER OF SURFACES AND ROOMS TO 10
C
      MAXSRF=10
C
C IF DAILY SUMMARIES ARE SPECIFIED  NO ROOM CONDITIONS REQUIRED
C
      IF (FLGTAB.GT.2.) GO TO 150
      IF (FLGINA.EQ.0.) PRINT 880
C
C ROOM DESCRIPTIONS  OCCUPANCY TYPES ASKED FOR
C
      READ (5,670) NNODES
      WRITE (7,670) NNODES
      NODES=NNODES
      MAXSRF=10-NODES
      IF (NODES.EQ.0) GO TO 150
      IF (FLGINA.EQ.0.) PRINT 890
      ICNV=3
      IF (IOUT.EQ.2) ICNV=2
      WATT=CONV(ICNV,7)
      ISTFLG=1
      DO 140 N=1,NODES
          NODOT(N)=N
          IF (FLGINA.EQ.0.) PRINT 900
          READ (5,670) NODTYP(N)
          WRITE (7,670) NODTYP(N)
          IF (FLGINA.EQ.0.) PRINT 80
80        FORMAT (39H ENTER 1. IF ROOM FACES PRIMARY STREET.,/,
     2 37H ENTER 2. IF ROOM FACES CROSS STREET.,/)
C
C READ THE TYPE OF STREET THE WINDOW IS FACING
C
          READ (5,670) FLGST(N)
          WRITE (7,670) FLGST(N)
          ISTS=FLGST(N)
          ZSLITE(N,9)=STW1(ISTS)/RLNZ
          ZSLITE(N,28)=ZSLITE(1,28)
```

```
          IF (NODTYP(N).GE.2.) GO TO 100
          IF (FLGINA.EQ.0.) PRINT 650
          READ (5,670) NODOCC(N)
          WRITE (7,670) NODOCC(N)
C
C MAXIMUM ELECTRICAL AND OCCUPANCY LOADS FOR RESIDENCES SET
C
          IF (FLGINA.EQ.0.) PRINT 90, A(IN,2)
90        FORMAT (49H ENTER THE AREA OF THE HOUSE AND AREA OF THE ROOM,/
     2,31H CONNECTED WITH THE WINDOW, IN ,A6,/)
          READ (5,670) NODFLA(N),NODRMA
          WRITE (7,670) NODFLA(N),NODRMA
          NODELC(N)=((NODOCC(N)-4.)/2.+4.)*NODRMA/NODFLA(N)
          NODOCC(N)=NODOCC(N)*110.*WATT*NODRMA/NODFLA(N)
          ZSLITE(N,11)=SQRT(NODRMA*RLN/RLNZ)
          ZSLITE(N,12)=ZSLITE(N,11)
C
C ASSUMED SQUARE RESIDENTIAL ROOM AND 8FT. CELING HEIGHT
C FOR DAYLIGHT CALCULATIONS
C
          ZSLITE(N,10)=8.
          GO TO 110
100       IF (FLGINA.EQ.0.) PRINT 910, A(IN,1)
          READ (5,670) FLWID,FLNGTH,FLHT
          WRITE (7,670) FLWID,FLNGTH,FLHT
          NODFLA(N)=FLWID*FLNGTH*AREA
          ZSLITE(N,11)=FLNGTH*RLN/RLNZ
          ZSLITE(N,12)=FLWID*RLN/RLNZ
          ZSLITE(N,10)=FLHT*RLN/RLNZ
          IF (FLGINA.EQ.0.) PRINT 920, A(IN,2)
          READ (5,670) NODOCC(N)
          WRITE (7,670) NODOCC(N)
          IF (FLGINA.EQ.0.) PRINT 930, A(IN,3)
          READ (5,670) NODELC(N)
          WRITE (7,670) NODELC(N)
          NODELC(N)=NODELC(N)*NODFLA(N)*WATT
          NODOCC(N)=110*CONV(ICNV,7)*NODFLA(N)/NODOCC(N)
110       NODFLA(N)=NODFLA(N)*AREA
          ICNT=1
          IF (FLGDLT.EQ.0.) GO TO 130
          IF (FLGINA.EQ.0.) PRINT 120
120       FORMAT (35H ENTER REFLECTANCE COEFFICIENTS OF:,/,
     2 39H WALLS, CEILING AND FLOOR.(RATIO OF 1.),/)
          READ (5,670) (ZSLITE(N,L),L=3,5)
          WRITE (7,670) (ZSLITE(N,L),L=3,5)
C
C CALL SURFACE INPUT DESCRIPTOR PROGRAM
C
C
C CALL INPUT DESCRIPTOR PROGRAM
130       CALL SURFAC (IN,ICNT,N,FLGINA,ISTFLG)
140       CONTINUE
      IF (NODES.EQ.10) GO TO 160
150   IF (FLGINA.EQ.0.) PRINT 940, MAXSRF
      READ (5,670) NNSURF
      WRITE (7,670) NNSURF
      NSURF=NNSURF
160   NO=N
```

```
          N1=N+1
          N2=N+NSURF
          IF (NSURF.EQ.0) GO TO 180
          ICNT=2
          DO 170 N=N1,N2
              NSRFOT(N)=N-N0
              IF (FLGINA.EQ.0.) PRINT 80
              READ (5,670) FLGST(N)
              WRITE (7,670) FLGST(N)
              ISTS=FLGST(N)
              CALL SURFAC (IN,ICNT,N,FLGINA,ISTFLG)
 170          CONTINUE
 180      CONTINUE
          DO 210 ISRF=1,N2
              ALU(ISRF)=ALS(ISRF)
              IF (ISRF.LE.N0) ALU(ISRF)=ALR(ISRF)
              IF (NODES.EQ.0) ALU(ISRF)=ALS(ISRF)
              IF (NSURF.EQ.0) ALU(ISRF)=ALR(ISRF)
C CALCULATE THE TRANSMISSION THROUGH THE GLAZING FOR EVERY 6
C DEGREE INCREMENT; FIRST ABSORPTION ON SURFACE, THEN
C TRANSMISSION
              AINC=-.078
              IF (FLGGL(ISRF).GT.0.) GO TO 190
              ABSL=SRFABS(ISRF)
              TRANL=SRFABS(ISRF)
 190          ANC=-.05236
              DO 200 IANG=1,15
                  ANC=ANC+.104719
C
C IF GLAZING ON WINDOW, TRANSMISSION CALCULATED FOR EVERY 6 DEG.
C INCIDENT ANGLE.
                  IF (FLGGL(ISRF).GT.0.) CALL TRANS (ANC,ISRF,ABSL,TRANL)
                  TRABS(ISRF,IANG)=ABSL
                  TRNMS(ISRF,IANG)=TRANL
 200              CONTINUE
 210          CONTINUE
C
C SUBROUTINE CALLED TO DETERMINE SURFACE VIEW FACTORS FOR
C DIFFUSE RADIATION CALCULATIONS.
          CALL VFSRF (ISTFLG,N2)
          DO 260 ISRF=1,N2
              DO 250 IV=1,5
                  IF (FLGGL(ISRF).EQ.0.) GO TO 240
                  IST=IVFD(IV,ISRF,1)
                  ISP=IVFD(IV,ISRF,2)
                  ISDT=ISP-IST+1
                  IF (ISDT.EQ.0) GO TO 230
                  DO 220 IA=IST,ISP
                      IAN=IA
                      IF (IAN.GT.15) IAN=31-IA
                      TRA(IV,ISRF)=TRABS(ISRF,IAN)/ISDT+TRA(IV,ISRF)
                      TRN(IV,ISRF)=TRNMS(ISRF,IAN)/ISDT+TRN(IV,ISRF)
 220                  CONTINUE
                  GO TO 250
 230              TRA(IV,ISRF)=0.
                  TRN(IV,ISRF)=0.
 240              TRA(IV,ISRF)=SRFABS(ISRF)
                  TRN(IV,ISRF)=SRFABS(ISRF)
```

```
250              CONTINUE
260          CONTINUE
         ITER=0
         IS=4
C
C
C BEGIN SOLAR AVAILABILITY CALCULATION FOR EACH MONTH, DAY AND HOUR
C
270      DO 580 MON=1,12
C          IS= SEASON INDEX (1=SPRING, 2=SUMMER, 3=AUTUMN, 4=WINTER)
             IF (MON.EQ.3) IS=1
             IF (MON.EQ.6) IS=2
             IF (MON.EQ.9) IS=3
             IF (MON.EQ.12) IS=4
C           P,Q,R = TABLE A-6, PAGE 16A, NESLD REF. MANUAL.
             P=PP(IS)
             Q=QQ(IS)
             R=RR(IS)
             MNMMIN(MON)=150.
             MNMMAX(MON)=-150.
             MONDA=LASTDA(MON)
             IF (FLGOUT.EQ.1.) GO TO 300
             DO 290 N=1,N2
                 NODMNT(N)=0.
                 SRFMNT(N)=0.
                 DO 280 ID=1,3
                     DLTML(N,ID)=0.
                     HRSLIT(N)=0.
280                  CONTINUE
290              CONTINUE
300          IF (FLGFIL.EQ.2.) MONDA=8
             IF (FLGOUT.EQ.1.) GO TO 320
             DO 310 N=1,N2
                 MOCCDA(N)=MONDA
310              CONTINUE
320          IF (IFINMN-ISTRMN) 330,340,340
330          IF (MON.LT.ISTRMN.AND.MON.GT.IFINMN) GO TO 350
             GO TO 370
340          IF (MON.LT.ISTRMN.OR.MON.GT.IFINMN) GO TO 350
             GO TO 370
350          DO 360 DAY=1,MONDA
                 IF (FLGRAD.EQ.2.) READ (8) DBT,DPT,WBT,WSP,BPR.CCT.TOC,WDR
        2,YY,IYEAR,IMON,IDAY,IC
                 IF (FLGRAD.EQ.1.) READ (8) DBT,DPT,WSP,BPR,RDT.RDR.WDR,TOC
        2,CCT,IYEAR,MN,IDAY,ICITY
360              CONTINUE
             GO TO 580
370          CONTINUE
             IF (FLGTAB.EQ.8.) WRITE (10,950) AMON(MON),A(IOUT,18),A(IOUT,5
        2),A(IOUT,6).(ALU(NA).NA=1,N2)
             IF (FLGDLT.EQ.0.) GO TO 380
             WRITE (12,970) AMON(MON),(ALU(NA),NA=1,N2)
             WRITE (13.960) AMON(MON),(ALU(NA),NA=1,N2)
380          IYRDAM=IYRDA(MON)
             DO 580 DAY=1.MONDA
                 ITER=ITER+1
                 DO 400 NN=1,N2
                     NODAT(NN)=0.
```

```
                     SRFDAT(NN)=0.
                     DO 390 IDD=1,3
                          DLTDL(NN,IDD)=0.
                          DLTDHL(NN,IDD)=0.
 390                      CONTINUE
 400                 CONTINUE
                IF (FLGTAB.GT.1.) WRITE (11,410) AMON(MON),DAY,A(IOUT,7),(
      2ALU(N),N=1,N2)
 410            FORMAT (/,/,1X,A6.I3,7H SOLAR ,A6.
      2 25H ON THE SURFACE AND ROOMS,/,1X,3HIHR,3X,A3,9(4X,A3),/)
                IF (FLGTAB.EQ.2.) WRITE (10,980) AMON(MON),DAY,A(IOUT,8),A
      2NOD(1),ANOD(2),ANOD(3),A(IOUT,5),(ALU(N),N=1,N2)
                IF (FLGTAB.EQ.1.) WRITE (10,590) MON,DAY
                IDYOYR=DAY+MIDDAY(MON)
                IF (FLGFIL.EQ.1.) IDYOYR=DAY+IYRDAM
C
C CALL SUBROUTINE TO READ WEATHER TAPES WITH RADIATION
                IF (FLGRAD.EQ.1.) CALL DAYRAD (RLATD,RLONG,TZN,MON,IDYOYR,
      2IYEAR,FLGURB,FLGOUT,ITER)
C
C CALL SUBROUTINE TO READ WEATHER TAPES WITH CLOUD DATA ONLY.
                IF (FLGRAD.EQ.2.) CALL DAYC (RLATD,RLONG,TZN,MON,IDYOYR,IY
      2EAR,FLGURB,FLGOUT,P,Q,R,ITER)
                INDAY=IDYOYR-IYRDAM
C
C DETERMINE DAY TYPES FOR CALCULATION OF INTERNAL GAINS AND LOADS.
                WKDAY=WKDY(MON,INDAY)
                IHOL=HLDY(MON,INDAY)
                IF (FLGOUT.EQ.1.) GO TO 530
C
C
C FOR ROOMS, CALL SUBROUTINE TO DETERMINE INTERNAL GAINS BASED
C DAY TYPES AND GAIN PROFILES FOUND IN SUBROUTINES.
                IF (NODES.GT.0) CALL OCHEAT (WKDAY,IHOL)
C
C
C SUBROUTINE DETERMINES ALL RADIATION ON SURFACE AND CALLS OTHER
C SUBROUTINES TO DETERMINE SHADOWS AND CANYON REFLECTANCE
C COEFFICIENTS
C
                CALL SUNSRF (ITER,DAY,DAMDBT,ISTFLG,FLGTAB)
C
C TOTAL HEAT GAINS CALCULATED
                DO 420 NO=1,N2
C
C IF BUILDING IS UNOCCUPIED, OCCUPIED DAYS SUBTRACTED FROM TOTAL
                     IF (IHST(NO).EQ.0.OR.IHEN(NO).EQ.0) MOCCDA(NO)=MOCCDA(
      2NO)-1
 420                 CONTINUE
                DO 460 IHR=1,24
                     DO 440 NO=1,N2
                          SRFHRT(NO)=RDTSRF(NO,IHR)
                          SRFDAT(NO)=SRFHRT(NO)+SRFDAT(NO)
                          ELEMAX=1.
                          IF (NODTYP(NO).GE.2.) GO TO 430
                          ELEMAX=176.*WATT
                          IF (MON.LT.5.OR.MON.GT.8) ELEMAX=820.*WATT
 430                      NODHRT(NO)=RDTSRF(NO,IHR)*SRFAR(NO)+NODELT(NO,IHR)
```

```
     2*ELEMAX+NODOCT(NO,IHR)
                      TMPOCC=NODELT(NO,IHR)*ELEMAX+NODOCT(NO,IHR)
                      NODAT(NO)=NODAT(NO)+NODHRT(NO)
440                   CONTINUE
                  WRITE (11,450) IHR,(SRFHRT(N),N=1,N2)
450               FORMAT (1X,I3,10F7.0)
                  IF (FLGTAB.EQ.1.) WRITE (10,600) (NODHRT(N),N=1,N2)
                  IF (FLGTAB.EQ.2.) WRITE (10,610) IHR.DBT(IHR),(NODHRT(
     2N),N=1,N2)
460               CONTINUE
C
C
C OUTPUT FORMAT AND FILES PREPARED
C
              NN2=N1-1
              IF (FLGTAB.GT.1.) WRITE (11,470) (SRFDAT(N),N=1,N2)
470           FORMAT (1X,3HDAY,10F7.0,/)
              IF (FLGTAB.EQ.1.) WRITE (11,480) (SRFDAT(N),N=1,N2)
480           FORMAT (4X,10F7.0)
              IF (FLGTAB.EQ.3.) WRITE (10,630) DAY,DAMDBT.DAMMAX,DAMMIN,
     2DAMWSP,(SRFDAT(N).N=1,N2)
              IF (FLGDLT.EQ.1.) WRITE (12,490) DAY,((DLTDL(N,I),I=1,3),N
     2=1,NN2)
490           FORMAT (1X,I2,1X.8(3F4.0.1X))
              IF (FLGTAB.EQ.2.) WRITE (10,620) DAMDBT,(NODAT(N),N=1,N2)
              DO 520 NO=1,N2
                  HRSLID(NO)=(DLTDHL(NO,1)+DLTDHL(NO,2)+DLTDHL(NO,3))/3.
500               FORMAT (1X,I3,10F7.0)
                  HRSLIT(NO)=HRSLIT(NO)+HRSLID(NO)
                  SRFMNT(NO)=SRFDAT(NO)/MONDA+SRFMNT(NO)
                  DO 510 ID=1,3
                      DLTML(NO,ID)=DLTML(NO,ID)+DLTDL(NO,ID)/MONDA
510                   CONTINUE
                  NODMNT(NO)=NODAT(NO)+NODMNT(NO)
520               CONTINUE
              WRITE (13,500) DAY,(HRSLID(NX),NX=1,NN2)
530           CONTINUE
          MNMDBT(MON)=MNMDBT(MON)/(MONDA*24)
          MNMWSP(MON)=MNMWSP(MON)/(MONDA*24)
          NN2=N1-1
          IF (FLGTAB.EQ.1.) WRITE (10,990) (NODMNT(N),N=1,N2)
          IF (FLGTAB.EQ.2.) WRITE (10,1000) MNMDBT(MON),(NODMNT(N),N=1,N
     22)
          IF (FLGTAB.EQ.3.) WRITE (10.1010) MNMDBT(MON),MNMMAX(MON),MNMM
     2IN(MON),MNMWSP(MON),(SRFMNT(N),N=N1,N2)
          IF (FLGDLT.EQ.0.) GO TO 580
          WRITE (11,540) MON,(SRFMNT(N),N=1,N2)
          WRITE (16.540) MON,(SRFMNT(N).N=1,N2)
540       FORMAT (1X,I3,10F7.0,/,/)
          WRITE (12,570) MON,((DLTML(N,I),I=1,3).N=1,NN2)
          WRITE (15,570) MON,((DLTML(N,I),I=1,3),N=1,NN2)
          DO 550 N=1,N2
              HRSLIT(N)=HRSLIT(N)/MOCCDA(N)
550           CONTINUE
          WRITE (13,560) MON,(HRSLIT(N),N=1,NN2)
          WRITE (14,560) MON,(HRSLIT(N),N=1,NN2)
560       FORMAT (1X,I3,10F7.0)
570       FORMAT (1X,I2,1X,10(3F4.0,1X)./,/)
```

```
580       CONTINUE
        REWIND 8
        REWIND 9
        STOP
C
C
590     FORMAT (2I4)
600     FORMAT (10E9.2)
610     FORMAT (I3,F7.0,10E9.2)
620     FORMAT (4H DAY,F6.0,10E9.2)
630     FORMAT (I3,F7.0,F5.0,F5.0,F5.0,10F7.0)
640     FORMAT (54H THIS PROGRAM READS A CLIMATE TAPE AND CALCULATES THE ,
       2 12HRADIATION ON,/,
       3 46H USER SPECIFIED SURFACES. IT ALSO ENABLES THE ,7HUSER TO,/,
       4 47H FIND TOTAL HEAT GAINS IN USER SPECIFIED ROOMS.,/,
       5 57H THIS OPTION IS USEFUL FOR THERMAL ANALYSIS PROGRAMS THAT,/,
       6 46H ARE NOT SPECIFIC TO BUILDING THERMAL ANALYIS..,/,
       7 52H THE FILES MUST BE ASSIGNED TO THE FOLLOWING DEVICES,/,
       8 44H FILE 7:THE INPUT DATA IS WRITTEN INTO FILE.,/,
       9 39H FILE 8:WEATHER DATA IS READ FROM FILE.,/,
       * 42H FILE 9:WEATHER DATA IS WRITTEN INTO FILE..,/,
       1 56H FILE 10:TABULATED OUTPUT TOTAL GAIN ON NODES INTO FILE.,/,
       2 50H FILE 11:TABULTED SOLAR GAIN ON SURFACE INTO FILE.,/,
       3 45H FILE 12:TABULATED DAYLIGHT LEVELS INTO FILE.,/,
       4 51H FILE 13:TABULATED USEABLE DAYLIGHT HOURS INTO FILE,/,
       5 49H ALL VARIABLES ENTERED MUST BE REAL NUMBERS.(X.Y)./)
650     FORMAT (47H ENTER THE NUMBER OF PERSONS IN THE APARTMENT.  ,/)
660     FORMAT (52H THE OUTPUT OF THE PROGRAM MAY BE IN THE FORM OF THE,/,
       2 50H INPUT TAPE, OR SUMMARIZED AND TABULATED, OR BOTH:,/,
       3 61H IF THE OUTPUT IS IN THE SAME FORMAT AS THE WEATHER DATA FILE,
       4/16H INPUT. ENTER 1.,/,37H IF THE OUTPUT IS TABULATED, ENTER 2.,/,
       5 56H IF THE OUTPUT IS BOTH IN THE FORM OF A WEATHER FILE AND,/,
       6 23H IN TABULATED FORM, ENTER 3.,/,)
670     FORMAT ()
680     FORMAT (42H THERE ARE 3 OPTIONS FOR TABULATED OUTPUT.,/,
       2 59H IF THE TABULATED OUTPUT IS TO BE USED AS INPUT FOR A LARGE,/,
       3 44H SCALE THERMAL ANALYSIS PROGRAM (EG.SINDA), ,/,
       4 23H HEAT GAIN ON USER SPECIFIED,
       5 48H ROOMS WILL BE WRITTEN INTO AN ASSIGNED FILE 10.,/,
       6 26H FOR THIS OPTION, ENTER 1.,/,
       7 57H IF THE TABULATED DATA ARE CREATED FROM A SHORTYEAR FILE.,/,
       8 55H AND THE OUTPUT IS TO BE USED AS INPUT FOR A HAND HELD ,/,
       9 34H CALCULATOR PROGRAM (EG. TEANET), ,/,9H ENTER 2.,/,
       * 61H IF THE TABULATED OUTPUT IS TO BE DAILY AND MONTHLY SUMMARIES,
       1/,41H OF RADIATION ON USER SPECIFIED SURFACES.,/,9H ENTER 3.,/)
690     FORMAT (51H THE INPUT WEATHER FILE MUST BE A IN THE SHORTMONTH,
       2 20H FORMAT(8DAYS/MONTH),/)
700     FORMAT (32H THE TYPE OF WEATHER DATA INPUT:,/,
       2 63H IF A SHORTMONTH FILE IS OUTPUT, THEN A SHORTMONTH FILE MUST B
       3E,/,59H INPUT.  IF A FULL MONTH WEATHER FILE IS INPUT, THEN A FULL
       4,/,30H MONTH WEATHER FILE IS OUTPUT..,/,
       5 26H ENTER 1. IF INPUT FILE IS,12H FULL MONTH.,/,
       6 46H ENTER 2. IF INPUT FILE IS SHORT MONTH (8DAYS),/)
710     FORMAT (45H IF THE WEATHER FILE CONTAINS RADIATION DATA,,
       2 16H AND CLOUD DATA,,/,9H ENTER 1.,/,
       3 47H IF ONLY CLOUD DATA IS IN WEATHER FILE ENTER 2..,/)
720     FORMAT (43H ENTER THE NUMBER OF THE FIRST MONTH TO BE ,
       2 11HCALCULATED.,/)
```

