WINDOW 4.0: Program Description

A PC PROGRAM FOR ANALYZING THE THERMAL PERFORMANCE OF FENESTRATION PRODUCTS

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MASTER

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1.0. Introduction

WINDOW 4.0 is a publicly available IBM PC compatible computer program developed by the Windows and Daylighting Group at Lawrence Berkeley Laboratory for calculating total window thermal performance indices (e.g. U-values, solar heat gain coefficients, shading coefficients, and visible transmittances). WINDOW 4.0 provides a versatile heat transfer analysis method consistent with the rating procedure developed by the National Fenestration Rating Council (NFRC). The program can be used to design and develop new products, to rate and compare performance characteristics of all types of window products, to assist educators in teaching heat transfer through windows, and to help public officials in developing building energy codes.

WINDOW 4.0 is a major revision to WINDOW 3.1 and we strongly urge all users to read this manual before using the program. Users who need professional assistance with the WINDOW 4.0 program or other window performance simulation issues are encouraged to contact one or more of the NFRC-accredited Simulation Laboratories. A list of these accredited simulation professionals is available from the NFRC (address/phone below).

For additional copies of WINDOW 4.0 and accompanying documentation, contact:

* the National Fenestration Rating Council (NFRC) at 962 Wayne Avenue, Suite 750, Silver Spring MD 20910; 301-589-NFRC or

* Bostik Construction Products, Attention: WINDOW 4.0; 1740 County Line Road; Huntingdon Valley, PA 19006

Call or write the NFRC for copies of the following related material:

* NFRC 100-91: Procedure for Determining Fenestration Product Thermal Properties (Currently Limited to U-values)

and

* FRAME: A Finite Difference Computer Program to Evaluate Thermal Performance of Window Frame Systems, developed by Enermodal Engineering (Waterloo, Ontario).
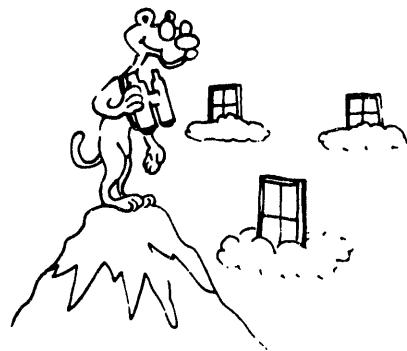
2.0 Program Overview

This section contains a quick overview of WINDOW 4.0's capabilities, a list of the performance indices calculated, and features planned for inclusion into future versions of WINDOW.

2.1 Program Capabilities

WINDOW 4.0 expands upon the capabilities of WINDOW 3.1 and offers the following features:

* An analysis methodology consistent with that developed by the National Fenestration Rating Council for the calculation of total fenestration product U-values;

* The ability to analyze products made from any combination of glazing layers, gas layers, frames, spacers, and dividers under any environmental conditions and at any tilt;

* Directly accessible libraries of window system components, (glazing systems, glazing layers, gas fills, frame and divider elements), and environmental conditions;

* The choice of working in English (IP), or Systeme International (SI) units;

* Help Screens containing much of the material in this manual;

* A print feature which generates detailed results for a window, window component, or library;

* The ability to specify the dimensions and thermal properties of each frame element (header, sills, jamb, mullion) in a window;

* New heat transfer correlations for common muntins and divided lites (dividers);

* A link with the FRAME 3.0 program;

* A multi-band (wavelength-by-wavelength) spectral model;

* A glazing library which can access spectral data files for many common glazing materials;

* A night-sky radiative model;

* A link with the DOE-2.1E building energy analysis program.

2.2 Performance Indices and Other Results

For a user-defined fenestration system and user-defined environmental conditions, WINDOW calculates:

* The U-value, shading coefficient, solar heat gain coefficient, and visible transmittance for the complete window system;

* The U-value, shading coefficient, solar heat gain coefficient, and visible transmittance for the glazing system (center-of-glass values);

* The correlated U-values of the frame and divider elements and corresponding edge-of-glass areas;

* The total solar and visible transmittance and reflectances of the glazing system;

* Color properties, i.e. L*, a*, and b* color coordinates, dominant wavelength, and purity for transmitted and reflected (outdoor) solar radiation;

* The damage-weighted transmittance of the glazing system between 0.3 and 0.6 microns.

* The transmittance of the glazing system between 0.30 and 0.38 microns;

* The angular dependence of the solar and visible transmittances, solar and visible reflectances, solar absorptance, and solar heat gain coefficient of the glazing system;

* The percent relative humidity of the inside and outside air for which condensation will occur on the interior and exterior glazing surfaces respectively;

* The center-of-glass temperature distribution.
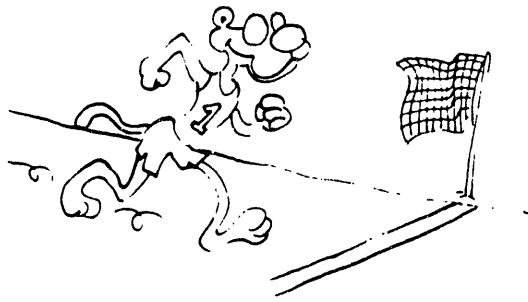
2.3 Future Work

The WINDOW program embodies the results of recent research in the field of fenestration performance. Future releases of the program are expected to incorporate:

* A more accurate analysis of the angular dependence of coated glazings;

* The influence of self-shading on performance indices;

* The effects of non-glass shading systems;

* The effects of optically complex glazing materials.

3.0. Installing and Running WINDOW 4.0

WINDOW 4.0 comes on three 3.5" IBM PC compatible diskettes. **Before installing the program, back-up the program diskettes!** To run WINDOW 4.0 you need an IBM compatible PC running DOS 2.1 or higher with at least 512K RAM. The use of a math coprocessor greatly decreases the calculation time.

3.1 Installing WINDOW 4.0

For efficient operation of WINDOW 4.0, the program should be installed on a hard drive. You may install only the program (Program Disk) or the program and accompanying spectral data files (Program Disk and Spectral Data Disks #1 and #2) on your hard disk. The program alone requires about 700K of disk space; adding the entire set of spectral data files requires a total of about 2.0 megabytes of disk space.

Before installing the program, make sure the files setting in your "config.sys" file in the root directory is set to at least 20; otherwise, the program will not operate. For example, use the following line in your config.sys file:

files=20.

Refer to your DOS manual for more information if you need it.

The install procedure copies the subdirectory tree structure shown in Figure 1 from the Program Disk onto a hard drive directory specified by you. To start the install procedure, insert the disk into a disk drive and then, from that disk drive prompt, type "w4instal".

You do not need to install the spectral data files to run the program at this time. You should to do this after you have read Appendix A: Use of Spectral Data Files. If at any time you wish to install the spectral data files, simply copy them to the subdirectory \W4LIB\SPECDAT. You may add or delete files from this subdirectory using DOS commands.

If you do not have a 3.5" drive, try and find a computer which you can use for a few minutes which has both a 3.5" drive and a 5.25" drive. If both computers can use high density 5.25" disks, you can simply use the DOS "copy" or "xcopy" (if available) command to copy all files, subdirectories, and sub-subdirectories from the 3.5" Program Disk to the 5.25" disk. If you are limited to the use of double density (360K) 5.25" disks, copy the files "W4.EXE" and SPECPACK.EXE onto one 5.25" disk; copy all other files and subdirectories onto another 5.25" disk. Return to your computer and install all the WINDOW 4.0 files, subdirectories and files, and sub-subdirectories and files (as shown in Figure 1) onto your machine. If you wish to use the data from Spectral Data Files #1 and #2, these must be similarly transferred onto 5.25" disks.

```
                    ┌─────────────────────────────┐
                    │ :\W4                        │
                    │                             │
                    │ W4.INSTAL.EXE               │
                    │ W4.EXE                      │
                    │ W4.SCR                      │
                    │ W4PARAM                     │
                    │ W4HELP.DAT                  │
                    │ W4SOLAR.DAT                 │
                    │ W4CONFIG.DAT                │
                    │ SPECPACK.EXE (Optional)     │
                    │ W4UPDATE.EXE (Optional)     │
                    └─────────────────────────────┘
```

:\W4\SOLAR	:\W4\W4LIB	
SOLSPECT.DAT	DIVEDGE.DAT	WINDOW.W4
CIE64C.DAT	GAS.DAT	DIVIDER.DAT
CIE64T.DAT	GLASS.DAT	EDGE.DAT
CIE31T.DAT	GLZSYS.W4	ENVCOND.DAT
ILLD65.DAT	SIZE.DAT	FRAME.DAT

:\W4\W4LIB\SPEDCAT	:\W4\W4LIB\FRAMEDAT
SPECTRAL DATA FILES (Optional)	FRAME 3.0 DATA FILES (Optional)
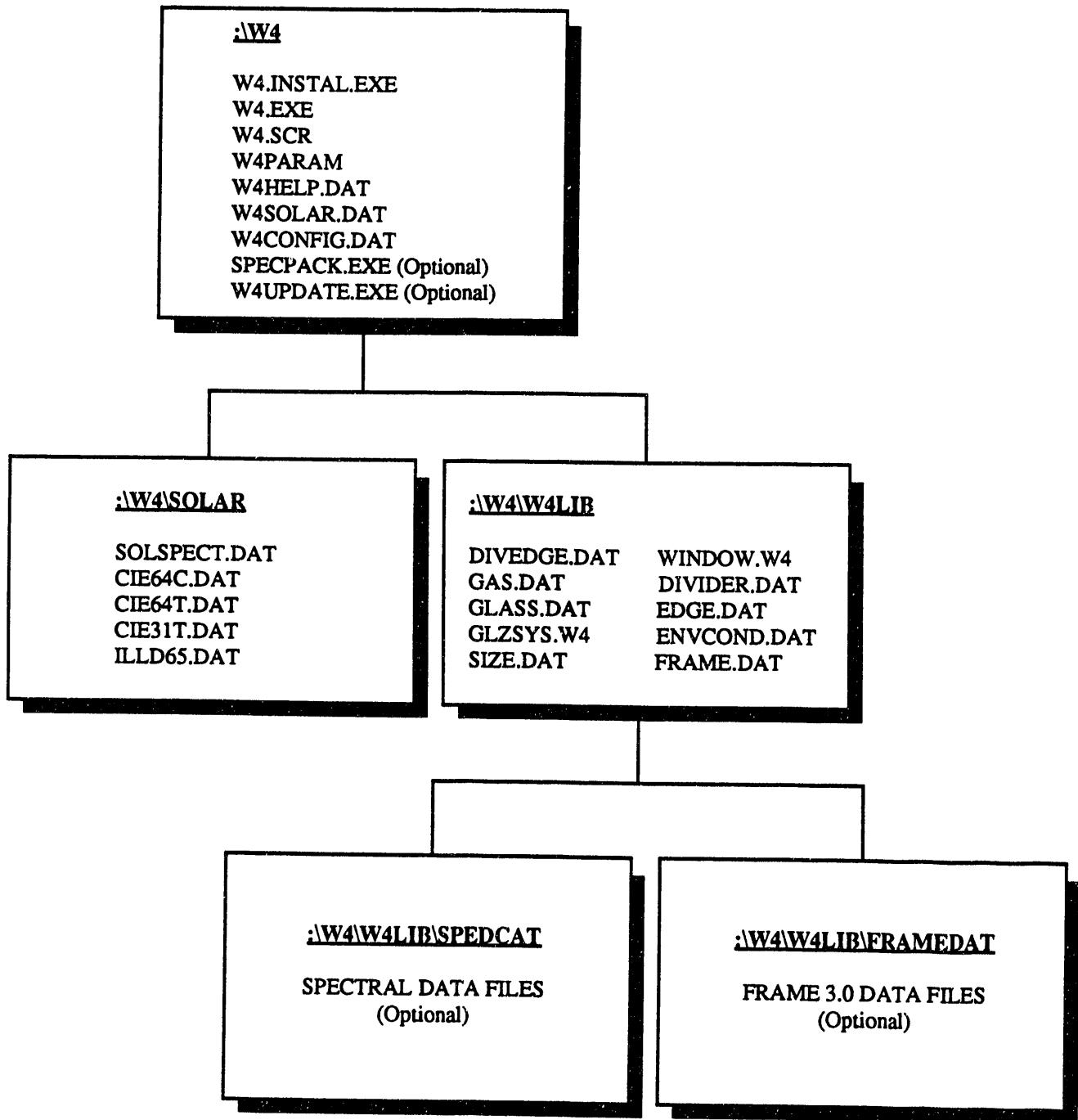
Figure 1:   Files needed to run WINDOW 4.0

If you do not have a hard disk and must run WINDOW 4.0 from a 3.5" floppy drive, simply insert the Program Disk into the floppy drive. You will not be able to access the glass manufacturers spectral data which resides on diskettes #2 and #3. You cannot run the program from a machine without a hard drive and with only a low density 5.25" floppy drive.

3.2 Running WINDOW 4.0

If you are running the program from a hard disk, go to the directory where WINDOW 4.0 was installed. Otherwise insert the WINDOW 4.0 diskette into the floppy drive. Go to the appropriate drive by typing the drive letter followed by a colon and press the "ENTER" key.

To start the program, type "W4" and press the "ENTER" key. At the title screen, you will be asked to choose between a black and white or color monitor. The program will then initialize its libraries before bringing up the Main Screen. This initialization may take several seconds or longer on a slow machine. This will happen every time you start the program. To reduce this start up time, delete entries in the glass library which you do not expect to use (see Section 4.6).

On the Main Screen you can design a fenestration product and view the performance characteristics. All libraries can be accessed from the Main Screen using the function keys. Figure 2 illustrates this program structure. Detailed descriptions for each screen are included in the next section of this manual. Read the remainder of this manual before using the program.
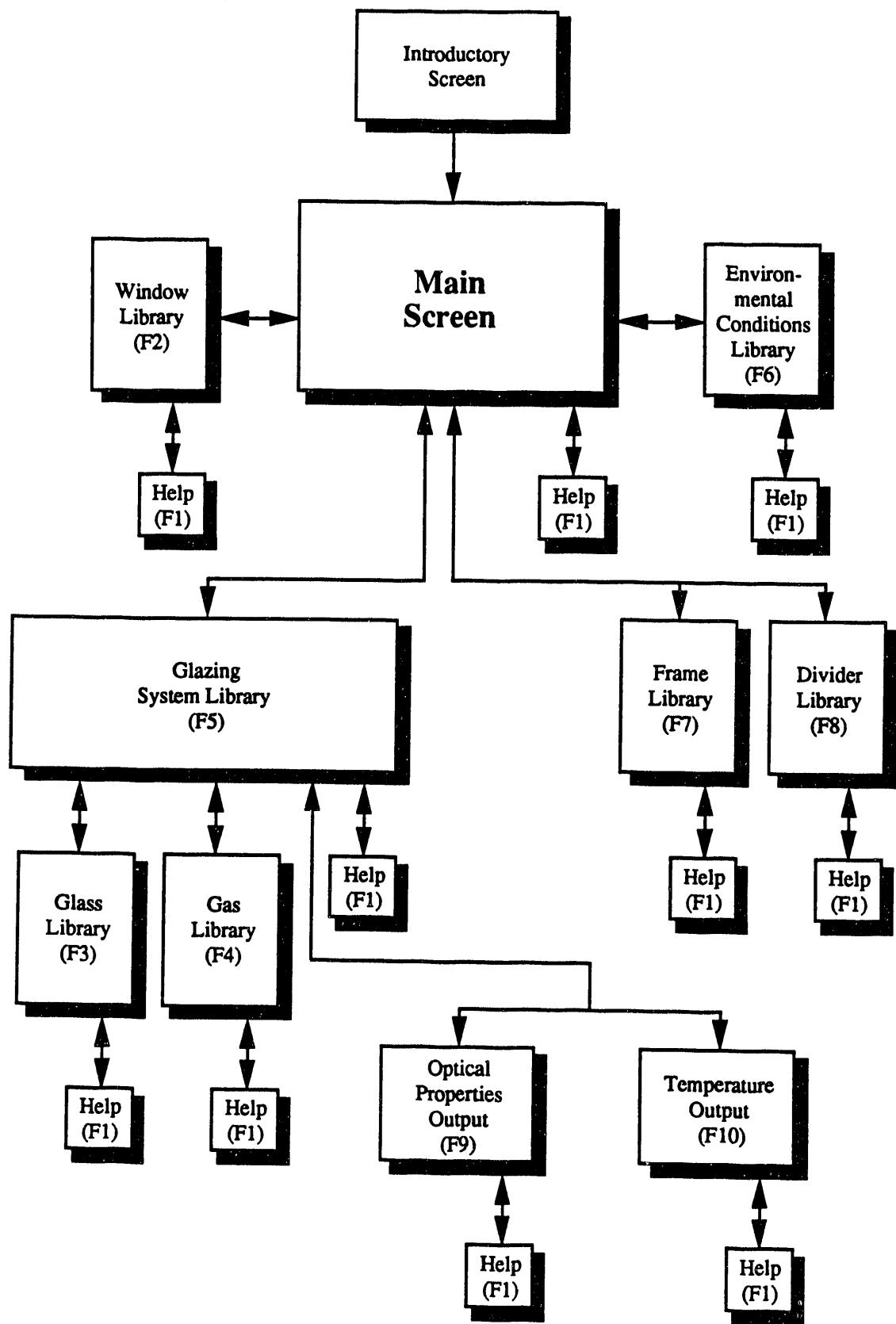
Figure 2: WINDOW 4.0 Screen Layout

4.0. Program Description

This section of the manual provides general and detailed information on the main screen, component libraries, and additional screens. For a summary of the computational methodology, see Appendix C. A glossary of terms used in WINDOW is found in Section 5.0.

4.1 General Information

WINDOW 4.0 defines a fenestration product as an assembly of one or two glazing systems, one or more frame/edge cross-sections, and, if applicable, divider elements (i.e. grilles, muntin bars, etc.). Note that we define a glazing system as an assembly of one or more glazing layers separated by gas layers (see Figure 3). WINDOW 4.0 provides libraries of system components which can be combined into a glazing system and/or a complete window system and then analyzed.

WINDOW 4.0 contains:

* a Main Screen for creating and viewing fenestration systems;
* Help Screens <F1> for each individual screen;
* a Window Library <F2> for storing assembled window systems;
* a Glass Library <F3>;
* a Gas Library <F4>;
* a Glazing System Library <F5> for creating, analyzing, and storing glazing systems;
* an Environmental Conditions Library <F6>;
* a Frame Library <F7>; and
* a Divider Library <F8>.

Thus, to construct a window, the user will first need to see if the appropriate frame elements, glazing systems, divider elements, and environmental conditions are stored in their respective libraries. Figures 4 and 5 illustrate these different window components; for more specific definitions, see [NFRC, 1991]. When all the components needed to create a window are stored in their respective libraries, a set of environmental conditions can be chosen, the glazing system and frame and divider components can be combined on the main screen, and results can be generated. If the user's glazing system(s), frame element(s), divider element(s), and/or environmental conditions are not available in their respective libraries, the user can go to the appropriate library screens and create new components. For example, additional glazing systems can be created on the Glazing System Library screen by combining glass layers and gasses from their respective libraries. Data on the thermal performance of a specific frame or divider profile generated by using the FRAME program or defined by the user can be entered into the Frame or Divider Libraries.

