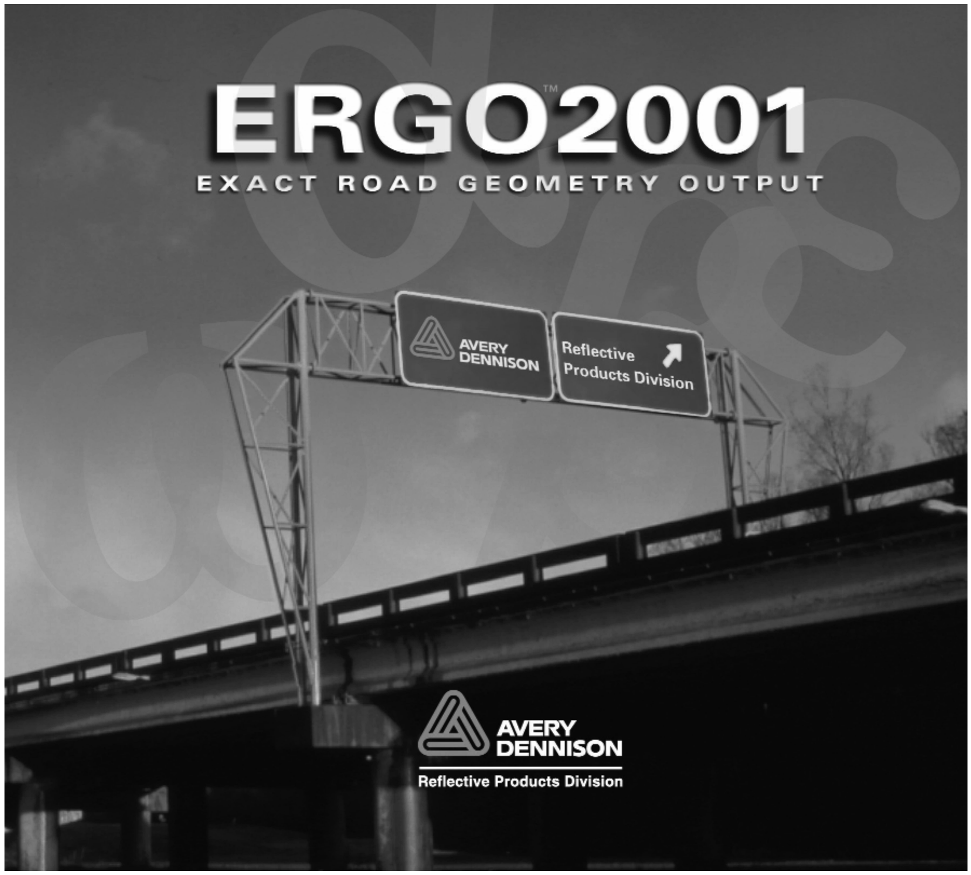

User's Guide

for Version 1.0.2 January 2002

AVERY DENNISON
Reflective Products Division

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ERGO™2001

. . . computes traffic sign luminance produced by retroreflectivity

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ERGO™ 2001

Table of Contents

What is ERGO™?

Avery Dennison's ERGO™2001 is the first Windows-based ERGO program. It replaces the DOS-based ERGO52 released in 1998. ERGO has been long evolving. It was originally developed for Stimsonite[1] in late 1991. The first program ran on a TI-59 calculator and simply computed the many different angles for describing retroreflection (observation angle, entrance angle, rotation angle, orientation angle, etc.) from dimensional inputs about the vehicle, the road, and the sign. The mathematical definitions for these angles had been long available, but using them for specific highway signing situations involved difficult interpretations and tedious computations. As a result, many researchers resorted to various 'approximations,' often leading to invalid conclusions about retroreflection applications. At the very least, ERGO (Exact Road Geometry Output) got the angles right.

By 1994, a DOS version of ERGO was freely distributed to researchers. ERGO became the benchmark program in calculating exact angles of retroreflection. The original ERGO angle computations are unchanged in the core of ERGO2001.

In 1996, ERGO46 added headlight intensity to its computations. Computing the illuminance on the sign required headlight beam data from outside sources. The data pool was greatly improved in 1997 with the publication of UMTRI-97-37 *"A Market-Weighted Description of Low-Beam Headlighting Patterns in the U.S."* The UMTRI data was broader based, at finer increments, and over wider beam angles than previous headlight data. The ERGO developers are indebted to UMTRI for making their headlight data available and for continuing to update it.

In 1998, ERGO50 added sheeting retroreflectance and sign luminance to its computations. To compute the sheeting coefficient of retroreflection (R_A) at the four angles describing the retroreflection geometry in an arbitrary circumstance required a large photometric database for each sheeting. Nothing of the sort was available, so Stimsonite spent a year photometering sheetings–theirs and competitors–to make ERGO50 functional.

The method was to obtain, from multiple sources around the U.S., many unused samples of each of six sheeting types. Each sample was photometered to a short protocol (625 test points). The median sample from each type was then photometered to a long protocol (62,000 test points for a glass bead sheeting; 186,000 test points for a prismatic sheeting) and this data represented the type. Those same six photometric datafiles accompany ERGO2001. It is hoped that others will follow similar screening and measurement procedures to add to the pool of sheeting photometric datafiles.

The acceptance of ERGO's computations and data has promoted a more informed and accurate understanding of retroreflective sign performance and a better foundation for research on the use and specification of signing materials. Note well: ERGO predicts the luminance of a retroreflective sign, under particular road, vehicle, and headlight conditions. For stated conditions, ERGO allows comparison of various sheetings according to the sign luminances that each material produces. However, it is still for the user

[1] by Dennis Couzin.

to assure relevance of comparisons. For this, the user must know the range of distances at which a sign can be noticed, recognized, and read. Also, the user must know what sign luminance levels are needed at each distance. These are still matters for human factors research, and far from being known. ERGO just calculates all that can be calculated from the geometry and the optics, making it a tool for researchers, and a modeler of the retroreflective road signs of the future.

ERGO2001 computes and/or provides the following data:

1. ANGLES of RETROREFLECTION: ERGO2001 will determine the exact on-the-road geometric parameters (angles commonly used to define retroreflection) for the user-designated specific situation. A 'sign scenario' is defined by the user by entering dimensional values (meters or feet) for 1) the locational parameters of the sign (height and offset from the road); 2) dimensions for the specific vehicle from which the sign is to be seen (relative to the driver-headlight location dimensions); and 3) the road distance to the sign. From these parameters all the angles used to define specific retroreflective geometry are determined by computations using a vector coordinate system.

A complete graph for any of these angles, showing the change as the driver approaches the sign, computed and presented separately for each headlight, is produced by ERGO's Graphic Output function simply by clicking on the selected angle name.

While the angles most often used in specifications are Observation Angle and Entrance Angle, four separate angles are actually required and, in ERGO2001 precise angular values are reported for eleven separate angles, each used in one or more of three different geometric systems of retroreflection. These angles, computed and reported separately for each headlight, are:

	Angle[1]	**Angle System**[2]
α	Observation Angle	A,I,C
β	Entrance Angle	A,I
γ	Presentation Angle	I
ε	Rotation Angle	A,C
ρ	Tilted Rotation Angle	
ω	Orientation Angle	A,I
β_1	Entrance Angle component	C
β_2	Entrance Angle component	C
H_v	Headlight Angle—Vertical	
H_h	Headlight Angle—Horizontal	
ν	Viewing Angle	

[1]Definitions of the angles and angle systems used in specifying retroreflection can be found in ASTM E 808 (Standard Practice for Describing Retroreflection) and in CIE Publication 54.2 (Retroreflection: Definition and Measurement). Note that the angle denoted by ω in ERGO is denoted by ω_S in these documents. Headlight angles H_v and H_h follow the conventions of SAE J575 (Tests for Motor Vehicle Lighting Devices and Components).

[2]Letters denote: A = Application System; I = Intrinsic System; and C = CIE Goniometer System.

