Calculux

Area

Version 6.6

Contents

Appendices

Chapter 1

Introduction

1 Introduction

This chapter describes the main features of Calculux and explains what you can expect from the package.

✍ Some of the Calculux features described in this manual partly only apply for Calculux Area or Calculux Road. If so, this is mentioned.

Calculux is a software tool which can help lighting designers select and evaluate lighting systems. Speed, ease of use and versatility are features of the package from Philips Lighting, the world's leading supplier of lighting systems.

1.1 Philips - your partner in lighting

Philips Lighting, established over a century ago, has vast experience in helping customers to select the optimum solutions for their lighting applications, in terms of quality, performance and economy.
Our customer partnership philosophy means that we can support you from the planning, design and commissioning of projects, right through to realisation and aftersales support. This philosophy maximises cost-efficiency by ensuring the ability to choose the most suitable equipment for your application.

Philips Lighting Design and Application Centres situated throughout the world offer extensive consultancy, training and demonstration services. Our lighting specialists can recommend existing solutions or develop new tailor made solutions for your application. Because Philips Lighting is the leading supplier, you're assured of getting the best support available.

Calculux is part of that support. For consultants, wholesalers and installers wishing to develop lighting designs, it's the ideal tool; saving time and effort, providing the most advanced lighting solutions available and guaranteeing satisfied customers.

1.2 What Calculux does

Calculux is a very flexible system which offers lighting designers a wide range of options:

- You can use the package to simulate real lighting situations and analyse different lighting installations until you find the solutions which suits your technical as well as your financial and aesthetic requirements best.
- Calculux uses luminaires from an extensive Philips database and photometric data which is stored in the Philips Phillum external formats. Additionally other luminaire data formats can be imported (CIBSE/TM14, IES, EULUMDAT and LTLI).
- Simple menus, logical dialogue boxes and a step by step approach help you to find the most efficient and cost-effective solutions for your lighting applications.

1.3 What you can do with Calculux Area

- Perform lighting calculations on rectangular calculation areas in any plane;
- Calculate a wide range of quality figures for your lighting design;
- Select luminaires from an extensive Philips database or from specially formatted files for luminaires from other suppliers;
- Specify luminaire positioning and orientation either individually or in a block, polar, line, point or free arrangement;
- Specify maintenance factors, calculation grids and calculation types;
- Compile reports displaying results in text and graphical formats;
- Predict financial implications including energy, investment, lamp and maintenance costs for different luminaire arrangements;
- Use Switching modes and Light regulation factors;
- Support multiple languages;
- Print reports in several languages.

The logical steps used for project specification save you time and effort, while the report facility gives you the opportunity to keep permanent records of the results.

1.4 Tailor make your design

Although Calculux was designed for general application fields,
it offers a number of built in standard application fields. This feature is extremely useful because a number of parameters related to a specific application field are predefined by the program in its default settings.
For instance, when a soccer field is selected the outlines of the field are automatically generated together with a calculation grid covering the soccer field and a horizontal illuminance calculation. The border outlines of the field and calculation grid can be defined in the default settings to suit local requirements.

1.5 Choose from a wide range of luminaires

Calculux is supplied with an extensive Philips database which includes the most advanced luminaires. For each luminaire you can view luminaire data, including the type of distributor, lamp type, output flux efficiency factors and power consumption. The light distribution can be shown in a Polar, Cartesian or Isocandela diagram, together with the luminaire quality figures.

Apart from the Philips database, the following other well known luminaire data formats from other suppliers can be used in Calculux:

- CIBSE/TM14;
- EULUMDAT;
- IES;
- LTLI.

The Photometric database is updated regularly (see www.lightingsoftware.philips.com).

1.6 Easy luminaire positioning and orientation individually or as a group

After you've made your luminaire selection, you can position and orientate luminaires individually or in groups. In sports lighting luminaires are often grouped in arrangements such as blocks or lines or mounted on a lighting mast. Calculux contains an option to define a number of arrangements. The position of the luminaires in such an arrangement is controlled by the arrangement rule but the orientation of each luminaire within an arrangement can be altered. It's even possible to free the luminaires positions so that they're no longer connected via the arrangement rule. This feature proves very useful e.g. when in a preliminary design a number of luminaires are placed on a line, but in the final stage one of the luminaires in the line doesn't entirely fulfil the line arrangement rule.

1.7 Symmetry lighting installation

Many designs contain a symmetric lighting installation. This simplifies luminaire arrangement entries where one or more of the luminaires have the same orientation. Calculux offers the possibility to include symmetry in the installation or a part of the installation.

1.8 Graphical manipulation of generated luminaires and/or aiming positions

Having defined luminaires as individuals or in arrangements, Calculux enables graphical manipulation (with a mouse) of the position and orientation of the luminaires. Graphical manipulation operates with the same arrangement rules.

1.9 Calculation Grids

A calculation grid can be in any situation and orientation (horizontal, vertical or sloping) the only restriction being that it has to be rectangular.

Preset Grids
In case an application field is used you don't have to define a calculation grid. Frequently used grids corresponding to the built in application fields can be automatically generated by setting a calculation grid default for each application field. Changing the position or the dimension of the application area will automatically update the calculation grid.

Automatically generated grids (Calculux Road only)

Calculation grids for the main road and kerb area are automatically generated by the schemes editor according to the road requirements and road definition given in the profile. For automatically generation of grids, Calculux supports the following grid methods:

- CEN Luminance;
- CEN Illuminance.

Calculux enables you also to define your own grids, or to change the specifications of existing grids.

1.10 Calculation possibilities

Calculux offers a wide range of calculation possibilities. One of the following calculations can be selected:

- Horizontal Illuminance;
- Vertical Illuminance in the four main directions;
- Illuminance in the direction of an observer;
- Semicylindrical Illuminance;
- Semispherical Illuminance;
- Veiling luminance;
- Glare rating for Sports lighting;
- Road luminance including Glare quality figures;
- Obtrusive light calculations;
- Uniformity on vertical planes;
- Gradient calculations.

1.11 Switching Modes

Calculux enables you to develop a lighting design in different switching modes.
You can for example, first generate a design for a training application. Then, by adding luminaires go on to generate a design for a competition application.

1.12 Light Regulation Factor (LRF)

This Calculux option enables you to dim luminaires or luminaire arrangements.

1.13 Save money by optimizing cost-effectiveness

Cost is a major consideration when specifying a lighting installation. Calculux provides a breakdown of the costs you can expect to incur with a particular installation, both in terms of initial investment and annual running costs. Thus it's possible to support you in the decision making process by comparing the cost-effectiveness of different lighting arrangements.

1.14 See your lighting design develop on screen

A special view menu is provided to enable you to monitor the development of your project on screen. A 3-D as well as a number of 2-D project overviews can be displayed on screen.

The view facility can also be used to study the calculated results in text and graphic format. Tables listing the calculated values are displayed. The view facility can also provide isotropic contours, mountain plots and graphic tables of the results.

1.15 Impress your customers with attractive reports

When you've finished a project you're able to generate attractive reports giving the results of the calculations. All you have to do is use the menu to select the elements which you wish to include in your report and they will be added automatically.
For example, you can incorporate:

- A table of contents;
- 2-D and 3-D project overviews;
- Summary;
- Luminaire information (including Polar or Cartesian diagram);
- Detailed information about the calculation results (in textual table, graphical presentation and/or Iso contour);
- Financial data.

It's also possible to add supplementary text. A convenient feature if you wish to comment on or draw conclusions from the results presented in the report.

1.16 Installation and operating platform

The Calculux application is supplied with the installation program and database.
The following target operating platform is recommended:

- CPU: Pentium 1G;
- RAM: 512 Mb;
- Hard disk: 100 Mb free disk space;
- Operating system: Windows 2000, Windows XP or later;
- Other: SVGA monitor (minimum 1024 x 768),
  mouse, Windows supported graphics printer or plotter.

Chapter 2

Getting Started

2 Getting Started

This chapter tells you how to install Calculux on your personal computer, what the resulting file structure looks like and how to set the environment directories and database settings.

✍ For this and more information on the installation, refer to the Readme.doc file, which is stored in the Calculux directory.