1/8" Glass
low-E coated

1/8" Glass

1/2" Argon-Filled Space
between Glass Panes
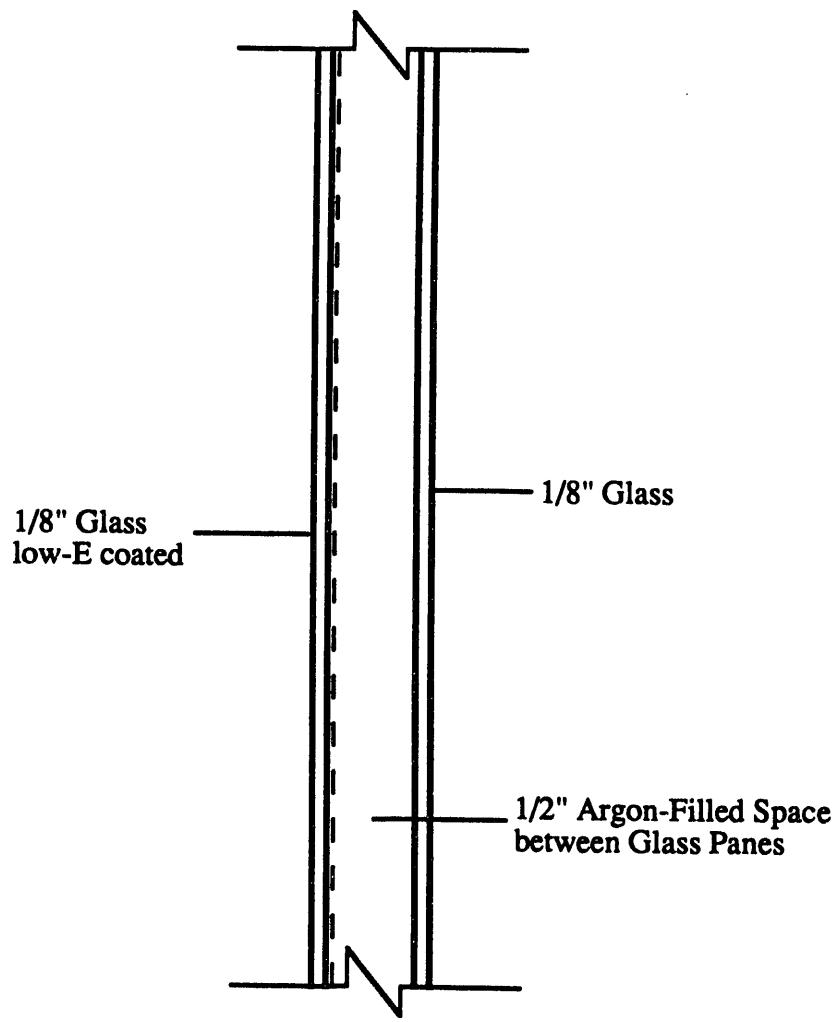
Figure 3: A Sample Glazing System

Installation
Clearance

Frame

Edge-of-Glass (2.5")

Center-of-Glass

Divider Edge (2.5")

Divider

Divider Edge (2.5")

Center-of-Glass

Edge-of-Glass (2.5")

Frame

Installation
Clearance

Projected
Fenestration
Product
Area
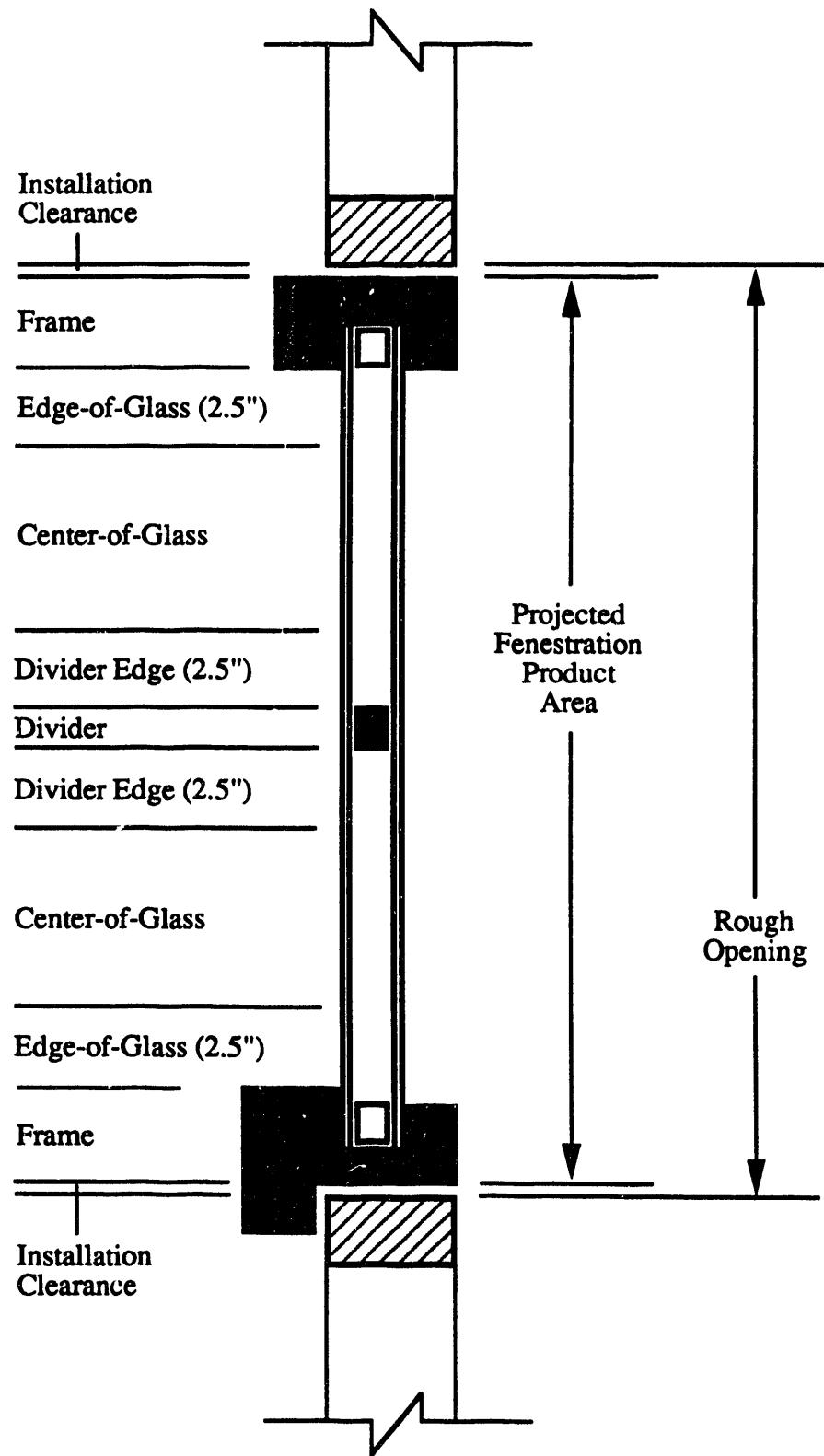
Rough
Opening

Figure 4:   Window Components in Section

Edge-of-Glass ─────

Center-of-Glass ─────

Divider ─────
Divider Edge ─────

Frame ─────
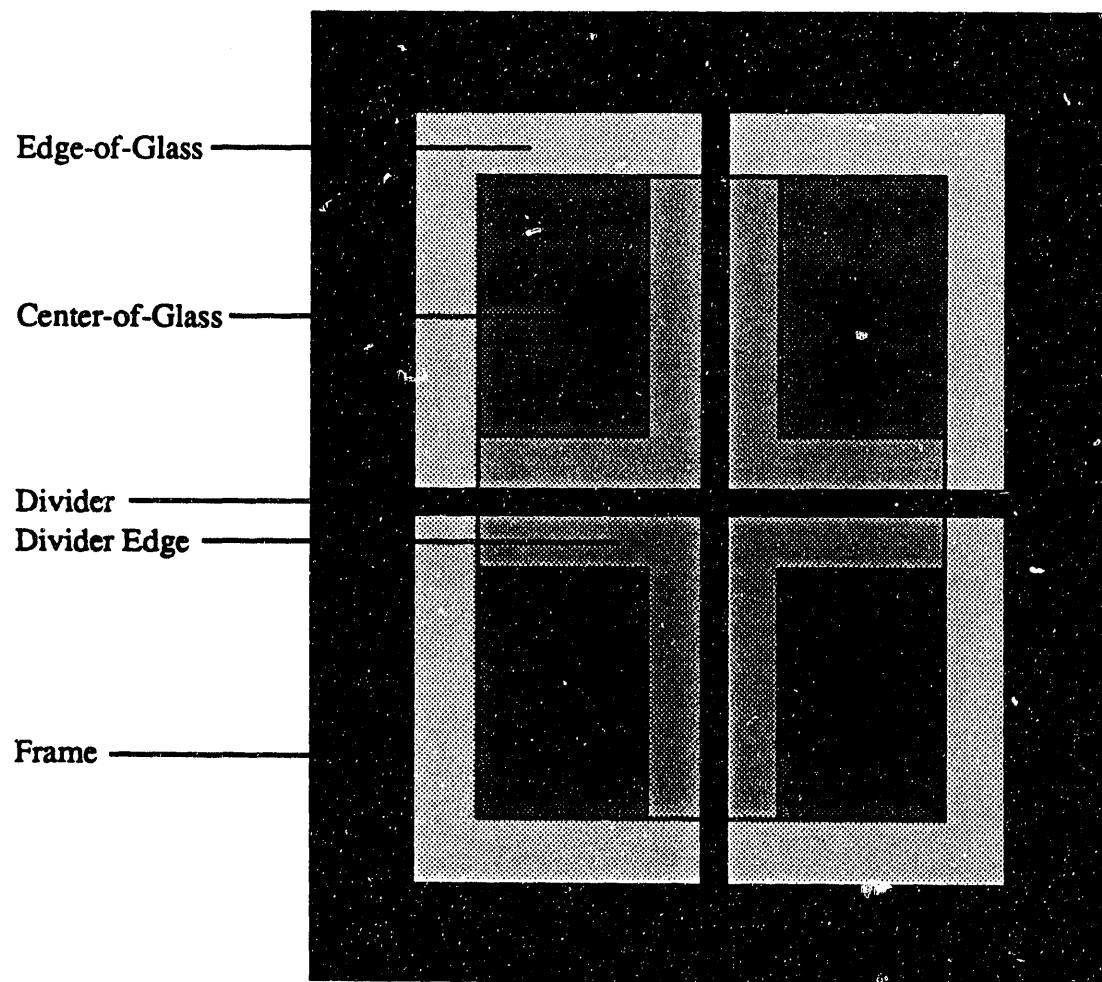
Figure 5: Window Components in Elevation

All screens can be accessed through the function keys from any other screen. "Esc" moves the user from a library screen to the Main Screen.

The WINDOW 3.1 user who is only interested in glass and glazing system properties can simply skip over the main screen and proceed directly to the Glazing System Library screen. All center-of-glass properties calculated by WINDOW 3.1 are now found on the Glazing System Library screen and its two back-up screens, the Optical Properties Output screen and the Temperature Output screen.

4.2 Main Screen

4.2.1 Layout

On the main screen, the user designs and analyzes a fenestration product made up of any combination of glazing systems, frame elements, and divider elements for a given set of environmental conditions. [Note that in this manual we use the terms fenestration product and window interc. angeably.] Remember, a glazing system is a user defined or default combination of glazing layers and gas layers. Glazing systems are discussed in more detail in Section 4.8. [Note: For the WINDOW 3.1 user, this distinction between fenestration or window systems and glazing systems was made in order to account for the influence of frame and divider elements in more detail, while preserving the capability to focus on the glazing elements (center-of-glass) alone.] The results presented on the Main Screen include the effects of all window components. Results for the glazing system alone (i.e. center-of-glass results) are presented on the Glazing System Library screen (F5) and accessory screens (F9 and F10).

The Main Screen is divided into six parts as shown in Figure 6. The functions of each of these six sections is discussed in the following paragraphs. A discussion of how to enter changes and calculate results on the Main Screen follows.

File management commands are found on the top left line of the main screen. These commands allow the user to save, print, quit, or change the default path for the library subdirectory. Most users will not need to use this last feature.

General Information on the window which the user must specify is found in the upper left rectangle of the main screen. Each window is identified by a window ID number and name; these must be specified so that windows saved to the Window Library will be easily catalogued. The user can choose between two modes of operation, Design or NFRC. Under the NFRC mode, the program will only accept the use of frame component U-values calculated by the FRAME program and will only operate under NFRC environmental conditions and at a vertical tilt. The Design mode allows the user complete flexibility. If the user is operating under the Design mode, a set of Environmental Conditions and a tilt must be specified. The window operator Type (i.e. casement, picture, horizontal slider, etc.), which influences the prompts for component specifications on the upper right rectangle, must also be specified here. A total window size must be chosen or specified; the total projected fenestration product area is then calculated by the program. A choice of units (SI or IP) is also offered.

Component Specifications for the operator Type chosen in the General Information section must be entered in the upper right rectangle. These include, at a minimum, frame and glazing system ID numbers. The program defaults to a case with no (i.e. 0) dividers. If

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File Management	
General Information	Component Specifications
Results	Cursor Feedback
Component Libraries	
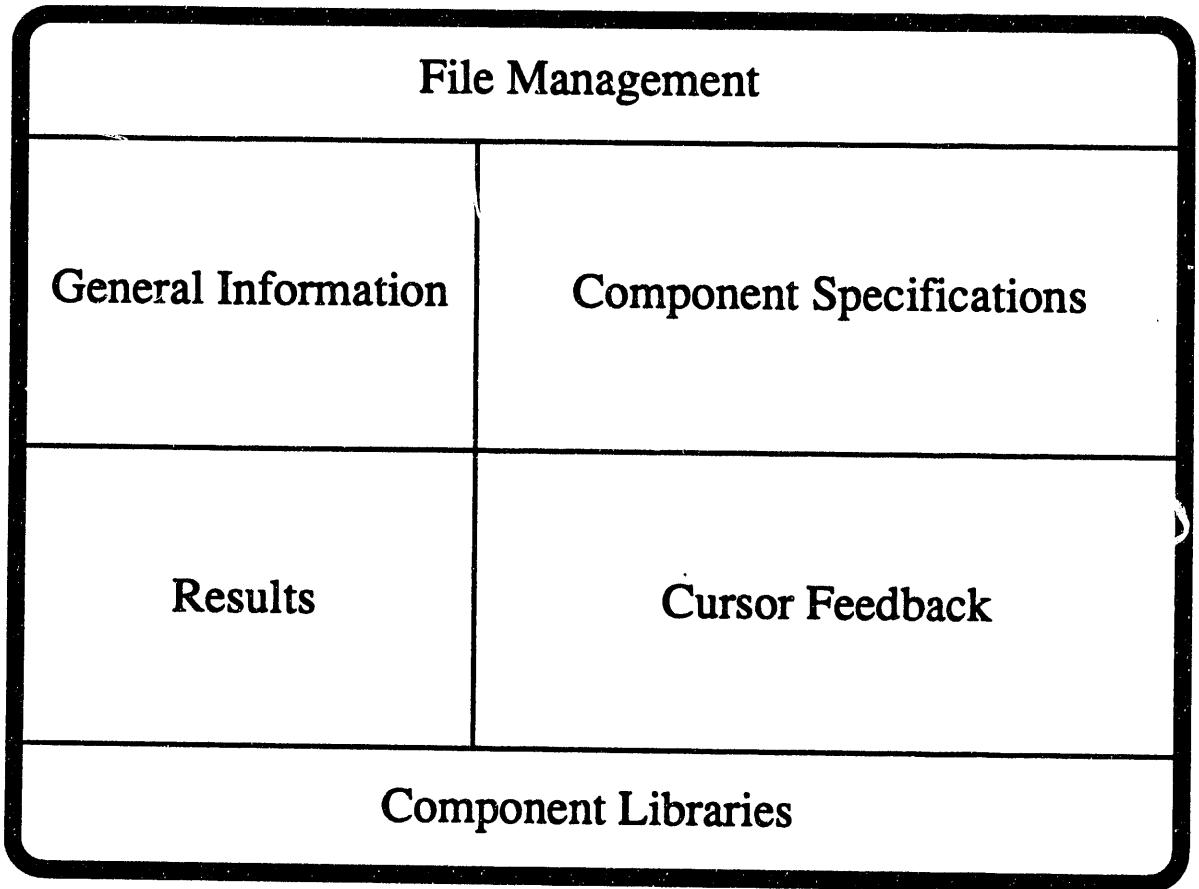
Figure 6: WINDOW 4.0 Main Screen Schematic

```
Alt-> Save  Print  Quit  Library                    W I N D O W  4 . 0

      ID:New                                    FrID:   4
    Name:Sample                        ┌──────────────────────────┐
    Mode:Design                        │  GlzSysID:  2            │
EnvCond:1 NFRC/ASHRAE        FrID:   4  │    Height:35.25"         │FrID:   4
                                        │    Div ID:  2 #H: 1 #V: 2│
    Type:Vert Slider                    │                         │
    Tilt: 90                            │         FrID:   4        │
    Size:Residential                    │  GlzSysID:  1            │
   Width:  59.06"            FrID:   4  │    Height:35.25"         │FrID:   4
  Height:  78.74"                       │    Div ID:  0            │
    Area: 32.29 ft2                     └──────────────────────────┘

   Units:IP                                     FrID:   4
                              Glazing System ID number [+,-]
 TOTAL WINDOW RESULTS
      U-value                          ID:1               Ucog: 1.11 Btu/h-ft2-F
(Btu/h-ft2-F):  0.75              Name:Single              SCc: 1.02
           SC:  0.86          # Layers:1                 SHGCc: 0.87
         SHGC:  0.74               Tilt:90                 Vtc: 0.90
           VT:  0.68          COG Area:10.20   ft2

F1-Help                   F3-Glass Lib          F5-Glz Sys Lib        F7-Frame Lib
F2-Window Lib             F4-Gas Lib            F6-EnvCond Lib        F8-Divider Lib
```

Figure 7: Sample Main Screen

dividers are used in a window product, the number of horizontal and vertical dividers per glazing system must be specified, along with the divider ID number(s). These component ID numbers are all available from their respective libraries.

Cursor Feedback information is provided in the bottom right rectangle. Detailed information on the field highlighted by the cursor is found in this area. This information can range from a simple clarification of the field (i.e. with "Units") to detailed technical information on a component (i.e. with "Glazing System").

Results for the total window system are included in the bottom left rectangle. These include the U-value, solar heat gain coefficient, shading coefficient, and visible transmittance for the total window system (all frame, divider, and glazing system elements). This area is not accessible by the cursor.

The **Component Libraries** available with the Function keys are listed at the bottom of the screen.

A sample Main Screen is shown in Figure 7.

4.2.2 Operation

Designing a window product on the main screen is a relatively simple process. To change any entry on the main screen, move the cursor there with the arrow keys, type in your change, and press the "Enter" key. The following paragraphs discuss some of the main screen's not-so-obvious features.

A window system will appear on the main screen. This is the last system which was modeled using the program. If you want to design your own window system, start changing the appropriate parameters until they describe your window system. Start with the General Information rectangle in the upper left before moving on to the Component Specifications section.

One of the first things you may want to do is to define a new name for your window system (change the number just before saving the completed window). Once you enter a new number, WINDOW will ask you if you wish to "add" this window to its window library; you must answer yes in order to keep working on it. Results for your window can be calculated at any time by pressing the space bar. Once you change a field, the results will be replaced with a question mark.

In the General Information section, the user can scroll through the options available for most fields by using the < + > and <-> keys. If this feature is available, it is noted on the top line of the Cursor Feedback section. Choices for each field are either fixed (i.e. tilt, units, type) or must be altered from specific library screens.

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Typical NFRC and ASHRAE sizes are available to the user. To access any of these sizes, use the < + > or <-> keys to circle through the available sizes until the appropriate size appears. For a user-defined size, circle through the options until the choice "Custom" appears; the width and the height can now be modified.

For most window types, the product's area is automatically calculated from the Height and Width and is not editable by the user. However, for Combination windows, which are constructed from a series of previously saved windows and are often used to represent greenhouse/garden and bay/bow windows, the user is allowed to specify an Area which is different from the total surface area. A greenhouse or bay window which projects out from a wall has window elements perpendicular to the wall; thus the surface area is greater than the opening area. Since a window's thermal properties are often multiplied by the rough-opening area to determine heat losses or gains, the U-value, solar heat gain coefficient, shading coefficient, and visible transmittance for a greenhouse or bay window should be based on the projected area, not the total surface area. Care should be taken when using solar heat gain and visible properties of projecting window products calculated using this or any other simplified procedure.