Note: Specifications (including ASTM) are written in the CIE Goniometer System since for testing purposes sample positioning is simple on readily-available goniometers using this system. However, it is very difficult to visualize some of the angular relationships of this system for signs on the road. The Application System is more intuitive and it's easier to see how each angle occurs for signs on the roadway. The Intrinsic System has some other advantages. Each system can define any angular geometry that occurs, and it is possible to convert from one system to another, such as the ERGO2001 Sheeting window does.

2. ILLUMINATION on the SIGN: ERGO2001 includes files containing data for the luminous intensity provided by various headlights, both U.S. and European, over a wide range of illumination angles. The user selects a specific headlight from the headlight files included. ERGO2001 then interpolates the relevant luminous intensity output value for that headlight at the correct angles as determined above and computes the illumination, separately for each headlight, at the surface of the sign at the designated distance. Complete illuminance graphs are produced simply by clicking on the 'Illuminance on Sign' tab in Graphic Output.

3. RETROREFLECTIVITY VALUES–SIX SIGN SHEETING MATERIALS: Simply designate the sheeting material, enter the four angular values for the angle system you want to use, and ERGO2001 will provide the R_A value in its files at that specific that test point. (This is like having your own laboratory photometer within your computer!).

For a graph of R_A values select 'Retroreflection' under Graphic Output.

4. SIGN LUMINANCE: In the same manner that ERGO2001 computes the illuminance on the sign, it uses the angular geometry values again, and the illuminance values, and it additionally now accesses the Retroreflection data to multiply, again separately for each headlight, the R_A value by the illumination from that headlight, and divides by the cosine of the viewing angle to give the sign luminance resulting from each headlight. Finally, it sums those two luminance values to give the total sign luminance at the designated distance (in Snapshot) as it will be seen by the driver.

5. GRAPHS of SIGN LUMINANCE: Commonly, the information sought regarding sign performance is best represented by a graph of the Luminance Values as they occur for that sign as a driver approaches the sign from a distance. In Graphic Output, the user simply clicks on a button to obtain this graph. The program will recompute all values at user-designated distance intervals (for example, every 5 meters). The luminance curve may be determined for any or all of the six sign sheeting materials and may be printed to provide a hard copy record.

ERGO2001–The 'Standard'

The angular computations in ERGO2001 have been checked and rechecked for ten years and the computations are proven accurate; they have become the 'benchmark' for determination of retroreflective geometry. Unlike any previous program, ERGO2001 does not use approximations but utilizes specific dimensional input for every relevant variable and computes each angle by a vector coordinate system. Since its inception ERGO has been used by many to determine geometry or to verify other data. During this decade of development, no error of angle value has been found in an ERGO computation. We're pleased to note that the reflective sheeting manufacturing community uses and acknowledges ERGO2001 data in studies and presentations, including those for ASTM.

The advanced level of information which ERGO2001 now provides the user can be exciting in the knowledge which the user can now develop and determine with certainty. The proper utilization of this tool can lead to a more accurate and complete understanding of the effect of variables in actual sign performance. This is certainly valuable in research, in preparing meaningful and accurate specifications, in selecting sign materials for general use or for particular applications, and even in the final application: determining optimal sign placement.

There are many various ways that ERGO 2001 computations and/or data may be applied to particular problems. Users can access the data, select portions of the data, make computations and express it in unique ways for their particular purpose. They can record the data using ERGO2001's graphing capabilities. ERGO2001 is specifically designed to provide 'output' which may be 'customized' by the user to best develop and express the data for his particular requirements or purposes.

Note: All ERGO 2001 reflectivity and luminance data assumes WHITE material. Nearly all principles of retroreflective signing can be determined and comparisons can be done validly in white, but for luminance values of signs in other colors a color factor may need to be applied.

IMPORTANT: The proper use and interpretation of the Luminance graphs requires attention to the vertical scale of luminance values. The graphing program adjusts the vertical luminance scale to make the highest curve fill the graph. Thus different scales occur for different graphs. If you print several graphs to compare them, be sure to note the vertical scale difference.

Luminance–how much is needed?
It isn't true that 'more' luminance is always better. Determining how much luminance is necessary *is important*, and ERGO2001 can be extremely useful as a research step to establish valid levels. In ERGO2001, the luminance is determined once the necessary resource data is available and the input geometry is entered. But the final luminance value for any viewing scenario tells nothing about how much luminance is needed by the approaching driver–for conspicuity, or for legibility, or for what period of time luminance must be maintained.

The user must refer to his own knowledge and/or research and/or to other sources of information to establish a 'minimum' acceptable level of luminance for a given situation. This minimum level will vary based upon assumptions as to the essential approach distances, vehicle speed, legend size, and other considerations. In the last two decades programs have been offered which attempted to include many such considerations. Unfortunately none of these escaped three major deficiencies: 1) they did not calculate luminance accurately; 2) the basis of their computations could not be checked; and 3) the input variables and the program assumptions could not be changed. Values had merit simply as values produced by that given program.

ERGO2001 is presented as providing accurate, checkable luminance values. The conditions to be studied are infinitely variable and under the user's control. The subsequent determination of the minimum adequate luminance level to meet drivers' needs in a given circumstance is a second tier determination, for which computations can be easily documented. Changes in program assumptions can be set forth and different results compared. Hopefully, such studies will use ERGO output data, together with empirical data and clearly stated performance criteria, to result in comparisons which are both accurate and valid.

ERGO2001 Today
ERGO2001 will continue to be refined to facilitate its use. New data will be included as it becomes available. As is, the program does provide the user the ability to add whatever data he acquires or postulates on additional vehicle dimensions, headlight types, or sheetings.

Its value, to you, will be determined by its use. The Avery Dennison Reflective Products Division will assist any user in obtaining from ERGO2001 whatever information they seek in whatever form they wish. In turn, we solicit your comments, suggestions for improvement, and ideas for additional sources of usable data.

ERGO2001 Citations
Where ERGO2001 is used as a data source or as a reference or tool in any research, please credit ERGO2001 in the references. The University of Michigan Transportation Institute (UMTRI), provider of much detailed headlight data, also requests proper credit when their data is used in the ERGO computations.

Updates
Updates to ERGO2001 are available on the Avery Dennison Reflective Products Division web site where you can also communicate requests for further information, guidance and assistance in its use. Registered users will be notified of updates.

http://www.reflectives.averydennison.com
email: optics@averydennison.com

ERGO™2001

. . . computes traffic sign luminance produced by retroreflectivity

Operating Instructions
These Operating Instructions are intended to help you to easily use the ERGO2001 program—to get the information you want. The program will prompt you to insert required input values and also to select from various data inputs available in the program. If you know the values you want to use, you will find the operation of this program to be quite fast, easy to use and productive. The first section, *"Step-by-Step Instructions - Sign Luminance"* will take you quickly through the basic program—and you'll soon be using ERGO by yourself.

As you begin to use the ERGO2001 program it is likely that you will have questions as to the basis of some of the required inputs in order to understand the choices that you're making. You might be wondering what input changes produce significant changes in the outputs so you can study their effects.

The last section of these instructions will give you the information how to add data files and make other changes to certain program inputs. A primary tenet of ERGO is that you are in control. You are encouraged to add data files which you may acquire; delete unused files as you choose; and customize ERGO2001 for your convenience. Refer to Appendix A, File Formats Used in ERGO.

Note: All values in ERGO are for white sheeting. This is appropriate for material comparison and represents both dark-background signs with white legend or white background signs with black legend. Appropriate color factors can be used if necessary, but they are not incorporated within the ERGO2001 application itself.

ERGO2001
Primary Function–Determining Sign Luminance

The primary function of ERGO2001 is to determine the nighttime luminance of signs in various roadway scenarios as it results from the retroreflection of the vehicle headlights. It will accurately determine sign luminance in virtually any roadway scenario that you can create and want to consider. This section documents that procedure step by step.

For determining sign luminance you will input geometric data which ERGO2001 will use to compute the exact retroreflective geometry of the sign:

- **the Road:** width and contour on which the vehicle approaches the sign
- **the Vehicle:** in which the driver views the sign and from which it is illuminated
- **the Sign:** its location and position

You will also provide inputs which will in turn select data from ERGO's data files to determine the quantity of light available to the sign (at the angle determined above) and the efficiency with which it is reflected to the driver:

- **the Headlights:** on the vehicle
- **the Reflective Sheeting:** on the sign.