2.1 Download program and database

To download the program and database:

- Go to www.lightingsoftware.philips.com.
- Under 'Choose your country', click the appropriate link. If your country is not in the list, click the **Others** link.
- Depending on the chosen country, a message may appear to redirect you to the Global Lighting Site. If so, click **OK**.
  (You are redirected to the Tools & Downloads page.)
- Click the appropriate download link(s) to download the CalcuLux program.
- Save the CalcuLux program (zipfile) do Disk.
- Click the **CalcuLux Database** link to download the database.
- Save the CalcuLux Database (zipfile) to Disk.

2.2 Install the program

To install the program:

- To install Calculux correctly, please stop all other applications before starting the installation.
- Unzip the .zipfile while leaving the map structure intact.
- Double-click on **Setup.exe** to run it.
- Follow the instructions on screen and make the appropriate decisions:
  - The installation Wizard will suggest 'C:\Program Files\Calculux' as installation directory. In case you already have an older version of Calculux installed in this directory you want to maintain, select another directory for this newer version. (Old files may be overwritten during installation and downward compatibility is not guaranteed.)
  - Together with the program itself, some example project files, phillum files, R-table files and vignette files are included in the installation. All these files are the same for both Calculux Area and Calculux Road. In case you have one of these programs already installed and want to install the other one in the same directory (for instance 'C:\Program Files\Calculux'), the installation Wizard will detect that project files, phillum files, R-table files and vignette files of the same name are already present and ask if you want them to be overwritten. So, in case you have made any changes to these example files you want to maintain, answer this question with 'No'.

✍ Project files (*.CAR/*.CRO) are upwards compatible. They can be used in the new releases. However, after saving, they cannot be used anymore in previous releases.

To uninstall the package:

- From the Windows Start menu, select Settings > Control Panel.
- Double click the Add/Remove Programs icon.
- Select **Calculux Area/Road**, click on the **Add/Remove** button and follow the instructions.

2.3 Install the database

To install the database:

- To install the Calculux database correctly, please stop all other applications before starting the installation.
- Unzip the .zipfile while leaving the map structure intact.
- Run **Setup.exe** and follow the instructions on screen.

2.4 Install other report languages

Calculux supports run-time selection of the report language.
To do so, each language requires an additional language file to be installed in the application folder of Calculux. All available report languages are installed automatically during installation. When addtional languages must be installed, the required file (named CAR_*.RPT or CRO_*.RPT) must be copied into this folder (e.g. C:\Program Files\Calculux\Area or Road).

2.5 File Structure

During the installation procedure a number of directories will be created. The default directory structure, which should be created during the installation of the program and the database, is described below.

C: \PROGRAM FILES\CALCULUX
\AREA (Calculux Area only)
\ROAD (Calculux Road only)
\ROADWIZARD
\DB
\IRRGRID
\PHILLUM
\PROJECT
\VIGNETTE
\RTABLE
\REQUIRMT (Calculux Road only)

- In the AREA and ROAD directories, the program and its necessary files are stored.
- In the DB directory, the database is installed.
- In the PHILLUM directory, the individual photometric data files, not available in the database, (i.e. Phillum) are stored. The program is supplied with some example Phillum files.
- In the PROJECT directory, the projects can be stored. The program is supplied with some example project files.
- In the VIGNETTE directory, the files (Vignette files) containing the company names and addresses are stored. The program is supplied with some test vignettes.
- In the RTABLE directory the Road reflection tables are stored.
  The program is supplied with some Road reflection tables.
- In the REQUIRMT directory (only relevant for Calculux Road) all Profile Requirement files for the CEN-13201 classes are stored. These classes are used by the RoadWizard.

For more detailed information relating to each of the above directories, use the Readme icon.

2.6 Environment settings and preferences

When the program and database are installed successfully, you can start the application and use the Environment Options in the Option menu to set the environment directories and database settings.
The environment directories and database settings can be checked at any time.

You are now ready to start developing your first lighting project.

Chapter 3

Background Information

3 Background Information

This chapter describes in detail the background principles used in Calculux.

3.1 Project Info and Vignette file

3.1.1 Project Info

When you start a new project in Calculux, it can be beneficial to enter summary information. This can include remarks and statistics about the project, e.g. name, date and designer, as well as customer details.

3.1.2 Vignette file

Calculux enables you to include details about yourself and your company in your reports. The information will be printed on the cover page of the reports and can be used for reference at any time.
This provides the customer with contact details, should they need to consult you over the contents of the report.

If you create what is called a Vignette file you can save the information to a disk. This eliminates the need to enter the same company information every time you open a new project. You can simply select the Vignette file to be included in your next project.

3.2 Application Fields

3.2.1 General

In Calculux an application field is represented by a 2-Dimensional rectangular shape. Application fields can be used to graphically mark the area of interest for lighting calculations. Calculux includes a number of different applications.

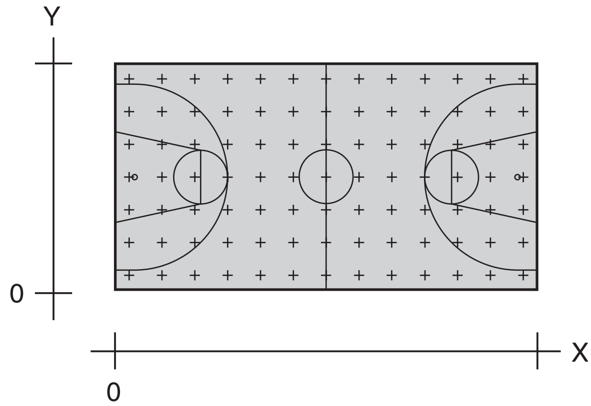
To differentiate between the field types, they contain zero or more predefined lines and/or markings that are associated with the different applications. The outlines of the built-in sports fields have already been drawn, requiring only the name, dimensions and centre position to be entered. You can choose from:

- Football Field;
- Tennis Court;
- Basketball Ground;
- Volleyball Ground;
- Hockey Field;
- Indoor hockey Field;
- Ice Hockey Field;
- Five-a-side football Pitch;
- Handball Court;
- Korfball Court;
- Badminton Court;
- Squash Court;
- Table Tennis Table;
- Softball Field*;
- Baseball Field*;
- Athletic Track*;
- Rugby Field ;
- Single Carriageway;
- Dual Carriageway;
- General Field.

*These application fields contain fixed shapes on the generated rectangular calculation grids to create application fields with special forms (see section 3.2.2).

In Calculux, for each type of application field the default dimensions and grid settings can be entered. This allows local standards to be set, limiting the input requirements of the designer. Upon selection, Calculux automatically draws the application field using the default values. Calculux also generates a grid and a surface illuminance calculation on this grid. You are then free to change the dimensions, if necessary, to suit your personal design requirements.

The following figure shows a basketball ground (dimensions 15 x 28 m.) with a calculation grid (grid spacing is 2m.) connected to it.

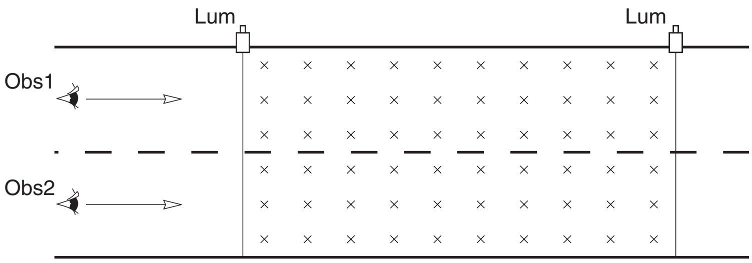


Single or Dual Carriageway

For a Single or Dual Carriageway, you need to specify the number of lanes and the grid method to be used. If the selected grid method is CEN Luminance, a Road Luminance calculation will automatically be performed. If the selected grid method is CEN Illuminance, an Illuminance calculation will automatically be performed.

For Road Luminance, observers will be placed automatically (depending on the number of lanes).

The following figure shows a Single Carriageway with two lanes and two observers. Both observers are placed in the middle of the lane.



General Field

The general application field is an empty rectangular field. It can be used when you wish to perform calculations for an application not included in the above list. A general field operates like any other application field. You can connect a grid to a general field, ensuring that any changes made to the field parameters automatically change the grid parameters.

Calculux also generates a grid and a surface illuminance calculation on this grid. You are free to change the dimensions, if necessary, to suit your personal design requirements.