Once entries in the General Information section have been defined, the user should move on to defining elements in the Component Specifications section. Frame elements must be defined separately for each frame element of the window by referencing the appropriate number from the Frame Library (see Section 4.10). If all frame elements are the same record, the user can use the "<Alt> C" command to copy a specific frame element entry to all other entries. A glazing system (see Section 4.8) can be chosen by entering the number of a predefined glazing system from the Glazing System Library. If you are specifying glazing systems for a horizontal or vertical slider or for a double door, the width or height of the glazing systems must also be specified. If no dividers (see Section 4.11) are part of the window, use 0 for divider type. If dividers are used, enter the number of vertical and horizontal bars (not glass units). Do not use dividers to refer to meeting rails in sliding windows; specify the appropriate window type in the General Information section.

The file management commands are all accessed by holding down the "Alt" key and pressing the first letter of the desired function. Save allows a user to save a window system to the Window Library (F2). Note that such a save from the Main Screen does not automatically save the window system to disk; this can be done from the Window Library screen or when prompted by the program when the user wants to quit. More detail on the Print feature is found in Section 4.5: Window Library. Quit first asks the user if he/she wants to save additions to the window or component libraries to the hard disk so that they will be available the next time the program is used. The <Alt> L command is an advanced feature of this program which allows the user to change the name of the default subdirectory where all library data files are located; more detail on this feature is found in Section 4.4.2 of this manual.

4.3 Help Screens <F1>

WINDOW 4.0 provides an extensive series of Help Screens, which can be accessed by pressing <F1> from any of the other screens. All input and output fields are defined on the Help Screens.

From any Help Screen, the <Page Up> and <Page Down> keys will circulate you through the entire sequence of Help Screens, giving you all the information to run the program. The <Tab> key moves you to the next topic; shift <Tab> moves to the last topic; <Home> moves to the first page; <End> moves to the last page. The <ESC> key returns you to the screen from which you originally accessed the Help Screens.

Read the Help Screens before using the program.

Figure 8 is a sample of a Help Screen.

```
MAIN SCREEN & INTRODUCTION                                      HELP

WINDOW 4.0 calculates the energy performance indices for fenestration
products (window systems) composed of glazing, frame, and divider
elements.  Libraries of window systems, glazing systems, glazing
materials, gases, frames, dividers, and environmental conditions for the
design of fenestration systems are supplied and can be expanded.

The program consists of 10 screens which can be accessed through the
function keys:

        <ESC>      MAIN SCREEN
        <F1>       HELP SCREENS (Help)
        <F2>       WINDOW LIBRARY (Window Lib)
        <F3>       GLASS LIBRARY (Glass Lib)
        <F4>       GAS LIBRARY (Gas Lib)
        <F5>       GLAZING SYSTEM LIBRARY (Glz Sys Lib)
        <F6>       ENVIRONMENTAL CONDITIONS LIBRARY (EnvCond Lib)
        <F7>       FRAME LIBRARY (Frame Lib)
        <F8>       DIVIDER LIBRARY (Divider Lib)
        <F9>       OPTICAL PROPERTIES (Optical)
        <F10>      TEMPERATURE DISTRIBUTION (Temperature)


PgDn/PgUp:next/previous screen    Tab/Shift-Tab:next/previous topic    Home:Intro
```

Figure 8: Sample Help Screen

4.4 General Library Features

WINDOW 4.0 contains seven libraries accessed with the <F2> through <F8> keys. While the following sections discuss each of these libraries in more detail, this section presents material common to all libraries and discusses how WINDOW 4.0 can access additional sets of libraries. Since the Save feature for the Window (F2) and Glazing System (F5) Libraries cross-references items in other component libraries, a discussion of the program's saving logic used is also included in this section.

As a general note, we remind the user that there is always the potential that one of WINDOW's many data files (which store library information) may become unusable. We therefore recommend that you regularly backup all files in the \W4LIB subdirectory and its two sub-subdirectories, FRAMEDAT and SPECDAT. Files in the \W4LIB subdirectory contain the information saved in WINDOW's libraries, as listed below. Do not edit these files outside of WINDOW. If problems do arise with one or more of your libraries, you can reinstall the program with your backed-up library data files.

File Name	Purpose
size.dat	Size Library from Main Screen
window.w4	Window Library
glass.dat	Glazing Library
gas.dat	Gas Library
envcond.dat	Environmental Conditions Library
glzsys.w4	Glazing System Library
divider.dat	Divider Library
frame.dat	Frame Library

4.4.1 Features Common to All Libraries

With each library, features are available to Add, Delete, Edit, Goto, Show detail, Update, and View library records. All of these options are not available with each of the libraries; refer to the specific section in this manual or the Help Screens for detailed information on the options available within individual libraries. The available features appear above the function keys at the bottom of each screen. By typing the first letter of the feature, you can:

> **Add** a record to a library using
> > **New** to enter values from scratch, or
> > **Copy** an existing record to a new record and then edit it.
>
> **Delete** a record or range of records from a library by
> > **Name** (use of wildcard * acceptable) or
> > **ID** number.
>
> **Edit** a record from a library by specifying its ID number.
>
> **Goto** a record in a library by specifying its ID number.

Show more information on a specific record.

Update a record, or range of records, in a library. Use this feature after changing information referenced by a library record. WINDOW will then perform the appropriate calculations and alter the properties of the record accordingly.

To save changes to disk, use the <Alt> S command or wait until you are prompted when you exit the program. See Section 4.4.3 on Editing/Saving Library Logic, Section 4.5 on the Window Library (F2), Section 4.6 on the Glass Library (F3), Section 4.8 on the Glazing System Library (F5), Section 4.10 on the Frame Library (F7), and Section 4.11 on the Divider Library (F8) for more information.

View a group of library records. Options (not available in all libraries) include viewing the contents by:
> **All:** all records,
> **Emiss:** enter minimum and maximum values of glazing emissivity,
> **Frame Attribute:** search by frame attribute
> **Layer:** enter the number of glazing layers,
> **Name:** enter a name or the beginning of a name common to any number of
>> library records using the DOS wild-card character, *, (e.g. CLE*),
> **SC:** enter minimum and maximum values of shading coefficient, SC,
> **Thickness:** enter minimum and maximum values of glazing thickness,
> **Type:** enter a window type (e.g. FIXED, CASEMENT, ...)
> **Vt:** enter minimum and maximum values of visible transmittance, Vt
> **U-value:** enter minimum and maximum values of U-value.

The arrow keys and the <PgUp> and <PgDn> can be used to move the user through the entries in the library when there are more entries than there is room on the screen. The <Home> key moves to the top of the library while the <End> key moves to the last entry in the library.

4.4.2 Using Another Set of Libraries

As shown in Figure 1, all the information stored in WINDOW 4.0's libraries is stored in files and sub-subdirectories under the \W4LIB subdirectory. If you would like to use another set of libraries (perhaps given to you by someone else), you may do so provided that all library files and sub-subdirectories are provided to you and stored in a subdirectory off of the main WINDOW 4 directory. Note that if only one library changes, a complete new subdirectory must be created which contains all the library files.

Thus, to use this feature, you would have another branch off your main directory running parallel to the \W4LIB subdirectory. You may have as many of these paths as you wish; however the basic set of library files must include those shown in Figure 1 under the \W4LIB subdirectory. The path to the replacement to \W4LIB can be chosen using the <ALT> L command on the top of the Main Screen.

4.4.3 Editing/Saving Library Logic

Saving existing entries which have just been edited can have unforeseen ramifications if the user does not completely understand the implications of saving an edited entry. This section should therefore be read very carefully.

Within WINDOW 4, there are three levels of saved components. Glass, gas, frame, divider, and environmental conditions are the basic building blocks. Glazing systems are an intermediate level and window systems represent the final level. Therefore, editing any one of the basic building blocks (i.e. a glass entry) can have significant implications on glazing systems and window systems previously saved which referenced that basic building block before it was edited.

For example, let's say Glass #99 has a low-emittance coating with an emittance of 0.12 and is used in glazing systems #11, #12, #13, and #14 and in turn, these four glazing systems are used in windows #55-#75. Suppose that, at some later point, the coating's emittance is improved to 0.10. The user now has two options on how to handle this change. Either option is acceptable and the choice depends on the user's intentions and operating style.

One option would be to call this a new glass product (#299 for example). The user would then have to create four new glazing systems (lets call them #211, #212, #213, and #214) and a new set of window products (named perhaps #255-#275).

A second option would be to simply change the emittance of Glass #99. Since glazing systems #11 - #14 referred to Glass #99, they would then have to change accordingly. Window products #55 - #75 would also have to change. When such a change is made, WINDOW prompts the user to Update the dependent library entries by replacing all the calculated results with a "?". In this example, if the emittance on Glass #99 is simply changed, all the results calculated for glazing systems #11 - #14 would first have to be Updated or recalculated and then all the results for windows #55 - 75 would also have to be Updated or recalculated. All previous data is then lost.

If, in a particular library, question marks appear for calculated results, it means that you have changed data or records which make up that entry. This is most likely to happen in the Glazing System Library and the Window Library. Use the Update feature to display the proper results. If data or records were inadvertently changed, quit the program and do not save any changes in the library or libraries in question to disk; this assumes your data was correct when you started and that you don't mind loosing all data entered since you began the session.

4.4.4 Updating WINDOW 3.1 Libraries

If you wish to use your glass, gas, or window libraries from WINDOW 3.1 or WINDOW 3.2, you may import the files "glass.dat", "gas.dat", and/or "window.dat" from your WINDOW 3 directory into the main WINDOW 4 directory. Then run the program W4UPDATE.EXE by simply typing "W4UPDATE." Your WINDOW 3 files will now be converted to WINDOW 4.0 format. Your glass library will still be called glass.dat, your gas library will still be called gas.dat, but your window library will be renamed to glzsys.w4 since it is now a Glazing System Library. These files must then be moved to the W4LIB subdirectory in order to be able to be used by the program. However, before doing this, copy the existing glass.dat. gas.dat, and glzsys.w4 files in the \W4LIB subdirectory which came with WINDOW 4.0 to new files for safekeeping.

However, because there is a substantial amount of glass and gas data included with WINDOW 4.0, we do not recommend that you simply replace the libraries which came with WINDOW 4 with your WINDOW 3 libraries. We suggest you use this opportunity to prune your existing libraries and merge them into the new WINDOW 4 libraries.
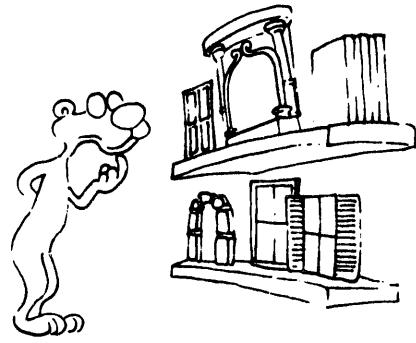
4.5 Window Library <F2>

The Window Library screen, accessed with the <F2> key from any other screen, contains a short descriptive summary of each window system stored in the Window Library. Performance indices are presented for the total window properties. Note that all window systems are designed and stored from the Main Screen. More detailed information than that shown on this screen can be seen by loading a window system onto the Main Screen. To do this, return to the Main Screen by using the <Esc> key and enter the ID number for the window system you wish to find out more about.

On the Window Library screen, the user can Add, Delete, Update, and View window system library records. The user can View by All, Name, Type, and U-value.

Window systems Added to the Window Library must be edited or altered on the Main Screen. Use the Update command to recalculate the properties of a window system whose component records have been edited and changed since the window system was last saved (see Section 4.4.3).

Use the <ALT> S command to automatically save current Window Library records to disk under the \W4LIB file "window.w4". A maximum of 9999 entries may be stored in this library if enough hard disk space is available on your computer.

With the <ALT> P print command the user may print a listing of the library. To print detailed information on a specific library entry that entry must be loaded onto the Main Screen and the <Alt> P option used from the Main Screen. If the user wishes to print detailed information on a specific entry (to a printer or a file), two report options are available. The "WINDOW 4" option prints all relevant data on the window system while the "DOE-2" option prints a file (in SI units only) for use by the DOE-2.1E program. The "WINDOW 4" option is recommended unless the user is looking to specifically analyze a window system with the DOE2.1E program.

<F1> will access the Window Library Help Screen for more information. See Section 4.4.1 for general library information which also relates to this library.

Figure 9 is a sample Window Library screen.

```
Alt-> Save   Print   Quit                        W I N D O W   4 . 0
                            ═══ Window Library ═══
                                     │Width │Height│U-Value│    │    │    │
        ID   Name           Type     │ in   │ in   │Btu/h- │ SC │SHGC│ VT │
                                     │      │      │ ft2-F │    │    │    │
       ─────────────────────────────────────────────────────────────────────
         1 Sample           Casement │59.055│78.740│  0.206│0.55│0.48│0.49│
         2 Test             Vert Slider│59.055│78.740│  0.749│0.86│0.74│0.68│




           End of Library

Add     Delete    View     Goto    Update           ESC returns to Main screen
F1-Help                  F3-Glass Lib        F5-Glz Sys Lib         F7-Frame Lib
F2-Window Lib            F4-Gas Lib          F6-EnvCond Lib         F8-Divider Lib
```

Figure 9: Sample Window Library
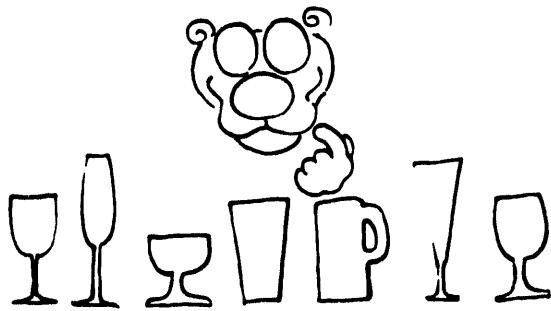
4.6 Glass Library <F3>

The thermal and optical properties of glazing materials, such as glass, acrylic, and polyester films, are stored in the Glass Library. The total solar, visible, and thermal infrared optical properties of a glazing along with the thickness and thermal conductivity are displayed. A record may also have detailed spectral data associated with it. Results which have an "*" at the end of their name have an associated spectral data file. Spectral-averaging and spectral data files are explained in detail in Appendix A.

Glazing records 1-605 in the Glass Library sent out with WINDOW 4.0 represent a broad cross-section of products available on the market today. These glazing were used in the compilation of the window library for the DOE-2.1E building energy simulation program. This listing includes the following:

* Typical clear and tinted glazings,
* Stainless steel reflective (REF A) coatings on clear and tinted (bronze) substrates,
* Titanium reflective (REF B) coatings on clear and tinted (bronze) substrates,
* Pewter reflective (REF C) coatings on clear and tinted (bronze) substrates,
* Pyrolitic low-emissivity coatings with an emittance of 0.4 (PYR A) on a clear substrate,
* Pyrolitic low-emissivity coatings with an emittance of 0.2 (PYR B) on a clear substrate,
* Typical sputtered low-emissivity coatings on clear and tinted (bronze) substrates,
* Typical spectrally selective low-emissivity coatings on clear and tinted (bronze) substrates,
* Thin polyester films with varying low-emissivity coatings resulting in varying solar and visible properties.

The remainder of the records in the library are specific manufacturers' products, the data for which was supplied by manufacturers in November, 1991. See Appendix A for more information on the manufacturers' products. The following table summarizes the manufacturers data in the Glass Library.

Glass ID Numbers	Description
1000-1001	AFG
1100-1116	DUP (DuPont)
1200-1224	MON (Monsanto)
1300-1333	FMC (Ford)
1400-1438	LOF
1500-1506	SWT (Southwall)
3000-3099	GRD (Guardian)
4000-4133	INT (Interpane)
5000-5136	PPG
6000-6103	VIR (Viracon)

Note that in total, approximately 700 entries are provided with the program. To improve the program's operating speed, the user may wish to delete those records which he/she

does not expect to use. However, before doing this, the \W4LIB file "glass.dat" should be copied to another name (i.e. "glass.bak") so that this data is not permanently lost.

The user can Add, Delete, Edit, Goto, Update, and View Glass Library records. The Update command is only relevant when spectral data files are used (see Appendix A). The user can View by All, Name, Thickness, or Emiss. A maximum and minimum is required with the Thickness and Emiss specifiers.

Use the <ALT> S command to save all changes to disk under the \W4LIB file "glass.dat". A maximum of 9999 glazing may be stored in this library if there is enough space on your hard disk.

The <ALT> P command prints a listing of the library contents to a file or a printer.

<F1> will access the Glass Library Help Screen for more information. See Section 4.4 for general library information which also relates to this library.

Figure 10 is a sample Glass Library screen.

```
Alt-> Save   Print   Quit                        W I N D O W   4 . 0
                               Glass Library
 ID   Name          Thick Tsol     Rsol    Tvis    Rvis    Tir     Emis     Cond
                    in          1     2          1     2          1     2    Btu/h-
                                                                             ft-F

  1  CLEAR          .0984 .856 .077 .077 .902 .082 .082 .000 .840 .840  0.520
  2  CLEAR          .1181 .837 .075 .075 .898 .081 .081 .000 .840 .840  0.520
  3  CLEAR          .1969 .800 .072 .072 .888 .080 .080 .000 .840 .840  0.520
  4  CLEAR          .2362 .775 .071 .071 .881 .080 .080 .000 .840 .840  0.520
  5  CLEAR          .3937 .701 .066 .066 .859 .078 .078 .000 .840 .840  0.520
  6  CLEAR          .4724 .653 .064 .064 .841 .077 .077 .000 .840 .840  0.520
  7  BRONZE         .1181 .645 .062 .062 .685 .065 .065 .000 .840 .840  0.520
  8  BRONZE         .1969 .544 .056 .056 .592 .060 .060 .000 .840 .840  0.520
  9  BRONZE         .2362 .482 .054 .054 .534 .057 .057 .000 .840 .840  0.520
 10  BRONZE         .3937 .326 .048 .048 .379 .050 .050 .000 .840 .840  0.520
 11  BRONZE         .4724 .246 .045 .045 .294 .047 .047 .000 .840 .840  0.520
 12  GREY           .1181 .626 .061 .061 .611 .061 .061 .000 .840 .840  0.520
 13  GREY           .1969 .519 .055 .055 .498 .055 .055 .000 .840 .840  0.520
     More...

Add      Delete    Edit      View    Goto      Update   ESC returns to Main screen
F1-Help                      F3-Glass Lib           F5-Glz Sys Lib        F7-Frame Lib
F2-Window Lib                F4-Gas Lib             F6-EnvCond Lib        F8-Divider Lib
```

Figure 10: Sample Glass Library

4.7 Gas Library <F4>
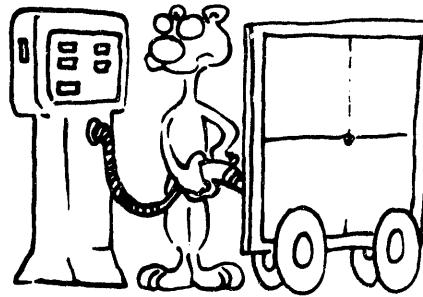
The Gas Library presents gas options for use as gap fills. The user can choose between air, argon, krypton, CO2, SF6, any fractional combinations of air, argon, and krypton, or any fractional combinations of argon and SF6 .

Note that WINDOW does not model infrared absorption in gases and thus the actual heat transfer through windows without low-emissivity coatings and filled with IR absorbing gases (SF6 , CO2 , and fluorocarbons) may be slightly less than that predicted by WINDOW [Reilly, 1990].

The user may Add, Delete, Edit, Goto, and View entries in the library. The first five entries in the library are permanent and must be copied with the Add command in order to Edit any one of them. For those who use several gas mixtures frequently, mixtures can be fixed and then copied to a new record. The user can View by Name only.

Use the <ALT> S command to save all changes to disk under the \W4LIB file "gas.dat". A maximum of 999 gas records may be stored in this library. The <ALT> P command prints a detailed summary of a gas record or a listing of the library contents to a file or a printer. Use the <ESC> command to return to the Main Screen, and the <ALT> Q command to quit the program.

<F1> will access the Gas library Help screen for more information. See Section 4.4.1 for general library information which also relates to this library.

Figure 11 is a sample Gas Library screen.