ERGO2001 will then compute the exact luminance resulting from those conditions.

Notation conventions used in this guide:

Tips: Usually pretty handy things to know; even Important—but usually not a sequential Operating Instruction. They look like this:

√ **TIP**	Check the Road View to be sure you have what you wanted.

Info, Discussion: More useful information - -. They look like this:

Info:	When you select a particular vehicle, the five basic dimensions for that vehicle will appear below in "View / Create a vehicle"

Comments: Comments provided within the Instructions that will be important to some users, not necessary to others, and not needed for the basic operations will appear in this format.

Step-by-Step Instructions—Sign Luminance

Once you've installed ERGO2001, launch the program. The main window, Figure 1, will fill your screen.

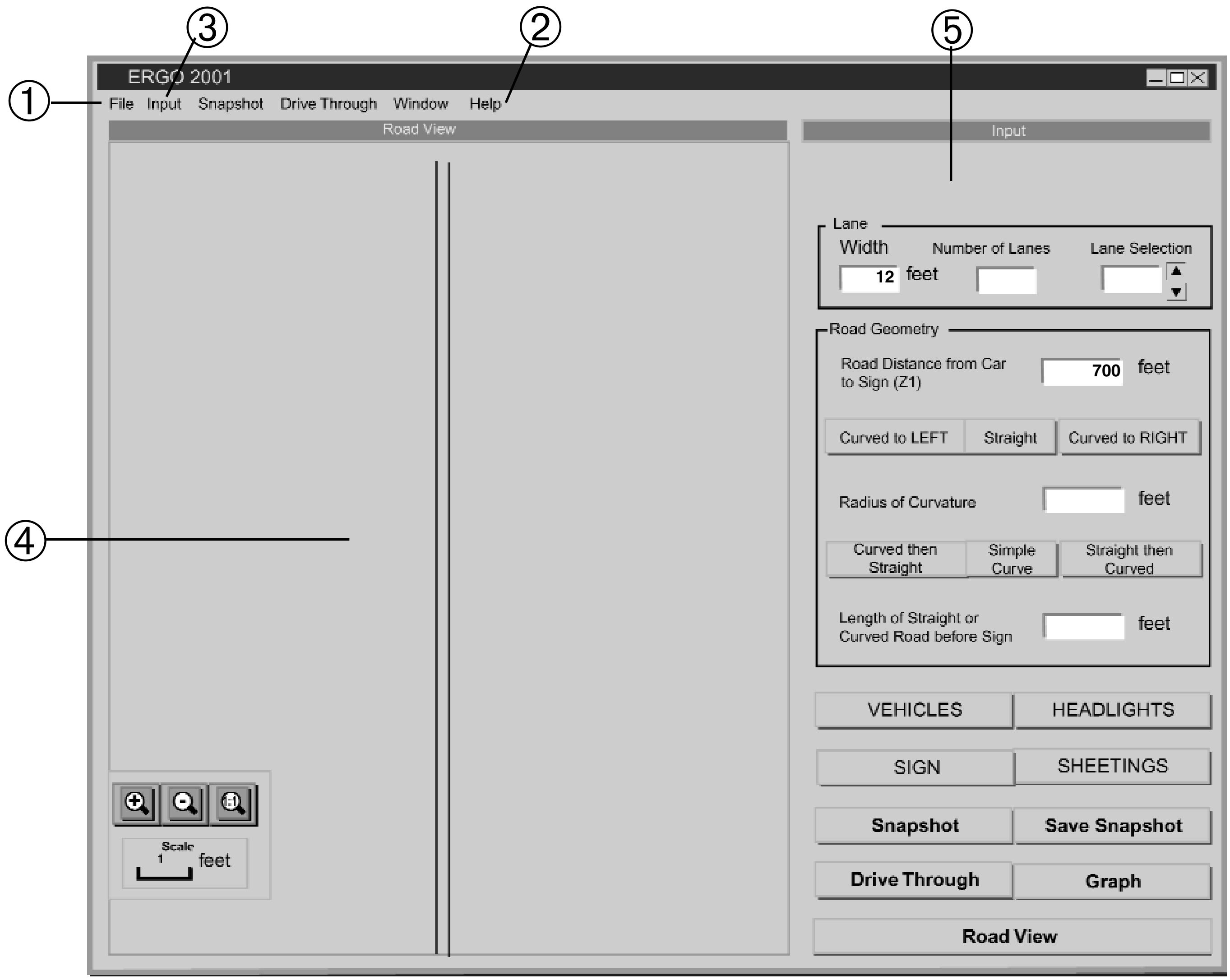

Figure 1. The main ERGO Window

① The Menu Bar:
② Help (on the Menu Bar) (After using ERGO the first time, you'll usually start directly with the "input" area of the main window.)

✔ tip	Click on **Help**; select: **How to Start** —this will access the ERGO QuickStart screen which provides minimum data requirements for each screen. You should print this one page document for reference as you become familiar with ERGO.

③ Input (on the Menu Bar) Click on it:
a. to switch the **Distance Unit** from meters to feet–or feet to meters.[1]
b. to choose between **Right side** or **Left side** traffic.[1]

Right side = USA, Europe; **Left side** = England, Japan, Australia

[1] Your settings will be retained until you decide to change them; subsequent sessions can start with the data Inputs of the ERGO main window.

④ **Road View** –Left segment of ERGO's main window)

Road View To help you see the kind of roadway your inputs are creating, a ‘picture’ of the road will appear on the left side of the screen, and will change as you enter various inputs for the road. Sometimes large road curvature will result in part of the road being out-of-view. While you cannot re-position it in the view, if you change the scale a step or two (by using the + an buttons at the lower left corner of Road View), the entire road will be included in the Road View screen. The sign is seen as a small red line (as if you’re looking down on the sign) and the vehicle will be positioned in the lane you select.

Use Road View to be sure you’ve created the scenario you wanted.

A road view example is shown here for illustration only; your screen will be blank at this point.

⑤ **Input**–Right segment of ERGO’s main window

The entire right side of the main window contains empty data fields or links to other screens required by ERGO.

Describing The Road:

1. Lane

Note: If ERGO has been used previously, the three entries under ‘Lane’ will recover the values that they last held. If you want to change them just overwrite with your new settings.

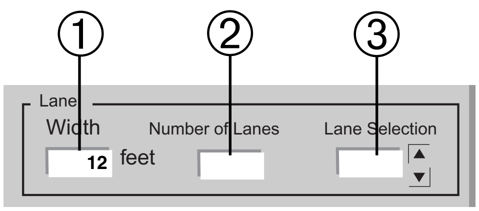

Figure 2. Lane input segment of ERGO main window.

① Width: Enter the width of your lanes. (US road lanes are often about 12 ft. wide.)

② Number of Lanes(Optional) Enter Number of lanes on the road you’re considering.

✔tip	Specifying an odd number of lanes creates a one-way roadway. All lane-lines in Road View will be white; the vehicle may occupy any lane. Specifying an even number of lanes creates a two-way roadway. The centerline in Road View will be yellow; the vehicle cannot occupy an oncoming traffic lane.

③ Lane(Optional): Select: the lane your vehicle is in.

✔tip	Check the Road View to be sure you have what you wanted.

2. Road Geometry

Discussion	The horizontal contour of the roadway leading up to signs may be straight during the entire approach. If it’s not “straight” it can be characterized as either a portion of a circle (Simple Curve) or as a combination of two segments. The two possible combinations in ERGO are: a) Straight, then Curved (sign at the end of the curved segment), or b) Curved, then Straight (sign at the end of the straight segment). Whether simple or compound, the curved portion may curve to the left or to the right. These selections are input into ERGO under Road *Geometry*. The total distance of the approach to the sign is set in ①. It can be a combination of first a length of straight road followed by a length ⑤ of curved road leading up to the sign or, it is first a length of curved road followed by a length of straight road ⑤ leading up to the sign. Entries ② through ⑤ define that choice.