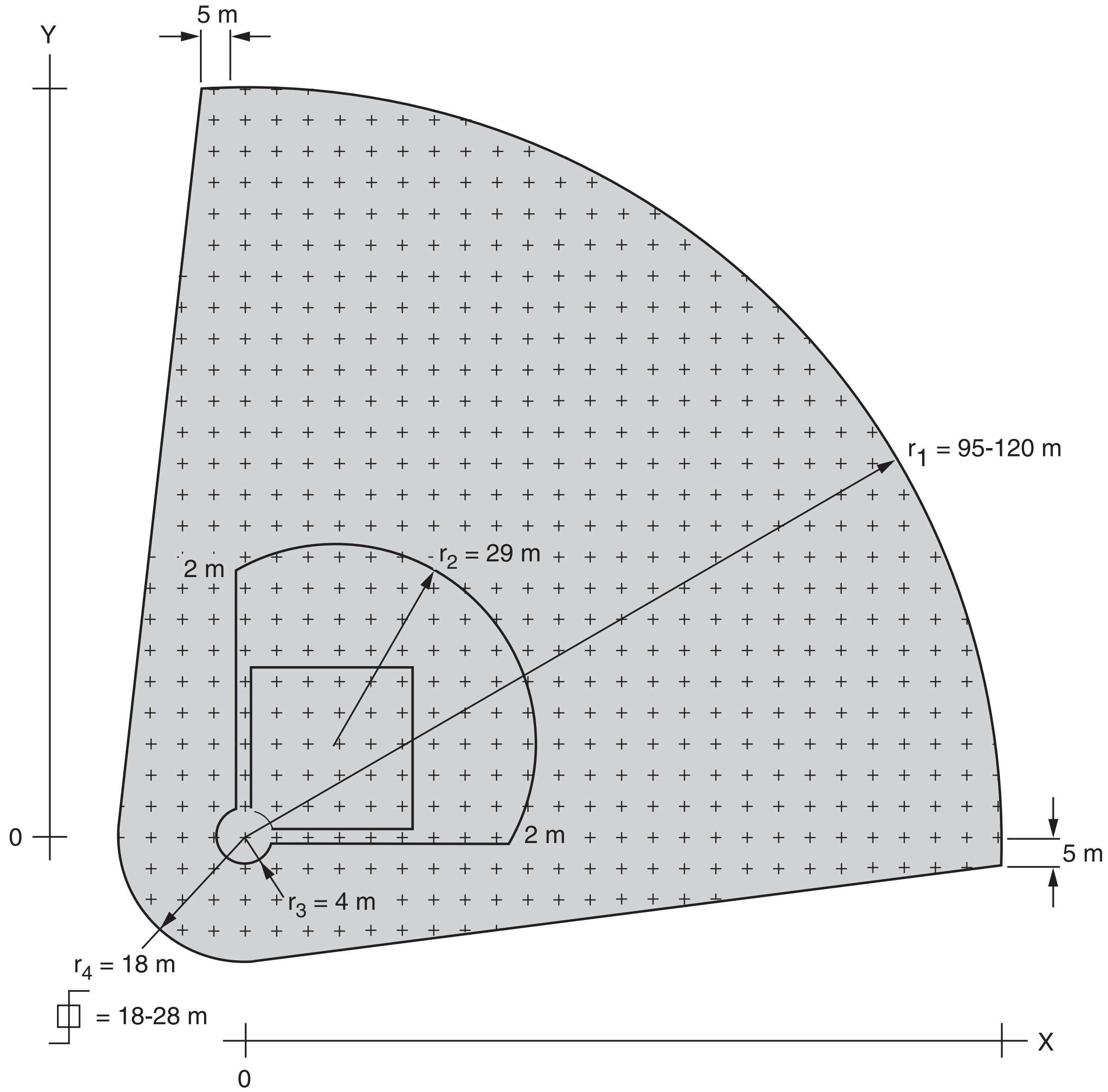
3.2.2 Application fields with fixed shapes

In Calculux the following application fields are created using shapes:

- Baseball field;
- Softball field;
- Athletic track.

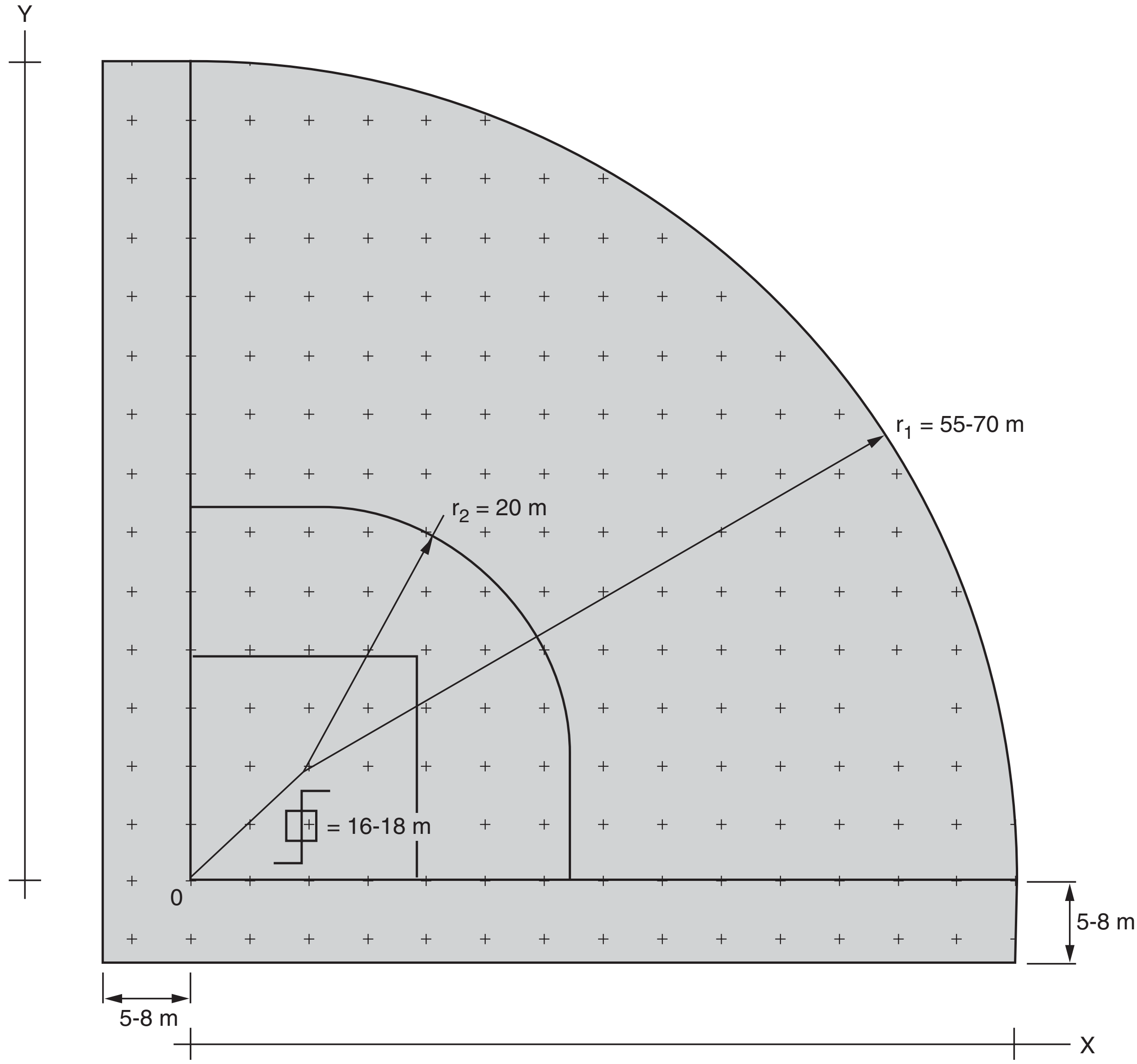
Baseball field

For a baseball field the radius (r_1) and the inner square can be defined by the user within certain limits, all other dimensions are fixed.