```
730    FORMAT (36H  ENTER THE NUMBER OF THE LAST MONTH,
      2 18H TO BE CALCULATED.,/)
740    FORMAT (37H THE UNIT STANDARD OF THE INPUT DATA:./,
      2 22H ENTER 1. IF SI UNITS.,/,27H ENTER 2. IF ENGLISH UNITS.,/)
750    FORMAT (38H THE UNIT STANDARD OF THE OUTPUT DATA:,/,
      2 22H ENTER 1. IF SI UNITS.,/,27H ENTER 2. IF ENGLISH UNITS.,/)
760    FORMAT (26H THE LOCATION OF THE SITE:,/,
      2 33H ENTER THE LATITUDE (IN DEGREES).,/)
770    FORMAT (35H ENTER THE LONGITUDE (IN DEGREES) .,/)
780    FORMAT (21H ENTER THE TIME ZONE;,/,22H ATLANTIC TIME ZONE=4.,/,
      2 22H EASTERN           =5.,/,22H CENTRAL            =6.,/,
      3 22H MOUNTAIN          =7.,/,22H PACIFIC            =8.,/)
790    FORMAT (52H IS THE SITE IN AN URBAN AREA, AS OPPOSED TO A RURAL,
      2 6H AREA:,/,18H ENTER 1. FOR YES.,/,17H ENTER 2. FOR NO.,/)
800    FORMAT (24H ISOMTERIC OF URBAN SITE,/,/,
      2 48H     !    !   !                  !    !   !     ,/,
      3 48H     !    !   !                  !    !   !     ,/,
      4 48H.....!    !   !..................!    !   !.....,/,
      5 48H    /     !  /                 /     !  /      ,/,
      6 48H   /      !HGT1                /      ! /       ,/,
      7 48H../       !/................../       !/........,/,
      8 48H  < STW2 ><   BLOCK LENGTH   >       *          ,/,
      9 48H              STREET AXIS  -->       *          ,/,
      * 48H                                   STW1         ,/,
      1 48H.....         ....................   *    ......,/,
      2 48H     !       /!                  !   *   /!     ,/,
      3 48H     !   HGT2 !                  !   *  / !     ,/,
      4 48H     !     /  !                  !   * /  !     ,/,
      5 48H     !    !   !                  !    !   !     ,/,
      6 48H     !    !   !                  !    !   !     ,/,/,/,)
810    FORMAT (41H FROM THE ISOMETRIC OF THE STREET ABOVE, ,/,
      2 19H ENTER THE.
      3 56H STREET AXIS, IN DEGREES, MEASURED CLOCKWISE FROM SOUTH,,/)
820    FORMAT (6H ENTER,
      2 56H THE WIDTH OF THE STREET (STW1), CONTAINING THE SURFACES,/.
      3 15H AND ROOMS, IN ,A6,/)
830    FORMAT (6H ENTER,
      2 47H THE WIDTH OF THE SECONDARY STREETS (STW2), IN ,A6,/)
840    FORMAT (6H ENTER,22H THE BLOCK LENGTH, IN ,A6,/)
850    FORMAT (26H ENTER THE BLOCK WIDTH IN ,A6,/)
860    FORMAT (6H ENTER,
      2 52H THE HEIGHT OF THE BUILDINGS ON SIDE 1 OF THE BLOCK,,/,
      3 11H (HGT1) IN ,A6,/)
870    FORMAT (42H ENTER THE HEIGHT OF THE BUILDINGS ON SIDE,
      2 16H 2 OF THE BLOCK,,/,11H (HGT2) IN ,A6,/)
880    FORMAT (51H ENTER THE NUMBER OF ROOMS REQUIRING HEAT GAIN DATA,/,
      2 36H A MAXIMUM OF 10 ROOMS MAY BE INPUT.,/)
890    FORMAT (15H FOR EACH ROOM:,/)
900    FORMAT (42H ENTER THE OCCUPANCY TYPE OF THE BUILDING:,/,
      2 18H IF RESIDENTIAL 1.,/,14H IF RETAIL, 2.,/,14H IF OFFICE. 3..,/)
910    FORMAT (42H ENTER THE FLOOR WIDTH, LENGTH AND HEIGHT ,/,3H IN,A6,/
      2)
920    FORMAT (53H ENTER THE MAXIMUM EXPECTED OCCUPANCY OF THE ROOM IN ,
      2 A6./)
930    FORMAT (55H ENTER THE MAXIMUM EXPECTED ELECTRICAL LOAD OF THE ROOM
      2,4H IN ,A6./)
940    FORMAT (45H ENTER THE NUMBER OF SURFACES TO BE ANALYZED.,/.
      2 55H THE MAXIMUM NUMBER OF SURFACES THAT MAY BE ENTERED IS ,I4,/)
```

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950   FORMAT (1X,/,/,/,A6,/,/,
     2 51H DAY  DRY   MAX  MIN WIND   RADIATION ON SURFACE   ,A6,/,
     3 28H      BULB TEMP TEMP SPEED  ,/,28H       TEMP
     4,/1X,9H          ,A6,5X,A6,1X,A3,9(4X,A3),/)
960   FORMAT (1X,A6,/,/,39H DAY        HOURS OF USEABLE DAYLIGHT/DAY,/.8X,
     2 A3,9(4X,A3),/)
970   FORMAT (1X,A6,/,/,40H DAY         FOOT CANDLES ON WORKING PLANE,/,,
     2 39H          DISTANCES FROM WINDOW IN FEET,/,8X,A3,9(10X,A3)./)
980   FORMAT (/,/,1X,A6,I4,/,30H HR DBTEMP TOTAL HEAT GAIN IN ,A6,4H ON
     2,A6,5H AND .2A6,/,5H      ,A6,3X,A3,9(6X,A3),/)
990   FORMAT (10E9.2)
1000  FORMAT (6H MONTH,F4.0,10E9.2)
1010  FORMAT (6H TOTAL,/,6H MONTH,F4.0,3F5.0,10F7.0,/)
C   .
      END
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SUNACT*SOLITE1(1).SURFAC(0)
      COMPILER (DIAG=3)
C
C     ******************************************************************
C
C      SUBROUTINE TO INPUT THE SURFACE DESCRIPTIONS
C
C     ******************************************************************
C
      SUBROUTINE SURFAC (IN,ICNT,N,FLGINA,ISTFLG)
C
C     ******************************************************************
C
C IN     FLAG FOR UNIT TYPE, SI=1, ENGLISH=2
C IRFC
C ICNT   FLAG FOR SURFACE TYPE, ROOM=1, WINDOW=2
C N      NUMBER OF THE SURFACE BEING DESCRIBED
C FLGINA FLAG FOR SUPPRESION OF PROMPTS, SUPPRESSED IF =1.
C ISTFLG NUMBER OF STREETS THE SURFACES FACE (MAXIMUM=2)
C FLGSRF INDICATES THE PLANE IN A STREET CANYON WHERE WINDOW IS LOCATED
C WALALT TILT OF WALL FROM HORIZONTAL
C WALAZ  ORIENTATION OF SURFACE FROM DUE SOUTH.
C DIST(1 DISTANCE OF EDGE OF SURFACE FROM EDGE OF BLOCK MEASURED
C        IN DIRECTION OF STREET AXIS
C SRFLN  WIDTH OF SURFACE
C SRFHT  HEIGHT OF SURFACE
C SRFABS ABSORPTION COEFFICIENT OF FINAL ABSORBING SURFACE
C SRFAR  AREA OF SURFACE
C SRFHAG HEIGHT ABOVE GROUND OF SURFACE
C        IF SURFACE IS FLAT, THEN IT IS DISTANCE FROM PRESCRIBED
C        LINE; ON STREET FROM THE CENRTRE LINE TOWARD SURFACE 1
C        ON ROOF, FROM THE STREET EDGE OF THE ROOF.
C HTABFL HEIGHT ABOVE INSIDE FLOOR OF THE SURFACE(WINDOW)
C WINLP  DISTANCE FROM RIGHT EDGE OF WINDOW TO RIGHT INTERIOR WALL,
C        LOOKING FROM THE INTERIOR OF THE ROOM
C FLGGL  FLAG IF GLAZING IS PRESENT
C GLAYR  NUMBER OF GLAZING LAYERS IN WINDOW ASSEMBLY
C GLTHIK GLAZING LAYER THINCKNESS
C GLEXT  GLAZING EXTINCTION COEFFICIENT BASED ON ENTERED
C        NORMAL TRANSMISSION COEFFICIENT
C GLRF   TYPE OF GLAZING MATERIAL INDICATOR.
C GLREF  REFRACTION INDEX OF GLAZING
C
C
      COMMON /RX/ RFM(2,5,2,2),RFMK(10,2),RFF(2,5)
      COMMON /OVR/ OVRLN(10),OVRHT(10),OVRWD(10),RDROVR(10.24),RFCLN(10)
     2,RFCWD(10),RFCHT(10),RDRFC(10,24),RMOVR(10.2,2),RRFC(10,2),
     3 RMRFC(10,2,2)
      COMMON /ST/ ISTS.IX,IST.IOST.IW.IWOP.IR,IROP,WALZ(2,2),IAZZ(2,24),
     2 ISS(2,24),WALFAC(2,2.24).ANGIN(2,5,24)
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
     2 DLTDEG(10,3)
      COMMON /WAL/ WALAZ(10),WALALT(10),STAXIS(2),STW1(2),STW2(2),
     2 BLKLEN(2),BLKHT(2,2),FLGST(10),CSWALT(10),SNWALT(10),CSWLAZ(10),
     3 SNWLAZ(10)
      COMMON /CON/ TEMP1.TEMP2,WIND.POWER,AREA.RLN,ENERGY.HEAT,RLNZ
      COMMON /SRF/ DIST(2,10).SRFHAG(10).SRFLN(10).SRFHT(10).SRFAR(10),
     2 SRFABS(10),A(2,13),FLGSRF(10),NODOT(10),NSRFOT(10).FLGGL(10),
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     3 FLGGLL(10)
      COMMON /TRA/ GLAREF(15,10),GLAEXT(15,10),GLATHK(15,10),NLAY(12),
     2 NSURF(15)
      DIMENSION AS(7,7),CLAS(15),GLREF(14),WPIC(11),GLTHIK(6),GLEXT(6),
     2 GLEX(14),GLRC(14),IGLR(6),ILAYR(15),ADJAC(6),GLASS(12),ALRF(2,2)
      DATA (GLAS(I),I=1,14) /6H  AIR ,6HPOLYCB,6H PMMA ,6H  PET ,
     2 6H  PVF ,6H  FEP ,6H WATER,6H  ICE ,6HQUARTZ,6H OTHER,6H GLASS,
     3 6HHI TRN,6HHT ABS,6HREFILM/
      DATA (WPIC(I),I=1,11) /11*1HI/
      DATA (GLEX(I),I=1,14) /.762,.000017,.6096,3.207,1.98,1.4986,1.98,
     2 1.67,.0254,.383,.762,.0762,5.08,.762/
      DATA (GLREF(I),I=1,14) /1.51,1.0,1.59,1.49,1.64,1.45,1.34,1.33,
     2 1.31,1.54,4*1.51/
      DATA (AS(1,I),I=1,4) /6HTHE WI,6HNDOW  ,6HOF THE,6H ROOM /
      DATA (AS(2,I),I=1,4) /6HTHE SU,6HRFACE ,6HON THE,6H PLANE/
      DATA AS(3,1) /6HHEIGHT/
      DATA AS(4,1) /6HWIDTH /
      DATA (AS(5,I),I=1,7) /6HHEIGHT,6H ABOVE,6H GROUN,6HD OF T,6HHE BOT
     2,6HTOM OF,6H      /
      DATA (AS(6,I),I=1,7) /6HDISTAN,6HCE FRO,6HM THE ,6HCL OF ,6HSTREET
     2,6H TO CL,6H OF   /
      DATA (AS(7,I),I=1,7) /6HDISTAN,6HCE FRO,6HM STRE,6HET EDG,6HE OF B
     2,6HUILDIN,6HG TO  /
C
C DATA FOR MATERIAL REFLECTANCE, IN 2X9 ARRAY, FIRST VALUE FOR
C EACH OF 9 MATERIALS IS SPECULAR REFLECTANCE AS A PERCENTAGE
C OF THE TOTAL. SECOND IS TOTAL REFLECTANCE COEFFICIENT.
      DATA ((RFINK(MI,NI).NI=1,2),MI=1,9) /.2,.18,.2,.14,.8,.88,.01,.15,
     2 .05,.55,1.,.15,.25,.85,1.,.7,1.,.67/
C
C COEFFIENTS FOR WINDOW REFLECTOR MATERIALS, SAME AS ABOVE.
      DATA ((RFRFC(NI,MI),NI=1,2),MI=1,10) /1.,.85,.2,.65,.1,.8,.1,.25,
     2 .1,.1,.1..45,.1,.12..1,.18,1.,.67,.2..4/
      DATA ((ALRF(NI,MI),NI=1,2),MI=1,2) /6HOVERHA,6HNG    ,6HREFLEC,
     2 6HTOR   /
C
C
      RLNK=RLN/RLNZ
      ISTS=FLGST(N)
      IF (N.EQ.1.AND.FLGINA.EQ.0.) PRINT 410
      ID=NODOT(N)
      IF (ICNT.EQ.2) ID=NSRFOT(N)
      IF (FLGINA.EQ.0.) PRINT 420, (AS(ICNT,I),I=1,2),ID,(AS(ICNT,I),I=3
     2,4),(AS(ICNT,I),I=1,2)
C ENTER THE DESCRIPTION OF THE WINDOW POSITION RELATIVE TO
C THE STREET CANYON
      READ (5,630) FLGSRF(N)
      WRITE (7,630) FLGSRF(N)
      II=FLGSRF(N)
      WALALT(N)=1.57
      WALAZ(N)=0.
      IF (FLGSRF(N).EQ.3.) WALALT(N)=0.
      IF (N.EQ.1.AND.FLGINA.EQ.0.) PRINT 10
10    FORMAT (42H THE SURFACES COMPRISING THE STREET CANYON,/,
     2 44H MAY BE PICKED FROM THE FOLLOWING. ENTER THE./,
     3 46H APPROPRIATE REFRENCE NUMBER FOR EACH SURFACE.,/,
     4 23H    TREES (DECID)     1.,/,23H    TREES(CONIF)      2.,/,
     5 23H    GRASS             3.,/,23H    BITUMINOUS        4.,/,
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          6 23H    BRICK              5.,/,23H     GLASS               6.,/,
          7 23H    CONCRETE           7.,/.23H     METAL               8.,/,
          8 23H    SNOW (SUMMER .2) 9.,/,23H     OTHER              10.,/)
C
C
C  SET THE OPPOSING STREET SIDE SURFACE DEPENDING ON THE
C ACTUAL SURFACE SIDE CHOSEN
C
C
C DETERMINE THE MATERIALS ON EACH OF THE STREET CANYON SURFACES
      GO TO (20,30,40,20,30), II
20    IW=1
      IWOP=2
      IR=4
      IROP=5
      GO TO 50
30    IW=2
      IWOP=1
      IR=5
      IROP=4
      GO TO 50
40    IW=1
      IWOP=2
      IR=0
      IROP=0
50    IX=IW
      IF (RFM(ISTS,IX,1,1).GT.0.) GO TO 60
C CALL SUBROUTINE TO DETERMINE THE REFLECTION COEFFICIENT OF
C THE SURFACE
      CALL RFX (ISTS,II,IX,FLGINA)
60    IX=IWOP
      IF (RFM(ISTS,IX,1,1).GT.0.) GO TO 70
      CALL RFX (ISTS,II,IX,FLGINA)
70    IX=3
      IF (RFM(ISTS,IX,1,1).GT.0.) GO TO 80
      CALL RFX (ISTS,II,IX,FLGINA)
80    IX=IROP
      IF (RFM(ISTS,IX,1,1).GT.0.) GO TO 90
      CALL RFX (ISTS,II,IX,FLGINA)
90    IF (ISTS.EQ.2) ISTFLG=2
      WALAZ(N)=WALZ(ISTS,IW)
C
C IF SURFACE IS NOT A ROOF SURFACE, THEN SURFACE TILT AND
C AZIMUTH ARE SET SAME AS THAT OF THE STREET.
      IF (FLGSRF(N).LT.4.) GO TO 100
C
C
C IF THE SURFACE IS A WALL, DO NOT CALCULATE PROJECTED AREAS
C
      IF (FLGINA.EQ.0.) PRINT 430, (AS(ICNT,I),I=1,2)
      READ (5,680) WALALT(N)
      WRITE (7,680) WALALT(N)
      IF (FLGINA.EQ.0.) PRINT 440, (AS(ICNT,I),I=1,2)
      READ (5,680) WALAZ(N)
      WRITE (7,680) WALAZ(N)
      WALALT(N)=WALALT(N)*3.14159/180.
      WALAZ(N)=WALAZ(N)*3.14159/180.
      IF (WALALT(N).GT.1.57) WALALT(N)=1.56
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100   SNWLAZ(N)=SIN(WALAZ(N))
      ZSLITE(N,2)=RFF(ISTS,IWOP)
      ZSLITE(N.20)=RFF(ISTS.3)
      CSWALT(N)=COS(WALALT(N))
      SNWALT(N)=SIN(WALALT(N))
      CSWLAZ(N)=COS(WALAZ(N))
      ZSLITE(N,19)=INT(WALAZ(N)*180./3.14159+.5)
      ICN=3
      IF (FLGSRF(N).GT.2.) ICN=4
      IF (FLGINA.EQ.0.) PRINT 450, (AS(ICNT,I),I=1,2),A(IN,1)
      READ (5,630) DIST(1,N)
      WRITE (7,630) DIST(1,N)
      DIST(1,N)=DIST(1,N)*RLN
      IF (FLGINA.EQ.0.) PRINT 460, (AS(ICNT,I),I=1,2),A(IN,1)
      READ (5,630) SRFLN(N)
      WRITE (7,630) SRFLN(N)
      SRFLN(N)=SRFLN(N)*RLN
      ZSLITE(N,13)=SRFLN(N)/RLNZ
C
C SET COEFFIENTS FOR MULLIONS AND WINDOW MAINTENANCE USED IN
C DAYLIGHTING SUBROUTINE
      ZSLITE(N,6)=.9
      ZSLITE(N,7)=.9
      IF (FLGINA.EQ.0.) PRINT 470, AS(ICN,1),(AS(ICNT,I),I=1,2),A(IN.1)
      READ (5,630) SRFHT(N)
      WRITE (7,630) SRFHT(N)
      SRFHT(N)=SRFHT(N)*RLN
      ZSLITE(N,14)=SRFHT(N)/RLNZ
      IF (ICNT.EQ.1) GO TO 110
      IF (FLGINA.EQ.0.) PRINT 480, (AS(ICNT,I),I=1,2)
      READ (5,630) SRFABS(N)
      WRITE (7.630) SRFABS(N)
110   IF (II.GT.2) GO TO 260
      IRT=1
      NN=1
      IF (FLGINA.EQ.0.) PRINT 120, A(IN,1)
C
C ENTER THE CHARACTERISTICS OF THE OVERHANG AND THE REFLECTOR
120   FORMAT (31H ENTER THE WIDTH OF OVERHANG IN,A6,17H IF NONE ENTER 0.
     2,/)
      READ (5,630) OVRWD(N)
      WRITE (7.630) OVRWD(N)
      IF (OVRWD(N).EQ.0.) GO TO 210
      IF (FLGINA.EQ.0.) PRINT 130
130   FORMAT (48H ENTER THE LENGTH, AND HEIGHT ABOVE TOP SILL IN,,A6,/)
      READ (5,630) OVRLN(N),OVRHT(N)
      WRITE (7,630) OVRLN(N),OVRHT(N)
      IF (FLGINA.EQ.0.AND.IRFC.EQ.0) PRINT 140
140   FORMAT (47H INDEX NUMBER FOR OVERHANG, REFLECTOR MATERIALS,/,
     2 30H          ALUMINIUM POLISHED   1.,/,
     3 30H          IRON WITH WHITE ENML 2.,/,
     4 30H          WHITE PAINT          3.,/,
     5 30H          GREY PANT            4.,/,
     6 30H          BLACK PAINT          5.,/,
     7 30H          BRICK                6.,/,
     8 30H          WOOD,LIGHT           7.,/,
     9 30H          WOOD,DARK            8.,/,
     * 30H          SNOW, ICE            9.,/,
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      1 30H        CONCRETE                19.,/)
150    IF (RMOVR(N,1,2).EQ.1.) GO TO 250
160    IF (FLGINA.EQ.0.) PRINT 170. (ALRF(NX,IRT),NX=1,2)
170    FORMAT (35H ENTER THE SURFACE MATERIAL OF THE ,2A6,/)
       READ (5,630) RMAT
       WRITE (7,630) RMAT
       IF (NN.EQ.2) GO TO 190
       IF (FLGINA.EQ.0.) PRINT 180, (ALRF(NX,IRT),NX=1.2)
180    FORMAT (21H ENTER PERCENTAGE OF ,2A6,20H WITH THIS MATERIAL.,/)
       READ (5,630) RPR
       WRITE (7,630) RPR
       RPR=RPR/100.
       GO TO 200
190    RPR=1.-RPR
200    IF (IRFC.EQ.1) GO TO 240
       RMOVR(N,NN,1)=RMAT
       IRMAT=RMAT
       RMRFC(1,IRMAT)=RMRFC(1,IRMAT)*RMRFC(2,IRMAT)
C
C %BEAM REFLECTANCE CHANGED TO ACTUAL BEAM REFELCTANCE COEFF.
       RMOVR(N,NN,2)=RPR
       NN=NN+1
       IF (NN.LE.2) GO TO 150
210    IF (FLGINA.EQ.0.) PRINT 220, A(IN,1)
220    FORMAT (47H ENTER THE WIDTH OF THE REFLECTOR IN FRONT  OF ,/,
      2 12H SURFACE. IN,A6,14H ELSE ENTER 0.,/)
       READ (5,630) RFCWD(N)
       WRITE (7,630) RFCWD(N)
       IF (RFCWD(N).EQ.0.) GO TO 260
       IF (FLGINA.EQ.0.) PRINT 230. A(IN.1)
230    FORMAT (40H ENTER THE LENGTH OF THE REFLECTOR, AND ,/,
      2 52H THE DISTANCE BELOW WINDOW SILL OF THE REFLECTOR IN ,A6,/)
       READ (5,630) RFCLN(N),RFCHT(N)
       WRITE (7,630) RFCLN(N),RFCHT(N)
       IRFC=1
       IRT=2
       NN=1
       GO TO 150
240    RMRFC(N,NN,1)=RMAT
       RMRFC(N,NN,2)=RPR
       NN=NN+1
       IF (NN.LE.2.AND.RMRFC(N,NN,2).LT.1.) GO TO 160
250    IF (IRFC.EQ.0.) GO TO 210
260    OVRWD(N)=OVRWD(N)*RLN
       OVRHT(N)=OVRHT(N)*RLN
       OVRLN(N)=OVRLN(N)*RLN
       RFCHT(N)=RFCHT(N)*RLN
       RFCLN(N)=RFCLN(N)*RLN
       RFCWD(N)=RFCWD(N)*RLN
       DIST(2.N)=BLKLEN(ISTS)-(DIST(1,N)+SRFLN(N))
       SRFAR(N)=SRFLN(N)*SRFHT(N)
       IT=5
       IF (FLGSRF(N).EQ.3.) IT=6
       IF (FLGSRF(N).GT.3.) IT=7
       IF (FLGINA.EQ.0.) PRINT 490, (AS(IT,I).I=1,7),(AS(ICNT,I),I=1,2),A
      2(IN.1)
       READ (5,630) SRFHAG(N)
       WRITE (7,630) SRFHAG(N)
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      SRFEAG(N)=SRFEAG(N)*RLN
      IF (ICNT.EQ.2) GO TO 290
      IF (FLGINA.EQ.0.) PRINT 270, A(IN,1)
270   FORMAT (44H ENTER THE HEIGHT OF BOTTOM SILL ABOVE FLOOR,A6,/)
      READ (5,630) HTABFL
      WRITE (7,630) HTABFL
C
C DETERMINE THE POSITION OF THE WORKPLANE (30"FROM FLOOR)
C WITH RESPECT TO THE WINDOW HEIGHT AND POSITION
      ZSLITE(N,16)=HTABFL*RLNX-2.5
      ZSLITE(N,8)=BLKHT(ISTS,IWOP)/RLNZ-SRFEAG(N)/RLNZ+2.5
      IF (ZSLITE(N,8).LE.0.) ZSLITE(N,8)=0.
      IF (FLGINA.EQ.0.) PRINT 280, A(IN,1)
280   FORMAT (54H ENTER THE DISTANCE FROM RIGHT PARTION WALL TO WINDOW 4
     2HLREC,/,42H LOOKING AT THE WINDOW FROM INSIDE ROOM IN,A6,/)
      READ (5,630) WINLP
      WRITE (7,630) WINLP
      ZSLITE(N,18)=ZSLITE(N,13)+WINLP*RLNX
      ZSLITE(N,15)=ZSLITE(N,12)*.5-ZSLITE(N,13)
C CALL SUBROUTINE TO DETERMINE THE TOTAL LIGHT ABSORPTION OF
C A ROOM.
C
C DETERMINE THE EQUIVALENT REFLECTANCE OF A ROOM CAVITY
      CALL SRFAB (N,SRFABS(N))
290   CONTINUE
      IF (FLGINA.EQ.0.) PRINT 500, (AS(ICNT,I),I=1,2)
C ENTER THE DESCRIPTION OF THE GLAZING COMPONENTS
      READ (5,630) FLGGL(N)
      WRITE (7,630) FLGGL(N)
      IF (FLGGL(N).EQ.0.) GO TO 390
      IF (FLGINA.EQ.0.) PRINT 510, (AS(ICNT,I),I=1,2)
      READ (5,630) GLAYR
      WRITE (7,630) GLAYR
      NLAYR=GLAYR
      NL=0
      LAYR=0
300   LAYR=LAYR+1
      NL=NL+1
      IF (FLGINA.EQ.0.) PRINT 530, LAYR
      IF ((NSRFOT(N).EQ.1.OR.NODOT(N).EQ.1).AND.LAYR.EQ.1.AND.FLGINA.EQ.
     20.) PRINT 540
      READ (5,630) GLRF
      WRITE (7,630) GLRF
      IGLR(NL)=GLRF
      IGE=IGLR(NL)
      IF (FLGINA.EQ.0.) PRINT 520, LAYR,A(IN,12)
      READ (5,630) GLTHIK(NL)
      WRITE (7,630) GLTHIK(NL)
      GLTHIK(NL)=GLTHIK(NL)*RLNZ
      J=LAYR-1
      IF (IGE.EQ.11) GO TO 350
      IF (IGE.GT.1) GO TO 320
      IF (FLGINA.EQ.0.) PRINT 310
310   FORMAT (36H IF MEASURED TRANSMITTANCE. ENTER 0.,/,
     2 28H IF ORDINARY GLASS. ENTER 1.,/,22H IF WATER WHITE, ENTER.8H 2.
     3,/,28H IF HEAT ABSORBING, ENTER 3.,/,21H IF REFLECTING, ENTER.
     4 3H 4.,/)
      READ (5,630) GLT
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       WRITE (7,630) GLT
       IF (GLT.EQ.0.) GO TO 330
       IF (GLT.EQ.4.) CALL RHO (GLRC(NL),GLEXT(NL),GLTHIK(NL),ADJAC(NL),N
      2L.NLAYR.LAYR,GLAYR.IGE,J,IGLR(NL-1))
       IGE=10+GLT
       IGLR(NL)=IGE
 320   GLEXT(NL)=GLEX(IGE)
       GLRC(NL)=GLREF(IGE)
       GO TO 370
 330   IF (FLGINA.EQ.0.) PRINT 340
 340   FORMAT (54H ENTER MEASURED NORMAL TRANSMISSION OF MATERIAL, RATIO,
      2 6H OF 1.,/)
       READ (5,630) GLEX(NL)
       WRITE (7,630) GLEX(NL)
       GO TO 360
 350   IF (FLGINA.EQ.0.) PRINT 560
       READ (5,630) GLRC(NL)
       WRITE (7,630) GLRC(NL)
       READ (5,630) GLEXT(NL)
       WRITE (7,630) GLEXT(NL)
 360   GLEXT(NL)=-ALOG(GLEXT(NL))
       GLEXT(NL)=GLEXT(NL)/GLTHIK(NL)
 370   IF (LAYR.GT,1.AND.FLGINA.EQ.0.) PRINT 550, LAYR,J
       IF (LAYR.EQ.1) ADJAC(NL)=0.
       IF (LAYR.GT.1) READ (5,630) ADJAC(NL)
       IF (LAYR.GT.1) WRITE (7,630) ADJAC(NL)
       IF (LAYR.LT.NLAYR) GO TO 300
       IF (FLGINA.EQ.0.) PRINT 400. LAYR
       READ (5,630) ADJ
       WRITE (7,630) ADJ
       ID=1
       IF (ADJ.EQ.1.) ID=0
       NLAYR=GLAYR+ID
       IAD=0
       IADD=0
       DO 380 I=1,NLAYR
           IAD=IAD+IADD
           N0=I+IAD
           IF (I.EQ.NLAYR) GO TO 380
           IREF=IGLR(I)
           GLAREF(N0,N)=GLRC(I)
           GLATHK(N0,N)=GLTHIK(I)
           GLAEXT(N0,N)=GLEXT(I)
           ILAYR(N0)=N0
           GLASS(N0)=GLAS(IREF)
           IADD=0
           IF (ADJAC(I+1).EQ.1.) GO TO 380
           IADD=1
           GLAREF(N0+1,N)=GLREF(2)
           GLATHK(N0+1,N)=1.
           GLAEXT(N0+1,N)=.000017
           ILAYR(N0+1)=N0+1
           GLASS(N0+1)=GLAS(1)
 380       CONTINUE
       NSURF(N)=N0
       NLAY(N)=N0-1
       N00=NLAY(N)
       IF (FLGINA.EQ.0.) PRINT 570
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      IF (FLGINA.EQ.0.) PRINT 580, (WPIC(J),J=1,N00)
      IF (FLGINA.EQ.0.) PRINT 600, (ILAYR(J),WPIC(J),J=1,N00)
      IF (FLGINA.EQ.0.) PRINT 580, (WPIC(J),J=1,N00)
      IF (FLGINA.EQ.0.) PRINT 610, (GLASS(J),WPIC(J),J=1,N00)
      IF (FLGINA.EQ.0.) PRINT 580, (WPIC(J),J=1,N00)
      IF (FLGINA.EQ.0.) PRINT 590
      FLGGLL(N)=0.
      IF (ICNT.EQ.2.AND.FLGINA.EQ.0.) PRINT 620
      IF (ICNT.EQ.2) READ (5,630) FLGGLL(N)
      IF (ICNT.EQ.2) WRITE (7,630) FLGGLL(N)
390   CONTINUE
      RETURN
C
C
400   FORMAT (18H ENTER 1. IF LAYER,I2,29H IS IN CONTACT WITH ABSORBING,
     2 9H SURFACE.,/,14H ELSE ENTER 0.,/)
410   FORMAT (24H ISOMETRIC OF URBAN SITE,/,/,
     2 48H     !    !   !                  !    !   !     ,/,
     3 48H     !    !   !        4.        !    !   !     ,/,
     4 48H.....!    !   !..................!    !   !.....,/,
     5 48H    /     !  /       /SRF/-DST1>/     !  /      ,/,
     6 48H   /      ! /        1.        /      ! /       ,/,
     7 48H../       !/................../       !/........,/,
     8 48H                                                ,/,
     9 49H              STREET AXIS  -->   3.              ,/,
     * 48H                                                ,/,
     1 48H......        ....................        ......,/,
     2 48H    /!       /!                 /!       /!     ,/,
     3 48H   / !      / !      2.        / !      / !     ,/,
     4 48H../  !     /..!. . . . . . .  /  !     /..!. . ..,/,
     5 49H  :  !    !   !               :  !    !   !      ,/,
     6 49H  !  !    !   !         5.    !  !    !   !      ,/,
     7 49H  .  !    !   !               .  !    !   !      ,/,)
420   FORMAT (16H DESCRIPTION OF ,2A6,I3,1X.2A6,/,
     2 52H A NUMBER ON THE ISOMETRIC REPRESENTS A PLANE WHERE ,/,1X,2A6,
     3 11HIS LOCATED.,19H ENTER THAT NUMBER.,/)
430   FORMAT (18H ENTER THE TILT OF,2A6,25H IN DEGREES FROM HORIZON.,/)
440   FORMAT (26H ENTER THE ORIENTATION OF ,2A6,12H IN DEGREES,,
     2 21H CLOCKWISE FROM SOUTH,/)