W I N D O W 4 . 0

Gas Library

ID	Name	Cond Btu/ h-ft- F	dCond Btu/h- ft-F2 x E-5	Visc lb-s/ ft2 x E-5	dVisc lb-s/ ft2-F x E-8	Dens lb/ft3	dDens lb/ft3- F	Pran	dPran 1/F
1	Air	.0139	2.4395	0.0361	0.1161	0.0805	-0.0002	.7200	.00100
2	Argon	.0094	1.6050	0.0441	0.0731	0.1111	-0.0002	.6800	.00037
3	Krypton	.0050	0.8988	0.0476	0.0871	0.2335	-0.0005	.6600	.00001
4	CO2	.0084	2.3753	0.0290	0.0581	0.1236	0.0000	.7900	.00001
5	SF6	.0075	2.2790	0.0295	0.0464	0.4120	-0.0008	.6900	.00150
6	Air/Argon/Kryp	Air:	44%	Argon:	22%	Kryp:	34%		
		.0095	1.6502	0.0443	0.0787	0.1382	-0.0003	.6908	.00052
7	SF6/Argon	SF6:	78%	Argon:	22%				
		.0078	2.1307	0.0310	0.0515	0.3447	-0.0007	.6878	.00125
	End of Library								

Add   Delete   Edit   View   Goto   ESC returns to Main screen
F1-Help   F3-Glass Lib   F5-Glz Sys Lib   F7-Frame Lib
F2-Window Lib   F4-Gas Lib   F6-EnvCond Lib   F8-Divider Lib

Figure 11: Sample Gas Library

4.8 Glazing System Library (GlzSys Lib) <F5>

This screen is both a library of glazing systems as well as the screen to work from if the user is only interested in designing and analyzing glazing systems. The user who is only interested in center-of-glass properties can consider this screen as their "main screen."

Remember, a glazing system consists of glazing elements separated by gas layers. A glazing system can be thought of as just the center-of-glass area of a window system. Performance indices for the glazing system do not include the influence of the frame, divider, and associated edge areas.

The top half of the screen shows a one line description of glazing systems which are currently stored in the library. This one line description includes a number, name, environmental conditions, and basic performance results. Even though only four glazing systems (four lines) can be viewed at any one time, the library can hold up to 999 entries, as long as there is enough hard disk space on your computer. Use the arrow keys or the <PgUp> and <PgDn> keys to view additional entries.

Note that each glazing system has a set of environmental conditions associated with it. When a glazing system is used as part of a window system on the main screen, the conditions specified for the total window system must match those in the Glazing System Library.

The bottom half of the screen displays layer by layer data on the glazing system highlighted on the top half of the screen. Use of the arrow keys will change the highlighted glazing system on the top half; the bottom half will follow accordingly. Pressing Edit allows the user to use the arrow keys to edit the glazing system layer by layer.

Be sure that when defining glazing systems with coated glazings, the coating is on the proper surface of the glazing system. Surfaces and layers are numbered from the outside in. Thus, surface 1 of layer 1 is the outer surface, surface 2 of layer 1 is the glazing system's #2 surface, surface 1 of layer 2 is the glazing system's #3 surface, etc. While editing a glazing system, you can flip the surfaces of an individual layer by moving the cursor to the layer ID# and pressing "F".

The user can also Delete, Goto, Update, and View glazing systems within the Glazing System Library. As presented in Section 4.4.3, the Update feature allows WINDOW to recalculate results for a series of glazing systems were a component property (i.e., a glass property) has changed. The user can View a group of entries by Name, Layer, U-value, SC, or Vt. A maximum and minimum value is required with the U-value, SC, and Vt specifiers.

Additional information on a specific glazing system can be accessed from this screen. Pressing the <F9> key brings up more information on the optical and solar properties of the glazing system while the <F10> key presents information on the temperature distribution throughout the glazing system.

Use the <ALT> S command to save all changes to disk under the \W4LIB binary file "glzsys.w4." A maximum of 999 glazings may be stored in this library. The <ALT> P command prints either a detailed summary of a glazing system or a listing of the library contents to a file or a printer. Use the <ESC> command to return to the Main Screen, and the <ALT> Q command to quit the program.

<F1> will access the Glazing System Library Help Screen for more information. See Section 4.4 for general library information which also relates to this library.

Figure 12 is a sample Glazing System Library screen.

4.8.1 Optical Properties <F9>

This screen provides detailed optical and solar properties for a glazing system selected on the Glazing System Library screen. This screen is therefore only accessible from the Glazing Systems Library screen.
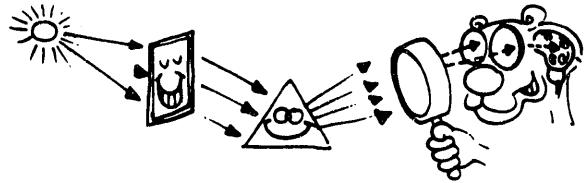
Solar and visible transmittances and reflectances for the glazing system, the solar heat gain coefficient (SHGC) for the glazing system, and the solar absorptance within each glazing layer at normal incidence are displayed. The user has the option of viewing these properties as a function of incidence angle.

The glazing system's shading coefficient, SC, damage-weighted transmittance (Tdw), unweighted transmittance between 0.30 and 0.38 microns (Tuv), and color properties for normal incidence solar radiation are presented. The color properties presented are for transmitted radiation and front surface reflected solar radiation and include the CIE 1976 L*, a*, b* color coordinates, the dominant wavelength, and percent purity. Tdw, Tuv, and the color properties are only calculated when spectral data files are present for all layers.

WINDOW 4 will optionally calculate the angular solar heat gain and optical properties of a glazing system. This option appears as the AngCalc feature displayed directly above the function keys on the screen and can be turned on and off by typing A. Unless you are specifically interested in these properties, we recommend keeping them off in order to speed up the program's calculation time.

Use the <ALT> P command to print the contents of this screen to a file or a printer. The <ESC> command returns the program to the Glazing System Screen, and the <ALT> Q command quits the program.

<F1> will access the Optical Properties Help Screen for more information.

Figure 13 is a sample Optical Properties screen.

Glazing System Library

ID	Name	#Lay	Tlt deg	Env Cond	KEFF Btu/h-ft-F	Width in	Uc Btu/h-ft2-F	SCc	SHGCc	Vtc	RHG Btu/h-ft2
1	Single	1	90	1NFRC/ASH	N/A	0.098	1.11	1.02	0.87	0.90	217
2	Double	2	90	1NFRC/ASH	0.0385	0.736	0.49	1.06	0.91	0.82	219
3	Six layered	6	90	1NFRC/ASH	0.0441	3.091	0.15	0.63	0.54	0.58	129
4	Triple	3	90	1NFRC/ASH	0.0163	1.335	0.15	0.58	0.50	0.62	118

More...

Glass and Gap Data for Double

	No.	Name	D(in)	Tsol	1 Rsol 2		Tvis	1 Rvis 2		Tir	1 Emis 2		Keff
Lay1	2	CLEAR	0.118	.837	.075	.075	.898	.081	.081	.000	.840	.840	.520
Gap1	1	Air	0.500										.038
Lay2	2	CLEAR	0.118	.837	.075	.075	.898	.081	.081	.000	.840	.840	.520

Add   Delete   Edit   View   Goto   Update   ESC returns to Main screen
F1-Help   F3-Glass Lib   F5-Glz Sys Lib   F7-Frame Lib   F9 -Optical
F2-Window Lib   F4-Gas Lib   F6-EnvCond Lib   F8-Divider Lib   F10-Temperature

Figure 12: Sample Glazing System Library

```
Alt-> Save   Print   Quit                          W I N D O W   4 . 0
      Optical Properties for 2 Double            Env. Cond: 1  NFRC/ASHRAE
      Angle    0°   10°   20°   30°   40°    50°   60°   70°   80°   90°  Hemis

        Vtc  0.812 0.811 0.810 0.806 0.794 0.763 0.690 0.533 0.270 0.000 0.709
        Rf   0.147 0.147 0.147 0.150 0.161 0.189 0.260 0.415 0.678 1.000 0.235
        Rb   0.147 0.147 0.147 0.150 0.161 0.189 0.260 0.415 0.678 1.000 0.235

        Tsol 0.705 0.704 0.700 0.693 0.678 0.646 0.577 0.436 0.204 0.000 0.601
        Rf   0.128 0.128 0.128 0.130 0.139 0.164 0.226 0.363 0.608 1.000 0.205
        Rb   0.128 0.128 0.128 0.130 0.139 0.164 0.226 0.363 0.608 1.000 0.205

        Abs 1 0.094 0.094 0.096 0.099 0.103 0.109 0.117 0.127 0.133 0.000 0.108
        Abs 2 0.074 0.074 0.076 0.078 0.080 0.081 0.081 0.074 0.055 0.000 0.076
        Abs 3
        Abs 4
        SHGCc 0.762 0.762 0.759 0.754 0.741 0.710 0.642 0.499 0.255 0.000 0.662

  SCc:  0.89 Color Properties    DomWL           Purity        L*       a*       b*
  Tdw:  N/A  Transmittance              um               %
  Tuv:  N/A  Reflectance                um               %

Angle Calcs                                  ESC returns to Main screen
F1-Help                  F3-Glass Lib        F5-Glz Sys Lib       F7-Frame Lib
F2-Window Lib            F4-Gas Lib          F6-EnvCond Lib       F8-Divider Lib
```

Figure 13: Sample Optical Properties Output

4.8.2 Temperature Distribution Output (Temperature) <F10>

On this screen, the temperature distribution across the glazing system selected in the Glazing System Library <F5> is displayed. This screen can only be accessed from the Glazing Systems Library screen. Temperatures for both the U-value and the Solar sets of Environmental Conditions are shown. The outside and inside air temperatures are shown, along with the temperature at each glazing surface and at the center of each glazing layer. Also included, are the percent relative humidities at which condensation will occur on the exterior and interior glazing surfaces for the U-value conditions only. If condensation will not occur, a "N/A" appears.

Use the <ALT> P command to print the contents of this screen to a file or a printer. The <ESC> command returns the program to the Glazing System Screen, and the <ALT> Q command quits the program.

<F1> will access the Temperature Help screen for more information.

Figure 14 is a sample Temperature screen.

4.8.3 Using Predetermined Glazing System Effective Conductivities

In rare situations, the user may wish to model the effect of a window system incorporating a glazing system which cannot be modeled by WINDOW (i.e. glazings with translucent insulation between them, aerogel windows, etc.). In such cases, if the glazing system's effective conductivity is determined experimentally, the user can use the effective conductivity with WINDOW 4 to determine total window system properties.

To do this, consider the entire glazing system as a glazing system of one layer consisting of a user defined glazing layer with the appropriate thickness, solar, visible, and infrared properties. The conductivity now represents the glazing system's effective conductivity. Film coefficients should not be included in the user entered effective conductivity. WINDOW will calculate these for the environmental conditions specified and add them in. All performance indices will now be calculated.

An effective conductivity of 0.02 Btu/hr-ft-F is the best available value for 0.50 pcf microlite fiberglass insulation.

```
Alt-> Save   Print   Quit                        W I N D O W  4 . 0
            Temperature Profile for Glazing System   2 Double
                                               Condensation
         Env. Conditions:   1 NFRC/ASHRAE   U-value       RH              SC

                    Outside Air           0.0°                         89.0°
                    Outer Surface         6.8°         N/A             93.9°
           Layer 1  Center                7.1°                         94.1°
                    Inner  Surface        7.5°                         94.0°
                    Outer Surface        44.7°                         90.7°
           Layer 2  Center               45.0°                         90.7°
                    Inner  Surface       45.4°         41.2%           90.5°
                    Inside Air           70.0°                         75.0°




F1-Help              F3-Glass Lib       F5-Glz Sys Lib       F7-Frame Lib
F2-Window Lib        F4-Gas Lib         F6-EnvCond Lib       F8-Divider Lib
```

Figure 14: Sample Temperature Output
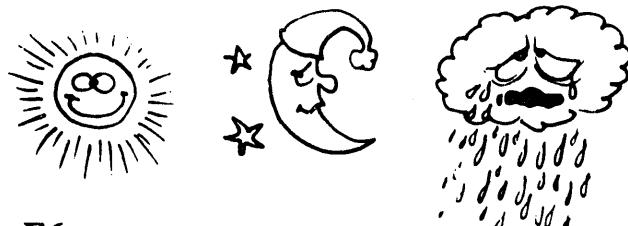
4.9 Environmental Conditions Library < F6 >

The Environmental Conditions Library contains sets of user-defined environmental conditions. Each set consists of two subsets: U-VALUE for which the U-value calculations are performed, and SOLAR for which the solar heat gain calculations are performed. U-value calculations are typically defined for winter, night-time conditions while solar heat gain calculations are defined for summer, daytime conditions.

Three different sets of environmental conditions are included in the library. The first is NFRC/ASHRAE conditions and is suitable for use in calculating U-values at NFRC and ASHRAE conditions and for calculating solar heat gain properties under ASHRAE Summer Conditions. ASHRAE Winter Conditions (for both U-VALUE and SOLAR subsets) is the second set while ASHRAE Summer Conditions (for both U-VALUE and SOLAR subsets) is the third set.

In general, window thermal property calculations are performed for cloudy sky conditions. Cloudy skies are assumed to have a sky temperature equal to the ambient air temperature, and a sky emissivity of 1.0. However, under real-world conditions, the sky is often "colder" than the ambient air; this will increase radiative heat transfer between the exterior glazing layer and the environment, thereby lowering the exterior glass surface temperature. This may in turn lead to condensation on the outside of the center of a high-performance glazing system (just like it forms on the outside of an insulated wall). This will typically not significantly change U-values for most glazing systems. The interested user can specify sky conditions different from the cloudy sky conditions by lowering Esky and/or Tsky and Esky appropriately. For more information on sky temperature and emissivity see [Martin and Berdahl, 1986]. To account for the view factors between the glazing surface and the surrounding surface see [Siegel and Howell, 1981] or other appropriate discussions on radiative heat transfer and view factors. Specifying a sky temperature different from the ambient temperature or a sky emittance less than 1.0 will lead to a warning that "non-standard" environmental conditions are being used; this is to remind the reader that such calculations are not typically used for comparing product performance.

The user can Add, Delete, Edit, Goto, and View library entries. The user can View by All or Name.

Use the < ALT > S command to save all changes to disk under the \W4LIB file "envcond.dat". A maximum of 999 sets of environmental conditions may be stored in this library. The < ALT > P command prints all or part of the library contents to a file or a printer. Use the < ESC > command to return to the Main Screen, and the < ALT > Q command to quit the program.

< F1 > will access the Environmental Conditions Library Help screen for more information. See Section 4.4 for general information which also relates to this library.

Figure 15 is a sample Environmental Conditions Library screen.

```
=================== Env Cond Library ====================
              Outside  Inside  Wind        Wind      Direct  Tsky  Esky
ID  Name       Temp    Temp   Speed      Direction   Solar
               F        F      mph                   Btu/h-   F
                                                     ft2
```

ID	Name		Outside Temp F	Inside Temp F	Wind Speed mph	Wind Direction	Direct Solar Btu/h-ft2	Tsky F	Esky
1	NFRC/ASHRAE	Uvalue	0.0	70.0	15.0	0 Windward	0.0	0.0	1.00
		Solar	89.0	75.0	7.5	0 Windward	248.2	89.0	1.00
2	ASHRAE-WINTR	Uvalue	-0.0	70.0	15.0	0 Windward	0.0	-0.0	1.00
		Solar	-0.0	70.0	15.0	0 Windward	0.0	-0.0	1.00
3	ASHRAE-SUMMR	Uvalue	89.0	75.0	7.5	0 Windward	248.2	89.0	1.00
		Solar	89.0	75.0	7.5	0 Windward	248.2	89.0	1.00
4	Cold	Uvalue	-40.0	77.0	15.0	0 Windward	0.0	-40.0	1.00
		Solar	89.0	75.0	7.5	0 Windward	248.2	89.0	1.00

More...

```
Add      Delete     Edit      View    Goto          ESC returns to Main screen
F1-Help                   F3-Glass Lib        F5-Glz Sys Lib       F7-Frame Lib
F2-Window Lib             F4-Gas Lib          F6-EnvCond Lib       F8-Divider Lib
```

Figure 15: Sample Environmental Conditions Library

4.10 Frame Library < F7 >
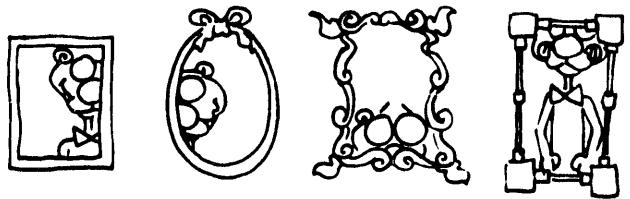
The Frame Library lists frame elements along with their associated frame and edge-of-glass properties for use on the Main Screen when defining the header, jambs, sill, and mullions (check rails, meeting rails) of a window system. Three different "Sources" or types of frame records can be included in the Frame Library.

The Frame Library includes five records representing the frame U-values that were determined for the 1989 ASHRAE Handbook of Fundamentals and utilized in WINDOW 3.1. These first five entries are referred to as "ASHRAE/LBL". The frame U-values, edge-of-glass correlations (see below), absorptance, and projected frame dimension (PFD) for these five records are protected. However, the user can create a variant on any one of these records by copying and editing it.

The user may also add "Generic" frame elements to the library. To do this, the user needs to enter a frame U-value, an edge-of-glass U-value or an edge correlation (not both), frame absorptance, and projected frame dimension. Remember that editing any previously used Generic frame may change previously saved window systems which reference that frame (see Section 4.4.3).

WINDOW can also import data generated by the FRAME 3.0 program. Data files generated by FRAME 3.0 will have the .F30 extension and be placed in the \FRAMEDAT sub-subdirectory. To bring data out of one of these files and into WINDOW, Add a frame with the same name as the .F30 file (with or without the .F30 extension). WINDOW will then read the FRAME 3.0 file and display the frame properties. The Source designation will now also reflect the structural function of the frame as modeled in FRAME 3.0, i.e. sill, head, jamb, or mullion (mull). An "N" at the end of the source name indicates that the frame profile was analyzed in FRAME 3.0 under NFRC conditions. See Appendix B for a detailed description of the use of FRAME 3.0 files. Note that for official NFRC simulations, only the use of FRAME frame records is allowed.

The term Projected Frame Dimension (PFD) refers to the width of the frame element in the plane of the glazing. For mullions, this is the sightline to sightline dimension. See [NFRC, 1991] for further clarifications. The PFD cannot be varied on the Main Screen.

Frame elements will absorb solar radiation and transmit some of it inwards into the space. The amount transmitted inwards depends on the frame's solar absorptance (Abs) and the frame's U-value. WINDOW 4.0 thus accounts for the influence of all opaque elements in a window system on the shading coefficient and the solar heat gain coefficient by calculating the inward flowing fraction of the solar radiation absorbed by the frame. A typical absorptance for a dark frame is 0.9 while that for a light frame is about 0.3. Visible transmittances of all frame elements are set to 0.

Edge-of-glass correlations are provided for ASHRAE/LBL frames and can also be used with Generic frames. Spacer/edge systems were chosen to create correlations which represent reasonable steps from highly conductive to highly insulating. These correlations

present edge-of-glass U-values as a function of center-of-glazing U-values and are identified in the program by "class" or number as shown below.. More details on these correlations can be found in [Arasteh, 1989]:

Number	Spacer Material
1	Aluminum - ASHRAE Metallic
2	Stainless steel; dual seal
3	Butyl/Metal (also Fiberglass, Wood, Glass Edge)
4	Insulated
5	U-edge = U-cog

The fifth correlation should always be used when modeling single glazing.

The user can Add, Delete, Edit, Goto, Update, and View frame library entries. Use the Update command to retrieve the frame properties from a FRAME 3.0 file that may have been modified since the Frame Library record was entered. The user can View by All, Name, Attribute or Source, and U-value. A maximum and minimum is required with the U-value specifier.