Softball field

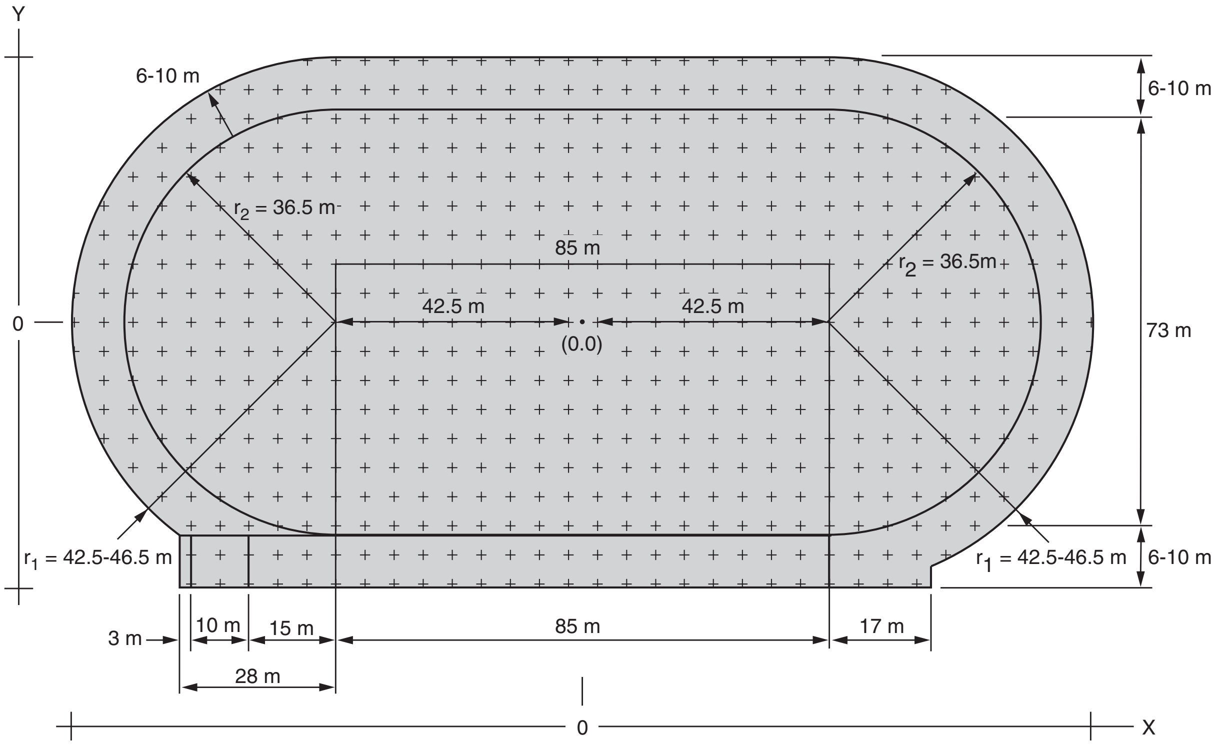
For a baseball field the radius (r_1) and the inner square can be defined by the user within certain limits, all other dimensions are fixed.



Athletic track

The radius (r_1) of an athletic track can be defined by the user within certain limits to specify the width of the running track, all other dimensions are fixed.

✍ If calculations only for the running track must be made, the user can add shapes to cover the inner side.



3.2.3 Connections with calculation Grids

A calculation grid usually lies within an application field. Calculux enables you to connect a grid to an application field, ensuring that any changes made to the field parameters automatically change the grid parameters. You can set a calculation grid for each application field.
For an example demonstrating this feature see chapter 'Grids', section 'Grid Coupling'.

3.3 Luminaire Photometric Data

Calculux can retrieve luminaire photometric data from two different sources:

- A luminaire database;
- A specially formatted ASCII data file.

3.3.1 Luminaire Database

The luminaire database is supplied with Calculux and contains a wide range of luminaires from your supplier.

✍ A regularly updated version of the luminaire database can be downloaded on www.lightingsoftware.philips.com.

The luminaire database, of which you want to select your project luminaires, can be selected in the Select Database dialogue box.
When a database is selected, luminaire types for a particular application area can be selected in the Application Area dialogue box. For each luminaire, details about housing, light distributors, colour, lamps and luminous flux intensity are presented on screen in a logical, step-by-step way so that choosing a suitable luminaire for an application is easy.

The default luminaire database and directory in which the luminaire database is stored is set in the Database tab of the Environment Options dialogue box (Options menu). If you wish to extend the range of luminaires you can save more than one database in this directory.

If you have the Philips product selector for Dialux/Relux/AutodeskVIZ installed, then the connected database can also be used by Calculux.
(Default place: C:\Program Files\Philips Lighting\Luminaires\Philips.mdb)

3.3.2 ASCII data file

Calculux is supplied with an extensive Philips luminaire database.
New Philips luminaires that are not yet available in the database are sometimes supplied in specially formatted ASCII data file, the PHILips LUMinaires data format (PHILLUM).

Apart from the Philips database and the PHILLUM format, Calculux allows you to use photometric data from other suppliers.
The following other well known formats can be used in Calculux:

- CIBSE/TM14;
- EULUMDAT;
- IES;
- LTLI.

Luminaire files are stored in the default directory. You can set the location of the default directory in the Directories tab of the Environment Options dialogue box (Options menu).

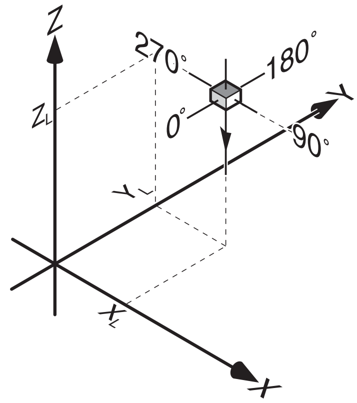
✍ The interpretation of the above luminaire formats can differ. You should pay attention when using them.

3.4 Luminaire Positioning and Orientation

3.4.1 Luminaire Positioning

XYZ-coordinates

To position a luminaire, Calculux requires the use of the (three dimensional) coordinate system XYZ. The $X_LY_LZ_L$ coordinates position the centre of the luminaire in relation to the origin of the coordinate system.
The arrow in the following illustration indicates the centre of the light emitting area of the luminaire and represents the main axis of that particular luminaire.

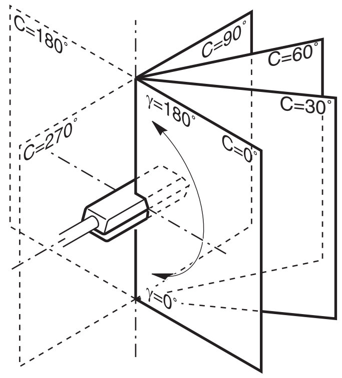


C-γ coordinate system

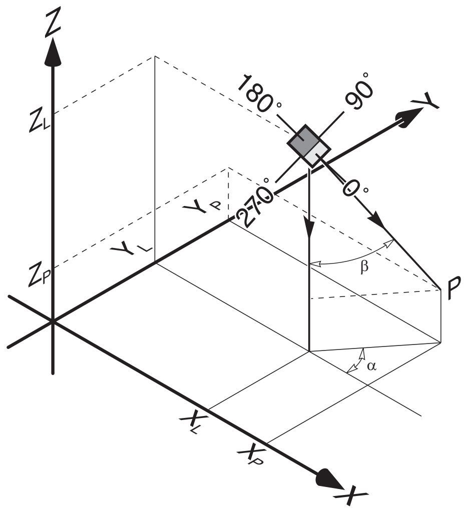
Each luminaire is given its own luminous intensity coordinate system, in order to provide information on its luminous flux distribution.
In general, the C-γ coordinate system is used. To create the required luminous flux distribution in your design you'll need to define a new orientation for the luminaire. This is done by rotating and/or tilting the luminaire in relation to its (local) coordinate system.

For indoor fluorescent luminaires the longitudinal axis of the lamp is called the C=90°/C=270° axis. The lateral axis of the lamp (perpendicular to the longitudinal axis) is called the C=0°/C=180° axis. For luminaires with an unusual shape, such as those used in outdoor applications, the mounting bracket is usually regarded as a reference which corresponds to the C=270° axis. The vertical axis of the lamp is normally called the γ=0°/γ=180° axis.