450   FORMAT (42H ENTER THE DISTANCE FROM THE SIDE EDGE OF ,2A6,6HTO THE
     2,/,31H CORNER OF THE BLOCK, DIST1 IN ,A6,/,
     3 54H (NOTE THAT DIST1 IS MEASURED IN THE DIRECTION OF THE ,
     4 10HSTREET AXIS.))
460   FORMAT (21H ENTER THE LENGTH OF ,2A6,4H IN ,A6,/)
470   FORMAT (11H ENTER THE ,A6,4H OF ,2A6,4H IN ,A6,/)
480   FORMAT (37H ENTER THE ABSORPTION COEFFICIENT OF ,2A6,/)
490   FORMAT (11H ENTER THE .7A6./,4H OF ,2A6,3HIN ,A6,/)
500   FORMAT (4H IS ,2A6.20HGLAZED.1.=YES. 0.=NO,/)
510   FORMAT (28H DESCRIPTION OF THE GLAZING:,/.
     2 39H ENTER THE NUMBER OF GLAZING LAYERS IN ,2A6,/)
520   FORMAT (37H ENTER THE THICKNESS OF GLAZING LAYER,I3,4H IN ,A6,/)
530   FORMAT (45H ENTER THE INDEX NO. OF THE MATERIAL OF LAYER,I3,/)
540   FORMAT (41H       MATERIAL          INDEX NUMBER    ,/,
     2 19H                   ,/,27H       GLASS             1.,/,
     3 27H       AIR                 2.,/,27H       POLYCARBONATE     3.,/
     4,27H       PLEXIGALSS(PMMA)  4.,/,27H       MYLR(PET)         5.,/
     5,27H       TEDLAR(PVF)       6.,/,27H       TEFLON(FEP)       7.,/
     6,27H       WATER-LIQUID      8.,/,27H       WATER-SOLID       9.,/
```

```
     7,27H       QUARTZ           10.,/,27H       OTHER            11.,/
     8)
 550  FORMAT (24H ENTER 1. IF THIS LAYER,,I3,14H IS IN CONTACT,
     2 11H WITH LAYER,I3,/,14H ELSE ENTER 0.,/)
 560  FORMAT (39H ENTER THE INDEX OF REFRACTION AND THE ,/
     2 40HTRANSMISSION COEFFIENCT OF THE MATERIAL.,/)
 570  FORMAT (27H SPECIFIED GLAZING SECTION:,/)
 580  FORMAT (11H           I,11(6X,A1))
 590  FORMAT (,/,/)
 600  FORMAT (11H LAYER     I,11(I3,3X,A1))
 610  FORMAT (11H MATERIAL  I,11(A6,A1))
 620  FORMAT (47H ENTER 0. FOR CALCULATION OF ENERGY ON ABSORBER,
     2 8H SURFACE,/,41H ELSE, ENTER THE LAYER NUMBER FOR ENERGY,,
     3 16H ABSROBED THERE.,/)
 630  FORMAT ()
C
      END
```

```
SUNACT*SOLITE1(1).RHO(3)
            COMPILER (DIAG=3)
      C
      C  SUBROUTINE TO ADD A LAYER TO A COMPOSITE GLAZING ASSEMBLY
      C  WHEN A REFLECTIVE GLAZING ASSEMBLY IS SPECIFIED WITH A
      C  HIGH COEFFICIENT OF REFRACTION .  THIS RESULTS IN A HIGH
      C  REFLECTION COEFFICIENT
      C *************************************************************
            SUBROUTINE RHO(GLREF,GLEXT,GLTHIK,ADJAC,NL,NLAYR,LAYR,GLAYR,IGE
         *,J,IGLRF)
            GLTHIK=.0001
            GLREF=1000.
            GLEXT=.78
            NL=NL+1
            LAYR=LAYR+1
            NLAYR=NLAYR+1
            J=J+1
            ADJAC=1.
            IGE=11
            IGLRF=14
            GLAYR=GLAYR+1
            RETURN
            END
```

```
SUNACT*SOLITE1(1).SRFAB(0)
      C       SUBROUTINE TO DETERMINE THE EFFECTIVE ABSORPTANCE OF A ROOM
      C       CAVITY.
      C       DETERMINES VIEW FACTORS FROM WINDOW (WVFX) TO SURFACE
      C       AND DETERMINES SURFACE VIEW FACTOR TO WINDOW (XVFW) USING
      C       THRELKELD VIEW FACTORS.
      C
              SUBROUTINE SRFAB (N,SRFABS)
      C
      C       ********************************************************************
      C
      C WVFX   VIEW FACTOR FROM WINDOW TO SURFAC
      C XVFW   VIEW FACTOR FROM SURFACE TO WINDOW
      C A      DISTANCE OF SURFACE MIDPOINT FROM VIEWING SURFACE
      C B      HALF THE LENGTH OF THE SURFACE
      C C      HALF THE SURFACE WIDTH
      C ASSUME ALL VIEW FACTORS ARE SYMMETRICAL
      C SRFABS EFFECTIVE ABSORPTION OF ROOM CAVITY N
              COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
             2 DLTDHG(10,3)
              A1=ZSLITE(N,18)-ZSLITE(N,13)*.5
              B1=ZSLITE(N,12)
              C1=ZSLITE(N,10)*.5
      C
      C VIEW FACTOR FROM WINDOW TO SIDE WALL
              WVFW=FPR(A1,B1,C1)
              A1=ZSLITE(N,12)*.5
              B1=ZSLITE(N.18)
              B2=B1-ZSLITE(N,13)
      C
      C VIEW FACTOR FROM SIDE WALL TO WINDOW
              WLVFW=FPR(A1,B1,C1)-FPR(A1,B2,C1)
              A1=ZSLITE(N,12)
              B1=ZSLITE(N,11)*.5
      C
      C VIEW FACTOR FROM WINDOW TO OPPOSITE WALL
              WVFWO=FPP(A1,B1,C1)
              B1=ZSLITE(N,13)*.5
              C1=ZSLITE(N,14)*.5
      C
      C VIEW FACTOR FROM OPPOSITE WALL TO WINDOW
              WOVFW=FPP(A1,B1,C1)
              A1=ZSLITE(N,10)-(.5*ZSLITE(N,14)+2.5+ZSLITE(N,16))
              B1=ZSLITE(N,12)*.5
              C=ZSLITE(N,11)*.5
      C
      C VIEW FACTOR FROM WINDOW TO CEILING
              WVFC=FPR(A1,B1.C)
              B1=A1+.5*ZSLITE(N,14)
              A1=ZSLITE(N,12)*.5
              B2=B1-ZSLITE(N,14)
              C=ZSLITE(N,13)*.5
      C
      C VIEW FACTOR FROM CEILING TO WINDOW
              CVFW=FPR(A1,B1,C)-FPR(A1.B2.C)
              A1=ZSLITE(N,14)*.5+3.5+ZSLITE(N,10)
              B1=ZSLITE(N,12)*.5
              C=ZSLITE(N,11)*.5
```

```
C
C VIEW FACTOR FROM WINDOW TO FLOOR
      WVFF=FPR(A1,B1.C)
      A1=ZSLITE(N,12)*.5
      B1=A1+ZSLITE(N,14)*.5
      B2=B1-ZSLITE(N,14)
      C=ZSLITE(N,13)*.5
C
C VIEW FACTOR FROM FLOOR TO WINDOW
      FVFW=FPR(A1,B1,C)-FPR(A1,B2,C)
      WR=ZSLITE(N,3)
      CR=ZSLITE(N,4)
      FR=ZSLITE(N,5)
      SRFABS=1.-(WR*WLVFW*WVFW*2+CR*CVFW*WVFC+FR*WVFF*FVFW+WR*WVFWO*WOVF
     2W)
      RETURN
      END
```

```
SUNACT*SOLITE1( 1).RFX( 0)
       COMPILER (DIAG=3)
C        SUBROUTINE FOR INPUT OF STREET CANYON SURFACE DESCRIPTORS
C
C      *******************************************************************
C
       SUBROUTINE RFX ( ISTS, I, IX,FLGINA)
C
C      *******************************************************************
C
C RFM( 1,2,3,4,5) STREET CANYON SURFACE MATERIAL ARRAY INDEX
C                 1=PRIMARY OR CROSS STREET INDICATOR
C                 2=SURFACE INDICATOR ON THAT STREET
C                 3=INDICATES FIRST, OR SECOND MATERIAL ON STREET SURFACE
C                 4=INDICATES MATERIAL TYPE( 1-10), AND % COVERED
C RFMX( 1,2)    MATERIAL REFLECTANCE COEFFICIENTS,
C               1=TOTAL REFLECTANCE
C               2=PERCENT OF TOTAL REFLECTANCE THAT IS SPECULAR
C
       COMMON /RX/ RFM(2,5,2,2),RFMX( 10,2),RFF(2,5)
       DIMENSION ALPHA(4,3)
       DATA ((ALPHA(N,M),M=1,3),N=1,4) /6HTHE WA,6HLL ITS,6HELF    ,
      2 6HTHE OP,6HPOSITE,6H WALL ,6HTHE ST,6HREET S,6HURFACE,6HTHE OP,
      3 6HPOSITE,6H ROOF /
       NN=0
       IA=IX
       IF (IX.EQ.5) IA=4
       IF (IA.LT.3) IA=1
       IF (IA.LT.3.AND.I.NE.IX) IA=2
10     NN=NN+1
       IF (FLGINA.EQ.0.) PRINT 20, (ALPHA(IA,N),N=1,3)
20     FORMAT (27H ENTER THE MATERIAL OF THE ,3A6,1H.,/)
       READ (5,30) RFM( ISTS,IX,NN,1)
30     FORMAT ()
       WRITE (7,30) RFM( ISTS,IX,NN,1)
C
C LIMITS NUMBER OF SURFACES PER EACH STREET CANYON AREA TO 2
       IF (NN.LT.2) GO TO 40
       RFM( ISTS,IX,NN,2)=1.-RFM( ISTS,IX,NN-1,2)
       GO TO 60
40     IF (FLGINA.EQ.0.) PRINT 50
50     FORMAT (50H ENTER THE PERCENTAGE OF THE PLANE COVERED IN THAT,
      2 10H MATERIAL.,/)
       READ (5,30) RFM( ISTS,IX,NN,2)
       WRITE (7,30) RFM( ISTS,IX,NN.2)
       RFM( ISTS,IX,NN,2)=RFM( ISTS,IX,NN,2)/100.
60     IF (RFM( ISTS,IX,NN,1).NE.10.) GO TO 80
       IF (FLGINA.EQ.0.) PRINT 70
70     FORMAT (45H ENTER THE PERCENT REFELCTED OFF THE MATERIAL,/,
      2 20H AT NORMAL INCIDENCE,/,
      3 48H ENTER THE PERCENT OF TOTAL REFLECTION SPECULARL11H REFLECTED.
      4,/)
       READ (5,30) R,RD
       WRITE (7,30) R,RD
       R=R/100.
       RD=R*RD/100.
       RFMX( 10,1)=RD
       RFMX( 10,2)=R
80     IM=RFM( ISTS,IX,NN,1)
       RF=RFMX( IM,2)
       RFMX( IM,1)=RF*RFMX( IM,1)
C
C TOTAL REFLECTANCE FROM A SURFACE IS CALCULATED BY AREA WEIGHTED
C REFLECTANCE COEFFICIENTS
       RFF( ISTS,IX)=RF*RFM( ISTS,IX.NN,2)+RFF( ISTS,IX)
       IF (RFM( ISTS,IX,NN.2).GT.0.AND.NN.LT.2.AND.RFM( ISTS,IX,NN,2).NE.1.
      2) GO TO 10
       RETURN
       END
```

```
SUNACT*SOLITE2(1).TRANS(0)
      COMPILER (DIAG=3)
C
C     ******************************************************************
C
      SUBROUTINE TRANS (AINC,NSRF,ABSOLA,TRIN)
C
C     ******************************************************************
C
C RHO   REFLECTION COEFFICIENT FOR SINGLE SURFACE
C TAU    TRANSMISSION COEFFICIENT FOR SINGLE LAYER
C RHHO  REFLECTION COEFFICIENT FOR ALL SURFACES UP TO AND INCLUDING
C TAAU  TRANSMISSION COEFFICIENT FOR ALL LAYERS INCLUDING THE LAYE
C       THE SURFACE
C ALL RHOP (RHO PRIME) AND TAUP(TAU PRIM) VARIABLES INDICATE REFELCTION
C AND TRANSMISSION FROM THE ABSORBER SIDE RESPECTIVELY
C
C PROGRAM CALCULATES THE TRANSMISSION FOR EACH LAYER IN A GLAZING ASSEMB
C AND THE REFLECTION FROM EACH SURFACE IN THE ASSEMBLY.
C BY USING THE SAME SOLUTION TO THE GEOMETRIC SERIES. THE ALGORITHM
C SUCCESSIVELY REPLACES EACH LAYER WITH THE SUM EFFECTS OF THE PRECEEDIN
C LAYERS FROM BOTH THE FRONT AND BACK (ABSORBER REFLECTANCE)
C
      COMMON /SRF/ DIST(2,10),SRFHAG(10),SRFLN(10),SRFHT(10),SRFAR(10),
     2 SRFABS(10),AS(2,10),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
     3 FLGGLL(10)
      COMMON /TRA/ GLAREF(15,10),GLAEXT(15,10),GLATHK(15,10),NLAY(12),
     2 NSURF(15)
      DIMENSION R(2,15),T(15),A(15),RHO(2,15,15),TAU(2,15,15),
     2 ALPHA(2,15),RHOP(2,15,15),RHHO(2,15),TAAU(2,15),TAUP(2,15,15)
      DIMENSION REFLX(15),ABSO(15),TRANS(15)
      ANGINC=AINC
      NLAYR=NLAY(NSRF)
      NSURFS=NSURF(NSRF)
      REFRAC=GLAREF(1,NSRF)
C
C BREAK GLAZING ASSEMBLY INTO SURFACES AND LAYERS SANDWICHED BY
C SURFACES
      DO 10 I=1,NLAYR
          IF (I.GT.1) REFRAC=GLAREF(I,NSRF)/GLAREF(I-1,NSRF)
          THETA=ASIN(SIN(ANGINC)/REFRAC)
          T(I)=EXP(-GLAEXT(I,NSRF)*GLATHK(I,NSRF)/COS(THETA))
          A(I)=1-T(I)
          R(1,I)=(SIN(ANGINC-THETA)/SIN(ANGINC+THETA))**2
          R(2,I)=(TAN(ANGINC-THETA)/TAN(ANGINC+THETA))**2
          ANGINC=THETA
10        CONTINUE
      R(1,I+1)=1-SRFABS(NSRF)
      R(2,I+1)=1-SRFABS(NSRF)
C
C FOR EACH AXIS OF POLARIZATION
      DO 80 I=1,2
C
C FOR EACH LAYER
          DO 50 J=1,NLAYR
              L=J-1
C
C AND FOR ALL THE SURFACES DEFINED IN THE GLAZING ASSEMBLY
```

```
                 DO 40 K=J,NLAYR
C DETERMINE REFLECTANCE FROM SURFACE
C AND TRANSMISSION (T1)
                      T1=T(K)
                      T2=T1*T1
                      RIK1=R(I,K+1)
                      N=K-J+1
                      TN1=T(N)
                      TN2=T1*T1
                      RIN=R(I,N)
                      IF (J.GT.1) GO TO 20
                      RHOP1=R(I,K)
                      RHOP2=RIK1
                      RHO1=RHOP1
                      TAUSBP=(1-RIK1)
                      RHO2=RIK1
                      TAUSUB=(1-RHOP1)
                      L=1
C
C TRANSMISSION OF LAYERS (GENOTRIC SUM)
20                    TAU(I,J,K)=TAUSUB*T1*(1-RIK1)/(1-T2*RIK1*RHOP1)
C
C REFLECTION FROM LAYER (GEOMETRIC SERIES)
                      RHO(I,J,K)=RHO1+TAUSUB*T2*RIK1*(1-RHOP1)/(1-T2*RIK1*RH
      2OP1)
                      TAUP(I,J,K)=TAUSBP*TN1*(1-RIN)/(1-TN2*RHO2*RIN)
                      RHOP(I,J,K)=RHOP2+TAUSBP*TN2*RIN*(1-RHO2)/(1-TN2*RIN*R
      2HO2)
                      M=K
                      IF (K.LT.NLAYR) GO TO 30
                      M=J
                      L=J
30                    TAUSUB=TAU(I,L,M)
                      TAUSBP=TAU(I,L,M+1)
                      RHO1=RHO(I,L,M)
                      RHO2=RHO(I,L,M+1)
                      RHOP1=RHOP(I,L,M)
                      RHOP2=RHOP(I,L,M+1)
40                    CONTINUE
50               CONTINUE
            DO 70 M=1,NLAYR
                 T1=T(M)
                 T2=T1*T1
                 IF (M.GT.1) GO TO 60
                 ROP=R(I,1)
                 TAUSUB=1-ROP
                 RO=RHO(I,NLAYR-1,NLAYR)
                 RO1=ROP
60               N=NLAYR-(M+1)
                 ALPHA(I,M)=TAUSUB*A(M)*(1+T1*RO)/(1-T2*RO*ROP)
C
C REFLECTION FROM SERIES OF SURFACES
                 RHHO(I,M)=RO1+TAUSUB*T2*RO*(1-ROP)/(1-T2*RO*ROP)
C
C TRANSMISSION OF A SERIES OF SURFACES.
                 TAAU(I,M)=TAUSUB*T1*(1-RO)/(1-T2*RO*ROP)
                 TAUSUB=TAU(I,M.M)
                 RO=1-SRFABS(NSRF)
```

```
                 IF (N.GT.0) RO=RHO(I,N,NLAYR)
                 ROP=RHOP(I,M,M)
                 RO1=RHO(I,M,M)
70               CONTINUE
80          CONTINUE
       DO 90 I=1,NLAYR
            REFLX(I)=(RHHO(1,I)+RHHO(2,I))*.5
            ABSO(I)=(ALPHA(1,I)+ALPHA(2,I))*.5
            TRANS(I)=(TAAU(1,I)+TAAU(2,I))*.5
90          CONTINUE
       NLAYP=NLAYR-1
C
C TRANSMISSION OF THE GLAZING ASSEMBLY
       TRIN=(TAU(1,NLAYP,NLAYP)+TAU(2,NLAYP,NLAYP))*.5
       IFL=FLGGLL(NSRF)
C
C ABSORPTION IN THE FINAL ABSORBER LAYER
       ABSOLA=ABSO(IFL)
       RFLXTO=(RHO(1,NLAYR,NLAYR)+RHO(2,NLAYR,NLAYR))*.5
       ABSOTO=(TAU(1,NLAYR,NLAYR)+TAU(2,NLAYR,NLAYR))*.5
       IF (FLGGLL(NSRF).EQ.0.) ABSOLA=ABSOTO
       RETURN
C
C
       END
```

```
SUNACT*SOLITE2(1).VFSRF(0)
            COMPILER (DIAG=3)
      C
      C     *************************************************************************************
      C
            SUBROUTINE VFSRF (ISTFLG,N2)
      C
      C     *************************************************************************************
      C
      C ALPHA  SOLID ANGLE FROM ROOF SURFACE TO OPPOSITE WALL.
      C ALPHA1  1.5708-ALPHA
      C A  DISTANCE FROM SURFACE TO LARGER, DIFFUSE REFLECTING SURFACE.
      C B  HEIGHT, OR WIDTH OF SURFACE DEPENDING ON CONTEXT.
      C C  LENGTH OF SURFACE, TAKEN AS 3 X BLOCK LENGTH
      C FPP  VIEW FACTOR FUNCTION FOR PARALLEL SURFACES
      C FPR  VIEW FACTOR FUNCTION FOR PERPENDICULAR SURFACES
      C FSPR  VIEW FACTOR FOR SURFACES WHERE B.GE.TAN(SURFACE TILT FROM NORMAI
      C FSPP VIEW FACOTR FOR SURFACES WHERE B.LT.TAN(SURFACE TILTXA)
      C VF(1-2)  VIEW FACTOR FROM WURFACE TO WALLS, INCLUCING REFLECTANCE
      C VF(5)    VIEW FACTOR TO SKY
      C VF(3)    VIEW FACTOR TO STREET INCLUDING REFLECTANCE
      C VF(4)   VIEW FACTOR TO ROOF INCLUDING REFLECTANCE FACTORS
      C IVFD(5) ANGLE OF VIEW RANGE FROM 1 (ANG=0) TO 15 (ANG=90DEGREES)
      C         ANGLE OF SKY VIEW
      C IVFD(3) ANGLE OF STREET VIEW FROM SURFAC
      C IVFD(1)  ANGLE OF WALL VIEW
      C IVFD(2)  ANGLE OF VIEW, OF WALL 2
      C IVFDR  ANGLE OF ROOF VIEW
      C VFRS   SIMPLIFIED VIEW FACTOR FROM AN ENTRIE SURFACE TO CLEAR SKY.
      C THETA  90 DEGREES-WALL TILT ANGLE
      C BETA   SUM OF THETA + ALPHA
      C
      C
      C     *************************************************************************************
      C
      C SUBROUTINE TO DETERMINE THE DIFFUSE RADIATION VIEW FACTORS FOR
      C THE SPECIFIED SURFACE.
            DIMENSION VFRS(2,5)
            COMMON /RX/ RFM(2,5,2,2),RFMK(10,2),RFF(2,5)
            COMMON /OVR/ OVRLN(10),OVRHT(10),OVRWD(10),RDROVR(10,24),RFCLN(10
           2,RFCWD(10),RFCHT(10),RDRFC(10,24),RMOVR(10,2,2),RRFC(10,2),
           3 RMRFC(10,2,2)
            COMMON /DIF/ IVFD(5,10,2),VF(5,10),TRA(5,10),TRN(5,10)
            COMMON /WAL/ WALAZ(10),WALALT(10),STAXIS(2),STW1(2),STW2(2),
           2 BLKLEN(2),BLKHT(2,2),FLGST(10),CSWALT(10),SNWALT(10),CSWLAZ(10),
           3 SNWLAZ(10)
            COMMON /SRF/ DIST(2,10),SRFHAG(10),SRFLN(10),SRFHT(10),SRFAR(10),
           2 SRFABS(10),AA(2,13),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
           3 FLGGLL(10)
      C CALCULATE THE SKY VIEW FACTORS OF THE LARGE PLANES IN THE
      C STREET CANYON, FOR THE PRIMARY AND CROSS STREETS.
            DO 40 ISTS=1,ISTFLG
                ISTC=2
                IF (ISTS.EQ.2) ISTC=1
                H1=BLKHT(ISTS,1)/2
                H2=BLKHT(ISTS,2)/2
                SW=STW1(ISTS)
                SL=BLKLEN(ISTS)
```

```
            RW=BLKLEN(ISTC)
            DBH1=BLKHT(ISTS,1)-BLKHT(ISTS,2)
            DBH2=BLKHT(ISTS,2)-BLKHT(ISTS,1)
C CARACTERIZE THE ANGLES SUBTENDING THE VIEW FACTORS.
C
            A1=ATAN(SW/H2)
            A2=ATAN(SW/H1)
            A=(H1+H2)/2
            B=(SW)
C
C BLOCK LENGTH ASSUMED AS OPPOSING VIEW FACTOR SURFACE IS 6X BLOCK
C LENGTH
C
            C=BLKLEN(ISTS)*3.
            IF (DBH1.GE.0.) GO TO 10
            A4=ATAN(DBH2/(SW+RW*.5))
            A5=0.
10          IF (DBH2.GE.0.) GO TO 20
            A5=ATAN(DBH1/(RW*.5+SW))
            A4=0.
20          IF (DBH2.NE.0.) GO TO 30
            A5=0.
            A4=A5
C CALCULATE THE VIEW FACTORS OF THE PLANES TO CLEAR SKY.
C
30          VFRS(ISTS,1)=.5*(1-COS(A1))
            VFRS(ISTS,2)=.5*(1-COS(A2))
            VFRS(ISTS,3)=FFP(A,B,C)
            VFRS(ISTS,4)=.5+.5*COS(A4)
            VFRS(ISTS,5)=.5+.5*COS(A5)
40          CONTINUE
C CALCULATE THE VIEW FACTORS OF THE SURFACE TO THE SURFACES
C IN THE SURROUNDING ENVIRONMENT.
C THRELKELD.
C
        DO 180 N=1,N2
            ISTS=FLGST(N)
            ISTC=1
            IF (ISTS.EQ.1.) ISTC=2
            I=FLGSRF(N)
            GO TO (50,60,70,50,60), I
50          IW=1
            IWOP=2
            IR=4
            IROP=5
            GO TO 80
60          IW=2
            IWOP=1
            IR=5
            IROP=4
            GO TO 80
70          IW=1
            IWOP=2
            IR=0
            IROP=0
80          HOP=BLKHT(ISTS,IWOP)
            IF (BLKHT(ISTS,IWOP).LE.0..AND.FLGSRF(N).NE.3.) GO TO 170
            IF (BLKHT(ISTS,IWOP).LE.0..AND.FLGSRF(N).EQ.3.) HOP=.001
```

```
          HAGMP=SRFHAG(N)+SRFHT(N)/2
          IF (I-3) 90,130,140
C TEST IF SURFACE IS WALL,STREET OR ROOF.
C VIEW FACTOR FROM WALL SURFACE TO CLEAR SKY
90        A=HOP-HAGMP
          IF (A.LT.0.) A=0.
          B=STW1(ISTS)
          C=BLKLEN(ISTS)*3.
          IF (OVRWD(N).EQ.0.) GO TO 100
          AO=SRFHT(N)/2
          BO=OVRWD(N)
          CO=OVRLN(N)/2
          VFOHNG=FPR(AO,BO,CO)
          IVFHG1=1
          IVFHG2=ATAN(BO/AO)/.10472
C
C OVERHANG VIEW FACTOR TO WINDOW CALCULATED IN ORDER TO DETERMINE
C PORTION OF CLEAR SKY BLOCKED BY OVERHANG
C
          IVFD(5,N,1)=IVFHG2+1
          GO TO 120
100       IVFD(5,N,1)=1
          IF (A.EQ.0.) GO TO 110
          IVFD(5,N,2)=ATAN(B/A)/.10472
          GO TO 120
110       IVFD(5,N.2)=15
120       VF(5,N)=FPR(A,B,C)-VFOHNG
C VIEW FACTOR FROM WALL SURFACE TO STREET.
          A=HAGMP
          B=STW1(ISTS)
          FS=FPR(A,B,C)
          VF(3,N)=FS*RFF(ISTS,3)*VFRS(ISTS,3)
          IVFD(3,N,1)=1
          IVFD(3,N,2)=ATAN(B/HAGMP)/.10472+.5
          VF(4,N)=0.
C VIEW FACTOR FROM WALL SURFACE TO OTHER WALL SURFACES
          FW=1-FS-VF(5,N)
          VF(IWOP,N)=FW*VFRS(ISTS,IWOP)*RFF(ISTS,IWOP)
          IVFD(IWOP,N,1)=1+IVFD(5,N,2)
          IVFD(IWOP.N,2)=1+IVFD(3,N,2)
C VIEW FACTOR FROM WALL SURFACE TO OPPOSITE ROOF
          IVFD(4,N,1)=0
          IVFD(4,N,2)=0
          IF (SRFHAG(N).LT.HOP) GO TO 180
          A1=HAGMP-HOP
          B1=STW1(ISTS)
          A2=A1
          B2=B1+BLKLEN(ISTC)
          FR=FPR(A2,B2,C)-FPR(A1,B1.C)
          VF(4,N)=FR*RFF(ISTS,IWOP)*VFRS(ISTS,IROP)
          IVFD(4,N,1)=ATAN(B1/A1)/.10472
          IVFD(4,N,2)=ATAN(B2/A2)/.10472
          VF(IWOP,N)=(FW-FR)*VFRS(ISTS.IWOP)*RFF(ISTS,IWOP)
          GO TO 180
C CALCULATE VIEW FACTORS FOR STREET SURFACE
C
C SKY VIEW FACTOR.
130       A1=BLKHT(ISTS,1)
```

```
          A2=BLKHT(ISTS,2)
          B1=STW1(ISTS)/2-SRFHAG(N)
          B2=STW1(ISTS)/2+SRFHAG(N)
          C=BLKLEN(ISTS)*3
          A=(A1+A2)*.5
          BX1=AMAX1(B1,B2)
          BX2=AMIN1(B1,B2)
          FC2=FPP(A,BX1,C)
          FC1=FPP(A,BX2,C)
          FCL=FC1+.5*(FC2-FC1)
          VF(5,N)=FCL
          SK1=ATAN(A1/B1)
          SK2=ATAN(A2/B2)
          IVFD(5,N,1)=15-SK1/.10472
          IVFD(5,N,2)=15-SK2/.10472
C WALL VIEW FACTORS
          A1=B1
          B1=BLKHT(ISTS,1)
          A2=B2
          B2=BLKHT(ISTS,2)
          VF(1,N)=RFF(ISTS,1)*FPR(A1,B1.C)*VFRS(ISTS,1)
          VF(2,N)=RFF(ISTS.2)*FPR(A2,B2,C)*VFRS(ISTS,2)
          IVFD(IWOP,N,1)=IVFD(5,N,1)+1
          VF(4,N)=0.
          VF(3,N)=0.
          IVFD(IWOP,N,2)=IVFD(5,N,2)+1
          GO TO 189
C CALCULATE VIEW FACTORS FOR ROOF APERATURES, COLLECTORS.
C
C SKY VIEW FACTOR
140       DHB=EOP-BLKHT(ISTS,IW)
          IF (DHB.LE.0.) DHB=0.
          SW=SRFHAG(N)+STW1(ISTS)
          THETA=1.570796-WALALT(N)
          THETA1=WALALT(N)
          THETA2=-THETA1
          ALPHA=ATAN(DHB/(SW))
          ALPHA1=1.57079-ALPHA
          BETA=ALPHA+THETA1
          VF(5,N)=.5+.5*COS(BETA)
          IF (BETA.GT.1.57079) VF(5,N)=.5*(1-COS(3.14159-BETA))
          IVFD(5,N,1)=1
          IVFD(5,N,2)=ALPHA/.10472+.5
C ROOF VIEW FACTOR
          A=SRFHT(N)*SNWALT(N)/2
          VF(4,N)=0.
          VF(3,N)=0.
          IF (A.EQ.0.) GO TO 180
          B=SRFHAG(N)
          B1=B+STW1(ISTS)
          FR=FSPR(THETA,A.B,C)
          VFW=VFRS(ISTS,IWOP)/(VFRS(ISTS,IWOP)+VFRS(ISTS,3))
          VFS=VFRS(ISTS.3)/(VFRS(ISTS,IWOP)+VFRS(ISTS,3))
          VF(3,N)=(FSPR(THETA.A,B1,C)-FR)*RFF(ISTS,IWOP)*VFW+RFF(ISTS,3)
     2*VFS
          VF(4,N)=FR*VFRS(ISTS,I)*RFF(ISTS,IR)
          IVFD(4,N,1)=1
          IVFD(4,N,2)=(ATAN(B/A)-THETA)/.10472
```

```
C  WALL VIEW FACTOR
          VF(IWOP,N)=0.
          IVFD(IWOP,N,1)=0
          IVFD(IWOP,N,2)=0
          IF (DHB.LE.0.) GO TO 180
          A=SW
          B=DHB
          R=DHB/SW
          T=TAN(THETA2)
          IF (T.GE.-R.AND.T.LE.R) GO TO 150
          B1=DHB