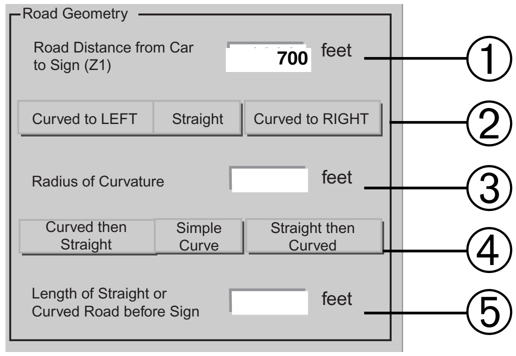

Figure 3. Road Geometry portion of the ERGO main window.

① Enter: The distance the vehicle will travel along the road from the distance or at the location in which you are interested all the way to the sign.

Note:	The distance you enter here is the basis of the single-distance numeric outputs (for angles, illuminance, luminance, etc.) which are provided in “Snapshot.” However, the “curves” of the changes in various outputs during an entire approach to the sign, created later in the program, will use distance inputs that you enter in that part of the program.

② Select: Straight Road; Curved to LEFT; or Curved to RIGHT.
If you haven’t entered the road distance in ①above you’ll be prompted first to enter a value for distance before proceeding.

➨ If you select “Straight Road” you are finished with this section and the data selection and input boxes relating to road curvature which follow will become inactive. Go on to “VEHICLES”.

If you have selected a road with any curvature:

③ Enter: A value for the radius of curvature

④ Select: The contour of the road for the road distance before the sign that you have input in ¨ above.
The three choices are: Curved, then Straight road,
Simple curve (a portion of a circle), or
Straight, then Curved road.

If you select ‘Simple Curve,’ no entry will be required for ⑤ below and the input box will go inactive.)

⑤ (If required) Enter: The length of the second portion of roadway (which is straight or curved, whichever you selected) at the end of which is the sign.

✔tip	Check the Road View to avoid ‘impossible’ scenarios and to be sure you have created the horizontal road contour that you wanted.

➨ You have completed the dimensions and contour of your ROADWAY. The Dialog Box will show the values you have entered and the “boxes” for your choices will be white.

3. VEHICLES

Click on the VEHICLES button. The “Define / Select Vehicles” Dialog Box will appear.

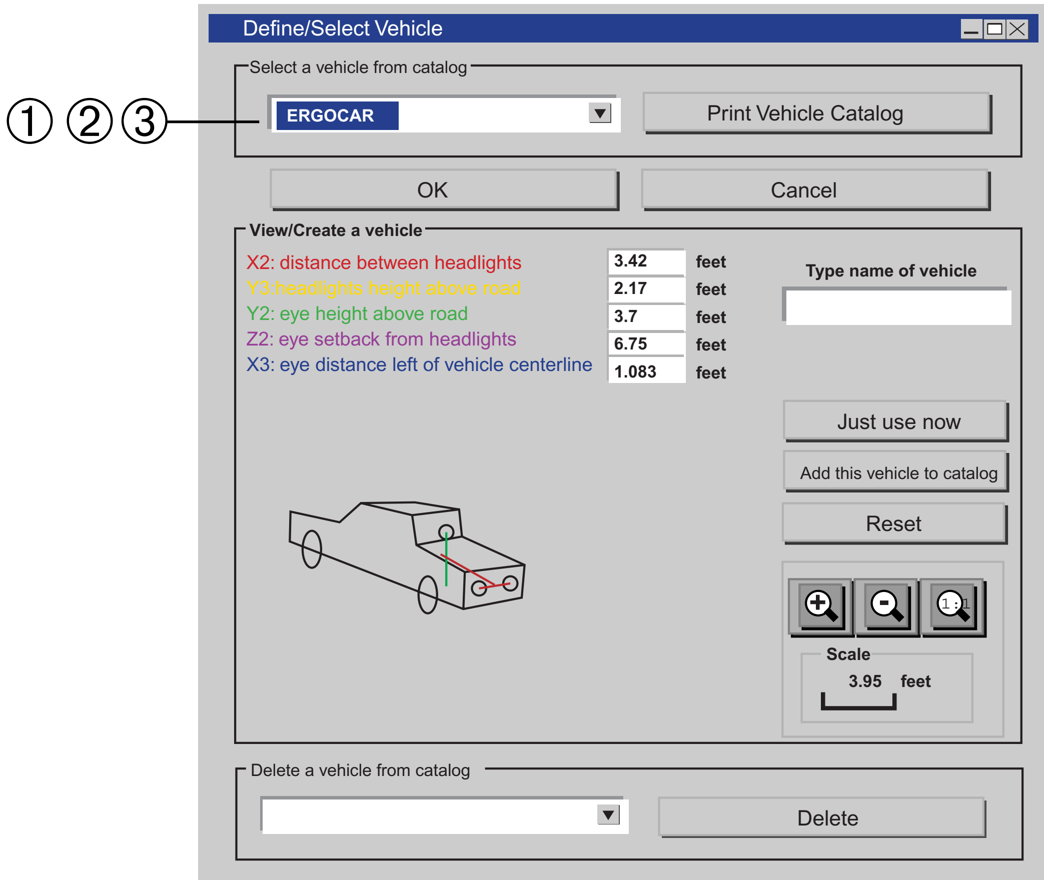

Figure 4. Define / Select Vehicles dialog box.

① Click on the drop arrow next to “Select a vehicle from catalog.” A listing of the vehicles in the “catalog” will drop down. Some information about the vehicles is in Table A below.

② Select: Highlight the name of the vehicle you want to use from the catalog.

Table A. Vehicles in ERGO Catalog as of January 2002

Filename	Vehicle Type	Source
ERGOCAR	Typical Medium-sized car	ERGO authors
CEN car	Typical Medium-sized car	CEN
UMTRIcar	Typical Medium-sized car	UMTRI
Woltman wide car	80s full-size car	CIE Pub. 113
Motorcycle (single HL)	motorcycle	CEN
UMTRI light truck/van	Light truck or Van	UMTRI
CEN bus/lorry	Bus or truck	CEN
Cobb Heavy Truck	Large Truck	TRRL

➩ *To print the dimensions of all the vehicles in the catalog, Click on ‘Print Vehicle Catalog.’*

➩ *When you select a vehicle, the five dimensions entered for that vehicle will appear in ‘View/Create a vehicle’ Dialog Box.*

Info:	Additional vehicles may be created by entering dimensions into the boxes under ‘View / Create a vehicle.’ You can use it one-time or it may be added into your vehicle catalog. Unwanted vehicles can be deleted using 'Delete a vehicle from catalog'.

③ When the vehicle you want to use is highlighted, Click: OK.

➨ You have completed your selection of a VEHICLE. The “VEHICLES” button on the main ERGO window will turn white and will show the filename of the selected vehicle.

4. HEADLIGHTS
Click on the HEADLIGHTS button. The “Headlights” Dialog Box will appear.

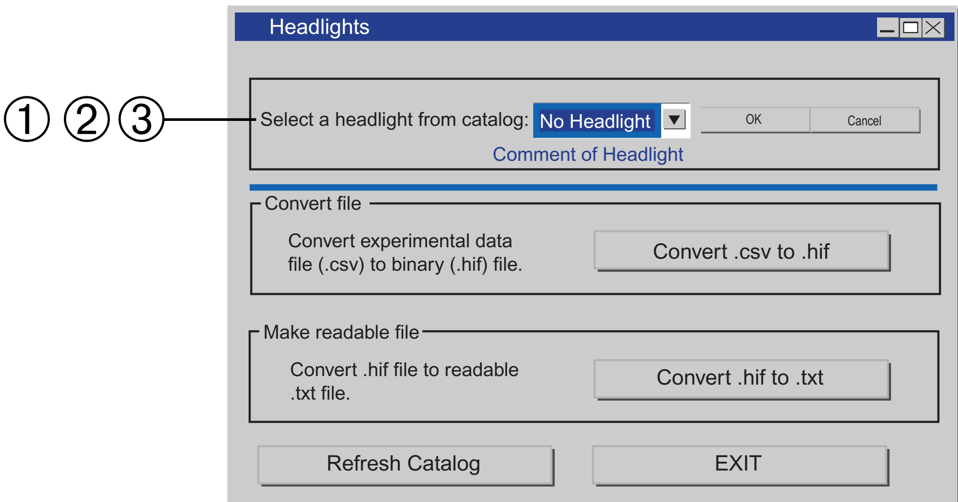

Figure 5. Headlights Dialog Box.