Use the <ALT> S command to save all changes to disk under the \W4LIB file "frame.dat". A maximum of 999 frame elements may be stored in this library. The <ALT> P command prints a detailed summary of a frame record or a listing of the library contents to a file or a printer. The <ESC> command returns the program to the Main Screen, and the <ALT> Q command quits the program.

<F1> will access the Frame Library Help screen for more information. See Section 4.4.1 for general library information which also relates to this library.

Figure 16 is a sample Frame Library screen.

```
Alt-> Save  Print  Quit                    W I N D O W  4 . 0
                              Frame Library
```

ID	Name	Source	U-Values Frame Btu/h-ft2-F	U-Values Edge Btu/h-ft2-F	Edge Corr	GlzSys Width in	Keff Btu/h-ft-F	Width (PFD) in	Abs
1	Al no break	ASH/LBL	1.90	N/A	1	var	N/A	2.250	0.90
2	Al w/break	ASH/LBL	1.00	N/A	1	var	N/A	2.250	0.90
3	Al flush	ASH/LBL	0.70	N/A	1	var	N/A	2.250	0.90
4	Wood	ASH/LBL	0.40	N/A	1	var	N/A	2.750	0.90
5	Vinyl	ASH/LBL	0.30	N/A	1	var	N/A	2.750	0.90
6	Sample	Generic	0.40	N/A	1	var	N/A	2.750	0.90
7	Wood	Generic	0.40	N/A	1	var	N/A	2.750	0.90
10	WD-DG1.F30	FRAME Sill N	0.40	0.66	N/A	0.4843	0.026	2.752	0.30
11	WD-LOE1.F30	FRAME Sill N	0.40	0.50	N/A	0.4843	0.011	2.752	0.30
12	WD-DG2.F30	FRAME Sill N	0.41	0.59	N/A	0.7362	0.038	2.752	0.30
13	WD-LOE2.F30	FRAME Sill N	0.41	0.46	N/A	0.7362	0.014	2.752	0.30
14	WD-DL1.F30	FRAME Sill N	var	var	N/A	0.4843	var	2.752	0.30
	More...								

```
Add  Del    Edit    View    Goto  Update   Show  ESC returns to Main screen
F1-Help                F3-Glass Lib        F5-Glz Sys Lib         F7-Frame Lib
F2-Window Lib          F4-Gas Lib          F6-EnvCond Lib         F8-Divider Lib
```

Figure 16: Sample Frame Library

4.11 Divider Library < F8 >

The Divider Library lists grilles, muntins, and other divider elements along with their associated divider and divider-edge-of-glass properties for use on the Main Screen. Dividers are an optional element of a complete window system. If dividers are not to be used in a window system, the Divider ID (Div ID) on the main screen should be kept at "0". If dividers are to be used, the user will be prompted for the ID # along with the number of horizontal and vertical dividers for each glazing system on the Main Screen. [Note that the number of bars, not glazing units are to be entered. For a 2x2 pattern, enter 1 horizontal and 1 vertical bar.] Three different "Sources" or types of divider records can be included in the Divider Library.

The Divider Library contains default data for typical "divided-lite" or true dividers and "suspended" or between glass dividers. Correlations for Divider U-values and Divider-Edge U-values were obtained through the use of Finite Element Modeling at Lawrence Berkeley Laboratory [Acevedo-Ruiz, 1991]. The correlations are functions of the glazing system U-value (center-of-glass) and the gap spacing. For suspended dividers, the divider is assumed to have a thickness of 0.19".

Divided lites (Figure 17) physically divide the space between two glazing layers by sealing a spacer to the glass panes, thus creating small individual insulating glass units (or a semblance of them). The visible part of the divider is a block or strip (typically wood or plastic) placed on the glass's exterior surface. The spacer can be hollow or solid, and is fabricated from a variety of materials. In the case of "true" divided lights, two edge systems would be mounted back to back.

Suspended dividers (Figure 17) are suspended in the gap of the glazing system. There is a space between the dividers and glass panes. The divider resembles a spacer, is hollow, and tends to be thinner than that used in divided lights.

Correlations for the above divider types cases are included in WINDOW 4.0 and are referred to as "LBL" correlations.

Correlation Number	Material
	Divided Lights:
1	Aluminum, hollow
2	Butyl, solid, with aluminum backing
3	Wood, solid
4	Insulating material, solid (k = 0.012 Btu/hr-ft-F)
	Suspended Dividers:
5	Aluminum, hollow
6	Vinyl, hollow

WINDOW displays warnings if the gap width is outside the bounds for which these correlations were developed. Use such results with caution. For glazing systems with more

Glazing Layers

Wooden Block — Wooden Block

Divider

Air or Gas Fill

"Divided Lites"

Glazing Layers

Muntin Bar
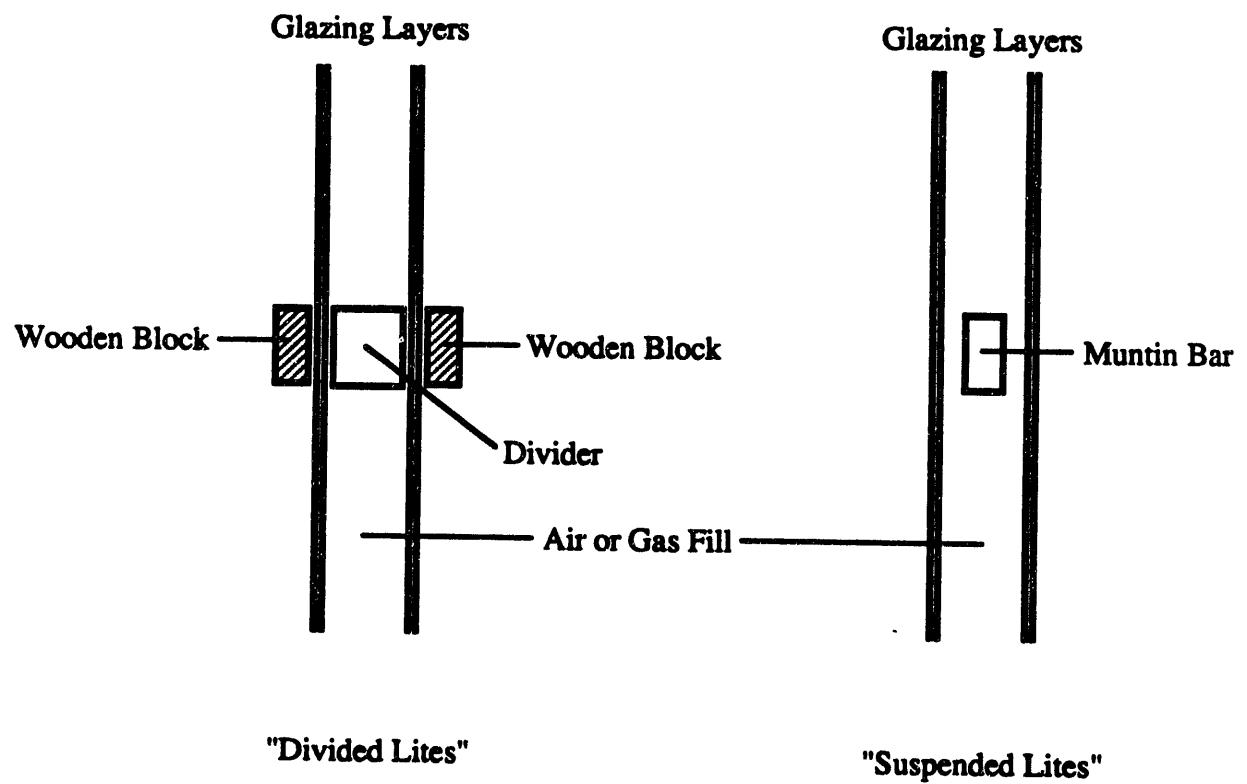
"Suspended Lites"

Figure 17: "Divided" versus "Suspended Lites" for Traditional Window Design

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than one gap, the divider is assumed to be placed in the outermost gap. These correlations cannot be used with single-pane glazing systems; use a user-defined Generic divider for single-pane glazing systems. The projected divider dimension must be specified within the divider library and cannot be varied at the Main Screen.

Generic Dividers represent a type of divider element that can be added to the library. The user needs to enter a divider U-value and a divider-edge U-value (or specify the number of a LBL divider-edge correlation), the divider's absorptance, and the projected divider dimension (PDD).

WINDOW can also import data generated by the FRAME 3.0 program. Data files generated by FRAME 3.0 must have the .F30 extension and be placed in the \FRAMEDAT sub-subdirectory. To bring data out of one of these files and into WINDOW, add a divider with the same name as the .F30 file (with or without the .F30 extension). WINDOW will then read the FRAME 3.0 file and display the divider properties. An "N" at the end of the source name indicates that the divider profile was analyzed in FRAME 3.0 under NFRC conditions. See Appendix B for a detailed description of the use of FRAME 3.0 files. Note that for official NFRC simulations, only the use of FRAME divider records is allowed.

Divider elements will also absorb solar radiation and transmit some of it inwards into the space. The amount transmitted inwards depends on the divider's solar absorptance (Abs) and its U-value. WINDOW 4.0 thus accounts for the influence of all opaque elements in a window system on the shading coefficient and the solar heat gain coefficient by calculating the inward flowing fraction of the solar radiation absorbed by the divider. A typical absorptance for a dark frame is 0.9. Visible transmittances of all divider elements are set equal to 0.

The user can Add, Delete, Edit, Goto, Update, and View divider library entries. Use the Update command to retrieve the divider properties from a FRAME 3.0 file that may have been modified since the Divider Library record was entered. The user can View by All, Name, Source, and U-value. A maximum and minimum is required with the U-value specifier.

Use the <ALT> S command to save all changes to disk under the \W4LIB file "divider.dat". A maximum of 999 dividers may be stored in this library if enough space exists on your hard disk. The <ALT> P command prints a detailed summary of a divider record or a listing of the library contents to a file or a printer. The <ESC> command returns the program to the Main Screen, and the <ALT> Q command quits the program.

<F1> will access the Divider Library Help screen for more information. See Section 4.4.1 for general library information which also relates to this library.

Figure 18 is a sample Divider Library screen.

```
Alt-> Save   Print   Quit                        W I N D O W   4 . 0
                            ══════ Divider Library ══════
 ┌────┬─────────────────┬─────────┬───────────────────┬──────┬────────┬────────┬────────┬─────┐
 │ ID │ Name            │ Source  │     U-Values      │ Corr │ GlzSys │ Keff   │ Width  │ Abs │
 │    │                 │         │ Divider │  Edge   │      │ Width  │ Btu/h- │ (PDD)  │     │
 │    │                 │         │ Btu/h-  │ Btu/h-  │      │   in   │  ft-F  │  in    │     │
 │    │                 │         │ ft2-F   │ ft2-F   │      │        │        │        │     │
 ├────┼─────────────────┼─────────┼─────────┼─────────┼──────┼────────┼────────┼────────┼─────┤
 │  1 │ Alum/Divided    │ LBL     │  N/A    │  N/A    │  1   │  var   │  N/A   │ 0.625  │0.90 │
 │  2 │ Butyl/Divided   │ LBL     │  N/A    │  N/A    │  2   │  var   │  N/A   │ 0.625  │0.90 │
 │  3 │ Wood/Divided    │ LBL     │  N/A    │  N/A    │  3   │  var   │  N/A   │ 0.625  │0.90 │
 │  4 │ Insul/Divided   │ LBL     │  N/A    │  N/A    │  4   │  var   │  N/A   │ 0.625  │0.90 │
 │  5 │ Alum/Suspended  │ LBL     │  N/A    │  N/A    │  5   │  var   │  N/A   │ 0.625  │0.90 │
 │  6 │ Vinyl/Suspended │ LBL     │  N/A    │  N/A    │  6   │  var   │  N/A   │ 0.625  │0.90 │
 │  7 │ Sample          │ Generic │  N/A    │  N/A    │  1   │  var   │  N/A   │ 0.625  │0.90 │
 │    │                 │         │         │         │      │        │        │        │     │
 │    │ End of Library  │         │         │         │      │        │        │        │     │
 └────┴─────────────────┴─────────┴─────────┴─────────┴──────┴────────┴────────┴────────┴─────┘

Add   Del    Edit    View     Goto  Update     Show   ESC returns to Main screen
F1-Help                     F3-Glass Lib       F5-Glz Sys Lib          F7-Frame Lib
F2-Window Lib               F4-Gas Lib         F6-EnvCond Lib          F8-Divider Lib
```

Figure 18: Sample Divider Library

4.12 Using WINDOW 4.0 with DOE2.1E or other Building Energy Analysis Programs

Many building energy analysis programs assume that heat transfer through windows can be represented by a simple U-value and a Shading Coefficient. However, the U-value and solar heat gain characteristics of a window are a function of many environmental conditions which include temperatures, wind speed, orientation, location, time and season.

To increase the accuracy with which building energy simulation programs model window heat transfer, the WINDOW 4.0 program will create a detailed output file of a window's thermal properties. These properties include solar and visible properties as a function of angle of incidence and U-values as a function of temperature and wind speed. This file is created by using the <Alt> P command and the "DOE-2" option from the Main Screen. Files created in this manner can be used by the DOE2.1E energy analysis program.

Developers of other building energy analysis programs are encouraged to build similar capabilities into their programs. For more information on the specifics of how to use these files, contact the WINDOW 4.0 program authors.

5.0 Glossary

Abs	frame absorptance for solar radiation at normal incidence.
Chromaticity	the chromaticity coordinates of a color stimulus.
Cond	thermal conductivity (SI:W/m-C, IP:Btu/h-ft-F).
D	glazing layer thickness (SI:mm, IP:in).
dCond	change in gas thermal conductivity with respect to temperature (SI:W/m2-C, IP:Btu/hr-ft2-F).
dDens	change in gas density with respect to temperature (SI:kg/m3-C. IP:lb/ft3-F).
Dens	gas density (SI:kg/m3, IP:lb/ft3).
DomWL	dominant wavelength or hue of a color stimulus.
dPran	change in Prandtl Number with respect to temperature (SI:1/C, IP:1/F).
dVisc	change in gas viscosity with respect to temperature (SI:kg-s/m2-C2, IP:lb-s/ft2-F2).
Emis	infrared emittance of the glazing layer (exterior facing surface is 1, and interior oriented surface is 2).
Esky	effective sky emittance for calculating radiation exchange between the exterior glazing surface and the sky (see Section 4.9).
Height	height of the window, including the glazing and frame components (SI:mm, IP:in).
ID	identification number for a given component from the component's associated library.
KEFF	total effective conductivity of all components of a glazing system except the inner and outer glazing layers (SI:W/m- C, IP:Btu/hr-ft- F).
Keff	a conductivity or effective conductivity of a window component (frame, divider, glass, gap)

#Lay	number of glazing layers in a glazing system or the position of a glass or gas entry in a glazing system.
Near Infrared	the portion of the solar spectrum in the wavelength range from 0.8 to 2.5 microns.
PDD	projected divider dimension or width of the divider element in the plane parallel to the glazing surfaces (SI:mm, IP:in).
PFD	projected frame dimension or width of the frame element in the plane parallel to the glazing surfaces (SI:mm, IP:in).
Photopic Response	the response of the human eye to visible light.
Pran	gas Prandtl Number.
Purity	purity of a color stimulus relating to saturation of the color.
Rb	the back (interior) surface reflectance of a glazing system
Rf	the front (exterior) surface reflectance of a glazing system
RHG	relative heat gain through the glazing system equal to Uc*(Ti-To)+SC*(Incident Solar Radiation). The incident solar radiation equals (200 Btu/hr-ft2- F).
Rsol	solar reflectance of the glazing layer (exterior-facing surface is 1, and interior-facing surface is 2).
Rvis	visible reflectance (exterior-facing surface is 1, and interior-facing surface is 2).
SC	the shading coefficient for the total window system representing the ratio of the solar heat gain through the window system relative to that through 3 mm (1/8") clear glass at normal incidence.
SCc	the shading coefficient for the glazing system (center-of-glass).
SHGC	the solar heat gain coefficient of the total window system representing the solar heat gain through the window system relative to the incident solar radiation.
SHGCc	the solar heat gain coefficient for the glazing system (center-of-glass) only.
Size	name referring to a window size stored in the size library.
Solar	subset of environmental conditions for which shading coefficients and solar heat gain coefficients are calculated (see Section 4.9).
Solar Spectrum	the wavelength range of the sun's energy used to calculate properties (from 0.30 to 2.5 microns).

Source	source of information for a frame or divider element.
Tdw	the damage weighted transmittance which includes the effects of damage from the ultraviolet and visible portions of the solar spectrum.
Thermal Infrared	a wavelength range from 5.0 to 25 microns (out to 40 microns constitutes a more complete range) over which a body at room temperature (300 K) emits energy.
Thick	glass thickness (SI:mm, IP:in).
Tilt	window tilt measured from the horizontal (90 represents a vertical surface, and 0 represents a horizontal surface).
Tir	thermal infrared transmittance of a glazing layer.
Tsky	effective sky temperature for calculating infrared radiation heat transfer between the exterior glass surface and the sky.
Tsol	solar transmittance of the glazing layer.
Tuv	the unweighted transmittance between 0.30 and 0.38 microns.
Tvis	visible transmittance of the glazing layer.
Type	operating mechanism (Casement, Awning, Horizontal Slider, Vertical Slider, Skylight, Door, Double Door, Combination) of the window to be analyzed.
U-value	the total heat transfer coefficient for the window system (SI:W/m2- C, IP:Btu/h-ft2- F).
Uc	the U-value for the glazing system (center-of-glass) only (SI:W/m2- C, IP:Btu/h-ft2- F).
Units	input and output can be displayed in IP (inch-pound) or SI (Systeme International) units.
Uvalue	subset of environmental conditions for which U-value calculations are made.
Visc	gas viscosity (SI:kg-s/m2-C, IP:lb-s/ft2-F).
Visible Spectrum	the wavelength range from 0.38 to 0.78 microns corresponding to those wavelengths which provoke a response by the human eye.
VT	the total window system's visible transmittance at normal incidence.
Vtc	visible transmittance of the glazing system (center-of-glass) only.

6.0 Program Speed, Warnings and Errors

6.1 Program Speed

Because WINDOW 4.0 is a more powerful tool than WINDOW 3.1, it will also take more time to run. The following are some suggestions for speeding up run time:

* Keep the angular calculations mode on the F9 screen off (see Section 4.8.1) unless required or until you are sure your window is described properly.

* Keep library sizes to a minimum. WINDOW comes with a default glass library which contains more glazings than the typical user will ever need to use. Before you delete entries, make a backup of the glass library data file (\W4LIB\glass.dat). Delete entries from within the program only.

* Avoid continual use of spectral data files if you are only interested in U-value results. You can use the Update feature in the glass library to upload a spectral data file into the glass library. If the spectral data file is renamed or moved out of the \W4LIB\SPECDAT subdirectory, the program will operate quicker.

6.2 Warnings and Errors

Most warnings and errors in WINDOW are self-explanatory and can be easily corrected by the user. Some, however, deserve further attention since their causes and cures might not be so obvious. These are discussed in the remainder of this section.

An error which says that the program **Cannot find** or **Cannot open** a specific file means that that file is not in its proper place or contains data of the wrong format. Refer to Figure 1 to see where that particular file belongs. You may need to recopy that file from the backup disk.

A **Bad Data File** error means that the given file has been damaged. You may have to get a backup version of the file off of a backup disk or the original disk.

A **Non Convergence** or **Solution Impossible** error indicates that the user has made an error in the input of a glazing system or has gone beyond the bounds of the program's capabilities. This is most likely to happen when the user defines a gap space too large, or a tilt too close to zero for some glazing layer systems. Reduce the gap width or increase the tilt until the program runs.

Appendix A: Use of Spectral Data Files in WINDOW 4

A.1 WINDOW 4.0's Multi-Band Spectral Model

Previous versions of the WINDOW program used the total optical properties of individual glazing layers to calculate the total optical properties for a system of glazing layers. For example, the WINDOW 3.1 glass library stored the total visible and solar transmittances and reflectances of individual layers. When two or more layers were combined in a glazing system, the total system properties were calculated based on the layer properties. This approach is known as the "single-band" approach because it considers the entire spectrum (either visible or solar) to be comprised of only one band. While this approach is adequate for glazing systems comprised of layers whose properties do not change dramatically over the solar spectrum, it introduces a noticeable error into the results for systems with more than one spectrally selective layers (i.e. layers whose properties vary over the solar spectrum).