          FW1=FSPP(THETA2,A,B,C)
          GO TO 160
150       B1=A*TAN(THETA2)
          FW1=FSPR(THETA2,A,B,C)
160       AX=SW-SRFHAG(N)/2
          FX=FPR(AX,B1,C)
          FWX=FR
          VF(IWOP,N)=(FW1-FWX*FX)*.5*RFF(ISTS,IWOP)
          IVFD(IWOP,N,1)=THETA1/.10472
          IVFD(IWOP.N,2)=BETA/.10472
          GO TO 180
170       VF(IWOP,N)=0.
          VF(3,N)=.5*RFF(ISTS,3)
          VF(4.N)=0.
          VF(5,N)=.5
          IVFD(5,N,1)=1
          IVFD(5,N,2)=15
          IVFD(IWOP,N,0)=1
          IVFD(IWOP,N,2)=0
          IVFD(3,N,1)=1
          IVFD(3,N,2)=15
          IVFD(4,N,1)=0
          IVFD(4,N,2)=0
          IF (I.LT.3) GO TO 180
          VF(3,N)=0.
          VF(5,N)=1-.5*(1-COS(WALALT(N)))
          VF(4,N)=1-VF(5,N)
180       CONTINUE
      DO 190 N=1,N2
190       CONTINUE
      RETURN
      END
```

```
SUNACT*SOLITE1(1).VFF(0)
      COMPILER (DIAG=3)
C FUNCTION VFF DETERMINES THE AMOUNT OF INTERREFLECTION FROM DIFFUSE
C GAIN IN STREET CANYONS AND FROM OVERHANGS AND REFLECTORS
C***********************************************************************
C
C     *********************************************************************
C
      FUNCTION VFF (ISTS,N,NO,F)
C
C     *********************************************************************
C
      COMMON /RX/ RFM(2,10,2,2),RFMX(10,2),RFF(2,7)
      COMMON /VW/ VFR(2,5,5),VFO(7,10),VRF(7,10)
      VFF=F*RFF(ISTS,NO)*VFR(ISTS,NO,5)
      DO 10 J=1,7
          IF (J.EQ.5.OR.J.EQ.N.OR.J.EQ.NO) GO TO 10
          VFF=VFF+F*RFF(ISTS,NO)*VFR(ISTS,NO,J)*VFR(ISTS,J,5)*RFF(ISTS,J
     2)
          DO 10 K=1,7
          IF (K.EQ.5.OR.K.EQ.N.OR.K.EQ.NO) GO TO 10
          VFF=VFF+F*RFF(ISTS,NO,K)*VFR(ISTS,J,K)*R(J)*VFR(ISTS,K,5)*RFF(
     2ISTS,K)
10        CONTINUE
      RETURN
      END
END PRT
```

```
SUNACT*SOLITE2(1).DAYRAC(0)
      COMPILER (DIAG=3)
C
C     ****************************************************************************
C
      SUBROUTINE DAYRAC (RLATD,RLONG,TZN,MON,IDYOYR,FLGURB,FLGOUT,ITER)
C
C     ****************************************************************************
C
      COMMON /WKD/ IYRDA(12),WKDY(12,31),HLDY(12,31)
      INTEGER DAY,HLDY,WKDY,HOL
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24),ISRT,ISST
      COMMON /DAM/ DAMDBT,DAMWBT,DAMWSP,DAMCCT,DAMTOC,DAMRDR,DAMRDF,
     2 DAMRDT,DAMWDR,DAMMAX,DAMMIN
      COMMON /WHT/ DBT(24),DPT(24),WBT(24),WSP(24),BPR(24),WDR(24),
     2 YY(24)
      COMMON /CLD/ CCT(24),TOC(24)
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /MNM/ MNMDBT(12),MNMWBT(12),MNMWSP(12),MNMCCT(12),
     2 MNMTOC(12),MNMWDR(12),MNMRDR(12),MNMRDF(12),MNMRDT(12),MNMMAX(12)
     3.MNMMIN(12)
      REAL MNMDBT,MNMWBT.MNMWSP,MNMCCT,MNMTOC,MNMWDR,MNMRDR,MNMRDF,
     2 MNMRDT,MNMMAX.MNMMIN
      COMMON /CON/ TEMP1,TEMP2,WIND,POWER.AREA,RLN,ENERGY,HEAT,RLNZ
      DAMDBT=0.
      MINDBT=150.
      MAXDBT=-100.
      DAMWBT=0.
      DAMCCT=0.
      DAMRDR=0.
      DAMRDF=0.
      DAMRDT=0.
      DAMWSP=0.
      DAMWDR=0.
      READ (8) DBT,DPT,WBT,WSP,BPR,CCT.TOC,WDR,RDT,RDR,IYEAR,IMON,IDAY,
     2C
      DAY=IDYOYR-IYRDA(MON)
      IF (ITER.EQ.1) NNDAY=WKDAY(IYEAR,MON.DAY)
      IF (ITER.NE.1) NNDAY=NNDAY+1
      IF (NNDAY.EQ.8) NNDAY=1
      WKDY(IYEAR,DAY)=NNDAY
C
C DETERMINES DAYLIGHT SAVINGS TIME INDICATOR
      CALL DST (IYEAR,MON,DAY,IDSTX,IDSTY,NNDAY)
C
C DETERMINES IF DAY IS L HOLIDAY.
      CALL HOLDAY (IYEAR.MON,DAY,NNDAY,HOL)
      HLDY(MON,DAY)=HOL
      IDST=0
      IF (MON.LT.4) IDST=1
      IF (MON.GT.10) IDST=1
      IF (MON.EQ.10.AND.DAY.GT.IDSTY) IDST=1
      IF (MON.EQ.4.AND.DAY.LT.IDSTX) IDST=1
C
C DETERMINES THE SOLAR RADIATION AND SOLAR POSITION FOR
C SHADING CALCULATIONS
      CALL SUNPOS (RLATD.RLONG,TZN.IDYOYR,IDST)
```

```
C
C CALLS SUBROUTINE THAT MODIFIES RADIATION BASED ON
C URBAN EMPIRICAL DATA
      IF (FLGURB.EQ.1.) CALL URBAN
C
C CALCULATES DAILY TOTALS FOR WEATHER VARIABLES
      DO 10 IH=1,24
          RDF(IH)=RDT(IH)-RDR(IH)
          DBT(IH)=DBT(IH)*TEMP1+TEMP2
          DPT(IH)=DPT(IH)*TEMP1+TEMP2
          WBT(IH)=WBT(IH)*TEMP1+TEMP2
          WSP(IH)=WSP(IH)*WIND
          DNORAD(IH)=DNORAD(IH)*POWER
          RDR(IH)=RDR(IH)*POWER
          RDF(IH)=RDF(IH)*POWER
          RDT(IH)=RDT(IH)*POWER
          MINDBT=MIN(DBT(IH),MINDBT)
          MAXDBT=MAX(DBT(IH),MAXDBT)
          DAMDBT=DBT(IH)+DAMDBT
          DAMWBT=WBT(IH)+DAMWBT
          DAMWSP=WSP(IH)+DAMWSP
          DAMCCT=CCT(IH)+DAMCCT
          DAMTOC=TOC(IH)+DAMTOC
          DAMRDT=RDT(IH)+DAMRDT
          DAMRDR=RDR(IH)+DAMRDR
          DAMRDF=RDF(IH)+DAMRDF
          DAMWDR=WDR(IH)+DAMWDR
10        CONTINUE
C
C CALCULATE MONTHLY WEATHER DATA MEANS
      DAMMAX=MAXDBT
      DAMMIN=MINDBT
      IF (FLGOUT.EQ.1.OR.FLGOUT.EQ.3.) WRITE (9) DBT,DPT,WBT,WSP,BPR,CCT
     2,TOC,WDR.RDT,RDR,IYEAR,MON.DAY,IC
      MNMMIN(MON)=MIN(DAMMIN,MNMMIN(MON))
      MNMMAX(MON)=MAX(DAMMAX.MNMMAX(MON))
      MNMDBT(MON)=DAMDBT+MNMDBT(MON)
      MNMWBT(IH)=DAMWBT+MNMWBT(MON)
      MNMWSP(MON)=DAMWSP+MNMWSP(MON)
      MNMTOC(MON)=DAMTOC+MNMTOC(MON)
      MNMCCT(MON)=DAMCCT+MNMCCT(MON)
      MNMRDT(MON)=DAMRDT+MNMRDT(MON)
      MNMRDR(MON)=DAMRDR+MNMRDR(MON)
      MNMRDF(MON)=DAMRDF+MNMRDF(MON)
      DAMDBT=DAMDBT/24.
      DAMDPT=DAMDPT/24.
      DAMWBT=DAMWBT/24.
      DAMWSP=DAMWSP/24.
      DAMRDR=DAMRDR
      DAMRDF=DAMRDF
      DAMRDT=DAMRDT
      RETURN
      END
```

```
SUNACT*SOLITE2(1).SUNPOS(0)
      COMPILER (DIAG=8)
C SUBROUTINE TO CALCULATE SOLAR POSITION AND INTENSITY FOR CLOUD RELATED
C SOLMET PROVIDED RADIATION DATA.
C
C
C     ******************************************************************************
C
      SUBROUTINE SUNPOS (RLATD,RLONG,TZN, IDYOYR, IDST)
C
C     ******************************************************************************
C
      DIMENSION A0(5),A1(5),A2(5),A3(5),B1(5),B2(5),B3(5),DNRAD(24)
      DATA A0 /.302,-.0002,368.44,.1717,0.0905/ ,A1 /-22.93,.4197,24.52,
     2 -.0344,-.0410/ ,A2 /-.229,-3.2265,-1.14,.0032,.0073/ ,A3 /-.243,
     3 -.0903,-1.09,.0024,.0015/ ,B1 /3.851,-7.351,.58,-.0043,-.0034/
     4 ,B2 /.002,-9.3912,-.18,0.,0.0004/ ,B3 /-.055,-.3361,.28,-.0008,
     5 -.0006/
      COMMON /LATITU/ CSLATD,SNLATD,TNLATD
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24), ISRT, ISST
      REAL MERID,LOND
C     RLATD= LATITUDE,DEGREES(+NORTH,-SOUTH)
C     RLONG= LONGITUDE,DEGREES(+WEST,-EAST)
C     TZN= TIME ZONE NUMBER
C               STANDARD  TIME        DAYLIGHT  SAVING TIME
C      ATLANTIC       4                     3
C      EASTERN        5                     4
C      CENTRAL        6                     5
C      MOUNTAIN       7                     6
C      PACIFIC        8                     7
C     IDYOYR= DAYS(FROM START OF YEAR)
C     IHR= TIME.HOUR AFTER MIDNIGHT)
C     CLEARN= CLEARNESS NUMBER
C     ISRT=SUN RISE TIME  (HOURS AFTER MIDNIGHT)
C     ISST=SUN SET TIME
C     COSINC=COS(Z)    DIRECTION COSINES
C     DIRCS2=COS(N)    DIRECTION COSINES
C     DIRCS3=COS(S)  DIRECTION COSINES)
C     GAMMA=GAMMA
C     SALT=SOLAR ALTITUDE ANGLE
C     DNORAD=DIRECT NORMAL RADIATION
C     RDT(IHR)=TOTAL SOLAR RADIATION INTENSITY
C     RDF(IHR)=DIFFUSE SKY RADIATION INTENSITY
C     RDR(IHR)=INTENSITY OF DIRECT SOLAR RADIATION ON SURFACE
C     SOLDEC=SUN DECLINATION ANGLE.DEGREES
C     EQTHR=EQUATION OF TIME ,HOURS
C     SOLFAC(1)=SUN DECLINATION ANGLE,.HOURS
C     SOLFAC(2)=EQUATION OF TIME, HOURS.
C     SOLFAC(3)=A    SOLAR FACTOR
C     SOLFAC(4)=B     SOLAR FACTOR
C     SOLFAC(5)=C     SOLAR FACTOR
C     HORANG=    HOUR ANGLE,DEGREE
      PI=3.1415927
      ISST=0
      DO 10 IH=1,24
          RDR(IH)=0.
```

```
                 RDF(IH)=0.
      10         CONTINUE
             X=2*PI/366.*IDYOYR
             C1=COS(X)
             S1=SIN(X)
             S2=2.*S1*C1
             C2=C1*C1-S1*S1
             C3=C1*C2-S1*S2
             S3=C1*S2+S1*C2
             DO 20 K=1,5
                 SOLFAC(K)=A0(K)+A1(K)*C1+A2(K)*C2+A3(K)*C3+B1(K)*S1+B2(K)*S2+B
            23(K)*S3
      20         CONTINUE
             EOTHR=SOLFAC(2)/60.
             SOLDEC=SOLFAC(1)
             MERID=15*TZN
             LOND=RLONG-MERID
             RADDEC=SOLDEC*PI/180.
             CSDEC=COS(RADDEC)
             SNDEC=SIN(RADDEC)
             TNDEC=SNDEC/CSDEC
             HRPOS=-TNDEC*TNLATD
             DEGHRP=180.*ACOS(HRPOS)/PI
             ABSDHP=ABS(DEGHRP)
             DO 90 IHR=2,24
                 HRANG=15*(IHR-12+TZN+EOTHR+IDST)-RLONG
                 CSHRA=COS(HRANG*PI/180.)
                 COSIIH=SNLATD*SNDEC+CSLATD*CSDEC*CSHRA
                 ABSHAN=ABS(HRANG)
                 IF (ABSDHP-ABSHAN) 80,30,30
      30         DIRCS2(IHR)=CSDEC*SIN(HRANG*PI/180.)
                 STEST=SQRT(1.-COSIIH*COSIIH-DIRCS2(IHR)*DIRCS2(IHR))
                 STEST1=CSHRA-TNDEC/TNLATD
                 IF (STEST1) 50,40,40
      40         DIRCS3(IHR)=STEST
                 GO TO 60
      C
      50         DIRCS3(IHR)=-STEST
      60         SOLALT(IHR)=ASIN(COSIIH)
                 IF (SOLALT(IHR).GT.0.) IT=IHR
                 SOLAZ(IHR)=ASIN(DIRCS2(IHR)/COS(SOLALT(IHR)))
                 IF (DIRCS3(IHR).LT.0.) SOLAZ(IHR)=PI-SOLAZ(IHR)
                 IF (SOLAZ(IHR).LT.0.0) SOLAZ(IHR)=2*PI+SOLAZ(IHR)
                 DNRAD(IHR)=(SOLFAC(3)*EXP(-SOLFAC(4)/COSIIH))
                 SOLALD=SOLALT(IHR)*180./PI
                 SOLAZD=SOLAZ(IHR)*180./PI
                 IF (COSIIH) 70,70,80
      70         COSIIH=0.
      80         IH=IHR-1
                 IF (DNRAD(IHR).GT.0..AND.DNRAD(IH).LE.0.) ISRT=IHR
                 IF (DNRAD(IHR).LE.0..AND.DNRAD(IH).GT.0.) ISST=IH
                 COSINC(IHR)=COSIIH
                 RDR(IHR)=DNORAD(IHR)*COSIIH
                 RDF(IHR)=RDT(IHR)-RDR(IHR)
                 IF (ISST.NE.0.) GO TO 100
      90         CONTINUE
      100    RETURN
      C

      C
             END
```

```
SUNACT*SOLITE1(1).DAYC(0)
      COMPILER (DIAG=3)
C
C     ***************************************************************************
C
C        SUBROUTINE TO READ WEATHER FILE AND CALL SOLAR INTENSITY
C        SUBROUTINE. CALCULATES DAILY AND MONTHLY AVERAGES
C        WEATHER DATA.
C
C     ***************************************************************************
C
      SUBROUTINE DAYC (RLATD,RLONG,TZN,MON,IDYOYR,IYEAR,FLGURB,FLGOUT,P,
     2 Q,R,ITER)
C
C     ***************************************************************************
C
      COMMON /WKD/ IYRDA(12),WKDY(12,31),HLDY(12,31)
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24), ISRT, ISST
      COMMON /DAM/ DAMDBT,DAMWBT,DAMWSP,DAMCCT,DAMTOC,DAMRDR,DAMRDF,
     2 DAMRDT,DAMWDR,DAMMAX,DAMMIN
      COMMON /WET/ DBT(24),DPT(24),WBT(24),WSP(24),BPR(24),WDR(24),
     2 YY(24)
      INTEGER DAY,WKDY,HLDY,HOL
      COMMON /CLD/ CCT(24),TOC(24)
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /MNM/ MNMDBT(12),MNMWBT(12),MNMWSP(12),MNMCCT(12),
     2 MNMTOC(12),MNMWDR(12),MNMRDR(12),MNMRDF(12),MNMRDT(12),MNMMAX(12)
     3,MNMMIN(12)
      REAL MNMDBT,MNMWBT,MNMWSP,MNMCCT,MNMTOC,MNMWDR,MNMRDR,MNMRDF,
     2 MNMRDT,MNMMAX,MNMMIN
      COMMON /CON/ TEMP1,TEMP2,WIND,POWER,AREA,RLH,ENERGY,HEAT,RLNZ
      DAMDBT=0. .
      MAXDBT=-100.
      MINDBT=150.
      DAMWBT=0.
      DAMRDR=0.
      DAMRDF=0.
      DAMRDT=0.
      DAMWSP=0.
      DAMWDR=0.
      READ (8) DBT,DPT,WBT,WSP,BPR,CCT,TOC,WDR,YY,IYEAR,IMON,IDAY,IC
      DAY=IDYOYR-IYRDA(MON)
      IF (1.EQ.ITER) NNDAY=WKDAY(IYEAR,MON,DAY)
      IF (1.NE.ITER) NNDAY=NNDAY+1
      IF (NNDAY.EQ.8) NNDAY=1
C
C DETERMINE TYPE OF DAY FOR CALCULATION OF OCCUPANT HEAT GAINS
      WKDY(MON,DAY)=NNDAY
      CALL DST (IYEAR,MON,DAY,IDSTX.IDSTY,NNDAY)
      CALL HOLDAY (IYEAR,MON,DAY,NNDAY,HOL)
      HLDY(MON,DAY)=HOL
      IDST=1
      IF (MON.LT.4) IDST=0
      IF (MON.GT.10) IDST=0
      IF (MON.EQ.10.AND.DAY.GT.IDSTY) IDST=0
      IF (MON.EQ.4.AND.DAY.LT.IDSTX) IDST=0
C
```

```
C SUBROUTINE TO DETERMINE SOLAR POSITION AND RADIATION INTENSITY
C DEPENDENT ON CLOUD COVER USING ASHRAE SOLAR CLEAR DAY
C ALGORITHM AND THE KIMURA STEPHENSON CLOUD DATA ALGORITHM
      CALL SUN (RLATD,RLONG.TZN,IDYOYR,MON,IDST,P,Q,R)
      IF (FLGURB.EQ.1.) CALL URBAN
C
C DAILY TOTAL VALUES CALCUALTED FOR WEATHER VARIABLES
      DO 10 IH=1,24
           MINDBT=MIN(DBT(IH),MINDBT)
           MAXDBT=MAX(DBT(IH),MAXDBT)
           DAMDBT=DBT(IH)+DAMDBT
           DAMWBT=WBT(IH)+DAMWBT
           DAMWSP=WSP(IH)+DAMWSP
           DAMRDT=RDT(IH)+DAMRDT
           DAMCCT=CCT(IH)+DAMCCT
           DAMTOC=TOC(IH)+DAMTOC
           DAMRDR=RDR(IH)+DAMRDR
           DAMRDF=RDF(IH)+DAMRDF
           DAMWDR=WDR(IH)+DAMWDR
           IF (FLGOUT.NE.1..AND.FLGOUT.NE.3.) GO TO 10
           DBT(IH)=DBT(IH)*TEMP1+TEMP2
           DPT(IH)=DPT(IH)*TEMP1+TEMP2
           WBT(IH)=WBT(IH)*TEMP1+TEMP2
           WSP(IH)=WSP(IH)*WIND
           DNORAD(IH)=DNORAD(IH)*POWER
           RDR(IH)=RDR(IH)*POWER
           RDF(IH)=RDF(IH)*POWER
           RDT(IH)=RDT(IH)*POWER
10         CONTINUE
      DAMMAX=MAXDBT*TEMP1+TEMP2
      DAMMIN=MINDBT*TEMP1+TEMP2
      IF (FLGOUT.EQ.1.OR.FLGOUT.EQ.3.) WRITE (9) DBT,DPT,WBT,WSP,BPR,CCT
     2.TOC.WDR,RDT,RDR,IYEAR.MON.DAY,IC
      DAMDBT=DAMDBT/24.*TEMP1+TEMP2
      DAMDPT=DAMDPT/24.*TEMP1+TEMP2
      DAMWBT=DAMWBT/24.*TEMP1+TEMP2
      DAMWSP=DAMWSP/24.*WIND
      DAMRDR=DAMRDR*POWER
      DAMRDF=DAMRDF*POWER
      DAMRDT=DAMRDT*POWER
      DAMCCT=DAMCCT/(ISST-ISRT+1)
      DAMTOC=DAMTOC/(ISST-ISRT+1)
C
C AVERAGE MONTHLY MEANS CALCULATED
      MNMMIN(MON)=MIN(DAMMIN.MNMMIN(MON))
      MNMMAX(MON)=MAX(DAMMAX,MNMMAX(MON))
      MNMDBT(MON)=DAMDBT+MNMDBT(MON)
      MNMWBT(MON)=DAMWBT+MNMWBT(MON)
      MNMWSP(MON)=DAMWSP+MNMWSP(MON)
      MNMTOC(MON)=DAMTOC+MNMTOC(MON)
      MNMCCT(MON)=DAMCCT+MNMCCT(MON)
      MNMRDT(MON)=DAMRDT+MNMRDT(MON)
      MNMRDR(MON)=DAMRDR+MNMRDR(MON)
      MNMRDF(MON)=DAMRDF+MNMRDF(MON)
      RETURN
      END
```

```
SUNACT*SOLITE2(1).SUN(0)
      COMPILER (DIAG=3)
C
C     **************************************************************************
C
C      SUBROUTINE TO DETERMINE CLOUDLESS AND CLOUDY SKY RADIATION
C      ON HORIZONTAL SURFACE, FROM NBSLD SUN SUBROUTINE
C      USING KIMURA/STEPHENSON MODIFIED CLOUD MODIFIER
C
C     **************************************************************************
C
      SUBROUTINE SUN (RLATD,RLONG,TZN,IDYOYR,MON,IDST,P,Q,R)
C
C     **************************************************************************
C
      DIMENSION A0(5),A1(5),A2(5).A3(5),B1(5).B2(5),B3(5)
      DATA A0 /.302,-.0002,368.44,.1717.0.0905/ ,A1 /-22.93,.4197,24.52,
     2 -.0344,-.0410/ ,A2 /-.229,-3.2265,-1.14,.0032,.0073/ ,A3 /-.243,
     3 -.0903,-1.09,.0024,.0015/ ,B1 /3.851,-7.351,.58,-.0043.-.0034/
     4 ,B2 /.002,-9.3912,-.18,0.,0.0004/ ,B3 /-.055,-.3361,.28,-.0006,
     5 -.0006/
      COMMON /LATITU/ CSLATD,SNLATD,TNLATD
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24),ISRT,ISST
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /CLD/ CCT(24),TCC(24)
      REAL MERID.LOND
C     RLATD= LATITUDE.DEGREES(+NORTH,-SOUTH)
C     RLONG= LONGITUDE.DEGREES(+WEST.-EAST)
C     TZN= TIME ZONE NUMBER
C              STANDARD  TIME          DAYLIGHT  SAVING TIME
C      ATLANTIC       4                    3
C      EASTERN        5                    4
C      CENTRAL        6                    5
C      MOUNTAIN       7                    6
C      PACIFIC        8                    7
C     IDYOYR= DAYS(FROM START OF YEAR)
C     IHR= TIME.HOUR AFTER MIDNIGHT)
C     CLEARN= CLEARNESS NUMBER
C     ISRT=SUN RISE TIME  (HOURS AFTER MIDNIGHT)
C     IST=SUN SET TIME
C     COSINC=COS(Z)     DIRECTION COSINES
C     DIRCS2=COS(N)     DIRECTION COSINES
C     DIRCS3(IHR)=COS(S)  DIRECTION COSINES)
C     GAMMA=GAMMA
C     SALT=SOLAR ALTITUDE ANGLE
C     DNORAD=DIRECT NORMAL RADIATION
C     RDT(IHR)=TOTAL SOLAR RADIATION INTENSITY
C     RDF(IHR)=DIFFUSE SKY RADIATION INTENSITY
C     RDR(IHR)=INTENSITY OF DIRECT SOLAR RADIATION ON SURFACE
C     SOLDEC=SUN DECLINATION ANGLE,DEGREES
C     EOTHR=EQUATION OF TIME .HOURS
C     SOLFAC(1)=SUN DECLINATION ANGLE, HOURS
C     SOLFAC(2)=EQUATION OF TIME, HOURS.
C     SOLFAC(3)=A    SOLAR FACTOR
C     SOLFAC(4)=B     SOLAR FACTOR
C     SOLFAC(5)=C     SOLAR FACTOR
C     HORANG=    HOUR ANGLE,DEGREE
```

```
      DATA PI /3.1415927/
      DO 10 IH=1,24
          RDR(IH)=0.
          RDT(IH)=0.
          RDF(IH)=0.
10        CONTINUE
C
C
C BEGIN SOLAR POSITION CALCULATION
      ISST=0
      X=2*PI/366.*IDYOYR
      C1=COS(X)
      S1=SIN(X)
      S2=2.*S1*C1
      C2=C1*C1-S1*S1
      C3=C1*C2-S1*S2
      S3=C1*S2+S1*C2
C
C CALCULATE SOLFAC COEFFICIENTS FOR DECLINATION AND INTENSITY BASED
C ASHRAE PROCEDURES.
      DO 20 K=1,5
          SOLFAC(K)=A0(K)+A1(K)*C1+A2(K)*C2+A3(K)*C3+B1(K)*S1+B2(K)*S2+B
     23(K)*S3
20        CONTINUE
      EOTHR=SOLFAC(2)/60.
      SOLDEC=SOLFAC(1)
      MERID=15*TZN
      LOND=RLONG-MERID
      RADDEC=SOLDEC*PI/180.
      SNDEC=SIN(RADDEC)
      CSDEC=COS(RADDEC)
      HRPOS=-SNDEC/CSDEC*TNLATD
      DEGHRP=180.*ACOS(HRPOS)/PI
      ABSDHP=ABS(DEGHRP)
C
C FOR EVERY HOUR  CALCULATE POSITION AND INTENSITY
      DO 110 IHR=2,24
          HRANG=15*(IHR-12+TZN+EOTHR-IDST)-RLONG
          CSHRA=COS(HRANG*PI/180.)
          COSIIH=SNLATD*SNDEC+CSLATD*CSDEC*CSHRA
          ABSHAN=ABS(HRANG)
          IF (ABSDHP-ABSHAN) 100,30,30
30        DIR2IH=CSDEC*SIN(HRANG*PI/180.)
          STEST=SQRT(1.-COSIIH*COSIIH-DIR2IH*DIR2IH)
          STEST1=CSHRA-SNDEC/CSDEC/TNLATD
          IF (STEST1) 50,40,40
40        DIRCS3(IHR)=STEST
          GO TO 60
50        DIRCS3(IHR)=-STEST
60        SOLAIH=ASIN(COSIIH)
          SOLZIH=ASIN(DIR2IH/COS(SOLAIH))
          IF (DIRCS3(IHR).LT.0.) SOLZIH=PI-SOLZIH
          IF (SOLZIH.LT.0.0) SOLZIH=2*PI+SOLZIH
C
C DIRECT NORMAL RADIATION CALCULATED IN BTU/H FT2
          DNOIHR=(SOLFAC(3)*EXP(-SOLFAC(4)/COSIIH))
          RDFIHR=SOLFAC(5)*DNOIHR
          RDRIHR=DNOIHR*COSIIH
```

```
            IF (COSIIH) 70,70,80
70          COSIIH=0.
            RDRIHR=0.
80          RDTIHR=RDRIHR+RDFIHR
C       CC= THE CLOUD COVER.(NOTE THAT CIRRUS IS COUNTED ONLY
C           AS HALF THE CLOUD COVER)
            CC=CCT(IHR)
            IF (TOC(IHR).EQ.0.0) CC=0.5*CC
            CM=P+Q*CC+R*CC**2
C       P= CLOUDLESS SKY FACTOR SHOWN IN TABLE A-6 IN THE CCF ROUTINE
C       SOLFAC(5)=STANDARD DIFFUSE SKY FACTOR
C       CC=CLOUD COVER CALCULATED IN THE CLOUD COVER CALCULATION
C       CM=CLOUD COVER FACTOR DETERMINED BY THE CLOUD COVER CALCULATION
            FACSLT=0.309-0.137*COSIIH+0.394*COSIIH**2
            EMPCST=COSIIH/(SOLFAC(5)+COSIIH)+(P-1)/(1-FACSLT)
C       DIRECT RADIATION ON A HORIZONTAL SURFACE UNDER A CLOUDY SKY.
            RDRIHR=RDTIHR*EMPCST*(1-CC/10.)
C       RADDIF= DIFFUSE RADIATION ON A HORIZONTAL SURFACE UNDER A
C       CLOUDLESS SKY
            RADDIF=RDFIHR
C       DIFFUSE RADIATION UPON A HORIZONTAL SURFACE UNDER A CLOUDY
C       SKY
            RDFIHR=RDTIHR*(CM-EMPCST*(1.-CC/10))
            IF (RDFIHR.LE.RADDIF) RDFIHR=RADDIF
C       TOTAL RADIATION UPON A SURFACE UNDER A CLOUDY
C       SKY
            IF (CC.NE.0.) GO TO 90
            RDRIHR=DNOIHR*COSIIH
            RDFIHR=RADDIF
90          RDT(IHR)=RDRIHR+RDFIHR
            IF (RDT(IHR).LT.0.) RDT(IHR)=0.
            RDR(IHR)=RDRIHR
            RDF(IHR)=RDFIHR
            SOLAZ(IHR)=SOLZIH
            SOLALT(IHR)=SOLAIH
            DIRCS2(IHR)=DIR2IH
            DNORAD(IHR)=DNOIHR
            COSINC(IHR)=COSIIH
100         IF (RDT(IHR).GT.0..AND.RDT(IHR-1).LE.0.) ISRT=IHR
            IF (RDT(IHR).LE.0..AND.RDT(IHR-1).GT.0.) ISST=IHR-1
            IF (ISST.NE.0) GO TO 120
110         CONTINUE
120     RETURN
C
        END
```

```
SUNACT*SOLITE2(1).WKDAY(0)
              FUNCTION WKDAY (YR,MO,DAY)
      C
      C       *****************************************************************
      C
      C         WKDAY=1 SUNDAY
      C         WKDAY=2 MONDAY
      C         WKDAY=3 TUESDAY
      C         WKDAY=4 WEDNESDAY
      C         WKDAY=5 THURSDAY
      C         WKDAY=6 FRIDAY
      C         WKDAY=7 SATURDAY
              INTEGER YR,DAY,WKDAY,TDAY,WKDY,HLDY
              COMMON /WKD/ IYRDA(12),WKDY(12,31),HLDY(12,31)
              N=YR/4
              ND=N-485
              IY=2
              IF (ND.EQ.0) GO TO 40
              IF (ND.LT.0) GO TO 10
              IADD=2
              GO TO 20
      C
      10      ND=-ND
              IADD=-2
      20      DO 30 J=1,ND
                  IY=IY-IADD
                  IF (IY.GT.7) IY=IY-7
                  IF (IY.EQ.0) IY=7
                  IF (IY.LT.0) IY=IY+7
      30          CONTINUE
      40      MD=YR-N*4
              IF (MD.EQ.0) IWK=IY
              IF (MD.EQ.1) IWK=IY+2
              IF (MD.EQ.2) IWK=IY+3
              IF (MD.EQ.3) IWK=IY+4
              IF (IWK.GT.7) IWK=IWK-7
              IF (MO.NE.1) GO TO 50
              TDAY=DAY-1
              GO TO 80
      C
      50      DO 60 J=1,12
                  IF (MO.NE.J) GO TO 60
                  TDAY=IYRDA(J)+DAY-1
                  GO TO 70
      60          CONTINUE
      70      IF (MD.EQ.0.AND.MO.GT.2) TDAY=TDAY+1
      80      NTX=TDAY/7
              NDX=TDAY-7*NTX+IWK