① Click on the Drop arrow next to “Select a headlight from catalog”
The available headlight filenames in the catalog will drop down as shown in Table B.
Once selected, an identifying comment will appear below the headlight window.

② Select the headlight you want to use.

Table B. Most Popular Headlights in ERGO Catalog (as of January 2002).

Filename	Description	Source
umtri us low 2001	Low-beam USA pass. veh.; mkt. weighted; 50th percentile	UMTRI-2001-19
umtri50e2000	Low-beam Europe pass. veh.; mkt. weighted; 50th percentile	UMTRI-2000-36

See description of ERGO’s .hif datafiles in **Appendix A, File Formats used in ERGO**.

Info:	See Appendix A for instructions how to make, add or delete headlight files.

③ When the headlights file you have selected is highlighted, click: OK.

➨ You have completed your selection of HEADLIGHTS. The HEADLIGHTS button on the main ERGO Window will be white and will show the filename of the selected headlights.

5. The Sign—Its Location and Angular Position

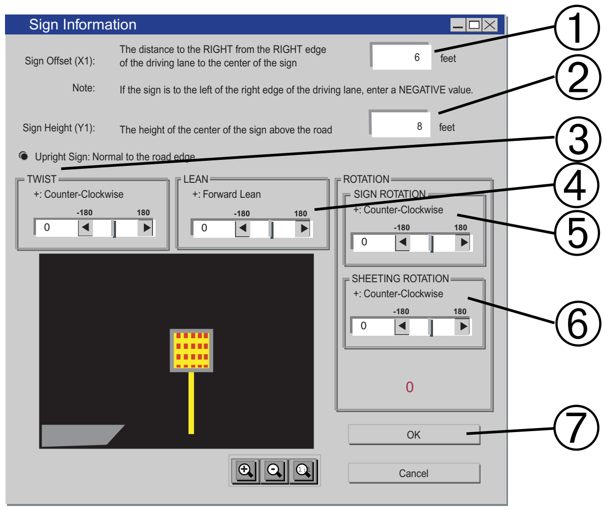

Figure 6. Sign Information Dialog Box.

A. The sign must be located relative to the roadway–Sign Offset & Height

① Enter a Value for **Sign Offset**: This is the distance to the RIGHT–from the RIGHT edge of the vehicle driving lane to the center of the sign.

Discussion	**Sign Offset values:** Sign Offset is measured from the right edge of the vehicle driving lane. **Right-Side Signs:** If the vehicle is *not* in the farthest right lane, be sure to add lane widths for the lanes to the right of the vehicle and then add the distance from the road edge to the center of the sign. To verify your values: Check the Road View or the road in the Sign Diagram. **Overhead and Left-side Signs:** Sign Offset is measured from the right edge of the vehicle driving lane. A sign which is left of this edge requires a negative value offset. To locate an Overhead Sign in the center of the same lane as the vehicle, requires a negative half lane-width (usually -6 ft.) Left-side signs on a two-way roadway will normally be at an offset of –12, –12, –x or about –30 ft. (where x is the distance to the left side sign from the road's other edge.) To verify your values: Check the Road View or the road in the Sign Diagram. Note: If Left-side traffic option was used, reverse left-right in these instructions.

② Enter Value for **Sign Height**: This is the height of the center of the sign above the roadway. Your entries for Sign Offset and Height have established the location of the sign.

B. Angular Position Settings: All angle entries are variable from –180° to +180°.

✔tip **Operation**	**Default angular position— Upright Sign**: Normal to the road edge. To make a simple, upright mounted sign, with TWIST, LEAN, and ROTATION all set to "0," click on **Upright Sign**.

To put the sign into any other angular position, you must specify a non-zero value for at least one of the angular position parameters: TWIST, LEAN, ROTATION. Note: At the beginning of operation, TWIST, LEAN, and ROTATION are each preset to zero.

CAUTION! The effect of change in the angular position parameters of the sign are not always the same as you might expect from the terms. Pay particular attention to the following definitions.

✔tip	**SIGN DIAGRAM:** To help you check the effect of your angular position entries, a diagram of the sign (with an attached 'sign post'–See below) is shown in the window. The sign image will update with each entry you make or change. The face of the sign displays arrows to indicate the sheeting orientation of the sign face. The sign and the roadway are both also in this scene at their relative location relationship and scale. The roadway may not always be visible in the scene with the sign if the scale is too large. Use the scale buttons to see the roadway/sign location relationship.

Discussion	In ERGO, both in computations and in the sign diagram, the sign center is always at the position determined by the dimensions for Sign Offset and Sign Height, regardless of the angular position settings. If the sign is 'tilted,' in ERGO the center of the sign stays in place and it is the sign 'post' (which exists only for the sign Image) which is displaced to the side. The 'sign-post' is introduced into the Sign Diagram simply as a visual aid to interpret the angular position of the sign. Initially, the sign in the Diagram will have no 'post.' The image acquires a post when you click on 'Upright Sign' or 'OK,' or if you Insert a non-zero value into any angular position parameter. Even an 'Overhead' location will have a 'post'–*in the middle of the roadway!*

③ **TWIST** is the change in position as the sign rotates about a vertical axis through the sign-center. (It's not "rotation about the axis of the sign post" unless the sign is exactly vertical.)

Note: You can even turn the sign around so you see the 'back' of the sign, but, as in the real world, all retroreflectivity outputs will then show 'NO DATA.'

④ **LEAN** is tilt, forward and back, in a plane which includes the hypothetical sign "post." This plane is perpendicular to the sign face.

✔tip	If you click and hold on either TWIST or LEAN, the sign position will continuously update, allowing you to see how each input works.

ROTATION:

⑤ **SIGN ROTATION** is the sign face rotated in its own plane.

⑥ **SHEETING ROTATION** is the sign sheeting rotated on the sign face.
Technically, this is exactly the same effect as "Sign Rotation" above, but by entering these separately, it allows easy combinations of the two without any separate calculations.

Note: The sum of the two rotations is shown as TOTAL ROTATION.

✔tip	If you want to quickly eliminate all the entries in the angular position settings, click on **Upright Sign**. All four position settings will reset to '0.' You can then re-enter any values you want or use the default '0' setting.

⑦ Click **OK**.

➨ You have completed specifying the location and angular position of the sign. The SIGN button in the basic window will be white and it will show 'Upright' or 'Tilted' to correspond to your selection.

6. Sheetings

Six different retroreflective sign sheetings are in the sheeting catalog (as of January 2002) and have a full data set of their reflectivity values[2] within ERGO.

[2]The data set for prismatic sheetings includes 186,000 separate test points; combinations of Observation angle, Entrance angle, Orientation angle and Rotation angle to provide data for virtually every signing geometry that can occur.