To more accurately model glazing systems with spectrally selective glazings, a multi-band model has been incorporated into WINDOW 4.0. In this model, WINDOW 4.0 calculates the transmittance and reflectances for the glazing layer or the glazing system wavelength by wavelength, and then weights the properties by the appropriate weighting functions to obtain the total solar, visible, thermal infrared properties, damage-weighted transmittance, and transmittance between 0.30 and 0.38 microns.

The following table presents the total visible, solar, and solar heat gain properties for a double glazed unit made up of 1/4" green (outer layer) and a typical 1/4" low-E on clear (inner layer). Properties were calculated using both the single band model and the multi-band model.

	Ts	Tv	SC	SHGC
Single Band	.24	.61	.39	.33
Multi-Band	.19	.61	.34	.29

A technical explanation of this model is included in [Arasteh et. al., 1989].

To use the multi-band model, WINDOW needs a spectral data file for each glazing layer. These files must be placed in the \SPECDAT subdirectory (see Figure 1). Once the files are placed in this subdirectory, they can be brought into the program by adding the files' names to the Glass Library and then using the Update feature. An * will appear following the names of glazings in the Glass Library which have spectral data files associated with them. A true multi-band analysis will be performed if all the glazing layers specified have an associated spectral data file. If some of the glazing layers have associated spectral data files and some do not, WINDOW assumes a flat spectral behavior of the glazings without spectral data files based on their stated visible and solar properties. If none of the glazings have associated spectral data files, WINDOW defaults to the one-band model used in WINDOW 3.1.

A.2 Spectral Data File Format

Spectral data files used in WINDOW must have a specified format. These spectral data files have two parts, the header and the spectral data.

The header contains information concerning the units, the material thickness and conductivity, and default thermal infrared properties. The header must follow the format below; no extra or blank lines separating the input lines are permitted. The last two lines of the header are optional entries. These options are provided for manufacturers who do not have the capabilities to make spectral measurements beyond 2.0 microns. (For uncoated glass the thermal infrared hemispherical emittance is 0.84, and the thermal infrared hemispherical transmittance is 0.0.) Otherwise, we suggest that normal reflectance data be supplied out to at least 25 microns.

The spectral data consists of four columns of data: wavelength, transmittance, front reflectance, and back reflectance. The spectral data portion must consist of only numbers; these numbers can be separated by spaces or commas. No other characters are permitted on these data lines.

The information in a spectral file is presented in the following order:

```
Units   wavelength
Glazing Thickness
Glazing Conductivity
tir = .xx
emis = ef eb
wl      Trans Rf    Rb
.         .     .     .
.         .     .     .
.         .     .     .
```

where:

Units can be either SI or IP.

A wavelength unit other than the default of "microns" can be specified. Alternatives are "nanometers" or "wavenumber".

Glazing Thickness is the thickness in either inches (for IP units) or mm (for SI units). The Glazing Conductivity is the thermal conductivity in Btu/hr-ft- F for (for IP units) or W/m- C (for SI units).

tir = .xx is a fixed thermal infrared hemispherical transmittance (< 1.0). This only needs to be specified if the user specifies a fixed emittance (see next line) and if the value is not 0.0. (All glass products have a thermal infrared transmittance of 0.0). Spectral data need only extend out to 2.0 (2.5 is preferred) microns when the infrared properties are fixed. Fixed infrared properties will override spectral data.

emis = ef eb are the thermal infrared hemispherical emittance (< 1.0) for the front surface, ef, and the back surface, eb. If only one value is entered both surfaces are assumed to have

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the same emittances. A value must be specified even if no coatings are used. Spectral data need only extend out to 2.0 (2.5 is preferred) microns when the infrared properties are fixed. Fixed infrared properties will override spectral data.

wl is the wavelength at which the properties are reported.

Trans is the normal transmittance at the specified wavelength.

Rf is the normal reflectance of the front surface at the specified wavelength.

Rb is the normal reflectance of the back surface at the specified wavelength.

You can enter * for Trans, Rf, and Rb indicating that the values are the same as those for the preceding line. Rb can be omitted if it equals Rf, and Rf can be omitted if it is the same as for the preceding wavelength.

Comments can be enclosed in brackets, {....}, and can span more than one line. See Section A.2.2 for sample spectral data files.

A.2.1 Recommended Wavelengths for Reporting Spectral Data

To accurately represent spectral data, we recommend measuring samples at the following wavelengths and increments. The data between 0.3 and 1.0 microns should be reported at 0.01 micron (10 nm) intervals, from 1.0-2.0 (out to 2.5 microns if you have the facilities) at 0.1 micron (100 nm) intervals, and from 2.5-25.0 (out to 40.0 microns if you have the facilities) microns at 0.5 micron intervals. A finer set of measurements should certainly be used if it is available.

Note that different files containing spectral data do not have to use the same wavelengths, even if these files are used in one glazing system. However, solar spectral data must extend from at least 0.35 to 2.0 microns, and preferably from 0.30 to 2.5 microns. If data is not available at 0.32 microns, WINDOW will extrapolate data from 0.35 microns or the lowest value to a value of 0 at 0.32 microns. The damage weighted transmittance and UV transmittance will not be calculated unless data is provided at 0.30 microns. If data is not presented out to 2.5 microns, WINDOW use the last input value (as long as it is at least at 2.0 microns) as a value at 2.5 microns also.

Once this data is measured, if disk space and/or calculation speed are issues, it can be filtered for use by WINDOW. For example, if there are several spectral data points all on a line, WINDOW does not need the intermediate data points since it performs a linear interpolation between any two data points. Note that it is impossible to know what points are on a line until they have been measured. The program SPECPACK.EXE performs this packing process and is located on the main directory. To use SPECPACK, type

SPECPACK [options] filename

where the following options are available:

      [-o] overwrites the original file with the new packed file. This is not recommended unless you have a copy of the original file and wish to keep the same name.

      [-e xxx] creates a packed file with a new file extension called xxx.

[-t yyy] specifies a tolerance of yyy for determining linearity. The default is 0.003 which means that a point can be considered to be a linear interpolation of the two points on either side if the exact linear interpolation is within 0.3% of the real point.

Note that options -o and -e cannot be used together. The default extension is .PAK if neither of these options are specified.

In order to save disk space and calculation time, we processed all the files we received by manufacturers with SPECPACK using a tolerance of 0.3% (.003). This processing will lead to changes in the reported data for a single glazing layer of not more than a difference of 0.001 in the final value.

A.2.2 Sample Spectral Data Files

A sample spectral data file for measurements made out to 40 microns (40000 nanometers in this case) is shown below.

```
{ units } SI  nanometers
{ thickness } 6.0
{ conductivity } .22
        300    .7     .2      .2
        310    .75    .15
        320    .8     .1
        330    .82    *
         .      .      .      .  {Not part of actual data file}
         .      .      .      .
         .      .      .      .
         .      .      .      .
        40000  0      .2      .2
```

A sample spectral data file for a piece of glass with a default emittance of 0.10 on the front surface is shown below:

```
SI
2.5
.9
{ IR transmittance   } tir =  0.0
{ hemispherical emittance } e = 0.10
        .3     .7     .2      .22
        .31    *      *       *
        .32    .8     .1      .13
        .33    .82    .09
         .      .      .      .   {Not part of actual data file.}
         .      .      .      .
         .      .      .      .
        2.5    0      .16     .70
```

Additional sample data files are included on the Program Disk under the \SPECDAT sub-subdirectory.

A.3 Manufacturer Supplied Spectral Data

Most of the glazing product manufacturers who supplied us with data listed in the glass library also provided us with associated spectral data files. Manufacturers did not necessarily provide spectral data for all of their products. These files are contained on the two spectral data disks. The data for a particular manufacturer is stored in a subdirectory on one of these disks. If you would like to use that manufacturer's spectral data, simply use the DOS copy command to copy all the desired spectral data files into the WINDOW 4 sub-subdirectory SPECDAT. Extensions (and subdirectories) unique to each manufacturer are listed below:

AFG Industries, Inc.   (no spectral data files)
DuPont   .dup
Ford Glass Division   .fmc
Guardian Industries, Inc.   .grd
Interpane   .inp
Libbey Owens Ford   .lof
Monsanto Company   .mon
PPG Industries, Inc.   .ppg
Southwall Technologies   .swt
Viracon, Inc.   .vir

A listing of all manufacturers' spectral data files and a cross-reference to their products follows.

All data supplied with WINDOW 4 is laboratory-measured data, and small deviations from sample to sample will occur, particularly for coated glazings. Questions regarding the optical data for these entries should be directed to the appropriate manufacturers. Although we provided guidelines to the manufacturers on how to prepare this data, it has not been checked by LBL. Much of the data has been condensed (see Section A.2.1); however, this will not lead to any noticeable changes in calculated results.

A.4 Glazing Product Cross Reference

AFG Glass Products

Window 4.0 Name	Product Name	Thickness (mm)
COME3.AFG	Comfort E	3.0
COME2-3.AFG	Comfort E2	3.0

Du Pont Butacite® Interlayer Laminated With Clear Lites

Spectral Data File Window 4.0 Name	Nominal Thickness (mm)	Construction Lite + PVB + Lite					Butacite® Designation
PVB15-6.DUP	6.38	3	+	0.38	+	3	.015 Clear
PVB30-6.DUP	6.76	3	+	0.76	+	3	.030 Clear
PVB60-6.DUP	7.52	3	+	1.52	+	3	.060 Clear
PVB15-10.DUP	10.38	5	+	0.38	+	5	.015 Clear
PVB30-10.DUP	10.76	5	+	0.76	+	5	.030 Clear
PVB60-10.DUP	11.52	5	+	1.52	+	5	.060 Clear
BLUGREEN.DUP	6.76	3	+	0.76	+	3	# 0377300
COOLBLUE.DUP	6.76	3	+	0.76	+	3	# 0637600
BZE-LITE.DUP	6.76	3	+	0.76	+	3	# 0645200
BZE-MEDM.DUP	6.76	3	+	0.76	+	3	# 0642800
BRN-LITE.DUP	6.76	3	+	0.76	+	3	# 0365500
BRN-MEDM.DUP	6.76	3	+	0.76	+	3	# 0362800
BRN-DARK.DUP	6.76	3	+	0.76	+	3	# 0360900
GRY15-6.DUP	6.38	3	+	0.38	+	3	# 1424400
GRY30-6.DUP	6.76	3	+	0.76	+	3	# 1424400
GRY15-12.DUP	12.38	6	+	0.38	+	6	# 1424400
GRY30-12.DUP	12.76	6	+	0.76	+	6	# 1424400

Monsanto Glass Products

Spectral Data File	Monsanto Name	Product Code
15MILCLR.MON	SR11 15 Ga. Clear	SR11
30MILCLR.MON	SR41 30 Ga. Clear	SR41
60MILCLR.MON	SR71 60 Ga. Clear	SR71
BL_GRN.MON	Blue Green	3773
MED_BLU.MON	Medium Blue	5056
COOL_BLU.MON	Cool Blue	6376
L_BL_GRY.MON	Light Blue Gray	0855
M_BL_GRY.MON	Medium Blue Gray	0828
SOL_BLU.MON	Solar Blue	7558
GRAY.MON	Gray	6544
TRNS_WHT.MON	Translucent White	2165
LT_BRNZ.MON	Light Bronze	6452
MED_BRNZ.MON	Medium Bronze	6428
DK_BRNZ.MON	Dark Bronze	6406
LT_BRN.MON	Light Brown	3655
MED_BRN.MON	Medium Brown	3628
DK_BRN.MON	Dark Brown	3609
LT_RED.MON	Opticolor 78% Red	8078
DK_RED.MON	Opticolor 50% Red	8050
LT_YEL.MON	Opticolor 86% Yellow	8186
DK_YEL.MON	Opticolor 50% Yellow	8150
LT_BLUE.MON	Opticolor 78% Blue	8278
DK_BLUE.MON	Opticolor 50% Blue	8250
LT_BLK.MON	Opticolor 78% Black	8378
DK_BLK.MON	Opticolor 50% Black	8350

All Monsanto products are reported as a layer of laminate sandwiched between two .125" layers of clear glass.

Ford Motor Company Glass Products

Spectral Data File	Thickness (mm)	Float Glass	Coating
CLEAR25.FMC	2.5	Clear	
CLEAR30.FMC	3.0	Clear	
CLEAR40.FMC	4.0	Clear	
CLEAR50.FMC	5.0	Clear	
CLEAR60.FMC	6.0	Clear	
GREEN25.FMC	2.5	Sunglas® Green	
GREEN30.FMC	3.0	Sunglas® Green	
GREEN40.FMC	4.0	Sunglas® Green	
GREEN50.FMC	5.0	Sunglas® Green	
GREEN60.FMC	6.0	Sunglas® Green	
BRONZE25.FMC	2.5	Sunglas® Bronze	
BRONZE30.FMC	3.0	Sunglas® Bronze	
BRONZE40.FMC	4.0	Sunglas® Bronze	
BRONZE50.FMC	5.0	Sunglas® Bronze	
BRONZE60.FMC	6.0	Sunglas® Bronze	
GREY25.FMC	2.5	Sunglas® Grey	
GREY30.FMC	3.0	Sunglas® Grey	
GREY40.FMC	4.0	Sunglas® Grey	
GREY50.FMC	5.0	Sunglas® Grey	
GREY60.FMC	6.0	Sunglas® Grey	
BLUE25.FMC	2.5	Sunglas® Blue	
BLUE30.FMC	3.0	Sunglas® Blue	
BLUE40.FMC	4.0	Sunglas® Blue	
BLUE50.FMC	5.0	Sunglas® Blue	
BLUE60.FMC	6.0	Sunglas® Reflective Grey	
REFLGREY.FMC	6.0	Sunglas® Reflective Bronze	
REFLBRZ.FMC	6.0	Sunglas® Jadeice™	
REFLGRN.FMC	6.0	Sunglas® Reflective Blue	
REFLBLUE.FMC	6.0	SUNGLAS HRp™	Pyrolytic Low E
LOWE25.FMC	2.5	SUNGLAS HRp™	Pyrolytic Low E
LOWE30.FMC	3.0	SUNGLAS HRp™	Pyrolytic Low E
LOWE40.FMC	4.0	SUNGLAS HRp™	Pyrolytic Low E
LOWE50.FMC	5.0	SUNGLAS HRp™	Pyrolytic Low E
LOWE60.FMC	6.0	SUNGLAS HRp™	Pyrolytic Low E

Libbey-Owens-Ford Glass Products

Spectral Data File	Thickness (mm)	Glass Substrate	Coating
CLEAR2.LOF	2.5	Clear	
CLEAR3.LOF	3.0	Clear	
CLEAR4.LOF	4.0	Clear	
CLEAR5.LOF	5.0	Clear	
CLEAR6.LOF	6.0	Clear	
CLEAR8.LOF	8.0	Clear	
CLEAR10.LOF	10.0	Clear	
CLEAR12.LOF	12.0	Clear	
CLEAR16.LOF	16.0	Clear	
CLEAR19.LOF	19.0	Clear	
CLEAR25.LOF	25.0	Clear	
GREY3.LOF	3.0	Grey	
GREY5.LOF	5.0	Grey	
GREY6.LOF	6.0	Grey	
GREY8.LOF	8.0	Grey	
GREY10.LOF	10.0	Grey	
GREY12.LOF	12.0	Grey	
BRONZE3.LOF	3.0	Bronze	
BRONZE5.LOF	5.0	Bronze	
BRONZE6.LOF	6.0	Bronze	
BRONZE8.LOF	8.0	Bronze	
BRONZE10.LOF	10.0	Bronze	
BRONZE12.LOF	12.0	Bronze	
BLUGRN10.LOF	10.0	Blue-Green	
BLUGRN6.LOF	6.0	Blue-Green	
BLUGRN8.LOF	8.0	Blue-Green	
EVERGRN3.LOF	3.0	Evergreen™	
EVERGRN5.LOF	5.0	Evergreen™	
EVERGRN6.LOF	6.0	Evergreen™	
ECL_CLR6.LOF	6.0	Clear	ECLIPSE®
ECL_BLG6.LOF	6.0	Blue-Green	ECLIPSE®
ECL_GRY6.LOF	6.0	Grey	ECLIPSE®
ECL_BRZ6.LOF	6.0	Bronze	ECLIPSE®
MIR_GRY6.LOF	6.0	Grey	MIRRORPANE™
L-E_CLR2.LOF	2.5	Clear	Energy Advantage Low-E™
L-E_CLR3.LOF	3.0	Clear	Energy Advantage Low-E™

Libbey-Owens-Ford Glass Products (cont.)

Spectral Data File	Thickness (mm)	Glass Substrate	Coating
L-E_CLR4.LOF	4.0	Clear	Energy Advantage Low-E^{TM}
L-E_CLR5.LOF	5.0	Clear	Energy Advantage Low-E^{TM}
L-E_CLR6.LOF	6.0	Clear	Energy Advantage Low-E^{TM}

Southwall Technologies Products

Spectral Data File	Product Name	Nominal Tvis
HM22.SWT	HEAT MIRROR^{TM}22	.22
HM33.SWT	HEAT MIRROR^{TM}33	.33
HM44.SWT	HEAT MIRROR^{TM}44	.44
HM55.SWT	HEAT MIRROR^{TM}55	.55
HM66.SWT	HEAT MIRROR^{TM}66	.66
HM77.SWT	HEAT MIRROR^{TM}77	.77
HM88.SWT	HEAT MIRROR^{TM}88	.88

Guardian Industries Glass Products

Spectral Data File	Coating Series/ Material	Description	Ref. Tvis on Clear	Glass Substrate	Thickness (mm)
SS08CL6.GRD	Stainless Steel	Silver	.08	Clear	6.0
SS14CL6.GRD	Stainless Steel	Silver	.14	Clear	6.0
SS20CL6.GRD	Stainless Steel	Silver	.20	Clear	6.0
CS14CL6.GRD	Chrome	Sterling	.14	Clear	6.0
CS20CL6.GRD	Chrome	Sterling	.20	Clear	6.0
TS20CL6.GRD	Titanium	Silver-Blue	.20	Clear	6.0
TS30CL6.GRD	Titanium	Blue	.30	Clear	6.0
TS40CL6.GRD	Titanium	Deep-Blue	.40	Clear	6.0
SS08GN6.GRD	Stainless Steel	Green	.08	Green	6.0
SS14GN6.GRD	Stainless Steel	Green	.14	Green	6.0
SS20GN6.GRD	Stainless Steel	Green	.20	Green	6.0
TS20GN6.GRD	Titanium	Blue-Green	.20	Green	6.0
TS30GN6.GRD	Titanium	Blue-Green	.30	Green	6.0
SS08BR6.GRD	Stainless Steel	Bronze	.08	Bronze	6.0
SS14BR6.GRD	Stainless Steel	Bronze	.14	Bronze	6.0
SS20BR6.GRD	Stainless Steel	Bronze	.20	Bronze	6.0
SS08GY6.GRD	Stainless Steel	Gray	.08	Gray	6.0
SS14GY6.GRD	Stainless Steel	Gray	.14	Gray	6.0
SS20GY6.GRD	Stainless Steel	Gray	.20	Gray	6.0
TS20GY6.GRD	Titanium	Silver Blue-Gray	.20	Gray	6.0
TS30GY6.GRD	Titanium	Sapphire Blue-Gray	.30	Gray	6.0
CB08CL6.GRD	Chrome	Bronze	.08	Clear	6.0
CB14CL6.GRD	Chrome	Bronze	.14	Clear	6.0
CB20CL6.GRD	Chrome	Bronze	.20	Clear	6.0
CP08CL6.GRD	Chrome	Pewter	.08	Clear	6.0
CP14CL6.GRD	Chrome	Pewter	.14	Clear	6.0
CP20CL6.GRD	Chrome	Pewter	.20	Clear	6.0
CR08CL6.GRD	Chrome	Royal	.08	Clear	6.0
CR14CL6.GRD	Chrome	Royal	.14	Clear	6.0
CR20CL6.GRD	Chrome	Royal	.20	Clear	6.0
CB08GN6.GRD	Chrome	Sandstone Green	.08	Green	6.0
CB14GN6.GRD	Chrome	Sandstone Green	.14	Green	6.0
CB20GN6.GRD	Chrome	Sandstone Green	.20	Green	6.0
CP08GN6.GRD	Chrome	Misty Green	.08	Green	6.0
CP14GN6.GRD	Chrome	Misty Green	.14	Green	6.0
CP20GN6.GRD	Chrome	Misty Green	.20	Green	6.0
CR08GN6.GRD	Chrome	Royal Teal	.08	Green	6.0

Guardian Industries Glass Products (cont.)