              IF (NDX.GT.7) NDX=NDX-7
              WKDAY=NDX
              KV=YR/100
              KTEST=YR-KV*100
              IF (MO.GT.2.OR.KTEST.NE.0) GO TO 90
              KV=KV-1
      90      LV=KV/4
              LTEST=KV-LV*4
              IF (LTEST.EQ.2) WKDAY=WKDAY+1
              IF (LTEST.EQ.1) WKDAY=WKDAY+2
              IF (LTEST.EQ.0) WKDAY=WKDAY+3
              WKDAY=WKDAY-3*(LV-4)
      100     IF (WKDAY.LE.0) WKDAY=WKDAY+7
              IF (WKDAY.LE.0) GO TO 100
              IF (WKDAY.GT.7) WKDAY=WKDAY-7
              RETURN
      C
              END
```

```
SUNACT*SOLITE2(1).HOLDAY(0)
      SUBROUTINE HOLDAY (YR,MO,DAY,NDAY,HOL)
C
C     ***********************************************************************
C
      INTEGER YR,DAY,HOL
      IF (MO.EQ.1.AND.DAY.EQ.1) GO TO 10
      IF (MO.EQ.12.AND.DAY.EQ.31.AND.NDAY.EQ.6) GO TO 10
      IF (MO.EQ.1.AND.DAY.EQ.2.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.2.AND.DAY.EQ.22) GO TO 10
      IF (MO.EQ.2.AND.DAY.EQ.21.AND.NDAY.EQ.6) GO TO 10
      IF (MO.EQ.2.AND.DAY.EQ.23.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.5.AND.DAY.EQ.30) GO TO 10
      IF (MO.EQ.5.AND.DAY.EQ.29.AND.NDAY.EQ.6) GO TO 10
      IF (MO.EQ.5.AND.DAY.EQ.31.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.7.AND.DAY.EQ.4) GO TO 10
      IF (MO.EQ.7.AND.DAY.EQ.3.AND.NDAY.EQ.6) GO TO 10
      IF (MO.EQ.7.AND.DAY.EQ.5.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.12.AND.DAY.EQ.25) GO TO 10
      IF (MO.EQ.12.AND.DAY.EQ.24.AND.NDAY.EQ.6) GO TO 10
      IF (MO.EQ.12.AND.DAY.EQ.26.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.9.AND.DAY.LT.7.AND.NDAY.EQ.2) GO TO 10
      IF (MO.EQ.11.AND.DAY.GT.24.AND.NDAY.EQ.5) GO TO 10
      HOL=0
      RETURN
   10 HOL=1
      RETURN
      END
```

```
SUNACT*SOLITE2(1).DST(0)
                SUBROUTINE DST (YR,MO,DAY,DSTX,DSTY,NDAY)
        C
        C       ************************************************************************
        C
                INTEGER YR,DAY,DSTX.DSTY
                IF (MO.LT.4.OR.MO.GT.10) GO TO 10
                IF (MO.EQ.4.AND.DAY.LT.24) GO TO 10
                IF (NDAY.EQ.1) DSTX=DAY
                IF (MO.EQ.10.AND.DAY.LT.24) GO TO 10
                IF (NDAY.EQ.1) DSTY=DAY
        10      CONTINUE
                RETURN
        C
                END
```

```
SUNACT*SOLITE2(1).URBAN(0)
              COMPILER (DIAG=3)
    C           SUBROUTINE URBAN:
    C           THIS SUBROUTINE MODIFIES THE AMOUNT OF CLEAR DAY
    C           RADIATION BY A FACTOR DETERMINED IN REF( ).
    C             ******************************************************************
    C
    C         **********************************************************************
    C
              SUBROUTINE URBAN
    C
    C         **********************************************************************
    C
              DIMENSION ALTRDR(10),ALTRDF(10)
              COMMON /SOL/ RDR(24),RDF(24),RDT(24)
              COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
             2 DIRCS3(24),DNORAD(24),ISRT,ISST
              DATA (ALTRDR(I),I=1,10) /3*.66,2*.64,.63,.53,.53,.48,0./
              DATA (ALTRDF(I),I=1,10) /3*.28,2*.22,.2,.19,.16,.13,0./
              DO 10 IHR=ISRT,ISST
                   I=10-SOLALT(IHR)/.1571
                   RRDF=RDF(IHR)
                   RRDR=RDR(IHR)
                   RDR(IHR)=ALTRDR(I)*RRDR
                   RDF(IHR)=ALTRDF(I)*RRDR
                   IF (RRDF.GE.RDF(IHR)) RDF(IHR)=RRDF
                   RDT(IHR)=RDR(IHR)+RDF(IHR)
    10             CONTINUE
              RETURN
              END
```

```
SUNACT*SOLITE2(1).OCHEAT(0)
C      ********************************************************************************
C
C      SUBROUTINE TO DETERMINE THE INTERNAL GAINS OF A ROOM
C      AS A FUNCTION OF TYPE OF DAY, AND OCCUPANCY TYPE.
C
       SUBROUTINE OCHEAT (KDAY,HOL)
C
C      ********************************************************************************
C
C NODOCT OCCUPANCY GAIN, HEAT GAIN FROM PEOPLE.
C NODELT OCCUPANCY GAIN, HEAT GAIN FROM ELECTRICAL EQUIPMENT,LIGHTS
C RO     RATIO OF MMAXIMUM PEOPLE GAINS
C HGELE  ARRAY OF RATIOS OF MAXIMUM ELECTRICAL GAINS
C HGOCC  ARRAY OF RATIO OF MAXIMUM PEOPLE GAINS.
C IDATP  TYPE OF DAY. 1=WEEKDAY, 2.=LONG DAY, 3.=CLOSED DAY
C        FOR COMMERCIAL ESTABLISHMENTS.
C NTYP   TYPE OF ROOM OCCUPANCY.
C DLLMIN DAYLIGHT LEVELS, MINIMUMS FOR OCCUPANCY, FROM IES.
C IEST   START OF OCCUPANCY HOURS
C IHEN   END OF OCCUPANCY HOURS
C DELC   ELECTRICAL LOADS/SQUARE AREA
C DOCC   PEOPLE OCCUPANCY IN ROOM.
C
       INTEGER HOL
       DIMENSION DLM(3)
       COMMON /DLL/ DLLMIN(10),IEST(10),IHEN(10)
       COMMON /OCC/ NODES.NODTYP(10),NODFLA(10),NODOCC(10),NODELC(10),
      2 NODELT(10,24),NODOCT(10,24),HGELE(3,24,3),HGOCC(3,24,3)
       REAL NODFLA,NODELC,NODELT.NODOCT,NODTYP,NODOCC
       DATA (DLM(I),I=1,3) /19.,57.,37./
       DO 10 NOD=1,NODES
           IEST(NOD)=0
           IHEN(NOD)=0
10         CONTINUE
       DO 20 NOD=1,NODES
           NTYP=NODTYP(NOD)
           IDATP=1
           IF ((NTYP.EQ.3.OR.NTYP.EQ.1).AND.(KDAY.EQ.1.OR.KDAY.EQ.7.OR.HO
      2L.EQ.1)) IDATP=3
           IF (KDAY.EQ.6.OR.HOL.EQ.1.AND.NTYP.EQ.2) IDATP=2
           IF (KDAY.EQ.1.AND.NTYP.EQ.2) IDATP=3
           DELC=NODELC(NOD)
           DOCC=NODOCC(NOD)
           DLLMIN(NOD)=DLM(NTYP)
           DO 20 IHR=1,24
           NODELT(NOD,IHR)=DELC*HGELE(IDATP,IHR,NTYP)
           RO=HGOCC(IDATP.IHR,NTYP)
           NODOCT(NOD,IHR)=DOCC*RO
           IF (IEST(NOD).EQ.0.AND.RO.GT..1) IEST(NOD)=IHR
           IF (IEST(NOD).GT.0.AND.IHEN(NOD).EQ.0.AND.RO.LT..1) IHEN(NOD)=
      2IHR
20         CONTINUE
       RETURN
       END
```

```
SUNACT*SOLITE2(1).SUNSRF(0)
      COMPILER (DIAG=3)
C
C     ****************************************************************************
C
      SUBROUTINE SUNSRF (ITER,IDAY,DAMDBT,ISTFLG,FLGTAB)
C
C     ****************************************************************************
C
C ANGIND ANGLE OF INCIDENCE, DEGREES.
C ANGINC ANGLE OF INCIDENCE, RADIANS
C BLKHT  HEIGHT OF BLOCK OF BUILDINGS.
C BLKLEN LENGTH OF BLOCK OF BUILDINGS.
C CCC    HOURLY CLOUD COVER
C CCT    HOURLY CLOUD COVER ARRAY
C CDR    CLEAR DAY RATIO OF DIRECT BEAM TO TOTAL
C COSIIH COSINE OF ZENITH ANGLE
C COSINC COSINE OF THE SURFACE INCIDENCE ANGLE
C CSWALT COSINE OF THE WALL TILT FROM HORIZONTAL
C CSWLAZ COSINE OF THE WALL AZIMUTH FROM SOUTH
C D      DISTANCE FROM WINDOW INTO ROOM. DALITE CALCULATIONS
C DD     CUMULATIVE DISTANCE FROM WINDOW INTO ROOM
C DEL    THIRD OF ROOM DEPTH
C DEL2   HALF OF DEL.
C DIRCS2 COSINE OF HOUR ANGLE.(FROM SUN)
C DIRCS3 COSINE OF ANGLE TO SOUTH VECTOR (FROM SUN)
C DIST   DISTANCE FROM CORNERS OF BLOCK TO SURFACE EDGES.
C DLTC   MAXIMUM AMOUNT OF DAYLIGHT FOR POINT IN ROOM.
C DLTDHG DAYLIGHT, DAILY LEVELS GREATER THAN ALLOWABLE.
C DLTDHL DAYLIGHT,DAILY HOURS LESS THAN ALLOWABLE.
C DLTDL  DAYLIGHT LEVELS AT 3 ROOM POINTS.
C DLTH   DAYLIGHT HOUR COUNTER (IF LIGHT GT.0.)
C DLTMAX MAXIMUM LEVEL OF LIGHTING AT A POINT
C DLTMIN LEVEL OF LIGHT AT WORKING PLANE ABOVE 50 FC.
C DLTWP  LEVEL OF LIGHT AT THE WORKING PLANE
C DNORAD DIRECT NORMAL CLEAR DAY RADIATION.
C DNORIH DIRECT NORMAL CLEAR DAY RADIATION.
C DRC2IH DIRCS2
C DRC3IH DIRCS3
C ERC    EXTERNALLY REFLECTED DAYLIGHT COMPONENT
C FLGDLT DAYLIGHT FLAG.
C FLGGL  GLAZING FLAG.
C FLGGLL GLAZING LAYER FLAG
C FLGSRF SURFACE FLAG.
C FLGST  FACING STREET INDICATOR
C GLAEXT EXTINCTION COEFFICIENT FOR GLAZING
C GLAREF REFRACTION COEFFICIENT, GLAZING,
C GLATHK THICKNESS OF GLAZING.
C GREFL  GROUND REFLECTION COEFFICIENT
C GRND   GROUND TYPE INDICATOR
C ISRT   SUN RISE TIME
C ISST   SUN SET TIME
C NLAY   NUMBER OF LAYERS IN GLAZING COMPOSITE.
C NN2    FINAL NUMBER OF SURFACES
C NODOT  NUMBER OF NODES
C NSRFOT NUMBER OF SURFACES
C NSURF
C RDF    DIFFUSE RADIATION CLEAR DAY
```

```
C RDFIHR RDF
C RDFSRF DIFFUSE RADIATION ON THE SPECIFIED SURFACE
C RDFTRA DIFFUSE RADIATION TRANSMISSION.
C RDGRND GROUND SCATTERED RADIATION
C RDWALL WALL SCATTERED RADIATION
C RDR    DIRECT RADIATION, CLEAR DAY HORIZONTAL
C RDRIHR RDR
C RDRRAT RATIO OF DIRECT TO TOTAL RADIATION (CLOUDY DAY)
C RDRSHD DIRECT SHADOW FACTOR
C RDRSRF DIRECT RADIATION ON SURFACE
C RDRTRA DIRECT RADIATION, TRANSMITTED.
C RDT    TOTAL HORIZONTAL CLEAR DAY RADIATION
C RDTSRF TOTAL RAIDATION ON SPECIFIED SURFACE
C RRDF   RATIO OF DIFFUSE RADIATION ON SURFACE (OR TRANSMITTED)
C RRDR   RATIO OF DIRECT RADIATION TRANSMITTED THROUGH SURFACE
C SALTIH SOLAR ALTITUDE
C SC     DAYLIGHT COMPONENT OF THE SKY VIEW
C SKYL   LUMINANCE OF SKY
C SLAZIH SOLAR AZIMUTH, HOURLY.
C SNWALT SIN OF WALL TILT
C SOLALT SOLAR ALTITUDE, HOURLY ARRAY
C SOLAZ  SOLAR ZIMUTH HOURLY ARRAY.
C SOLFAC ASHRAE FACTORS FOR DETERMINING CLEAR DAY RADIATION
C SRFABS ABSORPTION COEFFICIENT FOR THE SURFAC
C SRFAR  SURFACE AREA
C SRFHAG SURFACE HEIGHT ABOVE GROUND
C SRFHT  HEIGHT OF THE SURFACE
C SRFINC ANGLE OF INCIDENCE ON THE SURFACE
C SRFLN  LENGTH OF SURFACE
C STAXIS AXIS OF STREET, FROM SOUTH
C STW1   STREET WIDTH, PRIMARY STREET.
C STW2   STREET WIDTH SECONDARY STREET.
C TOC    TYPE OF CLOUD. 0=CIRRUS, 1=CUMULUS, 2=STRATUS.
C TRDR   WEIGHTED DIRECT TRANSMISSION FACTORS.
C WALALT WALL TILT FROM HORIZONTAL
C WALAZ  WAL AZIMUTH FROM SOUTH
C WALFAC DIFFUSE RADIATION FACTOR ON VERTICAL SURFACE, THRELKELD.
C XIRC   DAYLIGHT INTERNALLY REFLECTED COMPONENT.
C ZSLITE DAYLIGHT SUBROUTINE DATA ARRAY.
      DIMENSION DLTH(10,3),SKYL(3),RFKB(10,24),DLTWP(3),DROP(2.24).
     2 WDFP(10,3)
      COMMON /DLL/ DLLMIN(10),IEST(10),IHEN(10)
      COMMON /RX/ RFN(2,5,2,2),RFMX(10.2),RFF(2.5)
      COMMON /ST/  ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
     2 ISS(2,24),WALFAC(2,2,24),ANGIN(2,5,24)
      COMMON /DIF/ IVFD(5,10.2),VF(5,10),TRA(5,10),TRN(5,10)
      COMMON /CON/ TEMP1,TEMP2,WIND,POWER,AREA,RLN,ENERGY,HEAT,RLNZ
      COMMON /CLD/ CCT(24),TOC(24)
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
     2 DLTDHG(10,3)
      COMMON /RIL/ SC(10.3),ERC(10,3),XIRC(10,3)
      COMMON /TRA/ GLAREF(15,10),GLAEXT(15,10),GLATHK(15,10),NLAY(12),
     2 NSURF(15)
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24),ISRT,ISST
      COMMON /WAL/ WALAZ(10),WALALT(10),STAXIS(2),STW1(2),STW2(2),
     2 BLKLEN(2),BLKHT(2,2),FLCST(10).CSWALT(10),SNWALT(10),CSWLAZ(10),
     3 SNWLAZ(10)
```

```
      COMMON /SOL/ RDR(24),RDF(24),RDT(24)
      COMMON /ANS/ RDFSRF(10,24),RDRSRF(10,24),RDTSRF(10,24),N2,
     2 ANGINC(10,24),RDRSHD(10,24),TRABS(10,15),TRNMS(10,15)
      COMMON /SRF/ DIST(2,10),SRFHAG(10),SRFLN(10),SRFHT(10),SRFAR(10),
     2 SRFABS(10),A(2,10),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
     3 FLGGLL(10)
C
C INITIALIZE VALUES
C
      DO 10 N=1,N2
          DO 10 ID=1,3
          DLTH(N,ID)=0.
          DLTDL(N,ID)=0.
          DLTDHL(N,ID)=0.
          DLTDHG(N,ID)=0.
10        CONTINUE
C
C DETERMINE RADIATION FACTORS (THRELKELD, HOR. TO VER.) AND
C SUNNY SIDE OF STREET.
      CALL SUNSID (ISTFLG,DROP)
C     WRITE (26,20)
C 20    FORMAT (52H IH   RFXB    SED  SEDHT   RDFH   RDFC RDFSRF  RDFTR,
C    2 21H  RDFSR   DIFF  DIFFB,/)
C     WRITE (27,30)
      DO 180 IHR=ISRT,ISST
          SALTIH=INT(SOLALT(IHR)*180./3.14159+.5)
          SLAZIH=INT(SOLAZ(IHR)*180./3.14159+.5)
          CCC=CCT(IHR)
          COSIIH=COSINC(IHR)
          DNORIH=DNORAD(IHR)
          DRC2IH=DIRCS2(IHR)
          DRC3IH=DIRCS3(IHR)
          RDFC=RDF(IHR)
          RDRC=RDR(IHR)
          IF (RDRC.LT.0.) RDRC=0.
         .RDRH=DNORIH*COSIIH
          IF (RDRH.LT.0.) RDRH=0.
          RDTC=RDT(IHR)
          RDFH=DNORIH*SOLFAC(5)
C
C FACTORS OF PROPORTION OF RAD./HOUR ACTUAL TO CLEAR DAY AMOUNTS
C AS THE LATTER IS THE AMOUNT THAT WALL RAD. FACTORS ARE BASED ON
          DFFC=RDFC/RDFH
          DFBC=0.
          IF (RDRH.GT.0.) DFBC=RDRC/RDRH
C
C DETERMINE DIFFUSE AND BEAM RADIATION FACTORS FOR EACH SURFACE
          DO 140 ISURF=1,N2
              ZSLITE(ISURF,21)=SALTIH
              ZSLITE(ISURF,22)=SLAZIH
              ZSLITE(ISURF,24)=CCC
              SRFINC=CSWALT(ISURF)*COSIIH+SNWALT(ISURF)*SNWLAZ(ISURF)*D
     2C2IH+SNWALT(ISURF)*CSWLAZ(ISURF)*DRC3IH
              ANGINC(ISURF,IHR)=ACOS(SRFINC)
              RDRS=0.
              IF (SRFINC.GT.0.) RDRS=SRFINC*DNORIH
              I=FLGSRF(ISURF)
              ISTS=FLGST(ISURF)
```

```
                 IST=ISS(ISTS,IHR)
                 IOST=2
                 IF (IST.EQ.2) IOST=1
                 GO TO (20,30,40,20,30), I
20               IW=1
                 IWOP=2
                 IR=4
                 IROP=5
                 GO TO 50
30               IW=2
                 IWOP=1
                 IR=5
                 IROP=4
                 GO TO 50
40               IW=IST
                 IWOP=IOST
                 IR=0
                 IROP=0
50               FP=TEMP1*32.+TEMP2
C
C SNOW REFLECTANCE MODIFIER, FUNCTION OF AMBIENT TEMP.
                 RS=1.
                 IF (RFM(ISTS,3).EQ.8..OR.RFM(ISTS,IR).EQ.8..OR.RFM(ISTS,IR
     2OP).EQ.8..AND.DAMDET.LT.FP) RS=2.4
                 GO TO (60,60,70,80,80), I
60               DIFF=WALFAC(ISTS,I,IHR)*VF(5,ISURF)*TRA(5,ISURF)+WALFAC(IS
     2TS,IWOP,IHR)*TRA(IWOP,ISURF)*VF(IWOP,ISURF)
                 DIFFB=VF(3,ISURF)*TRA(3,ISURF)+VF(4,ISURF)*TRA(4,ISURF)
                 DIFFB=DIFFB*RS
                 DIFT=WALFAC(ISTS,I,IHR)*VF(5,ISURF)*TRN(5,ISURF)+WALFAC(IS
     2TS,IWOP,IHR)*TRN(IWOP.ISURF)*VF(IWOP.ISURF)
                 DIFTB=VF(3.ISURF)*TRN(3,ISURF)+VF(4,ISURF)*TRN(4,ISURF)
                 DIFTB=DIFTB*RS
                 DIFS=WALFAC(ISTS,I,IHR)*VF(5,ISURF)+WALFAC(ISTS,IWOP,IHR)*
     2VF(IWOP,ISURF)
                 DIFSB=VF(3.ISURF)+VF(4,ISURF)
                 DIFSB=DIFSB*RS
                 GO TO 90
70               DIFF=WALFAC(ISTS,IW,IHR)*VF(IW,ISURF)*TRA(IW,ISURF)+WALFAC
     2(ISTS,IWOP,IHR)*TRA(IWOP,ISURF)*VF(IWOP,ISURF)
                 DIFFB=VF(5.ISURF)*TRA(5,ISURF)
                 DIFT=WALFAC(ISTS,IW,IHR)*VF(IW,ISURF)*TRN(IW,ISURF)+WALFAC
     2(ISTS,IWOP,IHR)*TRN(IWOP,ISURF)*VF(IWOP,ISURF)
                 DIFTB=VF(5,ISURF)*TRN(5,ISURF)
                 DIFS=WALFAC(ISTS,IW,IHR)*VF(IW,ISURF)+WALFAC(ISTS,IWOP,IHR
     2)*VF(IWOP,ISURF)
                 DIFSB=VF(5,ISURF)
                 GO TO 90
80               WLF=.55+.437*SRFINC+.313**SRFINC
                 IF (SRFINC.LT.-.2) WLF=.45
                 WLF=WLF*(1-CSWLAZ)
                 DIFF=WLF*VF(5,ISURF)*TRA(5,ISURF)+WALFAC(ISTS,IWOP,IHR)*VF
     2(IWOP,ISURF)*TRA(IWOP,ISURF)
                 DIFFB=(VF(4,ISURF)*TRA(4.ISURF)+VF(3,ISURF)*TRA(3,ISURF))*
     2RS+SNWLAZ(ISURF)*VF(5,ISURF)*TRA(5,ISURF)
                 DIFT=WLF*VF(5.ISURF)*TRN(5,ISURF)+WALFAC(ISTS,IWOP.IHR)*VF
     2(IWOP,ISURF)*TRN(IWOP.ISURF)
                 DIFTB=(VF(4,ISURF)*TRN(4,ISURF)+VF(3,ISURF)*TRN(3,ISURF))*
```

```
     2RS+SNWLAZ( ISURF) *VF(5, ISURF) *TRN(5, ISURF)
               DIFS=WLF*VF(5, ISURF)+WALFAC( ISTS, IWOP, IHR) *VF( IWOP. ISURF)
               DIFSB=( VF(4, ISURF) +VF(3, ISURF)) *RS+SNWLAZ( ISURF) *VF(5, ISUR
     2F)
C
C DIFFUSE RADIATION ON A SURFACE=
C  DIFFUSE RADIATION+.8 BEAM RADIATION.   .8 IS AUTHOR'S FACTOR.
C FUTURE ALGORITHM SHOULD FURTHER DISCRIMINATE AND CALCULATE
C THIS FACTOR AS IS DONE FOR BEAM RADIATION IN BOUNCE AND
C REFLEX.
90             RDFSRF( ISURF, IHR) =( RDFH*( DIFF+DIFFB)) *DFFC+RDRH*.8*DIFFB*I
     2FBC
               RDFTR=( RDFH*( DIFT+DIFTB)) *DFFC+RDRH*.8*DIFTB*DFBC
               RDFSR=( RDFH*( DIFS+DIFSB)) *DFFC+RDRH*.8*DIFSB*DFBC
               IF ( IDAY.NE.1.AND.IDAY.NE.15) GO TO 110
               IF ( I.EQ.ICST) RDRSHD( ISURF. IHR) =0.
               IF ( I.EQ.ICST) GO TO 100
C
C SHADOWS, OVERHANGS, AND REFLECTOR COEFF. CALCULATED.
               CALL SHADOW ( ISURF, IHR, SHDHT)
100            SRFTP=SRFHAG( ISURF) +SRFHT( ISURF)
C
C CALL SUBROUTINE TO DETERMINE BEAM RADIATION REACHING SURFACE
C THROUGH STREET CANYON INTEREFLECTIONS
               CALL BOUNCE ( IHR, STW1( ISTS) , BLKHT( ISTS, IW) , BLKHT( ISTS, IWOP
     2) , SRFTP. SRFHAG( ISURF) , SRFHT( ISURF) , CSWLAZ( ISURF) , SNWLAZ( ISURF) , RS,
     3DROP( ISTS. IHR) , CLR)
               RFXB( ISURF, IHR) =CLR
C
C BEAM INCIDENCE ANGLES CALCULATED ON A 6 DEG. BASIS FOR
C USE WITH TRANSMISSION COEFFICIENTS.
110            ITA=ANGINC( ISURF, IHR) /.10472
               RDRRF=DNORIH*SRFINC
               ITAO=ANGINC( ISURF, IHR) /.10472
               IF ( I.GT.3..OR.SRFINC.GT.0.) GO TO 120
               ITAO=ANGIN( ISTS. IWOP. IHR) /.10472
               ITA=ANGIN( ISTS, IWOP, IHR) /.10472
               CSANWP=COS( ANGIN( ISTS, IWOP, IHR))
               RDRRF=DNORIH*CSANWP
120            IF ( RFXB( ISURF, IHR) .LT..009.OR.I.LT.3) GO TO 130
               DRCR=-DRC2IH
               SRFRIN=CSWALT( ISURF) *COSIIH+SNWALT( ISURF) *SNWLAZ( ISURF) *DR
     2CR+SNWALT( ISURF) *CSWLAZ( ISURF) *DRC3IH
               RDRRF=DNORIH*SRFRIN
               ITAO=( ACOS( SRFRIN)) /.10472
130            TRBH=TRABS( ISURF, ITA)
               TRBRH=TRABS( ISURF, ITAO)
               TRNB=TRNMS( ISURF, ITA)
               TRNBR=TRNMS( ISURF, ITAO)
               RDRSRF( ISURF, IHR) =( TRBH*RDRS*RDRSHD( ISURF, IHR) +RFXB( ISURF,
     2IHR) *RDRRF*TRBRH) *DFBC
               RDRTR=( RDRS*TRNB*RDRSHD( ISURF, IHR) +RFXB( ISURF, IHR) *RDRRF**
     2TRNBR) *DFBC
               RDRSR=( RDRS*RDRSHD( ISURF, IHR) +RFXB( ISURF, IHR) *RDRRF) *DFBC
               RDTSRF( ISURF. IHR) =RDRSRF( ISURF, IHR) +RDFSRF( ISURF, IHR)
               RDTTR=RDRTR+RDFTR
               RDTSR=RDRSR+RDFSR
               IF ( RDTSR.GT.0.) ZSLITE( ISURF, 1) =RDTTR/RDTSR
```

```
                 IF (RDTSR.LE.1..OR.RDTTR.LE.1.) ZSLITE(ISURF,1)=TRNB
C            WRITE (26,160) IHR,RFXB(ISURF,IHR),SHDET,RDRSHD(ISURF,IHR),RDF
C     2H,RDFC,RDFSRF(ISURF,IHR),RDFTR,RDFSR,DIFS,DIFSB
C 160          FORMAT (1X,I2,10F7.2)
C            WRITE (27,170) IHR,ANGINC(ISURF,IHR),TRBH,TRBRH,TRNB,TRNBR,ITA
C     2,ITAO,RDRH,RDRC,RDRSRF(ISURF,IHR),RDRTR,RDRSR,RDTTR,RDTSR
C 170          FORMAT (1X,I2,5F7.2,2I5,7F7.2)
                 ANGIND=ANGINC(ISURF,IHR)*180./3.14159
140              CONTINUE
             IF (FLCDLT.EQ.0.) GO TO 180
             DO 170 ISURF=1,N2
                 DEL=ZSLITE(ISURF,12)/3.
                 DEL2=DEL/2.
C DIFF   DIFFUSE RADIATION MODIFIER COEFFICIENT FOR ABSORBER SURFACE
C DIFFB DIFFUSE BEAM RADIATION MODIFIER COEFFICIENT FOR ABSORBER SURFACE
C DIFT   DIFFUSE RADIATION MOD.COEFF. FOR TRANSMITTANCE
C DIFTB  DIFFUSE BEAM RAD. MOD. COEFF.
C DIFS   DIFFUSE RAD. MOD. COEFF.
C DIFS  DIFFUSE  BEAM RAD.MOD.COEFF.
C
C ALL ABOVE COEFFICIENTS ARE DETERMINED FROM VIEW FACTOR OF SURFACE
C TO DIFFERENT RAD. SOURCES , AND TOTAL REFELCTION COEFFICIENTS.
                 D=0.
                 DO 150 ID=1,3
                     DD=DEL
                     IF (ID.EQ.1) DD=DEL2
                     D=DD+D
                     ZSLITE(ISURF,17)=D
                     WDFP(ISURF,ID)=D
C
C DETERMINE ILLUMINANCE OF SKY.
                     CALL SKYLUM (ISURF)
                     SKYL(ID)=ZSLITE(ISURF,26)*(1+RFXB(ISURF,IHR))
C
C CALCULATE DAYLIGHT IN SPECIFIED ROOMS
                     IF (ITER.EQ.1) CALL RMLITE (ISURF,ID)
150                  CONTINUE
                 DO 160 ID=1,3
                     DLTWP(ID)=(SC(ISURF,ID)+ERC(ISURF,ID)+XIRC(ISURF,ID))*
     2ZSLITE(ISURF,1)*ZSLITE(ISURF,6)*ZSLITE(ISURF,7)*SKYL(ID)
                     DLTDL(ISURF,ID)=DLTDL(ISURF,ID)+DLTWP(ID)
                     IF (DLTWP(ID).GT.0.) DLTH(ISURF,ID)=DLTH(ISURF,ID)+1
                     DLTMIN=DLTWP(1)
                     DLTMAX=SKYL(ID)
                     DLTC=DLTMIN*5.
C         IF(DLTC.LE.DLTMAX.AND.
                     IF (DLTMIN.GT.DLLMIN(ISURF).AND.IHR.GE.IHST(ISURF).AND
     2.IHR.LE.IHEN(ISURF)) DLTDHL(ISURF,ID)=DLTDHL(ISURF,ID)+1
160                  CONTINUE
170              .  CONTINUE
180          CONTINUE
       NN2=N2-1
       DO 190 N=1,N2
           DO 190 ID=1,3
           IF (DLTH(N,ID).LE.0.) GO TO 190
           DLTDL(N,ID)=DLTDL(N,ID)/DLTH(N,ID)
190        CONTINUE
       IF (FLGTAB.GT.1.AND.IDAY.EQ.1) WRITE (12,200) ((WDFP(IZ,IZD),IZD=1
     2,3),IZ=1,N2)
200    FORMAT (1X,2HFT,1X,10(3F4.0,1X),/)
       RETURN
       END
```

```
SUNACT*SOLITE2(1).SHADOW(0)
      COMPILER (DIAG=3)
C
C     ******************************************************************
C
C      SUBROUTINE TO DETERMINE AMOUNT OF SHADOW ON SURFACE
C
C     ******************************************************************
C
      SUBROUTINE SHADOW (N,IHR,SHDHT)
C
C     ******************************************************************
C
      DIMENSION PSRFX(2)
      COMMON /OVR/ OVRLN(10),OVRHT(10).OVRWD(10),RDROVR(10.24),RFCLN(10)
     2,RFCWD(10),RFCHT(10),RDRRFC(10,24),RMOVR(10,2,2),RRFC(10,2),
     3 RMRFC(10,2,2)
      COMMON /ST/ ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
     2 ISS(2,24),WALFAC(2,2,24).ANGIN(2,5,24)
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
     2 DLTDHG(10,3)
      COMMON /WAL/ WALAZ(10).WALALT(10),STAXIS(2),STW1(2),STW2(2),
     2 BLKLEN(2),BLKHT(2,2),FLGST(10),CSWALT(10),SNWALT(10),CSWLAZ(10),
     3 SNWLAZ(10)