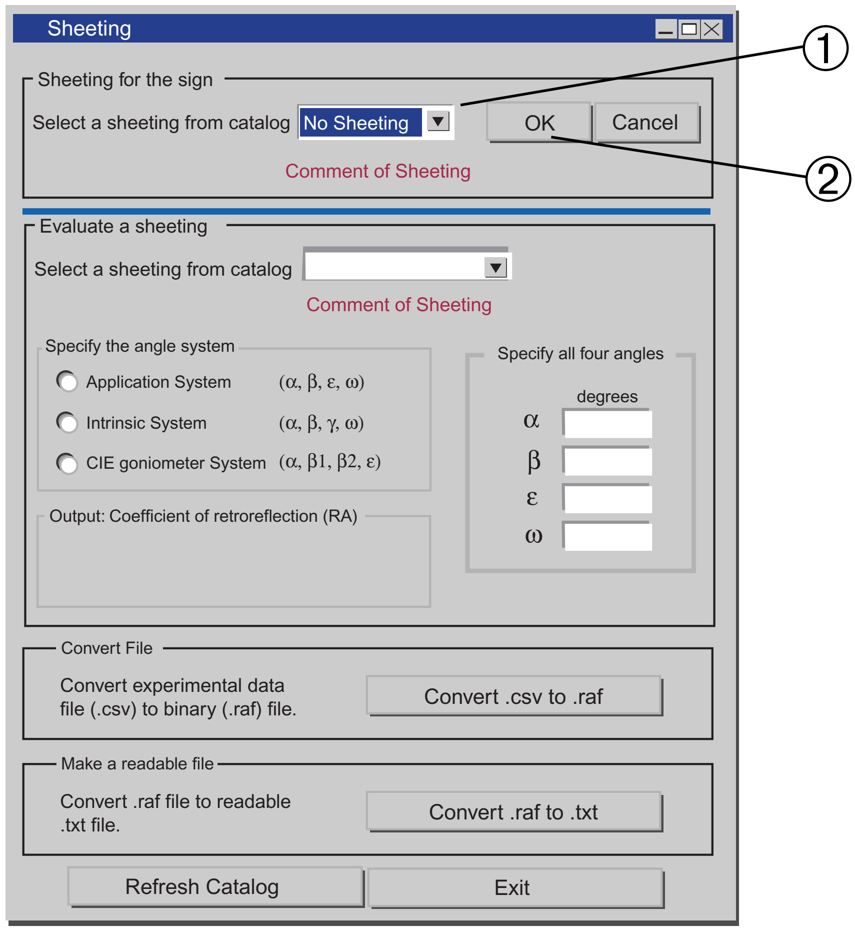

Figure 7. Sheetings Dialog Box.

① Select a sheeting from the drop-down catalog (Figure 7a)

Info	The single type of sheeting selected here will be the basis of the single-distance numeric outputs (for retroreflectivity, luminance, etc.) which are provided in ‘Snapshot.’ However, the ‘curves’ of changes in various outputs during an entire approach to the sign (see next section) can use any or all of the six sheetings as may be selected at that time.

② Click: **OK.**

➨ You have completed your selection of SHEETING. The ‘SHEETINGS’ button on the main ERGO window will go white and it will show the filename of the selected sheeting.

You have now completed the required basic inputs for determination of sign luminance by ERGO2001. You are now able to output the angles and values that result from those inputs.

7. Snapshot

The Snapshot is a single-distance, numeric data set of output angular, illuminance, retroreflectivity and luminance data (separately for the left and right headlights of the vehicle), resulting from the selected conditions of roadway, vehicle, headlight and sheeting. The Snapshot window (and its printout) includes a table with all the inputs (top) and a table of the resultant Output Data (bottom).

Click on the **Snapshot** button.

The Snapshot window will fill the left side of ERGO's main window, replacing "Road View."

	< INPUT DATA >
	RIGHT Side Traffic
	Scale Unit (distance) : feet, (angle) : degrees
	Road Distance (Vehicle to Sign) : 500.00
	Straight Road
	Lane Width : 12.00
	Sign Offset (RIGHT of RIGHT edge of driving lane) : 12.00
	Height (above Road) : 8.00 Twist : 0.00 Lean : 0.00 Rotation : 0.00
	Vehicle : ERGOCAR
	X2 :3.42 Y3 :2.17 Y2 :3.70 Z2 :6.75 X3 :1.08

	< OUTPUT DATA >	LEFT headlight		RIGHT headlight
α	Observation Angle	0.208	0.272	0.343
β	Entrance Angle	2.35		1.98
γ	Presentation Angle	44.51		128.28
ε	Rotation Angle	29.04		-57.99
ρ	Tilted Rotation Angle	29.03		-57.96
ω	Orientation Angle	73.52		70.31
β1	Entrance Angle Comp.	1.68		-1.23
β2	Entrance Angle Comp.	1.65		1.56
Hv	Headlight Angle-Vertical	0.67		0.67
Hh	Headlight Angle-Horizontal	2.26		1.87
v	Viewing Angle		2.21	
		Headlight	umtri50c	
	Headlight Intensity	2028	(cd)	1848
	Illuminance	0.08717	(lux)	0.07946
		Sheeting	AD T-7500-98	
RA	Coefficient of Retroreflection	813.7		756.9
	Luminance	70.98	(cd/m^2)	60.19
	Total Luminance		131.17	

Figure 8. Snapshot Window.

Obtaining the Snapshot data is sometimes a convenient preliminary step to creating the graphs desired (described below).

To SAVE the Snapshot: Click on Save Snapshot (next to Snapshot on the main ERGO window. It will save it to Ergodata and give it a filename.

✔tip	To print Snapshot data sheet: from the main menu, click on **File** then on **Print Snapshot**.

8. Drive Through

A **Drive Through** is a sequence of **Snapshot**s as a car approaches a sign.

Click on the **Drive Through** button. The **Drive Through Input** window will appear.

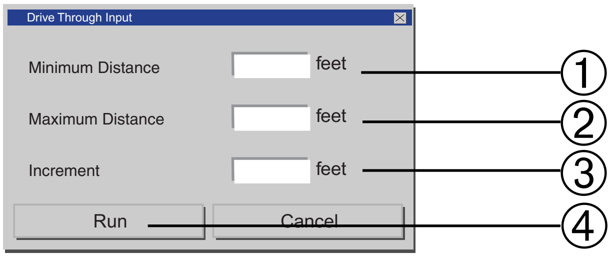

Figure 9. Drive Through Input Window.

① Enter value for the **Minimum Distance**. This is the closest distance to the sign you want to consider. The distances cannot go to ‘0’ since at very close distances the observation angles will exceed the largest (e.g., 4º) for which there is R_A data in the sheeting file. Sometimes, depending on sign position, it is a headlight angle which exceeds the largest angle in that datafile. Usually 50- or 100-feet works well as a close-distance cutoff. (The angle values can be computed for any distance.)

② Enter value for the **Maximum Distance**. This is the farthest distance to the sign you want to consider. It might be the “initial” distance–when it would first be useful for the driver to detect the sign.

③ Enter value for the increment of distance for which you want the program to re-compute the data. (Very small increments result in slightly longer running times; very large increments result in less-smooth curves. Generally, 10 foot (3 meter) increments work pretty well)

④ Click on **Run**. The program will take a few seconds to execute this command.

When the computations are completed a window will appear to declare: “Drive Through Run” finished; it will give the filename for the output file.

9. Graphs of a Drive Through

For many users, the most useful and productive outputs of ERGO2001 are the graphs of the various arameters which influence reflectivity performance and sign luminance, most of which change as a vehicle approaches a sign.

After running a Drive Through click the Graph button in the main ERGO window. The first graphs to appear show observation angle α for left and right headlights as shown in Figure 10.

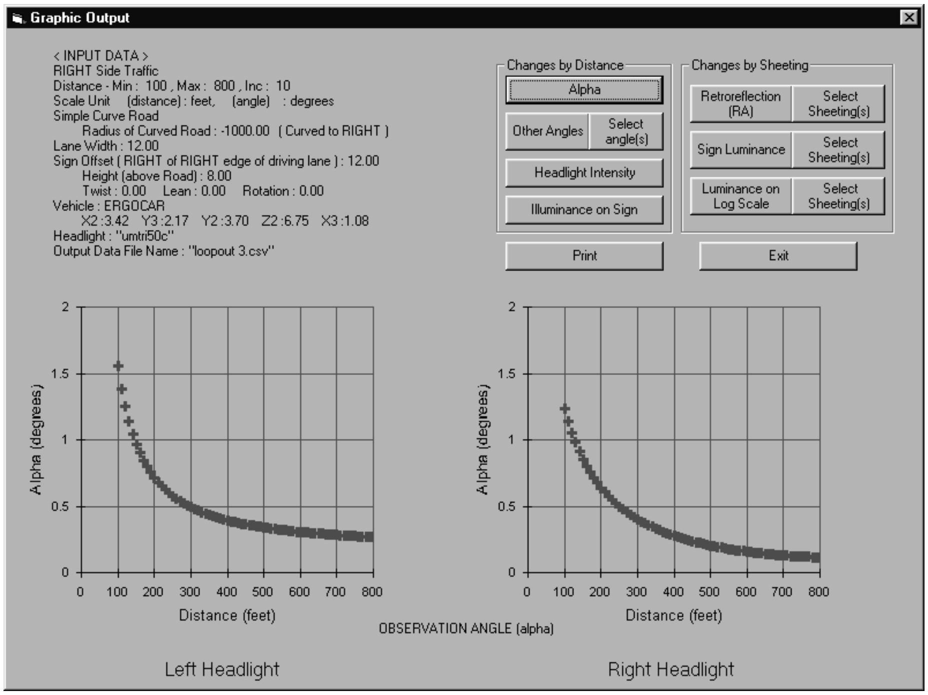

Figure 10. Graph of Observation Angle (α).