Spectral Data File	Coating Series/ Material	Description	Ref. Tvis on Clear	Glass Substrate	Thickness (mm)
CR14GN6.GRD	Chrome	Royal Teal	.14	Green	6.0
CR20GN6.GRD	Chrome	Royal Teal	.20	Green	6.0
CB08BR6.GRD	Chrome	Harvest Bronze	.08	Bronze	6.0
CB14BR6.GRD	Chrome	Harvest Bronze	.14	Bronze	6.0
CB20BR6.GRD	Chrome	Harvest Bronze	.20	Bronze	6.0
CP08BR6.GRD	Chrome	Misty Bronze	.08	Bronze	6.0
CP14BR6.GRD	Chrome	Misty Bronze	.14	Bronze	6.0
CP20BR6.GRD	Chrome	Misty Bronze	.20	Bronze	6.0
CB08GY6.GRD	Chrome	Charren Gray	.08	Gray	6.0
CB14GY6.GRD	Chrome	Charren Gray	.14	Gray	6.0
CB20GY6.GRD	Chrome	Charren Gray	.20	Gray	6.0
CP08GY6.GRD	Chrome	Misty Gray	.08	Gray	6.0
CP14GY6.GRD	Chrome	Misty Gray	.14	Gray	6.0
CP20GY6.GRD	Chrome	Misty Gray	.20	Gray	6.0
CR08GY6.GRD	Chrome	Royal Indigo Gray	.08	Gray	6.0
CR14GY6.GRD	Chrome	Royal Indigo Gray	.14	Gray	6.0
CR20GY6.GRD	Chrome	Royal Indigo Gray	.20	Gray	6.0
SP13CL6.GRD	Stainless Steel	Platinum	.13	Clear	6.0
SP18CL6.GRD	Stainless Steel	Platinum	.18	Clear	6.0
SP22CL6.GRD	Stainless Steel	Platinum	.22	Clear	6.0
SP33CL6.GRD	Stainless Steel	Platinum	.33	Clear	6.0
SP13GN6.GRD	Stainless Steel	Serenity Green	.13	Green	6.0
SP18GN6.GRD	Stainless Steel	Serenity Green	.18	Green	6.0
SP22GN6.GRD	Stainless Steel	Serenity Green	.22	Green	6.0
SP33GN6.GRD	Stainless Steel	Serenity Green	.33	Green	6.0
SP13BR6.GRD	Stainless Steel	Satin Bronze	.13	Bronze	6.0
SP18BR6.GRD	Stainless Steel	Satin Bronze	.18	Bronze	6.0
SP22BR6.GRD	Stainless Steel	Satin Bronze	.22	Bronze	6.0
SP33BR6.GRD	Stainless Steel	Satin Bronze	.33	Bronze	6.0
SP13GY6.GRD	Stainless Steel	Starlite Gray	.13	Gray	6.0
SP18GY6.GRD	Stainless Steel	Starlite Gray	.18	Gray	6.0
SP22GY6.GRD	Stainless Steel	Starlite Gray	.22	Gray	6.0
SP33GY6.GRD	Stainless Steel	Starlite Gray	.33	Gray	6.0
NU40GN6.GRD	Neutral (Silver)	NU-40 Neutral	.40	Green	6.0
NU40BR6.GRD	Neutral (Silver)	NU-40 Neutral	.40	Bronze	6.0
NU40GY6.GRD	Neutral (Silver)	NU-40 Neutral	.40	Gray	6.0
NU52CL6.GRD	Neutral (Silver)	NU-52 Neutral	.52	Glear	6.0

Guardian Industries Glass Products (cont.)

Spectral Data File	Coating Series/ Material	Description	Ref. Tvis on Clear	Glass Substrate	Thickness (mm)
NU52GN6.GRD	Neutral (Silver)	NU-52 Neutral	.52	Green	6.0
NU52BR6.GRD	Neutral (Silver)	NU-52 Neutral	.52	Bronze	6.0
NU52GY6.GRD	Neutral (Silver)	NU-52 Neutral	.52	Gray	6.0
LE75CL6.GRD	Low-E (Silver)	Low-E	.75	Clear	6.0
LE75GN6.GRD	Low-E (Silver)	Low-E	.75	Green	6.0
LE75BR6.GRD	Low-E (Silver)	Low-E	.75	Bronze	6.0
LE75GY6.GRD	Low-E (Silver)	Low-E	.75	Gray	6.0
AG40CL6.GRD	Silver	High Performance Silver	.40	Clear	6.0
AG40GN6.GRD	Silver	High Performance Silver	.40	Green	6.0
AG40BR6.GRD	Silver	High Performance Silver	.40	Bronze	6.0
AG40GY6.GRD	Silver	High Performance Silver	.40	Gray	6.0
AG46CL6.GRD	Silver	High Performance Silver	.46	Clear	6.0
AG46GN6.GRD	Silver	High Performance Silver	.46	Green	6.0
AG46BR6.GRD	Silver	High Performance Silver	.46	Bronze	6.0
AG46GY6.GRD	Silver	High Performance Silver	.46	Grey	6.0
RP20CL6.GRD	Rose (Copper)	Sunset Rose	.20	Clear	6.0
RP30CL6.GRD	Rose (Copper)	Sunset Rose	.30	Clear	6.0
RP20GN6.GRD	Rose (Copper)	Mara Rose	.20	Green	6.0
RP30GN6.GRD	Rose (Copper)	Mara Rose	.30	Green	6.0
RP20BR6.GRD	Rose (Copper)	Terra Rose	.20	Bronze	6.0
RP30BR6.GRD	Rose (Copper)	Terra Rose	.30	Bronze	6.0
RP20GY6.GRD	Rose (Copper)	Cinder Rose	.20	Gray	6.0
RP30GY6.GRD	Rose (Copper)	Cinder Rose	.30	Gray	6.0
CG08CL6.GRD	Copper Alloy	Nova Gold	.08	Clear	6.0
CG14CL6.GRD	Copper Alloy	Nova Gold	.14	Clear	6.0

Interpane Coatings Glass Products

Spectral Data File Window 4.0 Name	Thickness (mm)	Coating	Glass Substrate	Ref Tvis on Clear
ILE174_3.INT	3.0	IPLUS^{TM}	Clear	.74
ILE174.INT	6.0	IPLUS^{TM}	Clear	.74
ILE274.INT	6.0	IPLUS^{TM}	Green	.74
ILE374.INT	6.0	IPLUS^{TM}	Grey	.74
ILE474.INT	6.0	IPLUS^{TM}	Bronze	.74
ILE574.INT	6.0	IPLUS^{TM}	Blue	.74
ILE674.INT	6.0	IPLUS^{TM}	Blue-Green	.74
ILE774.INT	6.0	IPLUS^{TM}	Azurlite	.74
ILE874.INT	6.0	IPLUS^{TM}	Evergreen	.74
IPN141.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Clear	.41
IPN241.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Green	.41
IPN341.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Grey	.41
IPN441.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Bronze	.41
IPN541.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Blue	.41
IPN641.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Blue-Green	.41
IPN741.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Azurlite	.41
IPN841.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Evergreen	.41
IPN151.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Clear	.51
IPN251.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Green	.51
IPN351.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Grey	.51
IPN451.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Bronze	.51
IPN551.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Blue	.51
IPN651.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Blue-Green	.51
IPN751.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Azurlite	.51
IPN851.INT	6.0	IPASOL PLUS NEUTRAL^{TM}	Evergreen	.51
IG120.INT	6.0	24K Gold	Clear	.20
ICR120.INT	6.0	Coral Rose	Clear	.20
ICR420.INT	6.0	Coral Rose	Bronze	.20
ICR135.INT	6.0	Coral Rose	Clear	.35
ICR435.INT	6.0	Coral Rose	Bronze	.35
IA-108#2.INT	6.0	Antique Silver	Clear	.08
IA-208#2.INT	6.0	Antique Silver	Green	.08
IA-308#2.INT	6.0	Antique Silver	Grey	.08
IA-408#2.INT	6.0	Antique Silver	Bronze	.08
IA-508#2.INT	6.0	Antique Silver	Blue	.08
IA-608#2.INT	6.0	Antique Silver	Blue-Green	.08

Interpane Coatings Glass Products (cont.)

Window 4.0 Name	Thickness (mm)	Coating	Glass Substrate	Ref. Tvis on Clear
IA-708#2.INT	6.0	Antique Silver	Azurlite	.08
IA-808#2.INT	6.0	Antique Silver	Evergreen	.08
IA-114#2.INT	6.0	Antique Silver	Clear	.14
IA-214#2.INT	6.0	Antique Silver	Green	.14
IA-314#2.INT	6.0	Antique Silver	Grey	.14
IA-414#2.INT	6.0	Antique Silver	Bronze	.14
IA-514#2.INT	6.0	Antique Silver	Blue	.14
IA-614#2.INT	6.0	Antique Silver	Blue-Green	.14
IA-714#2.INT	6.0	Antique Silver	Azurlite	.14
IA-814#2.INT	6.0	Antique Silver	Evergreen	.14
IA-120#2.INT	6.0	Antique Silver	Clear	.20
IA-220#2.INT	6.0	Antique Silver	Green	.20
IA-320#2.INT	6.0	Antique Silver	Grey	.20
IA-420#2.INT	6.0	Antique Silver	Bronze	.20
IA-520#2.INT	6.0	Antique Silver	Blue	.20
IA-620#2.INT	6.0	Antique Silver	Blue-Green	.20
IA-720#2.INT	6.0	Antique Silver	Azurlite	.20
IA-820#2.INT	6.0	Antique Silver	Evergreen	.20
IA-132#2.INT	6.0	Antique Silver	Clear	.32
IA-232#2.INT	6.0	Antique Silver	Green	.32
IA-332#2.INT	6.0	Antique Silver	Grey	.32
IA-432#2.INT	6.0	Antique Silver	Bronze	.32
IA-532#2.INT	6.0	Antique Silver	Blue	.32
IA-632#2.INT	6.0	Antique Silver	Blue-Green	.32
IA-732#2.INT	6.0	Antique Silver	Azurlite	.32
IA-832#2.INT	6.0	Antique Silver	Evergreen	.32
IA-140#2.INT	6.0	Antique Silver	Clear	.40
IA-240#2.INT	6.0	Antique Silver	Green	.40
IA-340#2.INT	6.0	Antique Silver	Grey	.40
IA-440#2.INT	6.0	Antique Silver	Bronze	.40
IA-540#2.INT	6.0	Antique Silver	Blue	.40
IA-640#2.INT	6.0	Antique Silver	Blue-Green	.40
IA-740#2.INT	6.0	Antique Silver	Azurlite	.40
IA-840#2.INT	6.0	Antique Silver	Evergreen	.40
IS-108#2.INT	6.0	Stainless Steel	Clear	.08
IS-208#2.INT	6.0	Stainless Steel	Green	.08
IS-308#2.INT	6.0	Stainless Steel	Grey	.08

Interpane Coatings Glass Products (cont.)

Window 4.0 Name	Thickness (mm)	Coating	Glass Substrate	Ref. Tvis on Clear
IS-408#2.INT	6.0	Stainless Steel	Bronze	.08
IS-508#2.INT	6.0	Stainless Steel	Blue	.08
IS-608#2.INT	6.0	Stainless Steel	Blue-Green	.08
IS-708#2.INT	6.0	Stainless Steel	Azurlite	.08
IS-808#2.INT	6.0	Stainless Steel	Evergreen	.08
IS-114#2.INT	6.0	Stainless Steel	Clear	.14
IS-214#2.INT	6.0	Stainless Steel	Green	.14
IS-314#2.INT	6.0	Stainless Steel	Grey	.14
IS-414#2.INT	6.0	Stainless Steel	Bronze	.14
IS-514#2.INT	6.0	Stainless Steel	Blue	.14
IS-614#2.INT	6.0	Stainless Steel	Blue-Green	.14
IS-714#2.INT	6.0	Stainless Steel	Azurlite	.14
IS-814#2.INT	6.0	Stainless Steel	Evergreen	.14
IS-120#2.INT	6.0	Stainless Steel	Clear	.20
IS-220#2.INT	6.0	Stainless Steel	Green	.20
IS-320#2.INT	6.0	Stainless Steel	Grey	.20
IS-420#2.INT	6.0	Stainless Steel	Bronze	.20
IS-520#2.INT	6.0	Stainless Steel	Blue	.20
IS-620#2.INT	6.0	Stainless Steel	Blue-Green	.20
IS-720#2.INT	6.0	Stainless Steel	Azurlite	.20
IS-820#2.INT	6.0	Stainless Steel	Evergreen	.20
IS-140#2.INT	6.0	Stainless Steel	Clear	.40
IS-240#2.INT	6.0	Stainless Steel	Green	.40
IS-340#2.INT	6.0	Stainless Steel	Grey	.40
IS-440#2.INT	6.0	Stainless Steel	Bronze	.40
IS-540#2.INT	6.0	Stainless Steel	Blue	.40
IS-640#2.INT	6.0	Stainless Steel	Blue-Green	.40
IS-740#2.INT	6.0	Stainless Steel	Azurlite	.40
IS-840#2.INT	6.0	Stainless Steel	Evergreen	.40
IT-110#2.INT	6.0	Titanium	Clear	.10
IT-210#2.INT	6.0	Titanium	Green	.10
IT-310#2.INT	6.0	Titanium	Grey	.10
IT-410#2.INT	6.0	Titanium	Bronze	.10
IT-510#2.INT	6.0	Titanium	Blue	.10
IT-610#2.INT	6.0	Titanium	Blue-Green	.10
IT-710#2.INT	6.0	Titanium	Azurlite	.10
IT-810#2.INT	6.0	Titanium	Evergreen	.10

Interpane Coatings Glass Products (cont.)

Window 4.0 Name	Thickness (mm)	Coating	Glass Substrate	Ref. Tvis on Clear
IT-120#2.INT	6.0	Titanium	Clear	.20
IT-220#2.INT	6.0	Titanium	Green	.20
IT-320#2.INT	6.0	Titanium	Grey	.20
IT-420#2.INT	6.0	Titanium	Bronze	.20
IT-520#2.INT	6.0	Titanium	Blue	.20
IT-620#2.INT	6.0	Titanium	Blue-Green	.20
IT-720 #2.INT	6.0	Titanium	Azurlite	.20
IT-820 #2.INT	6.0	Titanium	Evergreen	.20
IT-130 #2.INT	6.0	Titanium	Clear	.30
IT-230 #2.INT	6.0	Titanium	Green	.30
IT-330 #2.INT	6.0	Titanium	Grey	.30
IT-430 #2.INT	6.0	Titanium	Bronze	.30
IT-530 #2.INT	6.0	Titanium	Blue	.30
IT-630 #2.INT	6.0	Titanium	Blue-Green	.30
IT-730 #2.INT	6.0	Titanium	Azurlite	.30
IT-830 #2.INT	6.0	Titanium	Evergreen	.30
IT-140 #2.INT	6.0	Titanium	Clear	.40
IT-240 #2.INT	6.0	Titanium	Green	.40
IT-340 #2.INT	6.0	Titanium	Grey	.40
IT-440 #2.INT	6.0	Titanium	Bronze	.40
IT-540 #2.INT	6.0	Titanium	Blue	.40
IT-640 #2.INT	6.0	Titanium	Blue-Green	.40
IT-740 #2.INT	6.0	Titanium	Azurlite	.40
IT-840 #2.INT	6.0	Titanium	Evergreen	.40

Azurlite is a registered tradename of PPG Industries

Evergreen is a registered trademark of Libbey-Owens-Ford

PPG Industries Glass Products

Spectral Data File	Thickness (mm)	Float Glass	Coating	Ref. Tvis on Clear
STRPH3E.PPG	3.3	STARPHIRE®		
STRPH4.PPG	4.0	STARPHIRE®		
STRPH5.PPG	5.0	STARPHIRE®		
STRPH6.PPG	6.0	STARPHIRE®		
STRPH10.PPG	10.0	STARPHIRE®		
STRPH12.PPG	12.0	STARPHIRE®		
STRPH16.PPG	16.0	STARPHIRE®		
STRPH19.PPG	19.0	STARPHIRE®		
CLR2H.PPG	2.5	Clear		
CLR3.PPG	3.0	Clear		
CLR5.PPG	5.0	Clear		
CLR6.PPG	6.0	Clear		
CLR8.PPG	8.0	Clear		
SLX2H.PPG	2.5	SOLEX®		
SLX3.PPG	3.0	SOLEX®		
SLX6.PPG	6.0	SOLEX®		
AZRLT2H.PPG	2.5	AZURLITE®		
AZRLT3.PPG	3.0	AZURLITE®		
AZRLT6.PPG	6.0	AZURLITE®		
BRNZ2H.PPG	2.5	SOLARBRONZE®		
BRNZ3.PPG	3.0	SOLARBRONZE®		
BRNZ6.PPG	6.0	SOLARBRONZE®		
BRNZ10.PPG	10.0	SOLARBRONZE®		
GRAY3.PPG	3.0	SOLARGRAY®		
GRAY6.PPG	6.0	SOLARGRAY®		
GRAY10.PPG	10.0	SOLARGRAY®		
BLK3.PPG	3.0	GRAYLITE®		
BLK6.PPG	6.0	GRAYLITE®		
SG100C2H.PPG	2.5	Clear	SUNGATE® 100	
SG100C3.PPG	3.0	Clear	SUNGATE® 100	
SG100C6.PPG	6.0	Clear	SUNGATE® 100	
SG100S3.PPG	3.0	SOLEX®	SUNGATE® 100	
SG100S6.PPG	6.0	SOLEX®	SUNGATE® 100	
SG100A.PPG	6.0	AZURLITE®	SUNGATE® 100	
SG100B3.PPG	3.0	SOLARBRONZE®	SUNGATE® 100	

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PPG Industries Glass Products (cont.)

Spectral Data File	Thickness (mm)	Float Glass	Coating	Ref. Tvis on Clear
SG100B6.PPG	6.0	SOLARBRONZE®	SUNGATE® 100	
SG100G.PPG	6.0	SOLARGRAY®	SUNGATE® 100	
SG300C2H.PPG	2.5	Clear	SUNGATE® 300	
SG300C3.PPG	3.0	Clear	SUNGATE® 300	
SG300C4.PPG	4.0	Clear	SUNGATE® 300	
SG300C5.PPG	5.0	Clear	SUNGATE® 300	
SG300C6.PPG	6.0	Clear	SUNGATE® 300	
SG40S.PPG	6.0	SOLEX®	SUNGATE® 40	
SG50C.PPG	6.0	Clear	SUNGATE® 50	
SG50S.PPG	6.0	SOLEX®	SUNGATE® 50	
SG50A.PPG	6.0	AZURLITE®	SUNGATE® 50	
SG50B.PPG	6.0	SOLARBRONZE®	SUNGATE® 50	
SG50G6.PPG	6.0	SOLARGRAY®	SUNGATE® 50	
SG50G10.PPG	10.0	SOLARGRAY®	SUNGATE® 50	
SG50BK.PPG	6.0	GRAYLITE®	SUNGATE® 50	
SGGOLDC.PPG	6.0	Clear	SUNGATE GOLD®	
SGGOLDS.PPG	6.0	SOLEX®	SUNGATE GOLD®	
SGGOLDA.PPG	6.0	AZURLITE®	SUNGATE GOLD®	
SGGOLDB.PPG	6.0	SOLARBRONZE®	SUNGATE GOLD®	
SGGOLDG.PPG	6.0	SOLARGRAY®	SUNGATE GOLD®	
SGGOLDBK.PPG	6.0	GRAYLITE®	SUNGATE GOLD®	
SB55013C.PPG	6.0	Clear	SOLARBAN® 550	.13
SB55013S.PPG	6.0	SOLEX®	SOLARBAN® 550	.13
SB55013A.PPG	6.0	AZURLITE®	SOLARBAN® 550	.13
SB55013B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 550	.13
SB55013G.PPG	6.0	SOLARGRAY®	SOLARBAN® 550	.13
SB55018C.PPG	6.0	Clear	SOLARBAN® 550	.18
SB55018S.PPG	6.0	SOLEX®	SOLARBAN® 550	.18
SB55018A.PPG	6.0	AZURLITE®	SOLARBAN® 550	.18
SB55018B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 550	.18
SB55018G.PPG	6.0	SOLARGRAY®	SOLARBAN® 550	.18
SB55022C.PPG	6.0	Clear	SOLARBAN® 550	.22
SB55022S.PPG	6.0	SOLEX®	SOLARBAN® 550	.22
SB55022A.PPG	6.0	AZURLITE®	SOLARBAN® 550	.22
SB55022B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 550	.22

PPG Industries Glass Products (cont.)