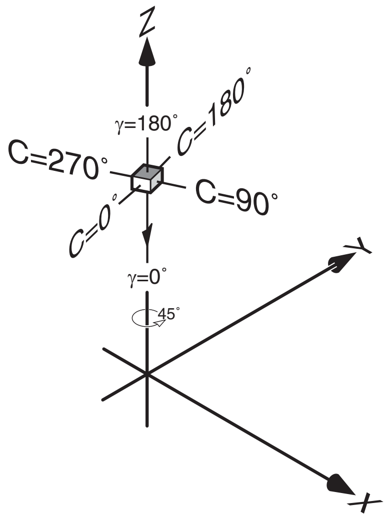
The following illustrations display the C-γ coordinate system for the three main luminaire types, being street, indoor and floodlighting.



Street



Indoor



Flood

3.4.2 Luminaire Orientation

Aiming types

To determine the orientation of a luminaire you can use either:

- Aiming by defining a fixed point (XYZ);
- Aiming by defining fixed angles (RBA).

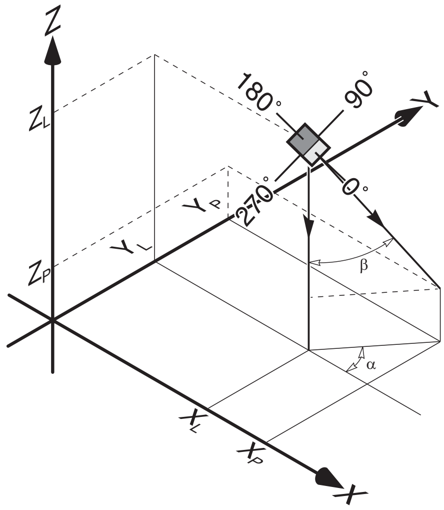
Calculux enables you to aim the luminaires with RBA aiming type and view the generated aiming point by switching from RBA aiming to XYZ aiming (and vice versa).

XYZ aiming

If XYZ aiming is used, the luminaire orientation is determined by defining its aiming point. This is the point (P) towards which the main axis (γ=0°) is directed, see figure below.

The position of the aiming point P (X_P, Y_P, Z_P) is related to the global coordinate system.

- α = Rot
- β = Tilt90



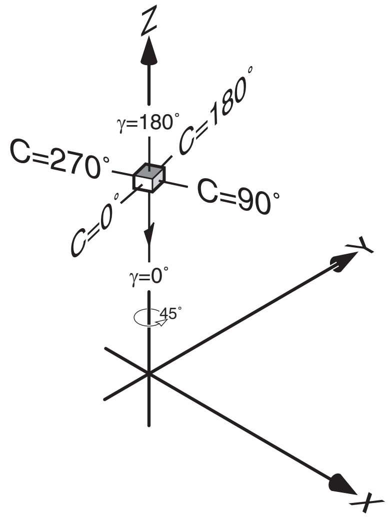
RBA aiming

The luminaire is aimed (orientated) by defining fixed angles for Rot (around the vertical axis), Tilt90 (around the C=0°/C=180° axis) and Tilt0 (around the C=90°/C=270° axis).

Rotation (Rot)

If you wish to change the angle of rotation of the luminaire about its vertical axis, you need to enter a value in degrees for the variable 'Rot'. This value can be positive or negative.

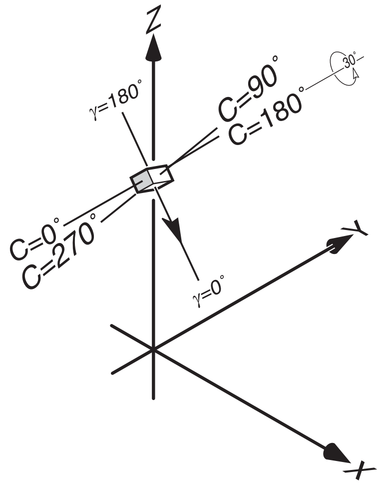
For example Rot = 45°:



Tilt90

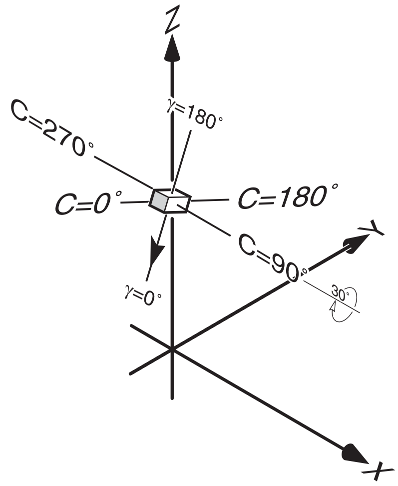
If you wish to change the angle of rotation of a luminaire about its C=0°/C=180° axis, you need to enter a value in degrees for the variable Tilt90. This value can be positive or negative.

For example Tilt90 = 30°:



Tilt0
If you wish to change the angle of rotation of a luminaire about its C=90°/C=270° axis, you need to enter a value in degrees for the variable Tilt0. This value can be positive or negative.

For example Tilt0 = 30°:



Luminaire orientation order

When specifying values for RBA aiming Calculux uses the following specification order:

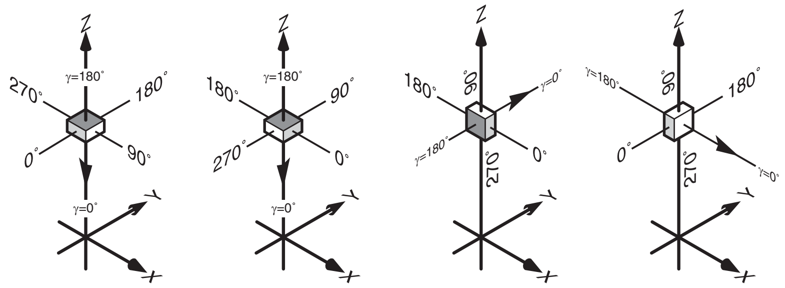
- Rot;
- Tilt90;
- Tilt0.

Extra attention must be paid, because the order in which the variables will be processed is of great influence on the resulting orientation.

For example if the following sequence of processing is executed for a luminaire:

- 90° rotation about the vertical axis (Rot=90°);
- 90° rotation about the C=0°/C=180° axis (Tilt90=90°);
- 90° rotation about the C=90°/C=270° axis (Tilt0=90°).

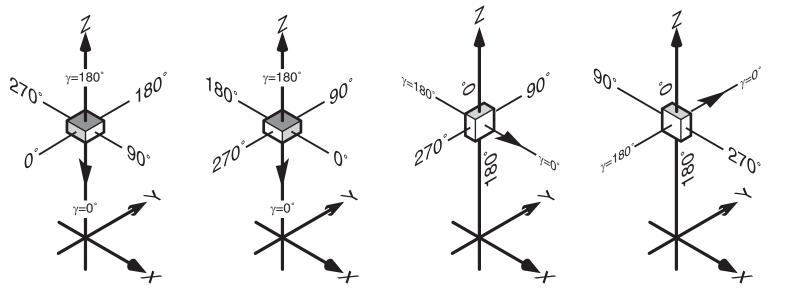
The result of the above order of processing gives the following orientation:



Consider this against the following order of processing:

- 90° rotation about the vertical axis (Rot=90°);
- 90° rotation about the C=90°/C=270° axis (Tilt0=90°);
- 90° rotation about the C=0°/C=180° axis (Tilt90=90°).

This will result in the following orientation:



Conversion of Aiming types

Conversion from RBA aiming to XYZ aiming

The XYZ coordinates of the aiming points are locked on the aiming plane. Conversion from RBA-aiming to XYZ-aiming is only possible when the Tilt0 of the luminaire is 0°.

This restriction is included to prevent the loss of orientation information. The XYZ coordinates are blanked out in case the luminaire has to be displayed in XYZ-aiming, and there is no intersection with the aiming plane.

In the case of a modification in the aiming type when there's no intersection with the aiming plane, the point on the aiming vector, one meter from the luminaire, is chosen as the aiming point.

Conversion from XYZ aiming to RBA aiming

The direction from the location of the luminaire to the aiming-point is determined. This direction is expressed in a Rotation, Tilt90 and Tilt0 (Tilt0 is always 0°).