      COMMON /SRF/ DIST(2,10).SRFHAG(10).SRFLN(10),SRFHT(10).SRFAR(10),
     2 SRFABS(10),A(2,13),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
     3 FLGGLL(10)
      COMMON /ANS/ RDFSRF(10,24),RDRSRF(10.24).RDTSRF(10,24),N2,
     2 ANGINC(10,24),RDRSHD(10,24).TRABS(10,15).TRNMS(10,15)
      COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
     2 DIRCS3(24),DNORAD(24).ISRT.ISST
C
C
C CALCULATE SHADOWS ON SURFACE FROM BUILDINGS OPPOSITE SURFACE.
C CACULATIONS ARE BASED ON GEOMETRY AND SHOULD BE PERFORMED USING
C MATRIX MANIMPULATION.
C
      IOVR=0
      IRFC=0
      SAZ=ABS(SOLAZ(IHR)-WALZ(ISTS,IST))
      IF (SAZ.GT.3.14159) SAZ=6.283-SAZ
      SALT=SOLALT(IHR)
      SNSALT=SIN(SALT)
      STW1TS=STW1(ISTS)
      STW2TS=STW2(ISTS)
      ANGC=ANGINC(N.IHR)
      CSAGIN=COS(ANGC)
      SNAGIN=SIN(ANGC)
      IAZ=IAZZ(ISTS.IHR)
C
C DEPENDING ON THE TYPE OF SURFACE, DIFFERENT PARTS OF ALGORITHM
C ACCESSED
C CONSULT MANUAL FOR CALCULATION LOGIC
      IF (FLGSRF(N)-3.) 10,70,80
10    IF (I.NE.IST) GO TO 120
      IF (IOVR.EQ.1.OR.IRFC.EQ.1) GO TO 30
      PSRFX(1)=DIST(1,N)
      PSRFX(2)=DIST(2,N)
```

```
      IF (FLGSRF(N).EQ.1.) GO TO 20
      PSRFX(1)=DIST(2,N)
      PSRFX(2)=DIST(1,N)
20    PSRFHG=SRFHAG(N)
      PSRFHT=SRFHT(N)
30    RANGIN=STW1TS/CSAGIN
      CONT=ABS(SNSALT/SNAGIN)
      IF (CONT.GT.1.) SNSALT=ABS(SNAGIN)
      PRAT=RANGIN*SNSALT/STW1TS
      PROFA=ATAN(PRAT)
      ANGHYP=ASIN(SNSALT/SNAGIN)
      PSRFTP=PSRFHG+PSRFHT
      HYP=RANGIN*SNAGIN
      IF (OVRWD(N).GT.0..OR.IOVR.EQ.1) GO TO 40
      DIFL=(OVRLN(N)-SRFLN(N))/2
      PSRFHG=(SRFHAG(N)+SRFHT(N)+OVRHT(N))-PRAT*OVRWD(N)
      PSRFHT=PRAT*OVRWD(N)
      GO TO 50
40    IF (RFCWD(N).EQ.0..OR.IRFC.EQ.1) GO TO 60
      DIFL=(RFCLN(N)-SRFLN(N))/2
      PSRFHG=SRFHAG(N)-RFCHT(N)-PRAT*RFCWD(N)
      PSRFHT=PRAT*OVRWD(N)
50    PSRFX(1)=DIST(1,N)-DIFL
      PSRFX(2)=DIST(2,N)-DIFL
      IF (FLGSRF(N).EQ.1.) GO TO 60
      PSRFX(1)=DIST(2,N)-DIFL
      PSRFX(2)=DIST(1,N)-DIFL
      SHDHT=BLKHT(ISTS,IWOP)-RANGIN*SNSALT
60    IF (SHDHT.LE.PSRFHG) GO TO 100
      SHDIN0=HYP*COS(ANGHYP)
      TNAGHP=TAN(ANGHYP)
      SHDIN1=SHDHT-STW2TS*TNAGHP
      SHDIN2=SHDIN0-STW2TS
      B=SHDIN0*TNAGHP+SHDIN1
      ISLOPE=-1
      GO TO 90
70    STMP=STAXIS(ISTS)-3.14159
      IF (STMP.LT.0.) STMP=STAXIS(ISTS)+3.14159
      IF (SOLAZ(IHR).EQ.STAXIS(ISTS).OR.SOLAZ(IHR).EQ.TMP) GO TO 180
      PSRFX(1)=DIST(1,N)
      PSRFX(2)=DIST(2,N)
      PSRFHG=STW1TS/2.-SRFHT(N)/2+SRFHAG(N)
      IF (SRFHAG(N).LT.0.) PSRFHG=STW1TS/2.+SRFHT(N)/2+SRFHAG(N)
      PSRFHT=SRFHT(N)
      PSRFTP=PSRFHT+PSRFHG
      RANGIN=BLKHT(ISTS,IWOP)/CSAGIN
      HYP=RANGIN*SNAGIN
      ANGHYP=SAZ
      SNAGHY=SIN(ANCHYP)
      SHDHT=HYP*SNAGHY
      IF (SHDHT.LE.PSRFHG) GO TO 100
      CSAGHY=COS(ANGHYP)
      SHDIN0=HYP*CSAGHY
      TNAGHY=SNAGHY/CSAGHY
      SHDIN1=SHDHT-STW2TS*TNAGHY
      B=0.
      SHDIN2=SHDIN0-STW2TS
      ISLOPE=1
```

```
        GO TO 90
80      IF (IW.EQ.IOST) GO TO 130
        IF (ANGHYP.GT.3.14159) ANGHYP=6.283-ANGHYP
        IF (BLKHT(ISTS,IWOP).LE.BLKHT(ISTS,I)) GO TO 130
        PSRFX(1)=DIST(1,N)
        WAZ=ABS(WALZ(ISTS,IW)-WALAZ(N))
        IF (WAZ.GT.3.14159) WAZ=6.283-WAZ
        COSWAZ=COS(WAZ)
        SINWAZ=SIN(WAZ)
        PSRFX2=SRFHT(N)*SINWAZ+SRFLN(N)*COSWAZ+PSRFX(1)
        PSRFX(2)=BLKLEN(ISTS)-PSRFX2
        IF (FLGSRF(N).EQ.5.) PSRFX(2)=PSRFX(1)
        IF (FLGSRF(N).EQ.5.) PSRFX(1)=BLKLEN(ISTS)-PSRFX2
        PSRFHG=STW1TS+SRFHAG(N)
        PSRFHT=SRFHT(N)/CSWALT(N)
        PSRFHT=PSRFHT*COSWAZ+SRFLN(N)*SINWAZ
        PSRFTP=PSRFHG+PSRFHT
        RANGIN=(BLKHT(ISTS,IWOP)-BLKHT(ISTS,IW))/SNSALT
        HYP=RANGIN*COS(SALT)
        SNAGHY=SIN(ANGHYP)
        SHDHT=HYP*SNAGHY
        IF (SHDHT.LE.PSRFHG) GO TO 130
        CSAGHY=COS(ANGHYP)
        SHDIN0=HYP*CSAGHY
        TNAGHY=SNAGHY/CSAGHY
        SHDIN1=SHDHT-STW2TS*TNAGHY
        SHDIN2=SHDIN0-STW2TS
        B=0.
        ISLOPE=1
90      PSRFLN=BLKLEN(ISTS)-(PSRFX(1)+PSRFX(2))
        PSRFXX=PSRFX(IAZ)+PSRFLN
C       WRITE(25.2501)SHDIN1,PSRFTP
C 2501     FORMAT(2F10.4)
        IF (SHDIN1.GE.PSRFTP) GO TO 120
        PSRFAR=PSRFHT*PSRFLN
        SHD=PSRFTP-SHDHT
        IF (SHD.LE.0.) SHD=0.
        RDRSHD(N,IHR)=SHD*PSRFLN/PSRFAR
        IF (SHDIN0.LE.PSRFX(IAZ)) GO TO 140
        IF (SHDIN2.GE.PSRFXX) GO TO 140
        SLOPE=ISLOPE*(SHDHT-SHDIN1)/(SHDIN0-SHDIN2)
        DELTAX=PSRFLN/5
        PSHDIN=0.
        PINX=PSRFX(IAZ)
        DO 100 INT=1,5
            PINY=SLOPE*PINX+B
            IF (SHDHT.GE.PSRFTP) YY=PSRFTP
            IF (SHDHT.LT.PSRFTP) YY=SHDHT
            IF (PINY.LT.PSRFHG) PINY=PSRFHG
            Y=YY-PINY
            IF (Y.LE.0.) Y=0.
            X=DELTAX
            SHDIN=ABS(X*Y)
            PINX=PINX+DELTAX
            PSHDIN=(PSHDIN+SHDIN)
100         CONTINUE
        PSHDIN=PSHDIN/PSRFAR
        RDRSHD(N,IHR)=RDRSHD(N,IHR)+PSHDIN
```

```
      IF (I.GT.2) GO TO 110
      IF (OVRWD(N).GT.0.) GO TO 150
      IF (RFCWD(N).GT.0.) GO TO 160
110   RETURN
C
C
C IF NO SHADING ON WINDOW, RDRSHD=1.
C
C
120   RDRSHD(N,IHR)=0.
      RETURN
C
130   RDRSHD(N.IHR)=1.
C
C IF SURFACES ARE OTHER THAN WALLS, OVERHANGS AND REFLECTORS ARE
C NOT CALCULATED
      IF (I.GT.2) GO TO 140
      IF (OVRWD(N).GT.0.) GO TO 150
      IF (RFCWD(N).GT.0.) GO TO 160
140   RETURN
C
C CALL OVERHANG AND REFLECTOR SUBROUTINES FOR SURFACES IF
C PRESENT
150   IF (IOVR.EQ.1) GO TO 160
      OVRSHD=RDRSHD(N,IHR)
      IOVR=1
      IF (RFCWD(N).EQ.0.) GO TO 170
      GO TO 10
160   IF (IRFC.EQ.1) GO TO 140
      RFCSHD=RDRSHD(N,IHR)
      IRFC=1
C
C CALL OVERHANG AND REFLECTOR SUBROUTINE
170   CALL OVRHNG (OVRSHD,RFCSHD,ANGC,ANGHYP,PROFA,IAZ,N,IHR)
      GO TO 10
C
C
      END
```

```
SUNACT*SOLITE2(1).OVRHNG(0)
              COMPILER (DIAG=3)
      C SUBROUTINE OVERHANG CALCULATES THE SHADOW CAST BY OVERHANGS, AND
      C THE COEFFICIENT FOR REFLECTION FROM A REFLECTING SURFACE.
      C
      C       ****************************************************************************
      C
              SUBROUTINE OVRHNG (OVRSHD,RFCSHD,ANGC,ANGHYP,TNIN,IAZ,N,IHR)
      C
      C       ****************************************************************************
      C
              DIMENSION W(2),O(2)
              COMMON /SRF/ DIST(2,10),SRFHAG(10),SRFLN(10),SRFHT(10),SRFAR(10),
             2 SRFABS(10),A(2,13),FLGSRF(10),NODOT(10),NSRFOT(10),FLGGL(10),
             3 FLGGLL(10)
              COMMON /ST/ ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
             2 ISS(2,24),WALFAC(2,2,24),ANGIN(2.5,24)
              COMMON /OVR/ OVRLN(10),OVRHT(10),OVRWD(10),RDROVR(10.24),RFCLN(10)
             2,RFCWD(10),RFCHT(10),RDRRFC(10,24),RMOVR(10,2,2),RRFC(10,2),
             3 RMRFC(10,2,2)
      C
      C ****************************************8*******************************************
              I=FLGSRF(N)
              ISD=ABS(I+IAZ-3)
              IF (ISD.EQ.0) ISD=2
              ISDM=2
              IF (ISD.EQ.2) ISDM=1
              IRF=0
              NN=1
      10      IM=RMRFC(N,NN,1)
      C
      C BEAM REFLECTION COEFFICIENT CALCULATED, INCIDENT ANGLE SAME
      C AS INCIDENT ANGLE ON STREET SURFACE.
              R=REFLEX(RRFC(IM.1),RRFC(IM,2),ANGIN(ISTS,3,IHR))
              RF=R*RMRFC(N,NN,2)+RF
              NN=NN+1
              IF (NN.LE.2) GO TO 10
              DIFH=OVRHT(N)
              DIFL=(OVRWD(N)-SRFLN(N))/2
              R=OVRWD(N)/SIN(ANGC)
              RW=R*SIN(ANGC)
              H=RW*SIN(ANGHYP)
              WW=RW*COS(ANGHYP)
              WT=SRFHT(N)
              W(ISDM)=SRFLN(N)
      C
      C BOTH SHADOWS AND REFLECTION ARE DETERMINED IN THE SAME ALGORITHM.
      C REFLECTIONS ARE CALULATED BY RETURNING TO THIS POINT IN THE PROGRAM
      C AND RESETTING VARIABLE VALUES.
      C
      20      WB=0.
              W(ISD)=0.
              O(ISD)=-DIFL
              O(ISDM)=OVRWD(N)+O(ISD)
              XMAX=W(ISDM)
              XSR=TAN(ANGHYP)*DIFH
              IF (XSR.GT.DIFL) XMAX=O(ISDM)-XSR
              YMIN=0.
```

```
      H1=WT+DIFH
      IF (H.GT.H1) YMIN=H1-H
      YMAX=WT
      XMIN=W(ISD)
      H2=H1-YMIN
      XS=H2*TAN(ANGHYP)
      XSL=O(ISD)-XS
      IF (XSL.GT.W(ISD)) XMIN=XSL
      SM=H/WW
      B=O(ISDM)-XS
      XSP=(YMIN-B)/SM
      DLX=(XMAX-XMIN)/10.
      X=XMIN
C
C AREA OF TRIANGLE DEFINED BY AN OVERHANG ARE ITERATIVELY CALCULATED
C
      DO 80 I=1,5
         X=X+DLX
         Y=YMIN
         IF (X.GT.XSP) Y=SM*X+B
         YY=YMAX
         XSP1=O(ISD)-(DIFH*W/H)
         IF (X.LT.XSP1) YY=SM*X+B
         SAR=(YY-Y)*2*DLX+SAR
         X=X+DLX
80       CONTINUE
      IF (IRF.EQ.0) RDROVR(N,IHR)=SAR/SRFAR(N)*OVRSID
      IF (IRF.EQ.1) RDRRFC(N,IHR)=RF*SAR/RFCSID*RFCAR
      IF (RFCWD(N).EQ.0..OR.IRF.EQ.1) GO TO 40
      WT=RFCWD(N)*TMIN
      W(ISDM)=RFCLN(N)
      WB=0.
      DIFH=SRFHT(N)+OVRHT(N)+RFCHT(N)
      DIFL=(OVRLN(N)-RFCLN(N))/2
      RFCAR=WT*W(ISDM)
      IRF=1
      GO TO 20
40    RETURN
      END
```

```
SUNACT*SOLITE2(1).REFLEX(0)
C FUNCTION CALCULATES THE PROPORTION OF BEAM REFLECTED ENERGY FROM
C A SURFACE AS AN EXPONENTIAL FUNCTION OF ITS ANGLE OF INCIDENCE.
C **********************************************************
      FUNCTION REFLEX (R1,R2,ANG)
C
C     ******************************************************************
C
      X=5.
      IF (ANG.LE.0.) GO TO 10
C
C EXPONENT GOES FROM 0-5 AS A LINEAR FUNCTION OF THE INCIDENT ANGLE FROM
C 90-0 DEGREES.
      IF (ANG.LT..78) X=5.-5*ANG/.7808
      R3=R2-R1
C
C R3, DIFFERENCE BETWEEN TOTAL AND BEAM REFLECTED PORTIONS AT NORMAL INC
C
C R1, BEAM REFLECTANCE COEFFICIENT ADDED TO AS ANGLE INCREASES
10    REFLEX=R1+R3*EXP(-X)
      RETURN
      END
```

```
SUNACT*SOLITE2(1).ANG(0)
C FUNCTION TO PROVIDE ANGLE AT SURFACE OF REFLECTOR
C **************************************************
      FUNCTION ANG (ANGIN)
C
C     ******************************************************************
C
      ANG=ANGIN
      IF (ANGIN.GT.1.5708) ANG=ANG-1.5708
      IF (ANG.LT.0.) ANG=0.
      RETURN
      END
```

```
SUNACT*SOLITE2(1).BOUNCE(0)
                 COMPILER (DIAG=3)
       C
       C         ******************************************************************************
       C
       C         SUBROUTINE TO DETERMINE THE BEAM REFLECTANCE FROM OPPOSITE
       C         SURFACES ONTO THE SURFACE ITSELF
       C
       C         ******************************************************************************
       C
                 SUBROUTINE BOUNCE (IHR,D,HT1,HT2,ST,SB,SLN,CSWLZ,SNWLZ,RS,DROPX,
                2 CLR)
       C
       C         ******************************************************************************
       C
                 COMMON /OVR/ OVRLN(10),OVRHT(10),OVRWD(10),RDROVR(10,24),RFCLN(10)
                2,RFCWD(10),RFCHT(10),RDRRFC(10,24),RNOVR(10,2,2),RRFC(10,2),
                3 RMRFC(10,2,2)
                 COMMON /ST/ ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
                2 ISS(2,24),WALFAC(2,2,24),ANGIN(2,5,24)
                 COMMON /RX/ RFM(2,5,2,2),RFMX(10,2),RFF(2,5)
       C
       C ANG    FUNCTION FOR DETERMINING REFLECTANCE ANGLE. GT.50 DEGREES.
       C ANGIN  ANGLE OF INCIDENCE ON ONE OF STREET CANYON SURFACES
       C ANGR  ANGLE OF INCIDENCE FOR BEAM REFLECTION CALCULATION
       C ANGW   ANGLE OF REFLECTION FROM WALL
       C BT1    BOTTOM OF REFLECTINGBEAM
       C BT2    BOTTOM OF REFLECTING BEAM
       C CLR    PROPORTION OF SURFACE. AND REFLECTION DECREMENT COEFFICIENT
       C          FOR SOLAR GAIN ONTO SURFACE
       C DROP   AMOUNT OF DOUBLE REFLECTING BEAM DROP
       C FA     CUMULATIVE REFLECTION
       C H1     SIDE OF WALL WITH SURFACE
       C H1P    H1 FOR ROOF
       C H2     HEIGHT OF WALL OPPOSITE SURFACE.
       C I      FLGSRF, STREET CANYON SURFACE INDICATOR
       C IAZZ   SUN INDICATOR, WHETHER IN STREET AXIS QUADRANT(1) OR OPPOSITE
       C IOST   SIDE OPPOSITE SUN RECEINVING WALL
       C IR     ROOF SURFACE ON SAME SIDE AS SURFACE
       C IROP   ROOF OPPOSITE SURFACE
       C ISS    SUN SIDE (ARRAY)
       C IST    SUN SIDE WALL SURFACE
       C ISTS   STREET INDICATOR (PRIMARY OR CROSS STREET)
       C IW     WALL ON SAME SIDE OF STREET CANYON AS SURFACE
       C IWOP   WALL ON OPPOSITE SIDE OF STREET CANYON
       C LN1    AMOUNT OF DROP OF REFLECTANCE BEAM
       C MR     SURFACE MATERIAL TYPE INDICATORS
       C RFM    SURFACE REFLECTION TYPE NUMERICAL INDICATOR
       C RFMX   SURFACE REFLECTION COEFFICIENT ARRAY
       C R1     REFLECTANCE OF WALL ITSELF
       C R2     REFLECTANCE OF OPPOSITE WALL
       C R3     REFLECTANCE OF STREET
       C SBT    BOTTOM OF SURFACE (HEIGHT)
       C SWD    AMOUNT OF WINDOW IN BEAM REFLECTANCE
       C STP    TOP OF WINDOW SURFACE
       C TNIN   TANGENT OF ANGLE. NORMAL DROP FROM OPPOSITE ROOF TO SURFACE.
       C TP1    TOP OF REFLECTANCE BEAM
       C
```

```
C      ****************************************************************************
C
      REAL LN1
      I1=1
C
C
C  SNOW REFLECTION COEFFICIENTS SET
      RFMX(9,1)=RFMX(9,1)*RS
      RFMX(9,2)=RFMX(9,2)*RS
      H1=HT1
      H2=HT2
      STP=ST
      SBT=SB
      TNIN=DROPX/D
      DROP=DROPX*2.
      CLR=0.
      FA=1.0
      M11=RFM(ISTS,IWOP,1,1)
C
C DETERMINE THE SPECULAR REFLECTANCE OF SURFACES IN THE STREET CANYON
C FROM THE AMOUNT AND PROPERTIES OF STREET CANYON FACING MATERIALS.
      M12=RFM(ISTS,IWOP,2,1)
      ANGR=ANG(ANGIN(ISTS,IWOP,IHR))
      R2=REFLEX(RFMX(M11,1),RFMX(M11,2).ANGR)*RFM(ISTS,IWOP,1,2)+REFLEX(
     2RFMX(M12,1),RFMX(M12,2),ANGR)*RFM(ISTS,IWOP,2,2)
      IF (I-3) 20,10,110
10    M=1
      IF (IST.EQ.2) M=-1
      STP=D-ST*SLN/2*M+D/2
      STP=STP*TNIN
      SBT=SLN*TNIN
      H1=H1+SBT+STP
      H2=H2+SBT+STP
      STP=SLN
      SBT=0.
20    MST1=RFM(ISTS,3,1,1)
      MST2=RFM(ISTS,3,2,1)
      ANGR=ANG(ANGIN(ISTS,3,IHR))
      R3=REFLEX(RFMX(MST1.1),RFMX(MST1.2),ANGR)*RFM(ISTS,3,1,2)+REFLEX(R
     2FMX(MST2,1),RFMX(MST2,2),ANGR)*RFM(ISTS,3,2,2)
C       WRITE(25,2500)ANGR,RFMX(MST1,1),R3,BT2,H2,DROPX,D
C 2500    FORMAT(1X.7F10.2)
      IF (IST-IW) 30,40,30
30    FA=R2
      BT2=H1-DROP/2.
      IF (BT2.GT.H2) GO TO 100
      H1=MIN(H1,H2-DROP)
      IF (STP.GT.H1) STP=H1
      SBT=STP-SLN
      H2=BT2
40    M11=RFM(ISTS,IW,1,1)
      M21=RFM(ISTS,IW,2,1)
      ANGR=ANG(ANGIN(ISTS,IST,IHR))
      R1=REFLEX(RFMX(M11,1),RFMX(M11.2),ANGR)*RFM(ISTS.IW,1,2)+REFLEX(RF
     2MX(M21,1),RFMX(M21,2),ANGR)*RFM(ISTS,IW,2,2)
      BT1=H2-DROP/2.
      IF (BT1.GT.H1) GO TO 100
      LN1=H1-BT1
```

```
      IF (LN1.GT.DROP) LN1=DROP
50    STPP=STP
      IF (STP.LE.BT1) GO TO 60
      SHD=(STP-AMAX1(BT1,SBT))/SLN
      IF (FA.LT.1.) CLR=CLR+SHD*FA
      IF (SBT.GE.BT1) GO TO 70
      STP=BT1
60    BT1=BT1-DROP
      TP1=LN1+BT1
      IF (TP1.LT.0..AND.I.LT.3) GO TO 80
      IF (BT1.LT.0..AND.I.LT.3) GO TO 90
      IF (TP1.LE.0.) GO TO 100
      FA=FA*R1*R2
      GO TO (50,70), I1
70    I1=2
      GO TO 60
80    TP1=ABS(TP1)
90    BT1=ABS(BT1)
      IF (TP1.GT.0.) TP1=0.
      FA=R3*FA
      IF (SBT.GE.BT1.OR.STPP.LE.TP1) GO TO 100
      IF (BT1.LT.STPP) STPP=BT1
      CLR=CLR+(STPP-AMAX1(SBT,TP1))/SLN*FA
C     WRITE(23,2501) CLR,FA,STPP
C 2501   FORMAT(1X,3F10.2)
100   RETURN
110   H1P=H1
      H1=H1+STP*TNIN
      BT2=H2-DROP/2
      MR1=RFM(ISTS,I,1,1)
      MR2=RFM(ISTS,I,2,1)
      ANGR=ANG(ANGIN(ISTS,I,IER))
      IF (IST-IW) 130,120,130
120   IF (BT2.GT.H1) GO TO 150
      CLR=REFLEX(RFMX(MR1,1),RFMX(MR1,2),ANGR)*RFM(ISTS,I,1,2)+REFLEX(RF
     2MX(MR2,1),RFMX(MR2,2),ANGR)*RFM(ISTS,I,2,2)
      CL1=CLR
      GO TO 140
130   ANGW=ANG(ANGIN(ISTS,IWOP,IER))
      MW1=RFM(ISTS,IWOP,1,1)
      MW2=RFM(ISTS,IWOP,2,1)
      CL=REFLEX(RFMX(MW1,1),RFMX(MW1,2),ANGW)*RFM(ISTS,IWOP,1,2)+REFLEX(
     2RFMX(MW2,1),RFMX(MW2,2),ANGW)*RFM(ISTS,IWOP,2,2)
      CLR=CLR*CL
140   IF (SNWLZ.LT.1.) CLR=CLR-CL1*CSWLZ/CLR
150   RETURN
      END
```

```
SUNACT*SOLITET(1).SUNSID(0)
          COMPILER (DIAG=3)
C          SUBROUTINE TO DETERMINE THE HORIZONTAL RADIATION
C          COEFFICIENT TO VERTICAL RADIATION ON STREET CANYON
C          SURFACES.  DETERMINES THE SIDE OF STREET SURFACE IS
C          ON
C
C         ******************************************************************
C
          SUBROUTINE SUNSID (ISTFLG,DROP)
C
C         ******************************************************************
C
          COMMON /POS/ SOLAZ(24),SOLALT(24),SOLFAC(5),COSINC(24),DIRCS2(24),
         2 DIRCS3(24),DNORAD(24),ISRT,ISST
          COMMON /WAL/ WALAZ(10),WALALT(10),STAXIS(2),STW1(2),STW2(2),
         2 BLKLEN(2),BLKHT(2,2),FLGST(10),CSWALT(10),SNWALT(10),CSWLAZ(10),
         3 SNWLAZ(10)
          COMMON /ST/ ISTS,I,IST,IOST,IW,IWOP,IR,IROP,WALZ(2,2),IAZZ(2,24),
         2 ISS(2,24),WALFAC(2,2,24),ANGIN(2,5,24)
          DIMENSION SNWAL(2,2),CSWAL(2,2),DROP(2,24)
          DO 60  ISTS=1,ISTFLG
              DO 60  I=1,5
              DO 60  IHR=ISRT,ISST
              IF (I-2) 10,20,40
10            ISS(ISTS,IHR)=1
20            SNSOLZ=SIN(SOLAZ(IHR))
              SNWAL(ISTS,I)=SIN(WALZ(ISTS,I))
              CSWAL(ISTS,I)=COS(WALZ(ISTS,I))
              SRFINC=SNWAL(ISTS,I)*DIRCS2(IHR)+CSWAL(ISTS,I)*DIRCS3(IHR)
              WALFAC(ISTS,I,IHR)=.55+.437*SRFINC+.313**SRFINC
              IF (SRFINC.LT.-.2) WALFAC(ISTS,I,IHR)=.45
              IF (SRFINC.GT.0..OR.I.NE.1) GO TO 30
              ISS(ISTS,IHR)=2
30            IAZZ(ISTS,IHR)=2
              IF (SNWAL(ISTS,I).GE.0..AND.SNSOLZ.LT.SNWAL(ISTS,I)) IAZZ(ISTS
         2,IHR)=1
              GO TO 50
40            SRFINC=COSINC(IHR)
50            ANGIN(ISTS,I,IHR)=ACOS(SRFINC)
60            CONTINUE
          DO 70  ISTS=1,ISTFLG
              DO 70  IHR=ISRT,ISST
              IST=ISS(ISTS,IHR)
              SNAGIN=SIN(ANGIN(ISTS,IST,IHR))
              CSAGIN=COS(ANGIN(ISTS,IST,IHR))
              SNSALT=SIN(SOLALT(IHR))
              ANGHYP=ASIN(ABS(SNSALT)/SNAGIN)
              D=STW1(ISTS)
              RANG=D/CSAGIN
              RHYP=RANG*SNAGIN
              DROP(ISTS,IHR)=SIN(ANGHYP)*RHYP
70            CONTINUE
          RETURN
          END
```

```
SUNACT*SOLITE2(1).FPP(0)
            COMPILER (DIAG=3)
      C FUNCTION TO DETERMINE THE VIEW FACTOR OF PARALLEL SURFACES
      C ****************************************************************************
      C
      C     ****************************************************************************************
      C
            FUNCTION FPP (A,B,C)
      C
      C     ****************************************************************************************
      C
            PI=3.14159
            IF (A.EQ.0..OR.B.EQ.0..OR.C.EQ.0.) GO TO 10
            AC=(A**2+C**2)**.5
            AB=(A**2+B**2)**.5
            FPP=(2*B/AB*ATAN(C/AB)+2*C/AC*ATAN(B/AC))/PI
            RETURN
       10   FPP=0.
            RETURN
      C
      C
            END
```

```
SUNACT*SOLITE2(1).FPR(0)
            COMPILER (DIAG=3)
      C
      C FUNCTION TO DETERMINE THE VIEW FACTOR TO PERPENDICULAR PLANES
      C ******************************************************************************
      C
      C     ****************************************************************************************
      C
            FUNCTION FPR (A,B,C)
      C
      C     ****************************************************************************************
      C
            IF (A.EQ.0..OR.B.EQ.0..OR.C.EQ.0.) GO TO 20
            PI=3.14159
            AB=(A**2+B**2)**.5
            AC=(A**2+C**2)**.5
            FPR=(ATAN(C/A)-A/AB*ATAN(C/AB))/PI
            WRITE (28,10) A,B,C,AB,AC,FPR
       10   FORMAT (1X,6F10.2)
            RETURN
       20   FPR=0.5
            RETURN
            END
```

```
SUNACT*SOLITE2(1).FSPP(0)
      COMPILER (DIAG=3)
C
C SUBROUTINE DETERMINES THE VIEW FACTOR TO A SURFACE THAT IS NOT
C PERPENDICULAR OR PARALLEL.  ANGLE OF SURFACE TO VIEWED SURFACE IS
C BETWEEN 0 AND 90 DEG.
C
C ********************************************************************
C
C     *******************************************************************
C
      FUNCTION FSPP (THETA,A,B,C)
C
C     *******************************************************************
C
      PI=3.14159
      AB=(A**2+B**2)**.5
      AC=(A**2+C**2)**.5
      FSPP=(-2*SIN(THETA)*(B/AB*ATAN(C/AB)+C/AC*ATAN(B/AC)))/PI
      WRITE (29,10) THETA,A,B,C,AB,AC,FSPP
10    FORMAT (1X,7F11.3)
      RETURN
      END
```

```
SUNACT*SOLITE2(1).FSPR(0)
      COMPILER (DIAG=3)
C FUNCTION DETERMINES VIEW FACTOR FROM A SURFACE TO ANOTHER
C THAT MAKES A GREATER THAN 90 DEG. ANGLE WITH IT, AND LESS THAN
C 180 DEG.
C
C ******************************8***********************************
C
C     *******************************************************************
C
      FUNCTION FSPR (THETA,A,B,C)
C
C     *******************************************************************
C
      PI=3.14159
      AC=(A**2+C**2)**.5
      AB=(A**2+B**2)**.5
      COST=COS(THETA)
      SINT=SIN(THETA)
      FSPR=(ATAN(C*COST/A)-(A*COST+B*SINT)/AB*ATAN(C/AB)+C*SINT/AC*(ATAN
     2(A*TAN(THETA)/AC)-ATAN(B/AC)))/PI
      RETURN
      END
```