Observation angle is graphed separately because it is almost always on a smaller scale than the other angles.

In the Graphic Output window press the **Other Angles** button to produce graphs of ten other angles for left and right headlights.

	Angle
β	Entrance Angle
γ	Presentation Angle
ε	Rotation Angle
ρ	Tilted Rotation Angle
ω	Orientation Angle
β_1	Entrance Angle component
β_2	Entrance Angle component
H_v	Headlight Angle—Vertical
H_h	Headlight Angle—Horizontal
ν	Viewing Angle

Press the **Select Angle(s)** button to display only the graphs of interest.

Press **Headlight Intensity** to see graphs of the candlepower directed toward the sign from each headlight.

Press **Illuminance on Sign** to see graphs of the lux (measured erpendicular to the illumination axis) on the sign from each headlight.

Press **Retroreflection (R_A)** to see graphs of the sheeting coefficient of retroreflection for the angles corresponding to each headlight. All sheetings in the catalog are graphed. Press **Select Sheeting(s)** to display only the graphs of interest.

Press **Sign Luminance** to see graphs of the sign luminance for the driver. There are separate graphs for left headlight contribution, right headlight contribution, and the total luminance due to two headlights. All sheetings in the catalog are graphed as shown in Figure 11.

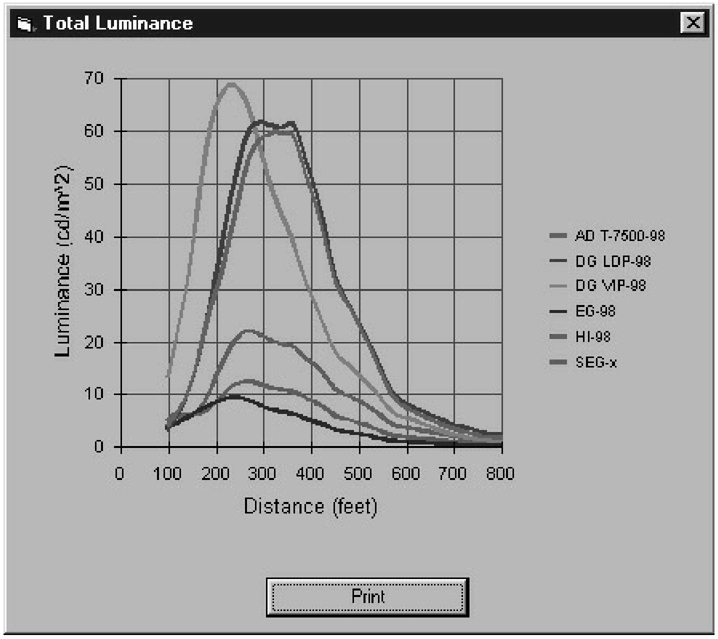

Figure 11. Graph of total Sign Luminance for the driver..

Press **Luminance on Log Scale** to see the three sign luminance graphs on a scale more nearly according with perceptual scaling. All sheetings in the catalog are graphed.

Any of the graphs can be printed by pressing the **Print** button.

NOTE: when comparing printed graphs from different Drive Throughs, be aware that the graphs are rescaled for the values occuring in each Drive Through.

✔tip	Alternate Graphing method: Those skilled in EXCEL may prefer to use it for their graphs to give them greater control. The data from the Drive Throughs are found in c:\ergodata, in files named <<loopoutNN.csv>>. after making graphs, be sure to save the file as .xls.

Appendix A
File Formats used in ERGO

HEADLIGHT INTENSITY DISTRIBUTION FILES:

Headlight distribution files have the extension .hif and are kept in C:\Ergodata\Hif\.

Removing a .hif file from this folder will make it unavailable to ERGO. Adding a new .hif file to the folder will make it available to ERGO.

New .hif files can be created by the user from headlight intensity distribution data.

ERGO presumes that the distribution for the left and right headlights are the same. (Hint: run ERGO twice to model unlike left and right headlights.) ERGO uses the horizontal and vertical headlight angles of SAE Recommended Practice J575. This can make H_v slightly different for the left and right headlights.

To create a .hif file the user can use a spreadsheet application and put the intensity data into an array of the following format.

Appearance of sample spreadsheet to be saved as *.csv

[ignored]	**-10**	**-5**	**0**	**5**	**10**	**15**
5	70.2	98.1	132.1	154.0	114.6	65.4
4.5	88.5	113.5	151.5	190.1	126.5	69.1
4	99.3	125.7	175.1	209.4	140.9	109.7
3.5	117.6	144.7	203.2	246.4	159.8	129.6
3	128.5	154.2	261.5	282.6	199.7	148.1
2.5	139.0	184.6	268.9	293.6	267.3	174.9
2	153.0	206.1	318.1	401.3	379.9	219.9
1.5	183.1	233.4	395.2	641.6	608.6	292.0
1	213.3	296.3	592.8	1181.2	1009.5	354.9
0.5	276.1	464.9	1228.5	2010.6	1355.1	486.3
0	371.0	917.9	2672.4	4363.7	1592.3	859.0
-0.5	562.8	1469.9	8463.4	8715.5	2058.6	1057.4
-1	1377.9	3368.4	13953.6	11900.4	3767.5	1324.5
comment						
[optional]	[ignored]	[ignored]	[ignored]	[ignored]	[ignored]	[ignored]

The example array covers 10° left to 15° right, and 5° up to 1° down. In the example array, horizontal increment is 5°. It may be any constant increment. 0.5° or smaller is desirable. Vertical increment is 0.5°. It may be any constant increment. 0.25° or smaller is desirable.

For headlight arrays:

1. Upper left cell is empty.

2. Rest of top row consists of ascending horizontal headlight angles, in degrees. Left angles are negative. Right angles are positive. Any range of angles is allowed, but they must be equally spaced.

3. Rest of first column consists of descending vertical headlight angles, in degrees. Upward angles are positive. Downward angles are negative. Any range of angles is allowed, but they must be equally spaced.

4. The array is a map of the pattern of illumination by one headlight. The array size must be at least 2x2. The numbers represent candelas.

5. Below the lowest vertical headlight angle, a comment may be entered.

Save the spreadsheet as a .csv file.

Note: headlight distribution files are constructed as if for right-side traffic. ERGO automatically mirror-images the distributions for the left-side traffic option.

Before the .csv file can be used by ERGO, it must be transformed to a .hif file. Open the Headlights window in ERGO2001. Press the Convert .csv to .hif button. Etc.

SHEETING PHOTOMETRIC FILES:
Sheeting photometric files have the extension .raf and are kept in C:\Ergodata\Raf\.

Removing a .raf file from this folder will make it unavailable to ERGO. Adding a new .raf file to the folder will make it available to ERGO.

New .raf files can be created by the user from sheeting R_A data.