Selecting Aiming Presentation types

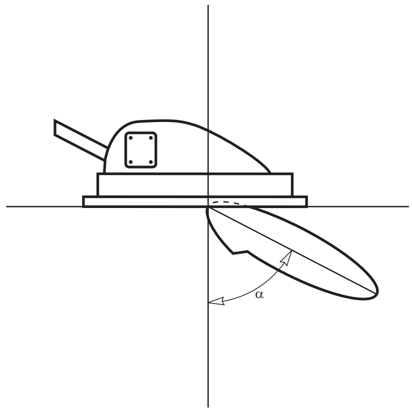
Calculux allows you to select either RBA aiming presentation to display the Rot, Tilt90 and Tilt0 aiming angles, or XYZ aiming presentation to display the aiming points. If the selected aiming presentation is different from the used aiming type, Calculux will convert the unit for aiming into the unit as selected for the aiming presentation. In this way it is possible to view the value of the aiming angles while the used aiming type is XYZ aiming or aiming points while the used aiming type is RBA aiming.
The aiming presentation of luminaires can be set in the luminaires list.

Conversion from RBA aiming presentation to XYZ aiming presentation for a luminaire is only possible when Tilt0=0°. This restriction is included to prevent the loss of orientation information. When a luminaire, aimed with RBA aiming, has to be displayed in XYZ aiming and there's no intersection with the aiming plane, the XYZ coordinate values are blanked out.

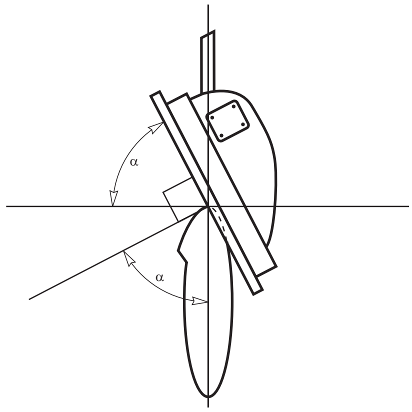
✍ Conversion of the *aiming presentation* type does not change the aiming type!

Aiming offset (Floodlights)

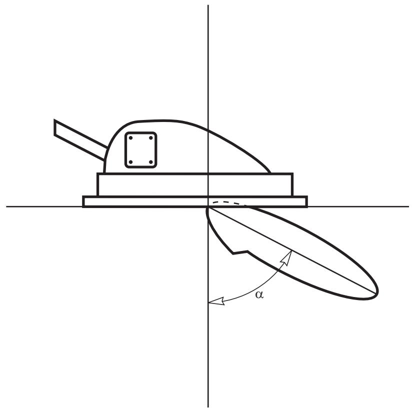
For some asymmetric flood lighting luminaires an aiming offset is given and stored in the database.
It can be viewed in the project luminaire details dimensions tab. The aiming offset is usually equal to the angle of the maximum intensity in the C=90° plane.



For a luminaire with an aiming offset the photometric data is treated with respect to the aiming of the luminaire as if the maximum intensity is at C=0° and γ=0°.
Aiming the above luminaire with an aiming offset of
α degrees at Rot=0° and Tilt90=0° gives the orientation displayed next.



To ensure that the front glass of the luminaire is horizontal, the aiming should be Rot=0° and Tilt90=α°.



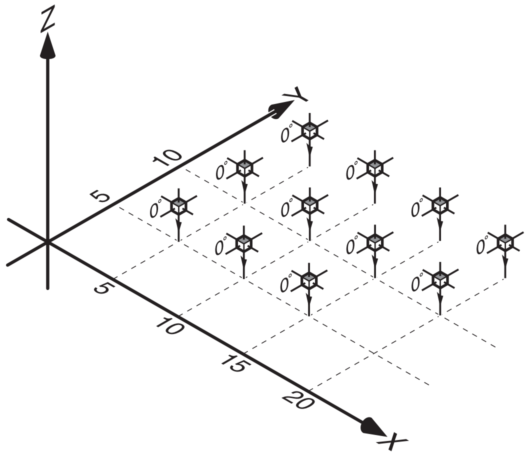
3.4.3 Number of luminaires per position (Luminaire Quantity)

Normally there will be one luminaire at each luminaire position. In some special cases it can be very useful to use a different number of luminaires, for instance;

- When a group of 5 luminaires (floodlights) with the same aiming point is situated on a pole, these luminaires can technically be regarded as one luminaire. In this case you can enter a luminaire quantity of 5.

- When in a block arrangement at one particular luminaire position no luminaire can be installed.

Example:
Luminaire Quantity of position (20,5) = 0.



3.5 Individual Luminaires

3.5.1 General

Calculux allows you to position luminaires individually as well as in groups.
The definition of individual luminaires is done in the 'Individual Luminaires' dialogue box. This dialogue box contains two tab pages.
In the Luminaires tab you can select the project luminaires which have been defined in the Project Luminaires dialogue box and set or change luminaire parameters. In the View tab you can view the luminaires graphically.

3.5.2 Luminaire Definition

In the Luminaires tab you can define and position individual luminaires.
For the definition of a new luminaire the following parameters, if applicable, have to be set:

- Project Luminaire Type;
- Aiming Presentation;
- Switching Modes.

When the above parameters have been set the luminaire(s) can be added to the *luminaire list* by clicking on the 'New' button.

Project Luminaire Type
If a project contains two or more luminaire types you will need to select the required luminaire type. For details about a project luminaire you can click on the 'Details' button.

Aiming Presentation
With this parameter you can set the aiming presentation of all luminaires in the luminaire list. Choose from either RBA or XYZ, aiming angles or aiming points.

Switching Modes
If switching modes are used, you can select which switching mode(s) will be applied to all new created luminaires in the luminaire list.

Luminaire List

The luminaire list contains information about the individually placed luminaires used in the project. You can view, set, edit, copy or delete information of project luminaires. In the luminaire list the following luminaire information, if applicable, can be set:

Luminaire Type
If a project contains more luminaires, and afterwards a different luminaire type is required, you can click on the down arrow in the project luminaire type box and make your selection.

Luminaire Quantity
With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Luminaire Position (POS X, POS Y and POS Z)
Use these parameters to enter the XYZ coordinates of the centre of the luminaire in relation to the origin of the coordinate system.

Luminaire Orientation (Aiming Type)
Depending on the defined Aiming Type and selected Aiming Presentation you can set and/or view the RBA angles (Rot / Tilt90 / Tilt0) or the XYZ coordinates Aim. Pnt. X / Aim. Pnt. Y / Aim. Pnt. Z.

✍ By pressing on the 'To XYZ' or 'To RBA' button you can convert the aiming type of selected luminaires from RBA aiming to XYZ aiming or vice versa.

Symmetry (Sym.)
If you want to apply symmetry, you can set the symmetry type for the luminaires. The **Sym.** column shows which type of Symmetry is used ('NONE', 'X', 'Y' or 'XY'). If X- or XY symmetry is used, for the **X-origin** the X coordinate of the YZ plane has to be entered. If Y- or XY symmetry is used, for the **Y-origin** column the Y coordinate of the XZ plane has to be entered.

For more information about symmetry, see chapter 'Symmetry'.

Switching Modes (1, 2, ...)
If switching modes are applied, you can view or set which of the available switching modes are activated for each luminaire.
Each column number is identical to the **switching mode sequence number** in the 'Switching Mode' list box. The switching modes columns will only be displayed if more then one switching mode(s) exist.

Light Regulation Factors (%)
If light regulation factors are applied, you can set and/or view the value of the light regulation factor (0 - 100%) for each luminaire.

3.5.3 View

The View tab displays the luminaires in the arrangement graphically.

3.6 Luminaire Arrangements

3.6.1 General

Calculux allows you to position luminaires individually as well as in groups. A number of luminaires defined as a group is called a luminaire arrangement. To simplify the definition of an arrangement, Calculux contains the 'Arranged Luminaires' option. The luminaires in an arrangement are positioned and aimed according to the arrangement rule and are stored under the 'arrangement name'.

The arrangement generation rules relate to all arrangements (where applicable) and are explained here for the following arrangements:

- Block;
- Polar;
- Line;
- Point;
- Free.

A Free arrangement is a special kind of arrangement allowing the luminaires to be positioned individually. The only thing they share is a common arrangement name. In the case of a Block, Line, Polar or Point arrangement, the luminaire positions are controlled by the arrangement rule. The other attributes can be set individually. In general, for each arrangement the following luminaire attributes (if applicable) must be set:

- Project luminaire Type;
- Position of the arrangement;
- Orientation of the arrangement (Aiming);
- Symmetry type and relevant symmetry origin;
- Number of Same (luminaires per position);
- Switching mode(s).

To simplify the definition of the attributes, the arrangements dialogue box is split into the following four tab pages.