APPENDIX E

LISTING OF THE DALITE PROGRAM

The programs are listed in the following order:

```
SUNACT*DALITE1(1).SKYLUM(1)
      SUBROUTINE SKYLUM (ISURF)
C
C     ******************************************************************
C
      COMMON /SINCOS/ CSSUWI,CSSALT,SNSALT
C
C     TO CALCULATE THE AVE SKY LUMINANCE AS SEEN THRU WINDOW
C
C     SUNALT=SOLAR ALTITUDE ANGLE (DEGREES ABOVE HORIZON)
C     SUNAZ =SOLAR AZIMUTH ANGLE (DEGREES FROM SOUTH)
C     LOCALT=LOCATION ALTITUDE (FEET ABOVE SEA LEVEL)
C     BETA  =HAZINESS FACTOR:RURAL=0.05 URBAN=0.10 INDUSTRIAL=0.20
C     WINAZ =WINDOW AZIMUTH ANGLE (DEGREES FROM SOUTH)
C     CC    =CLOUD COVER (CLEAR=0     PERFECTLY OVERCAST=10)
C     SKYLUM=SKY LUMINANCE @ WINDOW CENTROID (FOOTLAMBERTS)
C     CLRSKY=CLEAR SKY LUMINANCE
C     OVRSKY=OVERCAST SKY LUMINANCE
C     SUNLIT=DIRECT SUN ILLUMINANCE
C
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
     2 DLTDHG(10,3)
      SUNALT=ZSLITE(ISURF,21)
      SUNAZ=ZSLITE(ISURF,22)
      LOCALT=ZSLITE(ISURF,23)
      CC=ZSLITE(ISURF,24)/10.
      WINAZ=ZSLITE(ISURF,19)
      W=ZSLITE(ISURF,13)
      H=ZSLITE(ISURF,14)
      W1=ZSLITE(ISURF,15)
      H1=ZSLITE(ISURF,16)
      D=ZSLITE(ISURF,17)
       AAA=ABS(SUNAZ-WINAZ)
       IF(AAA.GT.180.)AAA=ABS(AAA-360.)
      AA=(ABS(AAA))*3.14159/180.
      CSSUWI=COS(AA)
      SUNALD=SUNALT*3.14159/180.
      CSSALT=COS(SUNALD)
      SNSALT=SIN(SUNALD)
      SKYLIT=CLRSKY(SUNALT,H,H1,D,W,W1)*(1.-CC)+OVRSKY(SNSALT)*CC
      SKYLUM=SKYLIT+SUNLIT(SUNALT,AA,LOCALT,H,W,D)*(1.-CC)
      ZSLITE(ISURF,26)=SKYLUM
      RETURN
      END
```

```
SUNACT*DALITE1(1).SUNLIT(0)
      FUNCTION SUNLIT (SUNALT,AA,LOCALT,H,W,D)
C
C     ******************************************************************
C
      COMMON /SINCOS/ CSSUWI,CSSALT,SNSALT
C
C      SUBROUTINE TO CALCULATE THE DIRECT SUN CONDITIONS
C
C     WATER =WATER VAPOR CONTENT IN ATMOSPHERE(ASSUMED CONST @ 2.0CM)
C     EX    =EXTRATERRESTRIAL ILLUMINANCE NORMAL TO SUN (FOOT-CANDLES)
C     SUNLIT=DIRECT SUNLIGHT INCIDENT ON SPECIFIED SURFACE (FOOT-CANDLES
C     SUNLUM=DIRECT LUMINANCE OF THE SOLAR DISC
C     T     =TURBIDITY FACTOR
C
      REAL M
C                 ASSUMES A CLEAN ENVIRONMENT (TO BE A VARIABLE IN
      BETA=0.05
      WATER=2.0
      SUNLIT=0.0
      PI=3.14159
C                 CONVERTS LOCALT TO KILOMETERS
      LOCALT=LOCALT*.000348
C                 ASSUMES VERTICAL GLAZING
      P=PI/2.
      W2=W/2
      PHI=ATAN(W2/D)
C
C     ALGORITHM TO DETERMINE IF DIRECT SUN IS VISIBLE
C
      IF (AA.GT.PHI) GO TO 50
      PSI=ATAN(H/D)
      SUNALD=SUNALT*PI/180.
      IF (SUNALD.GT.PSI) GO TO 50
      T=((SUNALT+85.)/(39.5*EXP(-WATER)+47.4)+0.1)+(16.+0.22*WATER)*BETA
C
C     ALGORITHM TO DETERMINE THE AEROSOL FACTOR
C
      IF (BETA-0.10) 10,20,30
10    AL=0.1512-0.0262*T
      GO TO 40
20    AL=0.1652-0.0215*T
      GO TO 40
30    AL=0.2021-0.0193*T
40    M=(1.-LOCALT*0.1)*(10.01+((SUNALT-5.)/(-1.217+((SUNALT-11.)/(-10.0
     234+((SUNALT-24.5)/(150.343+(SUNALT-40.)/1.821))))))
C
C     ALGORITHM TO DETERMINE THE SOLAR LUMINANCE & ILLUMINANCE
C
C                 EXTRATERRESTRIAL RADIATION (FOOT-CANDLES)
      EX=12176.0
C FOR P><PI/2.      COSJ=COS(P)*SNSALT+SIN(P)*CSSALT*CSSUWI
      COSJ=CSSALT*CSSUWI
      SUNLIT=EX*EXP(-AL*M*T)*COSJ
50    RETURN
      END
```

```
SUNACT*DALITE1(1).CLRSKY(0)
      FUNCTION CLRSKY (SUNALT,H,H1,D,W,W1)
C
C     ******************************************************************
C
      COMMON /SINCOS/ CSSUWI,CSSALT,SNSALT
C
C     SUBROUTINE TO CALCULATE THE AVERAGE CLEAR SKY LUMINANCE
C
C     ZLUM  =ZENITH SKY LUMINANCE (FOOTLAMBERTS)
C     AZ    =AZIMUTH ANGLE BETWEEN SUN AND VIEW POINT OF GLAZING
C     THETA =ALTITUDE ANGLE OF GLAZING VIEW POINT
C     GAMA  =SOLID ANGLE BETWEEN SUN AND GLAZING VIEW POINT
C
      PI=3.14159
      A0=0.8410
      A1=0.0011
      ZLUM=(A0+A1*SUNALT*SUNALT)*291.9
      IF (H1.GT.0.) GO TO 10
      THETA=0.5*ATAN(H/D)
      STHETA=SIN(THETA)
      CTHETA=COS(THETA)
      GO TO 20
10    THETA=0.5*ATAN((H+H1)/D)+ATAN(H1/D)
      CTHETA=COS(THETA)
      STHETA=SIN(THETA)
20    CSGAMA=STHETA*SNSALT+CTHETA*CSSALT*CSSUWI
      GAMA=ACOS(CSGAMA)
      CLRSKY=ZLUM*(0.910+10.*EXP(-3*GAMA)+0.45*CSGAMA*CSGAMA)*(1.-EXP(-0
     2.32/STHETA))/(0.27385*(0.91+10.*EXP(-3*(90.-SUNALT))+0.45*SNSALT*S
     3NSALT))
      RETURN
      END
```

```
SUNACT*DALITE1(1).OVRSKY(0)
              FUNCTION OVRSKY (SNSALT)
        C
        C     *******************************************************************
        C
        C     FUNCTION TO CALCULATE THE AVERAGE OVERCAST SKY LUMINANCE
        C     BASED ON CIE STANDARD OVERCAST SKY
        C     OVRSKY=OVERCAST SKY LUMINANCE @ 41.8 DEGREES
              OVRSKY=(0.123+8.6*SNSALT)*227.0982
              RETURN
              END
```

```
SUNACT*DALITE1(1).RMLITE(1)
      SUBROUTINE RMLITE (ISURF,ID)
C
C     *******************************************************************
C
C        TO COMPUTE DAYLIGHT ILLUMINATION
C
C     D= DISTANCE OF THE REFERENCE POINT FROM THE WINDOW,FT.
C     WA= WINDOW AREA, SQ. FT.
C     A= ROOM INTERNAL SURFACE AREA
C     RX= REFLECTANCE OF EXTERNAL OBSTRUCTION
C     RFW= AVERAGE REFLECTANCE FACTOR OF THE LOWER HALF OF THE ROOM
C     RCW= AVERAGE REFLECTANCE FACTOR OF THE UPPER  HALF OF THE ROOM
C     RAVE=AVERAGE REFLECTANCE OF THE ENTIRE ROOM
C     W= WINDOW WIDTH, FT.
C     H= WINDOW HEIGHT, FT.
C     HL =PROJECTED HEIGHT OF OBSTRUCTION ON WINDOW
C     HX =HEIGHT OF OBSTRUCTION FROM WORK PLANE
C     DX =DISTANCE OF OBSTRUCTION FROM WINDOW
C     RMH=ROOM HEIGHT
C     RML=ROOM LENGTH
C     RMW=ROOM WIDTH
C     W1 =DISTANCE FROM EDGE OF WINDOW TO PERP. REFERENCE LINE
C     H1 =SILL HEIGHT ABOVE WORK PLANE
C     WINLP=WINDOW LOCATION POINT(DIST FROM RIGHT EDGE OF WINDOW
C           TO LEFT EDGE OF WINDOW-WALL)
C     RG =GROUND REFLECTANCE
C     ISKY= TYPE OF SKY
C      DAYLTE= INDOOR ILLUMINATION
C      SC     = SKY COMPONENT, PERCENT
C      ERC    = EXTERNALLY REFLECTED COMPONENT, PERCENT
C      IRC    = INTERNALLY REFLECTED COMPONENT, PERCENT
C     SKYLUM  = SKY LUMINANCE @41.8 DEGREES (AVERAGE WINDOW LUMINANCE)
C     B       = CORRECTION FACTOR FOR GLAZING BARS
C     M       =MAINTENANCE FACTOR OF GLAZING
C
      COMMON /DLT/ FLGDLT,ZSLITE(10,30),DLTDL(10,3),DLTDHL(10,3),
     2 DLTDHG(10,3)
      COMMON /RML/ SC(10,3),ERC(10,3),XIRC(10,3)
      REAL M
      PI=3.14159
      RX=ZSLITE(ISURF,2)
C                  WALL REFLECTANCE
      RWL=ZSLITE(ISURF,3)
C                  CEILING REFLECTANCE
      RCN=ZSLITE(ISURF,4)
C                  FLOOR REFLECTANCE
      RFL=ZSLITE(ISURF,5)
      M=ZSLITE(ISURF,6)
      B=ZSLITE(ISURF,7)
      HX=ZSLITE(ISURF,8)
      DX=ZSLITE(ISURF,9)
      ALPHA=ZSLITE(ISURF,9)
      RMH=ZSLITE(ISURF,10)
      RML=ZSLITE(ISURF,11)
      RMW=ZSLITE(ISURF,12)
      W=ZSLITE(ISURF,13)
      H=ZSLITE(ISURF,14)
      W1=ZSLITE(ISURF,15)
      H1=ZSLITE(ISURF,16)
      D=ZSLITE(ISURF,17)
      WINLP=ZSLITE(ISURF,18)
      SKYLUM=ZSLITE(ISURF,26)
      RG=ZSLITE(ISURF,20)
      WA=W*H
      HL=HX*D/(D+DX)
      IF (HL.GT.H) HL=H
      A=2.*((RML*RMH)+(RML*RMW)+(RMH*RMW))
      FRAC=((H1+2.5)+(.5*H))/RMH
      ACN=RMW*RML
      AWL=(RML*RMH)+2*(RMW+RMH)
      RCW=(AWL*(1.0-FRAC)*RWL+ACN*RCN)/(AWL*(1.0-FRAC)+ACN)
      RFW=(AWL*FRAC*RWL+ACN*RFL)/(AWL*FRAC+ACN)
      RAVE=(AWL*RWL+ACN*RFL+ACN*RCN)/(AWL+ACN+ACN)
      SC(ISURF,ID)=0.
      IF (HL.GE.H) GO TO 10
      SC(ISURF,ID)=SF(W,H,W1.H1,HL,HH,D)
```

```
      10  ERC(ISURF,ID)=EOF(W,H,W1,H1,HL,HH,D)*RX
          CALL IRC (W,H,W1,H1,HL,WINLP,RMH,RML,RMW,RWL,RCN,RFL,RAVE,A,XIRC(I
         2SURF,ID),SKYLUM,RG,RX)
          RETURN
          END
```

```
SUNACT*DALITE1(1).SF(0)
      FUNCTION SF (W,H,W1,H1,HL,HH.D)
C
C     ******************************************************************
C
C     SF = SKY FACTOR FOR A POINT IN THE ROOM
C
      H2=H1+H
      HH=HL+H1
      W4=W1+W
      W1A=ABS(W1)
      W4A=ABS(W4)
      IF (HH.GE.H2) GO TO 30
      IF (W1.GT.0.) GO TO 20
      IF (W1.LT.0.) GO TO 10
      SF=BCF(W,H2,D)-BCF(W,HH,D)
      GO TO 30
10    IF (W4.LT.0.) SF=BCF(W1A,H2,D)-BCF(W4A,H2,D)-BCF(W1A,HH,D)+BCF(W4A
     2,HH,D)
      SF=BCF(W4,H2,D)+BCF(W1A,H2,D)-BCF(W4,HH,D)-BCF(W1A,HH,D)
      GO TO 30
20    SF=BCF(W4,H2,D)-BCF(W1,H2,D)-BCF(W4,HH,D)+BCF(W1,HH,D)
30    RETURN
      END
```

```
SUNACT*DALITE1(1).EOF(0)
      FUNCTION EOF (W,H,W1,H1,HL,HH,D)
C
C     *********************************************************************
C
C      EOF      = EXTERNAL OBSTRUCTION FACTOR
C
      H2=H1+H
      HH=HL+H1
      W4=W1+W
      W1A=ABS(W1)
      W4A=ABS(W4)
      IF (W1.GT.0) GO TO 10
      IF (W1.LT.0) GO TO 20
      EOF=BCF(W,HH,D)-BCF(W,H1,D)
      GO TO 30
   10 EOF=BCF(W4,HH,D)-BCF(W1,HH,D)-BCF(W4,H1,D)+BCF(W1,H1,D)
      GO TO 30
   20 IF (W4.LT.0.) EOF=BCF(W1A,HH,D)-BCF(W1A,H1,D)-BCF(W4A,HH,D)+BCF(W4
     2A,H1,D)
      EOF=BCF(W4,HH,D)+BCF(W1A,HH,D)-BCF(W4,H1,D)-BCF(W1A,H1,D)
   30 RETURN
      END
```

```
SUNACT*DALITE1(1).BCF(0)
      FUNCTION BCF (W,H,D)
C
C     ******************************************************************
C
C      BCF = BASIC GEOMETRIC FACTORS BETWEEN THE OVERCAST SKY AND
C            THE HORIZONTAL INTERIOR ILLUMINATION ; WALSH'S EQUATION
C
      PI=3.14159265
      X=W/D
      Y=H/D
      A=SQRT(1.+Y*Y)
      B=SQRT(1.+X*X+Y*Y)
      BCF=(3*(ATAN(X)-ATAN(X/A)/A)+4*(ATAN(X*Y/B)-X*Y/A/A/B))/14./PI
      RETURN
      END
```

```
SUNACT*DALITE1(1).IRC(1)
      SUBROUTINE IRC (W,H,W1,H1,HL,WINLP,RMH,RML,RMW,RWL,RCN,RFL,RAVE,A,
     2 XIRC,SKYLUM,RG,RX)
C
C     ******************************************************************
C
C     WINLP=WINDOW LOCATION POINT
C     RMH  =ROOM HEIGHT
C     RML  =ROOM LENGTH
C     RMW  =ROOM WIDTH
C     RWL  =REFLECTANCE OF WALL
C     RCN  =REFLECTANCE OF CEILING
C     RFL  =REFLECTANCE OF FLOOR
C     NOTE: WINDOWS ARE ASSUMED TO BE ONLY ALONG THE LONGER WALL
C
      REAL MOVE,MOVEA
      RML2=RML/2
      RMW2=RMW/2
      HH=H1+HL
      HH2=HH+3.5
      H2=H+H1
      H3=H2+3.5
      H4=RMH-HH2
      H5=RMH-H3
      H6=H+H5
      H7=H1+3.5
      W2=WINLP-W
      W3=RML2-W2
      MOVE=WINLP-RML2
      MOVEA=ABS(MOVE)
      ZERO=0.
C                   SINCE WINDOW WALL HAS LITTLE REFLECTED LIGHT
      FLUX1=0
      BCF2=BWF(H2,WINLP,RMW2)-BWF(H2,W2,RMW2)-BWF(HH,WINLP,RMW2)*(1.-RX)
     2+BWF(HH,W2,RMW2)*(1.-RX)+BWF(H1,WINLP,RMW2)*(RX)+BWF(H1,W2,RMW2)*(
     3RX)
      FLUX2=BCF2*RWL*RMW*RMH
      IF (WINLP.LT.RML2) GO TO 10
      BCF3=BCFV(W,H2,RMW2,MOVE)-BCFV(W,HH,RMW2,MOVE)*(1.-RX)-BCFV(W,H1,R
     2MW2,MOVE)*(RX)
      GO TO 20
 10   BCF3=BCFV(W3,H2,RMW2,ZERO)-BCFV(MOVEA,H2,RMW2,ZERO)+BCFV(MOVEA.HH,
     2RMW2,ZERO)*(1.-RX)-BCFV(W3,HH,RMW2,ZERO)*(1.-RX)-BCFV(W3,H1,RMW2,Z
     3ERO)*(RX)+BCFV(MOVEA,H1,RMW2,ZERO)*(RX)
 20   FLUX3=BCF3*RWL*RML*RMH
C                   SINCE SIDE WALLS ARE ASSUMED SYMMETRICAL
      FLUX4=FLUX2
      IF (WINLP.LT.RML2) BCF5=BWF(W3,H4,RMW2)*(1.-RX)-BWF(MOVEA,H4,RMW2)
     2*(1.-RX)-BWF(W3,H5,RMW2)+BWF(MOVEA,H5,RMW2)+BWF(W3,H6,RMW2)*(RX)-B
     3WF(MOVEA,H6,RMW2)*(RX)
      IF (WINLP.EQ.RML2) BCF5=BWF(W,H4,RMW2)*(1.-RX)-BWF(W,H5,RMW2)+BWF(
     2W,H6,RMW2)*(RX)
      IF (WINLP.GT.RML2) BCF5=BWF(MOVEA,H4,RMW2)*(1.-RX)+BWF(W3,H4,RMW2)
     2*(1.-RX)-BWF(W3,H5,RMW2)-BWF(MOVEA.H5,RMW2)+BWF(W3,H6,RMW2)*(RX)+B
     3WF(MOVEA,H6,RMW2)*(RX)
      FLUX5=BCF5*RCN*RML*RMW*RG
      IF (WINLP.LT.RML2) BCF6=BWF(W3,H3,RMW2)-BWF(MOVEA,H3,RMW2)+BWF(MOV
     2EA.HH2.RMW2)*(1.-RX)-BWF(W3,HH2,RMW2)*(1.-RX)-BWF(W3,H7,RMW2)*(RX)
     3+BWF(MOVEA,H7,RMW2)*(RX)
      IF (WINLP.EQ.RML2) BCF6=BWF(W,H3,RMW2)-BWF(W,HH2,RMW2)*(1.-RX)-BWF
     2(W,H7,RMW2)*(RX)
      IF (WINLP.GT.RML2) BCF6=BWF(W3,H3,RMW2)-BWF(W3,HH2,RMW2)*(1.-RX)-B
     2WF(MOVEA,HH2,RMW2)*(1.-RX)+BWF(MOVEA,H3,RMW2)-BWF(W3,H7,RMW2)*(RX)
     3-BWF(MOVEA,H7,RMW2)*(RX)
      FLUX6=BCF6*RFL*RML*RMW
      XIRC=(FLUX1+FLUX2+FLUX3+FLUX4+FLUX5+FLUX6)/A/(1-RAVE)
      RETURN
      END
  END PRT
```

```
SUNACT*DALITE1(1).BWF(0)
      FUNCTION BWF (W,H,D)
C
C     ******************************************************************
C
C      BWF = WINDOW FACTOR; HIGBIE'S EQUATION FOR HORIZ. ILLUMINATION FR
C
      PI=3.14159265
      A=SQRT(D*D+H*H)
      BWF=(ATAN(W/D)-D/A*ATAN(W/A))/2./PI
      RETURN
      END
```

```
SUNACT*DALITE1(1).BCFV(0)
      FUNCTION BCFV (W,H,D,MOVE)
C
C     ******************************************************************
C
C     BCFV=BASIC CONFIGURATION FACTOR BETWEEN A VERTICAL WINDOW
C     AND A VERTICAL PLANE
C
      REAL MOVE
      PI=3.14159265
      D2=D*D
      A=SQRT(D2+MOVE*MOVE)
      B=SQRT(D2+H*H)
      C=SQRT(D2+(MOVE-W)**2)
      E=SQRT(D2+W*W)
      IF (MOVE.EQ.0.) GO TO 10
      BCFV=(MOVE/A*ATAN(H/A)+H/B*ATAN(W*B/(B*B+D2-W*MOVE))+(W-MOVE)/C*AT
     2AN(H/C))/2./PI
      GO TO 20
10    BCFV=(H/B*ATAN(W/B)+W/E*ATAN(H/E))/2./PI
20    RETURN
      END
```

APPENDIX F

NBSLD WEATHER DATA DECODE PROGRAM

```
      SUBRCUTINE DECODE (WPOSX,WLONGX,NUM,OUTPUT,MM,YR,MO,DAY,LOCAL)
C
C     ******************************************************************
C
C     THIS SLBROUTINE PRODUCES HOURLY DATA OF  UP TO 10 WEATHER
C     PARAMETERS FOR A GIVEN YEAR,MO AND DATE
C   TAPE FCSOTION FOR EACH OF TEN PARAMETERS ARE
C        PARAMETERS          WPOSX     WLONGX
C        WIND SPEED          13        3
C        WINC DIRECTICN      11        2
C        DRY-BULB TEMP       16        3
C        WET-BULB TEMP       19        3
C        DEW-POINT TEMP      22        3
C        BAROMETRIC PRESS    34        4
C        TOTAL CLOUD AMOUNT  43        1
C        OPAQUE CLOUC COVER  44        1
C        PRECIPITATION(LIQUID) 68      2
C        PRECIPITATION(FRZ)  70        3
C   TAPE FCSITICN CN TAPE 280
C        SOLAR DATA          14        4
C        ELEVATION ANGLE     18        2
C         TOTAL CLGUD        42        1
C        1ST LAYER TYPE OF CLOUD 46    1
C        YR    .   YEAR
C        MO        MONTH
C        DAY       DAY
      INTEGER IPS(24),ICHAR(2000),WPOS,WLONG,OUTPUT(24,10),YR,DAY,WORD,
     2 WORDX(20),WPOSX(10),WLONGX(10),TAPE1,TAPE2
      COMMON TAPE1,TAPE2,NO1,NO2,INPUT(1100)
      IASS=1000000
      IF (MM.NE.0) GO TC 90
      DO 10 I=1,4
      CALL WD (0)
      DO 10 JJ=1,498
      KK=498*(I-1)+JJ
10    ICHAR(KK)=INPUT(JJ)
      DO 20 I=1,15
      IW=ICHAR(I)
      CALL WDX (IW)
20    ICHAR(I)=IW
      YR=ICHAR(10)*10+ICHAR(11)+1900
      MO=ICHAR(12)*10+ICHAR(13)
      DAY= ICHAR(14)*10+ICHAR(15)
      LOCAL=ICHAR(9)
      IPWR=1
      DO 30 I=1,4
      IPWR=IPWR*10
30    LOCAL=LCCAL+ICHAR(9-I)*IPWR
      DO 80 KU=1,NUM
      WPCS=WPOSX(KU)
      WLCNG=WLCNGX(KU)
      DO 40 I=1,6
      IPS(I)=15+WPOS+80*(I-1)
      DO 40 J=1,3
      II=I+J*6
```

```
   40 IPS(II)=IPS(I)+J*498
      DO 70 I=1,24
      KI=IPS(I)
      KL=KI+WLONG-1
      DO 50 L2=KI,KL
      IW=ICHAR(L2)
      CALL WDX (IW)
   50 ICHAR(L2)=IW
      LONG=WLONG-1
      IF (ICHAR(KI).EQ.IASS.AND.WLONG.GT.1) LONG=WLONG-2
      WORD=ABS(ICHAR(KL))
      IF (LONG.EQ.0) GO TO 70
      IPWR=1
      DO 60 JK=1,LONG
      IPWR=IPWR*10
   60 WORD=WORD+ICHAR(KL-JK)*IPWR
      IF (ICHAR(KL).LT.0) WORD=-WORD
   70 OUTPUT(I,KU)=WORD
   80 CONTINUE
      GO TO 240
C
   90 CALL WD (1)
      JZ=0
      DO 100 J=1,991,66
      JX=J
      JZ=JZ+1
      IW=INPUT(J)
      CALL WDX (IW)
      IF (IW.NE.IASS) GO TO 110
  100 CONTINUE
  110 IF (JX.LT.991) GO TO 130
      DO 120 KU=1,NUM
      DO 120 J=1,24
  120 OUTPUT(J,KU)=IASS
      GO TO 240
C
  130 JY=JX+20
      DO 140 I=JX,JY
      IW=INPUT(I)
      CALL WDX (IW)
  140 ICHAR(I)=IW
      YR=ICHAR(JX+5)*10+ICHAR(JX+6)+1900
      DAY=ICHAR(JX+9)*10+ICHAR(JX+10)
      MO=ICHAR(JX+7)*10+ICHAR(JX+8)
      IF (DAY.GT.0) GO TO 150
      IY=ABS(DAY)
      IF (IY.LT.20) DAY=DAY+20
      IF (IY.GE.20) DAY=DAY+40
  150 CONTINUE
      LOCAL=ICHAR(JX+4)
      IPWR=1
      DO 160 I=1,4
      IPWR=IPWR*10
      IF (ICHAR(JX+4-I).GT.0) GO TO 160
      LOCAL=IASS
      GO TO 170
  160 LOCAL=LOCAL+ICHAR(JX+4-I)*IPWR
  170 CONTINUE
      IHR=3+JZ
      IF (WPCS.EQ.0) GO TO 240
      DO 230 KU=1,NUM
      WPCS=WPCSX(KU)
      WLONG=WLONGX(KU)
```

```
      DO 180 I=1,24
180   OUTPUT(I,KU)=0
      DO 210 I=1,16
      KI=WPOS+66*(I-1)
      KL=KI+WLONG-1
      DO 190 L2=KI,KL
      IW=INPUT(L2)
      CALL WOX (IW)
190   ICHAR(L2)=IW
      LONG=WLONG-1
      IF (ICHAR(KI).EQ.IASS.AND.WLONG.GT.1) LONG=WLONG-2
      WORD=ICHAR(KL)
      IF (LONG.EQ.0) GO TO 210
      IPWR=1
      IPWR=IPWR*10
      DO 200 JK=1,LONG
      IF (ICHAR(KL).LT.0) WORD=-WORD
200   WORD=WORD+ICHAR(KL-JK)*IPWR
210   WORDX(I)=WORD
      DO 220 I=1,16
      KK=I+3
220   OUTPUT(KK,KU)=WORDX(I)
230   CONTINUE
240   RETURN
C
      END
```

DECODE PROGRAM FOR WEATHER DATA STRUCTURES CONFORMING TO DOE-2 DATA BLOCK STRUCTURE, (developed by Lawrence E. Flynn)

```
@ELT,SI SUNACT*CLIMAT(1).GETHR,,,245713112220,000500000001
      SUBROUTINE GETHR (IFIRST, IMNTH, IDAY, IHR)
C
C     ****************************************************************
C
      COMMON /DAY/ IDAWN(12),IDUSK(12),NDAY(12),RLATD,RLONG,TZN,TPLATD,
     2 TPLONG,TPTZN
      COMMON /COMHR/ IWDID(5), IWYR,LRECX, NUMDAY, TGRND
      COMMON /DAYDAT/ DBT(24),DPT(24),WBT(24),WSP(24),WDR(24),BPR(24),
     2 RHT(24),RDN(24),CCT(24),TOC(24),IS(24),IR(24)
C
C                THIS SUBROUTINE UNPACKS ONE HOUR OF A PACKED DOE-N
C                WEATHER FILE (TWO 60 BIT OR FOUR 30 BIT WORDS PER HOUR).
C                WET BULB TEMP            DEG F    HUMIDITY RATIO
C                DRY BULB TEMP            DEG F    DENSITY          LBM/FT3
C                ATMOSPHERIC PRESSURE     IN HG    ENTHALPY         BTU/LBM
C                CLOUD AMOUNT             TENTHS   SOLAR RADIATION  BTU/FT2
C                SNOW FLAG(UNUSED)        0 OR 1   DIRECT SOLAR     BTU/FT2
C                RAIN FLAG(UNUSED)        0 OR 1   CLOUD TYPE       CODE 1-9
C                WIND DIRECTION  NORTH=1-16 PTS     WIND SPEED         KNOTS
C
      COMMON /FILTYP/ IWSIZ,IWSCL,IFX,IDAT(1536)
C
      LOGICAL IEOF,IFIRST
C
C
      DIMENSION IMASK(16,2),ICALC(16),XMASK(16,2),LOOK(14)
      DIMENSION IDAT30(1536),IDAT60(768), IDATO(1488)
C
      EQUIVALENCE (IDAT(1),IDAT30(1)), (IDAT(1),IDAT60(1)), (IDAT(1),
     2 IDATO(1))
C
       DATA IMASK /255,255,255,15,1,1,15,1023,127,511,511,511,15,127,0,0,
     2 8,16,24,28,29,30,34,44,51,0,39,48,53,0,0,0/
       DATA XMASK /-99.0,-99.0,15.0,0.0,0.0,0.0,1.0,0.0,0.02,-30.0,0.0,
     2 0.0,0.0,0.0,0.0,10.0,1.0,1.0,0.1,1.0,1.0,1.0,1.0,0.0001,0.001,0.5
     3,1.0,1.0,1.0,1.0,0.0,0.0/
 C
 C                LRECX TELLS HOW MANY RECORDS HAVE BEEN READ
       IF (.NOT.IFIRST) GO TO 10
       IFIRST=.FALSE.
      READ (8) LOOK
       IF (EOF(INWTH).NE.0) GO TO 100
CIBM********** REPLACE ABOVE 2 CARDS WITH
C      READ (INWTH,END=255) LOOK
       IWSCL=LOOK(14)
       IF (LOOK(11).EQ.0) IWSCL=0
       IWSIZ=MOD(IWSOL,2)+1
       IFX=IWSCL+1
      BACKSPACE INWTH
10    CONTINUE
       IRECX=IMNTH
       IDX=IDAY
       IF (IFX.LT.3) GO TO 20
       IRECX=IMNTH*2+(IDAY-1)/16-1
       IDX=MOD(IDAY-1,16)+1
20    CONTINUE
       IF (IRECX-LRECX) 30,120,50
30    CONTINUE
C               BACKSPACE TO PROPER MONTH
       IDIF=LRECX-IRECX+1
      DO 40 I=1,IDIF
          BACKSPACE INWTH
40        CONTINUE
50    GO TO (60,60,70,80,70,  80), IFX
```

```
60    READ (INWTH) IWDID(1),IWDID(2),IWYR,TPLATD,TPLONG,IPTZN,LRECX,NUMD
     2AY,TGRND,CLRNES,IDUM,IDATD
      GO TO 90
70    READ (INWTH) IWDID,IWYR,TPLATD,TPLONG,IPTZN,LRECX,NUMDAY,CLRNES,TG
     2RND,IDUM,IDAT60
      GO TO 90
80    READ (INWTH) IWDID,IWYR,TPLATD,TPLONG,IPTZN,LRECX,NUMDAY,CLRNES,TG
     2RND,IDUM,IDAT30
90    TPTZN=IPTZN
      IF (EOF(INWTH).EQ.0) GO TO 10
CIBM********** REPLACE THE ABOVE 9 CARDS WITH
C 210 READ (INWTH,END=295) IWDID,IWYR,WLAT,WLONG,IWTZN,LRECX,NUMDAY,
C     %                      CLRNES,TGRND,IDUM,IDATD
C     GO TO 20
C 220 READ (INWTH,END=295) IWDID,IWYR,WLAT,WLONG,IWTZN,LRECX,NUMDAY,
C     %                      CLRNES,TGRND,IDUM,IDAT60
C     GO TO 20
C 230 READ (INWTH,END=295) IWDID,IWYR,WLAT,WLONG,IWTZN,LRECX,NUMDAY,
C     %                      CLRNES,TGRND,IDUM,IDAT30
C     GO TO 20
100   PRINT 110
110   FORMAT (1H1////27H *** WEATHER TAPE ERROR ***)
      IEOF=.TRUE.
      RETURN
120   CONTINUE
      IF (IWSIZ.EQ.2) GO TO 150
      IP1=48*(IDX-1)+2*IHR-1
      IPACK1=IDAT(IP1)
      IPACK2=IDAT(IP1+1)
      DO 130 I=1,10
          ICALC(I)=SHIFT(IPACK1,IMASK(I,2)).AND.IMASK(I,1)
130       CONTINUE
      DO 140 I=11,14
          ICALC(I)=SHIFT(IPACK2,IMASK(I,2)).AND.IMASK(I,1)
140       CONTINUE
      WBT(IHR)=FLOAT(ICALC)*XMASK(1,2)+XMASK(1,1)
      DBT(IHR)=FLOAT(ICALC)*XMASK(2,2)+XMASK(2,1)
      BPR(IHR)=FLOAT(ICALC)*XMASK(3,2)+XMASK(3,1)
      CCT(IHR)=FLOAT(ICALC)*XMASK(4,2)+XMASK(4,1)
      IS(IHR)=FLOAT(ICALC)*XMASK(5,2)+XMASK(5,1)
      IR(IHR)=FLOAT(ICALC)*XMASK(6,2)+XMASK(6,1)
      WDR(IHR)=FLOAT(ICALC)*XMASK(7,2)+XMASK(7,1)
      RHT(IHR)=FLOAT(ICALC)*XMASK(11,2)+XMASK(11,1)
      RDN(IHR)=FLOAT(ICALC)*XMASK(12,2)+XMASK(12,1)
      TOC(IHR)=FLOAT(ICALC)*XMASK(13,2)+XMASK(13,1)
      WSP(IHR)=FLOAT(ICALC)*XMASK(14,2)+XMASK(14,1)
CIBM*********** REPLACE THE ABOVE 11 CARDS WITH
C 600 CONTINUE
      RETURN
150   CONTINUE
      IP1=96*(IDX-1)+4*IHR-3
      LOOK(3)=IDAT(IP1)/65536
      LOOK(1)=MOD(IDAT(IP1),65536)/256
      LOOK(2)=MOD(IDAT(IP1),256)
      LOOK(11)=IDAT(IP1+1)/1048576
      LOOK(12)=MOD(IDAT(IP1+1),1048576)/1024
      LOOK(4)=MOD(IDAT(IP1+1),1024)/64
      LOOK(5)=MOD(IDAT(IP1+1),64)/32
      LOOK(6)=MOD(IDAT(IP1+1),32)/16
      LOOK(7)=MOD(IDAT(IP1+1),16)
      LOOK(8)=IDAT(IP1+2)/128
      LOOK(9)=MOD(IDAT(IP1+2),128)
```

```
      LOCK(10)=IDAT(IP1+3)/2048
      LOCK(13)=MOD(IDAT(IP1+3),2048)/128
      LOCK(14)=MOD(IDAT(IP1+3),128)
      WBT(IHR)=FLOAT(LOCK(1))*XMASK(1,2)+XMASK(1,I)
      DBT(IHR)=FLOAT(LOCK(2))*XMASK(2,2)+XMASK(2,1)
      BPR(IHR)=FLOAT(LOCK(3))*XMASK(3,2)+XMASK(3,1)
      CCT(IHR)=FLOAT(LOCK(4))*XMASK(4,2)+XMASK(4,1)
C     IS(IHR) = FLOAT(LOCK(5))*XMASK(5,2) + XMASK(5,1)
C     IR(IHR) = FLOAT(LOCK(6))*XMASK(6,2) + XMASK(6,1)
      WDR(IHR)=FLOAT(LOCK(7))*XMASK(7,2)+XMASK(7,1)
      RHT(IHR)=FLOAT(LOCK(11))*XMASK(11,2)+XMASK(11,1)
      RDN(IHR)=FLOAT(LOCK(12))*XMASK(12,2)+XMASK(12,1)
      TOC(IHR)=FLOAT(LOCK(13))*XMASK(13,2)+XMASK(13,1)
      WSP(IHR)=FLOAT(LOCK(14))*XMASK(14,2)+XMASK(14,1)
      RETURN
      END
```