ERGO-readable photometric files for any sheeting can be created by the user. The files must initially be simple lists of the setup and photometric data, as shown in the table below. These files are delimited either by commas, spaces, or carriage returns. In a spreadsheet application they would be saved as comma delimited files. In a word processing application they would be saved as text files. Very large files may have to be manipulated and saved by user-written programs. The file name must have the extension .csv (regardless of the actual mode of delimitation). ERGO will transform these files to more compact .raf files. when the user presses the Convert .csv to .raf button in the Sheetings window.

The sheeting .csv files are 4-dimensional data arrays which have been reduced to a list. The photometry may use any of three angle systems:

1. Application system $\{\alpha,\beta,\varepsilon,\omega\}$.
2. Intrinsic system $\{\alpha,\beta,\gamma,\omega\}$.
3. CIE goniometer system $\{\alpha,\beta_1,\beta_2,\varepsilon\}$.

The CIE goniometer system is not optically economical for retroreflector characterization, but is included for the convenience of some laboratories. The Application system is recommended for characterizing prismatic materials, and the Intrinsic system is recommended for characterizing beaded materials. Note: angles ε, ω, and γ must be in the range -180° to +180°. The first 13 data in the list are for structuring the list. The first datum is a number specifying the angle system: 1=Application; 2=Intrinsic; 3=CIE. The next twelve data give the angle ranges and increments. Then follow all the photometric R_A values.

Structure of sheeting.csv file

1.	1
2.	α_{min}
3.	α_{max}
4.	$\Delta\alpha$
5.	β_{min}
6.	β_{max}
7.	$\Delta\beta$
8.	ε_{min}
9.	ε_{max}
10.	$\Delta\varepsilon$
11.	ω_{min}
12.	ω_{max}
13.	$\Delta\omega$
14.	R_A at α_{min}, β_{min},ε_{min},ω_{min}
.	.
.	.
.	.
13+A·B·E·W	R_A at α_{max},β_{max},ε_{max},ω_{max}
	remarks

The illustration above is for data gathered in the Application system, but the structure is the same for the other systems.

Using the Application system, if A is the number of different α values, B the number of different β values, E the number of different ε values and W the number of different ω values, then the list contains a total of A·B·E·W photometric values. The photometric data ordering is lexicographic, as follows:

For two measurements made at unequal α, the one made at smaller α is prior.

For two measurements made at equal α but unequal β, the one made at smaller β is prior.

For two measurements made at equal α and equal β, but unequal ε, the one made at smaller ε is prior.

For two measurements made at equal α, equal β and equal ε, but unequal ε, the one made at smaller ε is prior.

In other words, the α ordering has precedence over the β ordering which has precedence over the ε ordering which has precedence over the ω ordering. The other two angle systems use corresponding lexicographic orderings. For the Intrinsic system, α ordering precedes β ordering precedes γ ordering precedes ω ordering. For the CIE goniometer system, α ordering precedes β_1 ordering precedes β_2 ordering precedes ε ordering.

Remarks, if any, follow the photometric data.

The data list ordering must be followed to the limits declared in the first 13 numbers. At α=0°, if this value is included, separate R_A values must be listed for all the ε values, or all the γ values. At β=0°, if this value is included, separate R_A values must be listed for all the ω values. However, ERGO allows voids within the data list. Voids can be either empty places or non-numbers in the .csv file. These data holes will be reported as "NO DATA" when encountered.

ERGO requires that each of the four angles increment at least twice. Thus, a beaded sheeting, photometered in the Intrinsic system and showing practically no variation of R_A with ω, would still require three values of ω in the list, for example, ω = –180°, 0°, +180°. For each sheeting, and each angle, the user must make the incrementation small enough that ERGO's simple 32- or 64-point interpolations yield acceptable accuracy. A successful laboratory technique involves exploratory photometry of the sample, to find the regions of rapid change, followed by in-depth photometry using finer increments where change is faster. Finally the data is interpolated by the user to the uniform incrementation required for the .csv file. Interpolation is most efficient when the data is arrayed in the angle system that best parametrizes the material: {$\alpha,\beta,\varepsilon,\omega$} for prismatic; {$\alpha,\beta,\gamma,\omega$} for beaded.

Before the .raf file can be used by ERGO, it must be transformed to a .raf file. Open the Sheetings window. Click the Convert .csv to .raf button. Etc.

Appendix B
Interpolation Methods Used in ERGO

For Headlight Intensity

The following method for headlight intensity interpolation has been found more acceptable than competing methods, and is used in ERGO:

Surround H_h by four consecutive values from the array:
$a < b \leq H_h \leq c < d$
Surround Hv by four consecutive values from the array:
$e < f \leq H_v \leq g < h$
Let H_h=a and do Type 1 interpolation to produce $I(H_v,a)$.
Let H_h=b and do Type 1 interpolation to produce $I(Hv,b)$.
Let H_h=c and do Type 1 interpolation to produce $I(H_v,c)$.
Let H_h=d and do Type 1 interpolation to produce $I(H_v,d)$.
Then do Type 1 interpolation on the four I values to produce $I(H_h,H_v)$.
Type 1 interpolation is defined below. For Type 1 interpolation the order of interpolation matters (unlike with Type 2 interpolation). The method specifies that vertical interpolation be performed before horizontal interpolation.

For Sheeting Photometrics

Interpolation on a 4-dimensional array is accomplished by interpolating the dimensions separately. For the simplest example, suppose a point is surrounded by just two neighbors in each of the 4 dimensions. This produces 16 data points surrounding the point in 4-space. Only linear interpolation is possible with two neighbors. Supposing the Intrinsic System, there will be 8 linear interpolations in the α direction. Next, using these, 4 linear interpolations in the β direction. Next using these, 2 linear interpolations in γ direction. Finally, a linear interpolation in the ω direction. The result is the same if a different sequence of dimensions is followed.

ERGO chooses interpolation methods system by system, rather than angle by angle. For example, ε effects are different in the Application system from in the CIE goniometer system. $\partial R_A/\partial\varepsilon$ (taken as a function of ε while the other three angles remain fixed) is smooth in the former system but jagged in latter system. The following describes ERGO's choices.

Application system
α: Type 2 on 2+2 surrounders
β: linear on 2 surrounders
ε: Type 2 on 2+2 surrounders
ω: linear on 2 surrounders

Intrinsic system
α: Type 2 on 2+2 surrounders
β: linear on 2 surrounders
γ: Type 2 on 2+2 surrounders
ω: linear on 2 surrounders

CIE goniometer system
α: Type 2 on 2+2 surrounders
β_1: linear on 2 surrounders
β_2: linear on 2 surrounders
ε: linear on 2 surrounders.

For these four-dimensional interpolations using combinations of Type 2 and linear, the sequence of dimensions interpolated does not affect the result.

Special rules apply when Type 2 interpolation is specified and there are not 2+2 surrounders. The one that is missing is supplied by linear extrapolation on the two nearest, except when this would result in supplying an R_A value at a negative alpha. In that case do supply an R_A value at the ersatz negative alpha, but make it equal to the R_A value at the corresponding positive alpha.

Two Types of Interpolation

a,b,c,d are four consecutive angle values for which there is data.

d-c = c-b = b-a = Δ

a,b,c,d surround x.

a < b < x < c < d

A,B,C,D are the photometric data.
f(a)=A
f(b)=B
f(c)=C
f(d)=D

Interpolate the value of f at x as:

Type 1

$$f(x) = \max\left\{\left(\frac{A-B-C+D}{6}\right)\left(\frac{x-b}{\Delta}\right)^2 + \left(\frac{-A-5B+7C-D}{6}\right)\left(\frac{x-b}{\Delta}\right) + B,\ 0.8\left[(C-B)\left(\frac{x-b}{\Delta}\right) + B\right]\right\}$$

Type 2

$$f(x) = \left(\frac{-A+3B-3C+D}{2}\right)\left(\frac{x-b}{\Delta}\right)^3 + \left(\frac{2A-5B+4C-D}{2}\right)\left(\frac{x-b}{\Delta}\right)^2 + \left(\frac{C-A}{2}\right)\left(\frac{x-b}{\Delta}\right) + B$$

When only three values are known, the missing A or D is supplied by linear extrapolation on B and C, except for one case for angle α: when A is missing because b = 0, then A is set equal to C.