Arrangement Definition

In the Arrangement Definition tab you can define the name and position of the arrangement in relation to the XYZ coordinate system.
Where applicable you can set the orientation (= aiming) of the arrangement.

Luminaire Definition

The Luminaire Definition tab defines the default settings for all luminaires in the arrangement. The settings are used for the generation of the luminaires at the position as set in the Arrangement Definition tab and determine the initial generation of the luminaire list.
The default settings can be changed at any time. By using the Apply buttons you ensure the setting changes are carried out for all luminaires in the luminaire list.

Caution:
Take care when you have created an arrangement with a unique aiming pattern. When you click on the Aiming Apply button the settings will be applied to all the luminaires in the luminaire list and the unique aiming pattern will be lost. If you don't want this and it does happen, click on the Cancel button and the action will be undone. Note that the Cancel facility is effective in any of the tabs of the arrangement dialogue box.

Luminaire List

In the Luminaire List tab you can view the attributes of each luminaire in the arrangement. All attributes, except the luminaire positions can be changed. For a Free arrangement, it's possible to change the position of the luminaires as well.

View

The View tab displays the luminaires in the arrangement graphically.

3.6.2 Block Arrangement

In a Block arrangement the luminaires are arranged in a rectangular shape.

Arrangement Definition

For the definition of a Block arrangement, the following parameters have to be set:

- Name of the arrangement;
- Position of the arrangement;
- Orientation of the arrangement;
- Number of luminaires in AB and AC direction;
- Spacing between the luminaires in AB and AC direction.

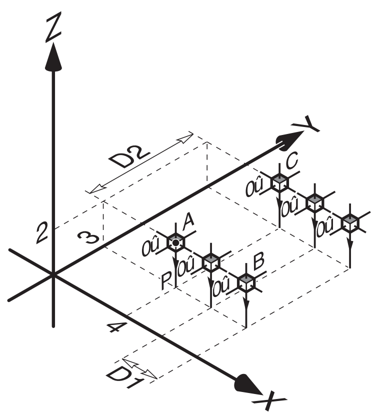
✍ To simplify the definition of a Block arrangement you should first define a Block arrangement without orientation (rotation or tilt) and afterwards (if applicable) apply rotation and/or tilt.

Example:

For the definition of a Block arrangement without rotation or tilt, set:

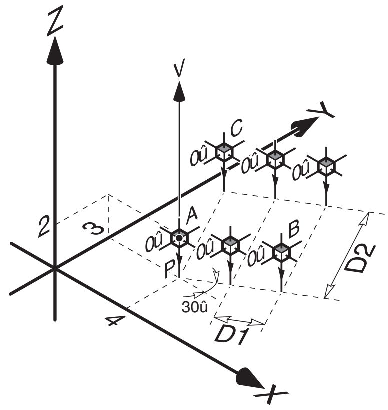
Position A	The block position.
P	Reference point P is the position of the bottom left luminaire in the arrangement (if no rotation and tilt is applied).
N_{AB}	The number of luminaires in AB direction (if the block is not rotated, AB is parallel to the XZ-plane).
N_{AC}	The number of luminaires in AC direction (if the block is not rotated, AC is parallel to the YZ-plane).
$Spacing_{AB}$	The distance between the luminaires in the AB direction (D1).
$Spacing_{AC}$	The distance between the luminaires in the AC direction (D2).

P = 4.0, 3.0, 2.0
N_{AB} = 3
N_{AC} = 2
$Spacing_{AB}$ = 2.0 m
$Spacing_{AC}$ = 6.0 m



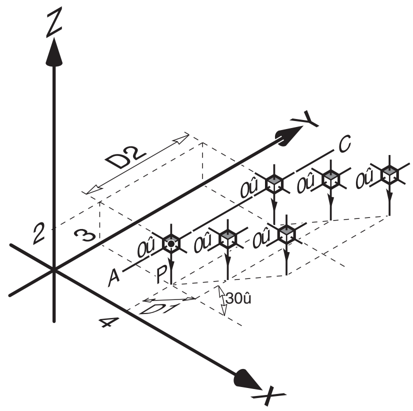
Now the Block arrangement is generated, you can apply rotation and/or tilt.

For instance:
Rotation = 30°:
The Block arrangement is rotated 30° anti clockwise around the V-axis, which passes through P and is parallel to the Z-axis.

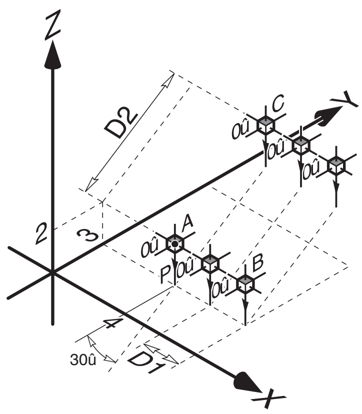


✍ In a Block Arrangement the luminaires are oriented in relation to the XYZ coordinate system (= global coordinate system). Therefore, only the arrangement is rotated, the orientation of the individual luminaires is not changed.

Tilt90 = 30°:
The block is rotated 30° around the AC-axis towards the positive Z-axis.



Tilt0 = -30°:
The block is rotated 30° around the AB-axis towards the negative Z-axis.



✍ The block Rotation, Tilt90 and Tilt0 are equivalent to the luminaire Rotation, Tilt90 and Tilt0 in the way they operate, but they are in fact separate orientations. The block orientation is set in the 'Arrangement Definition' tab, and controls the luminaire positions, while the luminaire orientation (= 'Aiming') is set in the 'Luminaire Definition' tab. If you want to have the luminaires orientated in the same direction as the arrangement, the angles of the arrangement and luminaire orientation have to be the same.

Luminaire Definition

For the definition of the luminaires, the following parameters can be set:

- Project Luminaire Type;
- Aiming Type;
- Symmetry;
- Number of Same;
- Switching Modes.

✍ For each parameter there is a separate Apply button. When settings are changed you can click on the Apply button to carry out the settings for all luminaires in the luminaire list. Selection of different parameter settings for individual luminaires of the arrangement is done in the luminaire list.

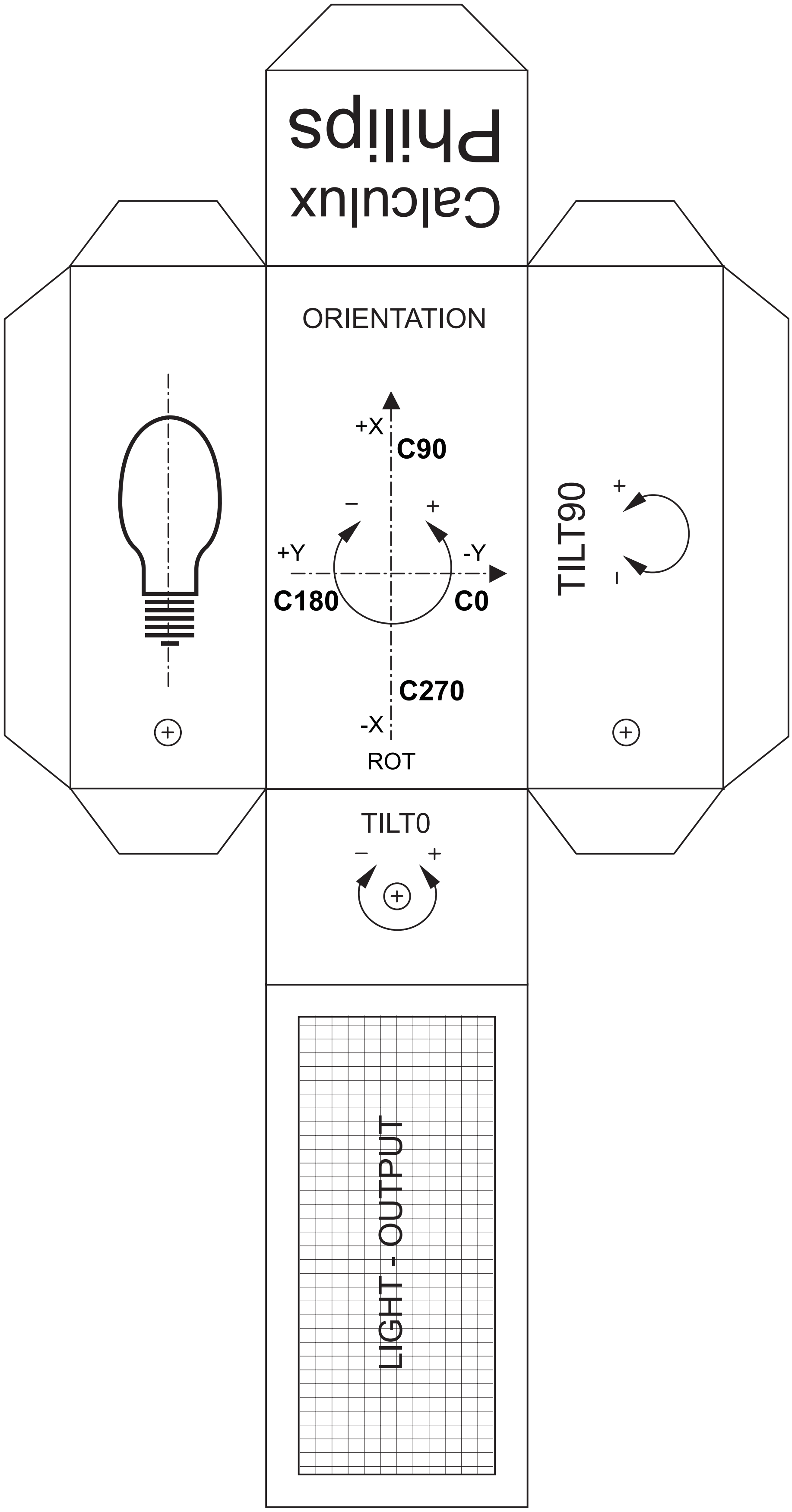
Project Luminaire Type
If a project contains two or more luminaire types, you need to select the required luminaire type. If afterwards a different luminaire type is needed, you can click on the down arrow in the Project Luminaire Type box and make your selection.