APPENDIX G

GRAPHIC BUILDING SHADOW CALCULATION PROGRAM

```
10 REM ** BUILDING SHADOW GRAPHICS PROGRAM
20 REM ** WRITTEN BY SCOTT WRIGHT, JUNE 1981
30 REM
40 PRINT
50 PRINT
60 PRINT
70 PRINT "=========================================="
80 PRINT "     BUILDING SHADOW GRAPHICS PROGRAM"
90 PRINT "=========================================="
100 PRINT
110 PRINT
120 INPUT "ENTER AZIMUTH , ALTITUDE ? ",A1,A2
130 !
140 REM ** Convert degrees to radians
150 Azi=A1*.0174532
160 Alt=A2*.0174532
170 !
180 PRINT "CHOICE OF VIEWS FOR DRAWING:"
190 PRINT "    (1) VIEW FROM AZI,ALT ENTERED"
200 PRINT "    (2) PLAN VIEW WITH SHADOWS"
210 INPUT "ENTER VIEW CHOICE ? ",Vc
220 INPUT "ENTER NO. OF PLANAR CO-ORDS. (STREETS) ? ",Ns
230 INPUT "ENTER NO. OF SOLID CO-ORDS. (BUILDINGS) ? ",Nb
240 IF Nb=0 THEN GOTO 310
250 PRINT "DRAWING CHOICES FOR EACH BUILDING:"
260 PRINT "    (1) DRAW ALL LINES"
270 PRINT "    (2) REMOVE HIDDEN LINES"
280 PRINT "    (3) POCHE BUILDING PLAN"
290 PRINT "    (4) POCHE BUILDING SHADOW"
300 PRINT "ENTER EACH CHOICES AFTER THE BLDG. CO-ORDS."
310 PRINT
320 PRINT "ENTER ALL PLANAR AND BUILDING"
330 PRINT "CO-ORDINATES IN A CLOCKWISE SEQUENCE."
340 !
350 REM ** Dimension arrays
360 DIM A((2+Ns+Nb)*4,8)
370 DIM B((2+Ns+Nb)*4,8)
380 DIM Rz(4,4),Rx(4,4),T(4,4),Dc(2+Ns+Nb)
390 !
400 REM ** Enter exterior boundary of site
410 PRINT
420 PRINT "ENTER EXTERIOR BOUNDARY (X,Y,Z)"
430 FOR I=1 TO 4
440 INPUT A(I,1),A(I,2),A(I,3)
450 A(I,4)=1
460 NEXT I
470 !
480 REM ** Enter interior limits of shadow site
490 PRINT
500 PRINT "ENTER INTERIOR LIMITS (X,Y,Z)"
```

```
510 FOR I=5 TO 8
520 INPUT A(I,1),A(I,2),A(I,3)
530 A(I,4)=1
540 NEXT I
550 !
560 REM ** Enter street co-ordinates
570 IF Ns=0 THEN GOTO 690
580 PRINT
590 FOR I=8 TO ((1+Ns)*4) STEP 4
600 PRINT "ENTER STREET (PLANAR) CO-ORDS. (X,Y,Z)"
610 FOR J=1 TO 4
620 IpJ=I+J
630 INPUT A(IpJ,1),A(IpJ,2),A(IpJ,3)
640 A(IpJ,4)=1
650 NEXT J
660 NEXT I
670 !
680 REM ** Enter building co-ordinates
690 IF Nb=0 THEN GOTO 940
700 PRINT
710 FOR I=((2+Ns)*4) TO ((1+Ns+Nb)*4) STEP 4
720 PRINT "ENTER BUILDING (SOLID) ROOF CO-ORDS. (X,Y,Z)"
730 FOR J=1 TO 4
740 IpJ=I+J
750 INPUT A(IpJ,1),A(IpJ,2),A(IpJ,3)
760 A(IpJ,4)=1
770 NEXT J
780 INPUT "ENTER GROUND CO-ORDS. (Y OR N) ? ",Gc$
790 IF Gc$="Y" THEN 800 ELSE 850
800 FOR J=1 TO 4
801 IpJ=I+J
810 INPUT A(IpJ,5),A(IpJ,6),A(IpJ,7)
820 A(IpJ,8)=1
830 NEXT J
840 GOTO 910
850 FOR J=1 TO 4
851 IpJ=I+J
860 A(IpJ,5)=A(IpJ,1)
870 A(IpJ,6)=A(IpJ,2)
880 A(IpJ,7)=0
890 A(IpJ,8)=1
900 NEXT J
910 INPUT "DRAWING CHOICE ? ",Dc(I/4)
920 NEXT I
930 !
940 PRINT
950 PRINT "PROGRAM NOW RUNNING"
960 PRINT
970 !
980 !
990 REM ** Transform all co-ordinates
1000 GOSUB 1870
1010 !
1020 REM ** Retransform all points if plan view selected
1030 IF Vc=2 THEN 1040 ELSE 1170
1040 FOR I=1 TO ((1+Ns+Nb)*4) STEP 4
1050 GOSUB 2890
1060 FOR J=1 TO 4
```

```
1070 IPj=I+J
1080 IF B(IPj,3)=Zl THEN B(IPj,3)=1E-04 ELSE B(IPj,3)=0
1090 NEXT J
1100 NEXT I
1110 !
1120 Azi=-Azi
1130 Alt=-Alt
1140 GOSUB 1870
1150 !
1160 !
1170 REM ** DRAW  Planar co-ordinates
1180 FOR I=0 TO ((1+Ns)*4) STEP 4
1190 Zu=9999
1200 Zl=-9999
1210 GOSUB 3070
1220 NEXT I
1230 !
1240 REM ** DRAW  Building co-ordinates
1250 FOR I=((2+Ns)*4) TO ((1+Ns+Nb)*4) STEP 4
1260 Zu=9999
1270 Zl=-9999
1280 !
1290 IF Dc(I/4)=1 THEN GOTO 1300 ELSE GOTO 1350
1300 GOSUB 3070
1310 GOSUB 3240
1320 GOSUB 3520
1330 GOTO 1670
1340 !
1350 IF Dc(I/4)=2 THEN GOTO 1360 ELSE GOTO 1420
1360 GOSUB 3070
1365 IF B(I+1,3)=B(I+3,3) AND B(I+2,3)=B(I+4,3) THEN GOTO 1380
1370 GOSUB 2800
1380 GOSUB 3240
1390 GOSUB 3410
1400 GOTO 1670
1410 !
1420 IF Dc(I/4)=3 THEN GOTO 1430 ELSE GOTO 1500
1430 GOSUB 3240
1435 IF B(I+1,3)=B(I+3,3) AND B(I+2,3)=B(I+4,3) THEN GOTO 1450
1440 GOSUB 2980
1450 GOSUB 3070
1460 GOSUB 3630
1461 C1=1
1462 C2=2
1463 C3=3
1464 C4=4
1470 GOSUB 4060
1480 GOTO 1670
1490 !
1500 IF Dc(I/4)=4 THEN GOTO 1510 ELSE GOTO 1300
1510 GOSUB 3240
1520 GOSUB 2980
1530 GOSUB 3070
1540 GOSUB 3520
1550 GOSUB 3730
1560 C1=1
1570 C2=2
1580 C3=3
1590 C4=4
```

```
1600 GOSUB 4060
1610 C1=5
1620 C2=6
1630 C3=7
1640 C4=8
1650 GOSUB 4060
1660 !
1670 NEXT I
1680 !
1690 !
1700 REM ** Do another drawing if desired
1710 PRINT
1720 PRINT "DO YOU WISH TO MAKE ANOTHER DRAWING"
1730 INPUT "USING THE SAME CO-ORDINATES (Y OR N) ? ",Ad$
1740 IF Ad$="N" THEN GOTO 1810
1750 PRINT
1760 INPUT "ENTER AZIMUTH , ALTITUDE ? ",A1,A2
1770 REM ** Convert to radians
1780 Azi=A1*.0174532
1790 Alt=A2*.0174532
1791 INPUT "ENTER NEW DRAWING TYPE FOR BLDGS. (Y OR N) ? ",Dt$
1792 IF Dt$="N" THEN GOTO 1800
1793 FOR I=(2+Ns) TO (1+Ns+Nb)
1794 PRINT "BLDG. NO.",I," ",
1795 INPUT Dc(I)
1796 NEXT I
1800 GOTO 940
1810 PRINT
1820 PRINT "PROGRAM TERMINATED"
1830 PRINT
1840 END
1850 !
1860 !
1870 REM ** SUBROUTINE Transform all co-ordinates
1880 REM ** Set up rotation matrices
1890 LET Rz(1,1)=COS(Azi)
1900 LET Rz(1,2)=-SIN(Azi)
1910 LET Rz(2,1)=SIN(Azi)
1920 LET Rz(2,2)=COS(Azi)
1930 LET Rz(3,3)=1
1940 LET Rz(4,4)=1
1950 !
1960 LET Rx(1,1)=1
1970 LET Rx(2,2)=SIN(Alt)
1980 LET Rx(2,3)=-COS(Alt)
1990 LET Rx(3,2)=COS(Alt)
2000 LET Rx(3,3)=SIN(Alt)
2010 LET Rx(4,4)=1
2020 !
2030 REM ** Set up transformation matrix
2040 FOR I=1 TO 4
2050 FOR J=1 TO 4
2060 Sum=0
2070 FOR K=1 TO 4
2080 Sum=Sum+Rz(I,K)*Rx(K,J)
2090 NEXT K
2100 T(I,J)=Sum
2110 NEXT J
```

```
2120 NEXT I
2130 !
2140 REM ** Transform planar and building roof co-ordinates
2150 FOR I=0 TO (+Ns+Nb)*4) STEP 4
2160 FOR J=1 TO 4
2170 Ipj=I+J
2180 FOR K=1 TO 4
2190 Sum=0
2200 FOR L=1 TO 4
2210 Sum=Sum+A(Ipj,L)*T(L,K)
2220 NEXT L
2230 B(Ipj,K)=Sum
2240 NEXT K
2250 NEXT J
2260 NEXT I
2270 !
2280 REM ** Transform building ground plane co-ordinates
2290 IF Nb=0 THEN GOTO 2440
2300 FOR I=((2+Ns)*4) TO ((1+Ns+Nb)*4) STEP 4
2310 FOR J=1 TO 4
2320 Ipj=I+J
2330 FOR K=1 TO 4
2340 Sum=0
2350 FOR L=1 TO 4
2360 Sum=Sum+A(Ipj,L+4)*T(L,K)
2370 NEXT L
2380 B(Ipj,K+4)=Sum
2390 NEXT K
2400 NEXT J
2410 NEXT I
2420 !
2430 !
2440 REM ** Check limits of X and Y axes
2450 LET Xl=9999
2460 LET Xu=-9999
2470 LET Yl=9999
2480 LET Yu=-9999
2490 FOR I=1 TO ((2+Ns+Nb)*4-1)
2500 IF B(I,1)<Xl THEN Xl=B(I,1)
2510 IF B(I,1)>Xu THEN Xu=B(I,1)
2520 IF B(I,2)<Yl THEN Yl=B(I,2)
2530 IF B(I,2)>Yu THEN Yu=B(I,2)
2540 NEXT I
2550 IF Ns=0 AND Nb=0 THEN GOTO 2700
2560 FOR I=((2+Ns)*4+1) TO ((2+Ns+Nb)*4)
2570 IF B(I,5)<Xl THEN Xl=B(I,5)
2580 IF B(I,5)>Xu THEN Xu=B(I,5)
2590 IF B(I,6)<Yl THEN Yl=B(I,6)
2600 IF B(I,6)>Yu THEN Yu=B(I,6)
2610 NEXT I
2620 !
2630 REM ** Find largest axes
2640 LET U=Xu
2650 IF Yu>Xu THEN U=Yu
2660 LET L=Xl
2670 IF Yl<Xl THEN L=Yl
2680 !
2690 !
2700 REM ** Set limits of drawing
```

```
2710 PLOTR (5)
2720 LOCATE (0,100,0,100)
2730 SCALE (L,U,L,U)
2740 PEN (1)
2750 LINE (0)
2760 !
2770 RETURN
2780 !
2790 !
2800 REM ** SUBROUTINE  Calculate minimum Z co-ord.
2810 Zl=9999
2820 FOR J=1 TO 4
2830 Ipj=I+J
2840 IF B(Ipj,7)<=Zl THEN Zl=B(Ipj,7)
2850 NEXT J
2860 RETURN
2870 !
2880 !
2890 REM ** SUBROUTINE  Calculate minimum Z co-ord. of roof
2900 Zl=9999
2910 FOR J=1 TO 4
2920 Ipj=I+J
2930 IF B(Ipj,3)<=Zl THEN Zl=B(Ipj,3)
2940 NEXT J
2950 RETURN
2960 !
2970 !
2980 REM ** SUBROUTINE  Calculate maximum Z co-ord.
2990 Zu=-9999
3000 FOR J=1 TO 4
3010 Ipj=I+J
3020 IF B(Ipj,3)>=Zu THEN Zu=B(Ipj,3)
3030 NEXT J
3040 RETURN
3050 !
3060 !
3070 REM ** SUBROUTINE  Draw boundary, street, or building roof
3080 PENUP
3090VE (B(I+1,1),B(I+1,2))
3100 FOR J=2 TO 4
3110 Ipj=I+J
3120 IF B(Ipj,3)<Zu AND B(Ipj-1,3)<Zu THEN GOTO 3130 ELSE GOTO 31
3130 DRAW (B(Ipj,Ipj,2))
3140 GOTO 3160
3150 MOVE (B(Ipj,1),B(Ipj,2))
3160 NEXT J
3170 IF B(I+1,3)<Zu AND B(I+4,3)<Zu THEN GOTO 3180 ELSE GOTO 3200
3180 DRAW (B(I+1,(I+1,2))
3190 GOTO 3210
3200 MOVE (B(I+1,1),B(I+1,2))
3210 RETURN
3220 !
3230 !
3240 REM ** SUBROUTINE  Draw building ground plane
3250 PENUP
3260 MOVE (B(I+1,5),B(I+1,6))
3270 FOR J=2 TO 4
3280 Ipj=I+J
3290 IF B(Ipj,7)>Zl AND B(Ipj-1,7)>Zl THEN 3300 ELSE 3320
```

```
3300 DRAW (B(Ipj,B(Ipj,6))
3310 GOTO 3330
3320 MOVE (B(Ipj,5),B(Ipj,6))
3330 NEXT J
3340 IF B(I+1,7)>Zl AND B(I+4,7)>Zl THEN 3350 ELSE 3370
3350 DRAW (B(I+1,,B(I+1,6))
3360 GOTO 3380
3370 MOVE (B(I+1,5),B(I+1,6))
3380 RETURN
3390 !
3400 !
3410 REM ** SUBROUTINE  Connect vertical lines of buildings
3420 REM **            w/out least Z co-ords. if set
3430 FOR J=1 TO 4
3440 Ipj=I+J
3450 PENUP
3460 IF A(Ipj,7)>Zl THEN MOVE (B(Ipj,5),B(Ipj,6)) ELSE GOTO 3480
3470 DRAW (B(Ipj,(Ipj,2))
3480 NEXT J
3490 RETURN
3500 !
3510 !
3520 REM ** SUBROUTINE  Connect vertical lines of buildings
3530 REM **             w/out maximum Z co-ords. if set
3540 FOR J=1 TO 4
3550 Ipj=I+J
3560 PENUP
3570 IF B(Ipj,3)<Zu THEN MOVE (B(Ipj,1),B(Ipj,2)) ELSE 3590
3580 DRAW (B(Ipj,B(Ipj,6))
3590 NEXT J
3600 RETURN
3610 !
3620 !
3630 REM ** SUBROUTINE  Translate ground plane co-ordinates
3640 REM **             into correct sequence of points in C
3650 FOR J=1 TO 4
3660 Ipj=I+J
3670 C(J,1)=B(Ipj,5)
3680 C(J,2)=B(Ipj,6)
3690 NEXT J
3700 RETURN
3710 !
3720 !
3730 REM ** SUBROUTINE  Translate co-ordinates to poche
3740 REM **             building shadow into matrix C
3750 FOR J=1 TO 4
3760 Ipj=I+J
3770 IF B(Ipj,7)=Zl THEN GOTO 3800
3780 NEXT J
3790 !
3800 C(1,1)=B(Ipj,5)
3810 C(1,2)=B(Ipj,6)
3820 IF Ipj>1 THEN C(2,1)=B(Ipj-1,5) ELSE C(2,1)=B(I+1,5)
3830 IF Ipj>1 THE,2)=B(Ipj-1,6) ELSE C(2,2)=B(I+1,6)
3840 !
3850 IF Ipj>1 THEN C(3,1)=B(Ipj-1,1) ELSE C(3,1)=B(I+1,1)
```

```
3860 IF IpJ>1 THE C(3,2)=B(IpJ-1,2) ELSE C(3,2)=B(I+1,2)
3870 !
3880 C(4,1)=B(IpJ,1)
3890 C(4,2)=B(IpJ,2)
3900 !
3910 C(5,1)=B(IpJ,5)
3920 C(5,2)=B(IpJ,6)
3930 !
3940 IF IpJ<4 THEN C(6,1)=B(IpJ+1,5) ELSE C(6,1)=B(I+1,5)
3950 IF IpJ<4 THE C(6,2)=B(IpJ+1,6) ELSE C(6,2)=B(I+1,6)
3960 !
3970 IF IpJ<4 THEN C(7,1)=B(IpJ+1,1) ELSE C(7,1)=B(I+1,1)
3980 IF IpJ<4 THE C(7,2)=B(IpJ+1,2) ELSE C(7,2)=B(I+1,2)
3990 !
4000 C(8,1)=B(IpJ,1)
4010 C(8,2)=B(IpJ,2)
4020 !
4030 RETURN
4040 !
4050 !
4060 REM ** SUBROUTINE  Poche between 4 points in sequence C(x,y)
4070 LET Dx=C(C2,C(C1,1)
4080 LET X2=Dx*Dx
4090 LET Dy=C(C2,2)-C(C1,2)
4100 LET Y2=Dy*Dy
4110 LET L1=SQR(X2+Y2)
4120 !
4130 LET Dx=C(C4,1)-C(C3,1)
4140 LET X2=Dx*Dx
4150 LET Dy=C(C4,2)-C(C3,2)
4160 LET Y2=Dy*Dy
4170 LET L2=SQR(X2+Y2)
4180 !
4190 IF L1>L2 THEN Lmax=L1 ELSE Lmax=L2
4200 PENUP
4210 MOVE (C(C1,1),C(C1,2))
4220 FOR J=0 TO Lmax STEP .2
4230 LET X1=C(C1,1)+(C(C2,1)-C(C1,1))*(J+.1)/L1
4240 LET Y1=C(C1,2)+(C(C2,2)-C(C1,2))*(J+.1)/L1
4250 LET X2=C(C4,1)+(C(C4,1)-C(C3,1))*(J+.1)/L2
4260 LET Y2=C(C4,2)+(C(C4,2)-C(C3,2))*(J+.1)/L2
4270 !
4280 DRAW (X1,Y1)
4290 DRAW (X2,Y2)
4300 !
4310 LET X1=C(C1,1)+(C(C2,1)-C(C1,1))*(J+.2)/L1
4320 LET Y1=C(C1,2)+(C(C2,2)-C(C1,2))*(J+.2)/L1
4330 LET X2=C(C4,1)+(C(C4,1)-C(C3,1))*(J+.2)/L2
4340 LET Y2=C(C4,2)+(C(C4,2)-C(C3,2))*(J+.2)/L2
4350 !
4360 DRAW (X2,Y2)
4370 DRAW (X1,Y1)
4380 !
4390 NEXT J
4400 RETURN
4410 !
4420 !
4430 END
```

REFERENCES

1. City of Los Angeles, Mayor's Office, Department of City Planning, City Attorney's Office, SOLAR ENVELOPE ZONING: APPLICATION TO THE CITY PLANNING PROCESS, LOS ANGELES CASE STUDY, Solar Energy Research Institute (SERI), Golden Co. , 1980, p.iii

2. Horacio Caminos, Reinhard Goethert, URBANIZATION PRIMER, M.I.T. Press, Cambridge Mass., 1978, p.82

3. Gail Boyer Hayes, SOLAR ACCESS LAW, PROTECTING ACCESS TO SUNLIGHT FOR SOLAR ENERGY SYSTEMS, Environmental Law Institute; U.S. Department of Energy, H-8213G, Washington D.C., May 1979, p.51

4. Peter Hall, URBAN AND REGIONAL PLANNING, John Wiley and Sons, New York, NY, 1975, p. 263

5. Kalev Ruberg, "Passive Solar Potential in Urban Environments", THE FIFTH NATIONAL PASSIVE SOLAR CONFERENCE, October 19, University of Massachusetts, Amherst, Proceedings of the American Section of the International Solar Energy Society; October 1980, p. 836

6. Hittman Associates Inc., "Physical Characteristics, Energy Consumption , and Related Institutional Factors in the Commercial Sector", HIT-630, Columbia, Maryland, October 1975; p. III-1

7. H.L. Horak, Bruce D. Hunn, John L. Peterson, Mark A Roschke, Eva F. Tucker, Don A. York, DOE-2 REFERENCE MANUAL, Los Alamos Scientific Laboratories, (LASL), Lawrence Berkeley Laboratories, LA-7689-M, LBL-8706, U.S. Department of Energy, Feb. 15, 1979

8. D.C. Hittle, et.al., BLAST: THE BUILDINGS LOADS ANALYSIS AND SYSTEM THERMODYNAMICS PROGRAM, USERS MANUAL-VOL I., U.S. Army Construction Engineering Research Laboratory, (CERL), June 1979

9. Fransisco Arumi-Noe, THE DEROB SYSTEM VOL.II, EXPLANATORY NOTES AND THEORY, Numerical Simulation Laboratory, School of Architecture, University of Texas, Austin TX, July 1979

10. Booze, Allen, Hamilton Inc., PREDESIGN ENERGY ANALYSIS, A NEW GRAPHICS APPROACH TO ENERGY CONSCIOUS DESIGN FOR BUILDINGS, Office of Conservation and Solar Energy, DoE, DOE/CS-0171, Washington D.C., September 1980

11. T.R. Oke, BOUNDARY LAYER CLIMATES, Methuen and Co., London, 1978, p.229

12. Gail Boyer Hayes, SOLAR ACCESS LAW, PROTECTING ACCESS TO SUNLIGHT FOR SOLAR ENERGY SYSTEMS, pp.17-28

13. The Center for Landscape Architectural Education and Research, OPTIONS FOR PASSIVE ENERGY CONSERVATION IN SITE DESIGN, U.S. Department of Energy, Conservation and Solar Applications, Washington D.C. June, 1978, p.106

14. City of Los Angeles, SOLAR ENVELOPE ZONING, p. 7

15. For a complete list of building related thermal analysis algorithms, refer to: P.L. Versteegen, SURVEY OF CURRENTLY USED SIMULATION METHODS, Science Applications Inc., McLean Va.: U.S. Department of Energy, EM-78-C-04-4261, 1978

16. James P. Smith, SINDA USER'S MANUAL, April 1971, TRW Systems Group: National Aeronautics and Space Administration, NAS9-10435

17. Hittman Assoc. Inc., PHSYSICAL CHARACTERISTICS OF ENERGY CONSUMPTION AND RELATED INSTITUTIONAL FACTORS IN THE COMMERCIAL SECTOR, Federal Energy Administration, CO-04-51888-00, Washington D.C., Oct. 1975, p.iv-25

18. Frank Kreith, Jan F. Kreider, PRINCIPLES OF SOLAR ENGINEERING, Hemisphere Publishing Corp., Washington D.C., 1978, p.174

19. Fransisco Arumi-Noe, developed a glazing transmission algorithm that accounts for molecular films at the surface of the glazing. This is the most precise algorithm encountered to date. Numerical Simulation Laboratory, School of Architecture, University of Texas, Austin TX, July 1979

20. Dr. T. Kusuda, "NBSLD, the Computer Program for Heating and Cooling Loads in Buildings", NBS BUILDING SCIENCE SERIES 69, Center for Building Technology, National Bureau of Standards, (CBT, NBS), U.S. Department of Commerce, July 1976, pp.144a-149a

21. Gary Gillette, "A Daylighting Computation Procedure for Use in DoE-2 and Other Dynamic Energy Analysis Programs", Paper for Illumination Engineering Society, CBT, NBS, U.S. Department of Commerce, June 1981

22. Steve Treado, Gary Gillette, "Measurement of Sky Luminance, Sky Illuminance, and Horizontal Solar Radiation",NBSIR, CBT, NBS, U.S. Department of Commerce, Washington D.C., May 1981

23. Dr. T. Kusuda, "NBSLD", pp.6a-27a

24. J.L. Threlkeld and R.C. Jordan, ASHRAE, HANDBOOK OF FUNDAMENTALS, 1977, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., New York, NY, 1978, pp. 26.1-26.9

25. K. Kimura, D.G. Stephenson, "Solar Radiation of Cloudy Days", ASHRAE TRANSACTIONS, New York, NY, March 1969: from semi-annual meeting in Chicago, Jan. 27-30, 1969

26. Boeing Co., SUMMARY OF SOLAR RADIATION OBSERVATIONS, Report D2-90577-1, Dec. 1974

27. Frank T. Quinlan, SOLMET VOL.II, FINAL REPORT, TD-9724, HOURLY SOLAR RADIATION-SURFACE METEOROLOGICAL OBSERVATIONS, National Oceanic and Atmospheric Administration, (NOAA), U.S. Department of Commerce: U.S. Department of Energy, E49-269-1041, Feb. 1979

28. Frank T. Quinlan, SOLMET VOL. I-USER'S MANUAL TD-9724, HOURLY SOLAR RADIATION SURFACE METEOROLOGICAL OBSERVATIONS, Environmental Data and Information Services, NOAA, U.S. Department of Commerce, Ashville, NC, August 1978

29. Test Reference Year Developed by NBS and NOAA for ASHRAE, TAPE REFERENCE MANUAL, TEST REFERENCE YEAR, NOAA, Ashville, NC, 1970 The Test Reference Year is chosen from a 30 year pool of weather years and is picked with a heavy bias towards average ambient temperatures.

30. NOAA, TDF-14, SURFACE OBSERVATIONS, National Climatic Center, NOAA, U.S. Department of Commerce, Ashville, NC

31. Aden B. Meinel and Marjorie P. Meinel, APPLIED SOLAR ENERGY, Addison-Wesley Publishing Co., Reading Massachussetts, 1977, p.45

32. Scott Wright developed a building shadow algorithm at the College of Architecture, Georgia Institute of Technology, Atlanta, GA. June 1981

33. Dr. Edward A. Arens, D.H. Nall, "Climate Data Abbreviation for Computerized Calculation of Heating and Cooling Requirements in Buildings", ENERGY AND BUILDINGS 2, Ellsevier, Sequoia S.A., Lausanne, Switzerland, 1979, pp.135-139 The interval is chosen by weighting various weather parameters. Dry bulb temperature is the most important parameter followed by cloud cover.

34. Arthur I. Rubin, Editor, "Lighting Issues in the 1980's, Summary and Proceedings of a Lighting Roundtable Held June 14 and 15, 1979, New York, New York", NBS SPECIAL PUBLICATION 587, U.S. Department of Commerce, Washington D.C., July 1980, p.96

35. Ronald N. Helms, ILLUMINATION ENGINEERING FOR ENERGY EFFICIENT LUMINOUS ENVIRONMENTS, Prentice-Hall Inc., Englewood Cliffs, NJ., 1980, p.165

36. Ralph Knowles, SOLAR ENVELOPE CONCEPTS MODERATE DENSITY BUILDING APPLICATIONS, SERI/SP-98155-1, April 1980

37. Dr. T. Kusuda, "NBSLD",BSS 69, p.61d

38. ASHRAE, HANDBOOK OF FUNDAMENTALS, p.26.2

39. The DoE-2 algorithm for clear day insolation is similiar to the ASHRAE

calculation procedure.
Henry L. Horak, et.al., DOE-2 REFERENCE MANUAL, pp.111-189

40. M.A. Atwater, J.T. Ball, "Effects of Clouds on Insolation Models", SOLAR ENERGY, Vol 27, No.1, 1981. Pergammon Press, Oxford, U.K., p.37

41. SOLMET uses regressions from surface stations measuring solar radiation to determine solar radiation at proximate locations

42. Richard Bird, Roland L. Hulstrom, "Direct Insolation Models", SERI/TR, 335-344, U.S. Department of Energy, NTIS, Springfield Va., 22161, Jan. 1980

43. Kimura/Stephenson cloud modifiers are based on experimental measurements in 3 Canadian cities. Correlation was found between surface reported cloud data and solar radiation intensity. The intensity was also a function of the zenith angle.
K. Kimura, D.G. Stephenson, "Solar Radiation on Cloudy Days"

44. Boeing method used in DoE-2 uses a correlation to cloud cover. However, the ratio between direct and diffuse radaition is constant.

45. SOLMET data is based on regressions developed for closest cities with term measured data. Comparison of these regressions with methods based on functions reveals that the SOLMET method is heavily influenced by the presence of rain. Both Boeing and Kimura/Stephenson algorithms are insensitive to rain .

46. K. Ruberg, E.L. Flynn, "Comparison of Solar Radiation Algorithms from TRY Data Bases", NBS paper, June 1982, CBT, NBS, U.S. Department of Commerce, Washington D.C.

47. Dr. T. Kusuda and K. Ishii, "Hourly Solar Radiation Data for Vertical and Horizontal Surfaces on Average Days in the U.S. and Canada", NBS BSS 96, CBT, NBS, U.S. Department of Commerce, Washington D.C., April 1977

48. Benjamin Y.H. Liu, Richard C. Jordan, "Daily Insolation on Surfaces Tilted Toward the Equator", ASHRAE JOURNAL, Oct. 1968, AHSRAE, New York, NY

49. A.B. Meinel, M.P. Meinel, APPLIED SOLAR ENERGY, AN INTRODUCTION, Addsion Wesley, Reading Mass., 1976, p.47

50. B.P Liu, K.R. Rao, K. Tharmaratnum, A.M. Mattar, ENVIRONMENTAL FACTORS IN THE DESIGN OF BUILDING FENESTRATION, Applied Science Publishers Ltd., London 1979, p.65

51. R. G. Eckert, Robert M. Drake, HEAT AND MASS TRANSFER, McGraw Hill Book Co., New York, NY, 1959, p. 398

52. L. Threlkeld, THERMAL ENVIRONMENTAL ENGINEERING, Prentice-Hall Inc., Englewood Cliffs, N.J. 1962, p.358

53. B. P. Liu, et.al., ENVIRONMENTAL FACTORS IN THE DESIGN OF BUILDING FENESTRATION, p.169

54. Charles S. Barnaby et.al. "Research into the Empirical Correlation of Insolation Measurement with Daylighting Performance", PROCEEDINGS OF THE FIFTH NATIONAL PASSIVE SOLAR CONFERENCE, Amherst, Mass, 1980, AS/ISES, University of Delaware, 1980, p.1197

55. Fransisco Arumi-Noe, THE DEROB SYSTEM VOL.II, EXPLANATORY NOTES AND THEORY, Numerical Simulation Laboratory, School of Architecture, University of Texas, Austin TX, July 1979, p.10
Tensors (vectors) are used to describe interreflections and shading in rooms.

56. Frank Kreith, Jan F. Kreider, PRINCIPLES OF SOLAR ENGINEERING, p.176

57. Albert G.H. Dietz, PLASTICS FOR ARCHITECTS AND BUILDERS, M.I.T. Press, Cambridge Mass., 1969, p.71

58. Stephen Hale, "Energy Systems for Multifamily Housing: An Urban Case Study", Master of Architecture in Advanced Studies, School of Architecture and Urban Planning, Massachusetts Institute of Technology, June 1979, p.20

59. Roy E. Clark, S. Robert Hastings, "Quantified Occupant Use Factors Affecting Energy Consumption in Residences", NBSIR-78-1501, CBT, NBS , U.S. Department of Commerce, July 1979

60. Office of Technology Assessment, APPLICATION OF SOLAR TECHNOLOGY TO TODAY'S ENERGY NEEDS, VOL II, Congress of the United States, Washington D.C. 20510, Sept. 1978.

61. D. Finn Carlson, Report to Economics Group, CBT, NBS, Honeywell Energy Resources Center, Aug. 30. 1980

62. William Carroll, Building Energy Performance Standards Studies, LBL, Nov. 29,1980.

63. Ayres Assoc., DEVELOPMENT OF BUILDING MODELS FOR ENERGY BUDGETS, Vol III, Appendix II, State of California, Energy Rsources Conservation and Development Commission, Oct. 30, 1977

64. Westinghouse, PHASE 0, ERDA, pp.6-46

65. TRW, PHASE 0, ERDA, pp.2.1-2.6

66. General Electric, PHASE 0, p.54

67. Ish Sud, Robert W. Wiggins, Jr. et. al., FINAL REPORT: DEVELOPMENT OF THE DUKE UNIVERSITY BUILDING ENERGY ANALYSIS METHOD, DUBEAM, Duke University Center for the Study of Energy Conservation, Durham, N.C.,

Nov. 30, 1979 p.L-1

68. Steven Hale, "Energy Systems for Multifamily Housing: An Urban Case Study", p.24

69. Roy E. CLark, S. Robert Hastings, "Quantified Occupant Use Factors", NBSIR 78-1501, p.55

70. Ayres Assoc., DEVELOPMENT OF BUILDING MODELS FOR ENERGY BUDGETS, Vol III, Appendix II, State of California, Energy Resources
D. Finn Carlson, HONEYWELL, report to NBS,
Conservation and Development Commission, Oct. 30, 1977.
Descriptions of commercial building profiles for weekdays and holidays are from these sources.

71. Roy E. Clark, S. Robert Hastings, NBSIR 78-1501, p.73

72. Roy E. Clark, S. Robert Hastings, NBSIR 78-1501, p.103

73. ASHRAE, HANDBOOK OF FUNDAMENTALS, 1977, p.25.17
Assuming occupants are seated, with light work

74. C.I.E, "The Availability of Daylight", TECHNICAL REPORT NR, Prepared by the C.I.E. Technical Committee, T.C.-4.2 on Daylighting, 1975

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

An interactive computer program, SOLITE, has been written to determine the incident solar radiation on urban building surfaces, street surfaces and rooms facing urban street canyons. Hourly weather data and surface descriptors are interactively entered by the user. Solar radiation data are calculated with NOAA weather tape (TMY or TRY) cloud data using the Kimura/Stephenson cloud cover algorithm. SOLITE also calculates solar radiation transmission through user specified glazing assemblies. Shadows cast by surrounding buildings and overhangs are computed, as are the interreflection effects in street canyons. In addition, internal heat gains from occupants and lighting, and daylight availability on the workplane of a room are calculated. Output options include weather data summaries, incident insolation, occupant heat gain in rooms and useable hours of daylight in a room with a given occupancy. Either hourly or daily values may be specified as output.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Daylighting; glazing transmission; solar access; solar radiation data; shading algorithms; urban solar application

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