Spectral Data File	Thickness (mm)	Float Glass	Coating	Ref. Tvis on Clear
SB55022G.PPG	6.0	SOLARGRAY®	SOLARBAN® 550	.22
SB55030C.PPG	6.0	Clear	SOLARBAN® 550	.30
SB55030S.PPG	6.0	SOLEX®	SOLARBAN® 550	.30
SB55030A.PPG	6.0	AZURLITE®	SOLARBAN® 550	.30
SB55030B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 550	.30
SB55030G.PPG	6.0	SOLARGRAY®	SOLARBAN® 550	.30
SB55040C.PPG	6.0	Clear	SOLARBAN® 550	.40
SB55040S.PPG	6.0	SOLEX®	SOLARBAN® 550	.40
SB55040A.PPG	6.0	AZURLITE®	SOLARBAN® 550	.40
SB55040B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 550	.40
SB55040G.PPG	6.0	SOLARGRAY®	SOLARBAN® 550	.40
SB55060C.PPG	6.0	Clear	SOLARBAN® 550	.60
SB55060S.PPG	6.0	SOLEX®	SOLARBAN® 550	.60
SB5608C.PPG	6.0	Clear	SOLARBAN® 560	.08
SB5608S.PPG	6.0	SOLEX®	SOLARBAN® 560	.08
SB5608A.PPG	6.0	AZURLITE®	SOLARBAN® 560	.08
SB5608B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 560	.08
SB5608G.PPG	6.0	SOLARGRAY®	SOLARBAN® 560	.08
SB56014C.PPG	6.0	Clear	SOLARBAN® 560	.14
SB56014S.PPG	6.0	SOLEX®	SOLARBAN® 560	.14
SB56014A.PPG	6.0	AZURLITE®	SOLARBAN® 560	.14
SB56014B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 560	.14
SB56014G.PPG	6.0	SOLARGRAY®	SOLARBAN® 560	.14
SB56020C.PPG	6.0	Clear	SOLARBAN® 560	.20
SB56020S.PPG	6.0	SOLEX®	SOLARBAN® 560	.20
SB56020A.PPG	6.0	AZURLITE®	SOLARBAN® 560	.20
SB56020B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 560	.20
SB56020G.PPG	6.0	SOLARGRAY®	SOLARBAN® 560	.20
SB56040C.PPG	6.0	Clear	SOLARBAN® 560	.40
SB56040S.PPG	6.0	SOLEX®	SOLARBAN® 560	.40
SB56040A.PPG	6.0	AZURLITE®	SOLARBAN® 560	.40
SB56040B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 560	.40
SB56040G.PPG	6.0	SOLARGRAY®	SOLARBAN® 560	.40
SB56520C.PPG	6.0	Clear	SOLARBAN® 565	.20
SB56520S.PPG	6.0	SOLEX®	SOLARBAN® 565	.20

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PPG Industries Glass Products (cont.)

Spectral Data File	Thickness (mm)	Float Glass	Coating	
SB56520A.PPG	6.0	AZURLITE®	SOLARBAN® 565	.20
SB56520B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 565	.20
SB56520G.PPG	6.0	SOLARGRAY®	SOLARBAN® 565	.20
SB57020C.PPG	6.0	Clear	SOLARBAN® 570	.20
SB57020S.PPG	6.0	SOLEX®	SOLARBAN® 570	.20
SB57020A.PPG	6.0	AZURLITE®	SOLARBAN® 570	.20
SB57020G.PPG	6.0	SOLARGRAY®	SOLARBAN® 570	.20
SB57030C.PPG	6.0	Clear	SOLARBAN® 570	.30
SB57030S.PPG	6.0	SOLEX®	SOLARBAN® 570	.30
SB57030A.PPG	6.0	AZURLITE®	SOLARBAN® 570	.30
SB57030G.PPG	6.0	SOLARGRAY®	SOLARBAN® 570	.30
SB57520C.PPG	6.0	Clear	SOLARBAN® 575	.20
SB57520S.PPG	6.0	SOLEX®	SOLARBAN® 575	.20
SB57520A.PPG	6.0	AZURLITE®	SOLARBAN® 575	.20
SB57520B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 575	.20
SB57520G.PPG	6.0	SOLARGRAY®	SOLARBAN® 575	.20
SB57530C.PPG	6.0	Clear	SOLARBAN® 575	.30
SB57530B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 575	.30
SB57530G.PPG	6.0	SOLARGRAY®	SOLARBAN® 575	.30
SB58020C.PPG	6.0	Clear	SOLARBAN® 580	.20
SB58020S.PPG	6.0	SOLEX®	SOLARBAN® 580	.20
SB58020A.PPG	6.0	AZURLITE®	SOLARBAN® 580	.20
SB58020B.PPG	6.0	SOLARBRONZE®	SOLARBAN® 580	.20
SB58020G.PPG	6.0	SOLARGRAY®	SOLARBAN® 580	.20
SB58030C.PPG	6.0	Clear	SOLARBAN® 580	.30
SCBRNZ3.PPG	3.0	SOLARBRONZE®	SOLARCOOL®	
SCBRNZ6.PPG	6.0	SOLARBRONZE®	SOLARCOOL®	
SCBRNZ10.PPG	10.0	SOLARBRONZE®	SOLARCOOL®	
SCGRAY3E.PPG	3.3	SOLARGRAY®	SOLARCOOL®	
SCGRAY6.PPG	6.0	SOLARGRAY®	SOLARCOOL®	
SCGRAY10.PPG	10.0	SOLARGRAY®	SOLARCOOL®	
SCBLK6.PPG	6.0	GRAYLITE®	SOLARCOOL®	

Viracon Glass Products

Spectral Data File	Coating Type	Glass Subtrate	Ref. Tvis on Clear
VA113.VIR	Antique	Clear	.13
VA118.VIR	Antique	Clear	.18
VA122.VIR	Antique	Clear	.22
VA135.VIR	Antique	Clear	.35
VA213.VIR	Antique	Green	.13
VA218.VIR	Antique	Green	.18
VA222.VIR	Antique	Green	.22
VA235.VIR	Antique	Green	.35
VA313.VIR	Antique	Gray	.13
VA318.VIR	Antique	Gray	.18
VA322.VIR	Antique	Gray	.22
VA335.VIR	Antique	Gray	.35
VA413.VIR	Antique	Bronze	.13
VA418.VIR	Antique	Bronze	.18
VA422.VIR	Antique	Bronze	.22
VA435.VIR	Antique	Bronze	.35
VA513.VIR	Antique	Blue	.13
VA518.VIR	Antique	Blue	.18
VA522.VIR	Antique	Blue	.22
VA535.VIR	Antique	Blue	.35
VA613.VIR	Antique	Blue-Green	.13
VA618.VIR	Antique	Blue-Green	.18
VA622.VIR	Antique	Blue-Green	.22
VA635.VIR	Antique	Blue-Green	.35
VA713.VIR	Antique	Azurlite	.13
VA718.VIR	Antique	Azurlite	.18
VA722.VIR	Antique	Azurlite	.22
VA735.VIR	Antique	Azurlite	.35
VA813.VIR	Antique	Evergreen	.13
VA818.VIR	Antique	Evergreen	.18
VA822.VIR	Antique	Evergreen	.22
VA835.VIR	Antique	Evergreen	.35
VE140.VIR	Low-E	Clear	.40
VE155.VIR	Low-E	Clear	.55
VE185.VIR	Low-E	Clear	.85
VE240.VIR	Low-E	Green	.40
VE255.VIR	Low-E	Green	.55

Viracon Glass Products (cont.)

Spectral Data File	Coating Type	Glass Substrate	Ref. Tvis on Clear
VE285.VIR	Low-E	Green	.85
VE340.VIR	Low-E	Gray	.40
VE355.VIR	Low-E	Gray	.55
VE385.VIR	Low-E	Gray	.85
VE440.VIR	Low-E	Bronze	.40
VE455.VIR	Low-E	Bronze	.55
VE485.VIR	Low-E	Bronze	.85
VE540.VIR	Low-E	Blue	.40
VE555.VIR	Low-E	Blue	.55
VE585.VIR	Low-E	Blue	.85
VE640.VIR	Low-E	Blue-Green	.40
VE655.VIR	Low-E	Blue-Green	.55
VE685.VIR	Low-E	Blue-Green	.85
VE740.VIR	Low-E	Azurlite	.40
VE755.VIR	Low-E	Azurlite	.55
VE785.VIR	Low-E	Azurlite	.85
VE840.VIR	Low-E	Evergreen	.40
VE855.VIR	Low-E	Evergreen	.55
VE885.VIR	Low-E	Evergreen	.85
VS108.VIR	Stainless Steel	Clear	.08
VS114.VIR	Stainless Steel	Clear	.14
VS120.VIR	Stainless Steel	Clear	.20
VS208.VIR	Stainless Steel	Green	.08
VS214.VIR	Stainless Steel	Green	.14
VS220.VIR	Stainless Steel	Green	.20
VS308.VIR	Stainless Steel	Gray	.08
VS314.VIR	Stainless Steel	Gray	.14
VS320.VIR	Stainless Steel	Gray	.20
VS408.VIR	Stainless Steel	Bronze	.08
VS414.VIR	Stainless Steel	Bronze	.14
VS420.VIR	Stainless Steel	Bronze	.20
VS508.VIR	Stainless Steel	Blue	.08
VS514.VIR	Stainless Steel	Blue	.14
VS520.VIR	Stainless Steel	Blue	.20
VS608.VIR	Stainless Steel	Blue-Green	.08
VS614.VIR	Stainless Steel	Blue-Green	.14
VS620.VIR	Stainless Steel	Blue-Green	.20

Viracon Glass Products (cont.)

Spectral Data File	Coating Type	Glass Substrate	Ref. Tvis on Clear
VS708.VIR	Stainless Steel	Azurlite	.08
VS714.VIR	Stainless Steel	Azurlite	.14
VS720.VIR	Stainless Steel	Azurlite	.20
VS808.VIR	Stainless Steel	Evergreen	.08
VS814.VIR	Stainless Steel	Evergreen	.14
VS820.VIR	Stainless Steel	Evergreen	.20
VT120.VIR	Titanium	Clear	.20
VT130.VIR	Titanium	Clear	.30
VT140.VIR	Titanium	Clear	.40
VT220.VIR	Titanium	Green	.20
VT230.VIR	Titanium	Green	.30
VT240.VIR	Titanium	Green	.40
VT320.VIR	Titanium	Gray	.20
VT330.VIR	Titanium	Gray	.30
VT340.VIR	Titanium	Gray	.40
VT420.VIR	Titanium	Bronze	.20
VT430.VIR	Titanium	Bronze	.30
VT440.VIR	Titanium	Bronze	.40
VT520.VIR	Titanium	Blue	.20
VT530.VIR	Titanium	Blue	.30
VT540.VIR	Titanium	Blue	.40
VT620.VIR	Titanium	Blue-Green	.20
VT630.VIR	Titanium	Blue-Green	.30
VT640.VIR	Titanium	Blue-Green	.40
VT720.VIR	Titanium	Azurlite	.20
VT730.VIR	Titanium	Azurlite	.30
VT740.VIR	Titanium	Azurlite	.40
VT820.VIR	Titanium	Evergreen	.20
VT830.VIR	Titanium	Evergreen	.30
VT840.VIR	Titanium	Evergreen	.40

Azurlite is a registered trademark of PPG Industries

Evergreen is a registered trademark of Libbey-Owens-Ford

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Appendix B: Use of FRAME 3.0 Output Files

As discussed in Sections 4.10 and 4.11, the results for frame and divider elements that have been modeled with FRAME 3.0 can be imported into the WINDOW 4.0 frame and divider libraries. This appendix describes this process in more detail. While this process includes divider and divider-edge U-values as well as frame and frame edge-of-glass U-values, we will refer to frame and frame edge-of-glass U-values for the sake of brevity.

With the FRAME 3.0 program, three different types of simulations are possible:

(1) modeling of the frame and edge-of-glass U-values for a specific glazing system;

(2) modeling of the frame and edge-of-glass U-values for two different glazing systems with equal glazing system widths but different center-of-glass properties (i.e. coatings and/or gas fills can vary); and

(3) modeling of the frame and edge-of-glass U-values for two sets of glazing systems. Each set has two glazing systems with the same glazing system width, but different center-of-glass properties. The two sets however may have different glazing system widths.

Each type of FRAME 3.0 file has a distinguishable format in WINDOW 4.0:

For type (1), WINDOW displays the frame and edge-of-glass U-values, the Width and U-value of the glazing system (Uc), and the Projected Frame Dimension (PFD) and Absorptance (Abs) of the frame from the FRAME 3.0 file.

For type (2), WINDOW displays only the Width of the glazing systems, and the PFD and Abs of the frame from the FRAME 3.0 file. The abbreviation "var" appears in the frame and edge-of-glass U-value fields, and the glazing system U-value field.

For type (3), WINDOW displays only the PFD and Abs of the frame from the FRAME 3.0 file. The abbreviation "var" appears in the frame and edge-of-glass U-values fields, and the glazing system Width and U-value fields.

The influence of FRAME 3.0 frame elements from the Frame Library on a window system can be viewed on the Main Screen. WINDOW recognizes the type of FRAME 3.0 file and calculates the frame and edge-of-glass effects on the total window heat transfer according to the type of FRAME 3.0 file.

For type 1, the Width and U-value of the glazing system used in WINDOW 4.0 must be within 5% of the Width and U-value of the glazing system used to model the frame in FRAME 3.0. The frame and edge-of-glass U-values, and the PFD are fixed. Note that the Widths and U-values for specific glazing systems are given on the top half of the Glazing System Library.

For type 2, the Width of the glazing system used in WINDOW 4.0 must be within 5% of the Width of the glazing systems used to model the frame in FRAME 3.0. The glazing system U-value must be between or within 5% of the U-values of the glazing systems used in the FRAME 3.0 frame modelling. WINDOW linearly interpolates the frame and edge-of-glass U-values with respect to the glazing system U-value and displays these interpolated frame and edge-of-glass U-values on the Main Screen. The PFD is fixed.

For type 3, the Width of the glazing system used in WINDOW 4.0 must be between or within 5% of the Widths of the glazing systems used to model the frame in FRAME 3.0, and the glazing system U-value must be between or within 5% of the U-values of the glazing systems used in the FRAME 3.0 frame modelling. WINDOW interpolates the frame and edge-of-glass U-values with respect to the glazing system Width and U-value, and displays these U-values on the Main Screen. The PFD is fixed.

For all FRAME 3.0 frame elements used in a window system, the PFD appearing on the Main Screen is set equal to that from the FRAME 3.0 data file which appears on the Frame Library. Note that for all FRAME 3.0 frame records, the PFD field is protected and cannot be changed.

Note that the Show Detail option can be used in the Frame Library to provide more information on the .F30 file. For all information on this entry, use FRAME 3.0 to review the results of a specific .F30 file.

Appendix C: Summary of Computational Methodology

The algorithms used in WINDOW 4.0 build upon those documented in [Arasteh et. al., 1989]. Additions to the calculational procedure discussed in this reference are presented in this appendix.

The underlying premise in the WINDOW 4.0 calculation procedure is that the total window properties are an area weighted average of the component properties (i.e. glazing system, frame, edge-of-glass, divider, and divider-edge-of-glass). In some cases, i.e. edge-of-glass U-values, a component property depends on other properties (i.e. frame U-values and center-of-glass U-values). Refer to Figures 4 and 5 for a description of each window system component.

Glazing system (center-of-glass) thermal and optical properties are calculated using the methodology presented in [Arasteh et. al., 1989]. Note the use of specific spectral weighting functions specified in Appendix B.

Frame and divider U-values are either "inexact" typical U-values for generic cross-sections or are determined using the FRAME 3.0 [Enermodal Engineering, 1992] computer program. Typical frame U-values for several different product types, chosen by ASHRAE TC4.5, are listed in the Frame Library. Typical divider U-values for several different generic products are listed in the Divider Library [Acevedo-Ruiz, 1991]; note that these divider U-values are typically a function of glazing system properties (U-value, width). Exact frame or divider U-values can be determined by the FRAME program or other FD/FEA computer code. Visible transmittances of frames and dividers are always zero. The solar heat gain through a frame or divider is a function of the absorptance multiplied by the inward-flowing fraction. Inward flowing fractions are derived using a simple one-dimensional model and are the ratio of the resistance from the absorbing surface to the outside divided by the total resistance.

Edge-of-Glass U-values and Divider-edge-of-glass U-values can also be obtained from default correlation or determined using the FRAME program. Default correlations for Edge and Divider-edge U-values for generic spacers and divider types are given in the Frame Library and the Divider Library; note that these correlations also depend on the glazing system properties. These correlations were determined using Finite Element Modeling [Arasteh, 1989; Acevedo-Ruiz, 1991] and are intended to give the user an idea of the performance level obtainable with a generic spacer or divider type. Exact edge and divider-edge U-values can be determined using the FRAME computer program or other similar Finite Element Modeling program. Solar and visible properties of edge and divider-edge areas are assumed to be the same as those of the center-of-glass or glazing system. This is a reasonable assumptions as shown in [Carpenter, 1991].

Each of the solar optical properties for the glazing system is weighted by an appropriate weighting function(s). All properties are weighted with a solar spectral irradiance function [ASTM E87-891] which represents the direct normal radiation incident on a surface at 37 northern latitude (AM1.5). Visible properties (0.38 to 0.78 microns) are also are weighted

by the photopic response of the eye, which is taken as the Y tristimulus value for the CIE 1931 standard observer. However, the CIE 1964 supplementary observer is used for the calculation of the color indices [ASTM E308-90]. The damage-weighted transmittance is a relative measure of the influence sunlight has on fabrics. Solar radiation in both the ultraviolet (0.3 to 0.38 microns) and visible spectrums have been shown to cause fabrics to degrade. The damage-weighted transmittance is thus also weighted by the Krochman's Damage Function (Krochman, 1978). The unweighted "ultraviolet" transmittance does not include the effects of any damage weighting functions. The thermal infrared properties (5.0 to 40.0 microns) are weighted by the black body spectrum at room temperature (300 K). The data for each one of these weighting functions lies in ASCII files which are found in files specified in the W4SOLAR.DAT file on the main directory. At this point in time, we do not recommend making any changes to these files. However, if you do, Update all spectral data files and associated glazing systems and windows.

For uncoated glazings, WINDOW 4.0 calculates the angular properties of a glazing system based on algorithms developed by Furler (1991). For coated glazings, the angular properties are assumed to have the same relationship as either typical 1/8" clear glass (if the solar transmittance is greater than 0.65) or typical 1/8" bronze glass (if the solar transmittance is less than 0.65).

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Acknowledgements

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