Aiming Type
With this parameter you can set the default aiming type (choose from either RBA or XYZ), aiming angles or aiming points for the luminaires in the arrangement.

Symmetry
If you want to apply symmetry, you can set the default symmetry type for the luminaires in the arrangement.

Number of Same
With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Switching Modes
If switching modes are used, you can select which switching mode you want to apply to the luminaires in the arrangement.


Calculux
Philips
ORIENTATION
+X
C90
+Y
-Y
C180
C0
C270
-X
ROT
TILT90
TILT0
LIGHT - OUTPUT

3.6.3 Polar Arrangement

In a Polar arrangement the luminaires are arranged in one or more concentric arcs.

Arrangement Definition

For the definition of a Polar arrangement, the following parameters have to be set:

- Name of the arrangement;
- Centre position of the arrangement;
- Orientation of the arrangement (orientation of the plane);
- Number of luminaires per arc;
- Spacing between the luminaires on an arc;
- Length of an arc;
- Number of concentric arcs;
- Distance between two adjacent arcs;
- Radius of the arc that is nearest to the centre.

When the Polar arrangement has been entered, a number of ways of updating are possible:

Changing	Updates
Luminaires per Arc	Spacing along Arc
Spacing along Arc	Length of an Arc (Total Arc)
Length of the Arc	Spacing along Arc

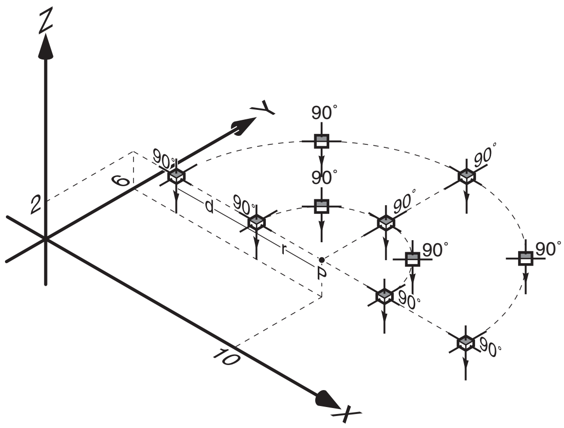
✍ To simplify the definition of a Polar arrangement you can best first define an arrangement without orientation (rotation or tilt) and afterwards (if applicable) apply rotation and/or tilt.

Example:

For a Polar arrangement without rotation or tilt, the following definition is given:

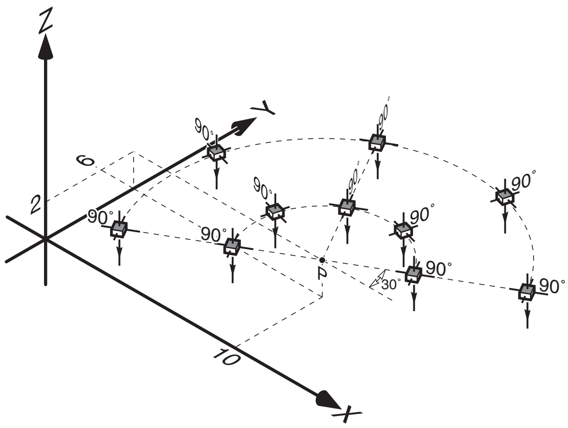
Centre Position (P)	= (10.0, 6.0, 2.0)
Luminaires per Arc	= 5
Spacing along Arc	= 45°
Total Arc	= 180°
# of Concentric Arcs	= 2
Distance between Arcs (d)	= 5.0 m
Radius of First Arc (r)	= 4.0 m

Which results in the following arrangement:



Now rotation and tilt is applied to the previously defined Polar arrangement.

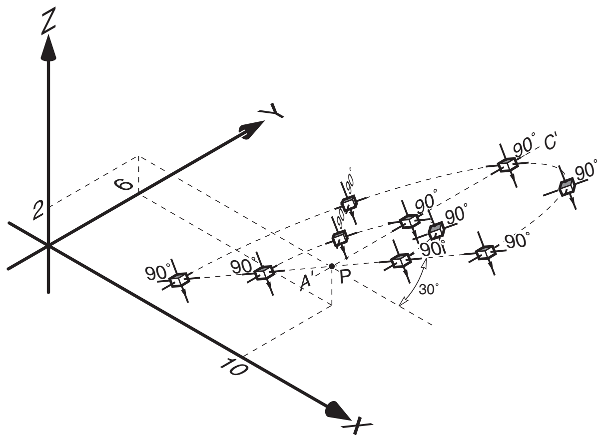
For instance:
Rotation = 30°:



The arrangement is rotated 30° counter clockwise around the V-axis, which passes through
P and is parallel to the Z-axis.

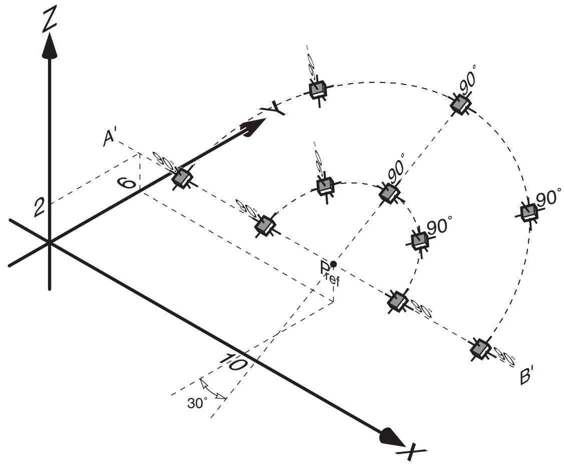
✍ In a Polar arrangement, the orientation of the luminaires is related to the centre point (P) of the arrangement. So every time you change the orientation of the arrangement, the orientation of the luminaire will change too.

Tilt90 = 30°:



The arrangement is rotated 30° around the A'C'-axis towards the positive Z-axis.
If no rotation is applied, A'C' is parallel to the YZ-plane.

Tilt0 = -30°:



The arrangement is rotated 30° around the A'B'-axis towards the negative Z-axis.
If no rotation is applied, A'B' is parallel to the XZ-plane.

Luminaire Definition

For the definition of the luminaires, the following parameters can be set:

- Project Luminaire Type;
- Aiming Type;
- Symmetry;
- Number of Same;
- Switching Modes.

✍ For each parameter there is a separate Apply button. When settings are changed you can click on the Apply button to carry out the settings for all luminaires in the luminaire list. Selection of different parameter settings for individual luminaires of the arrangement is done in the luminaire list.

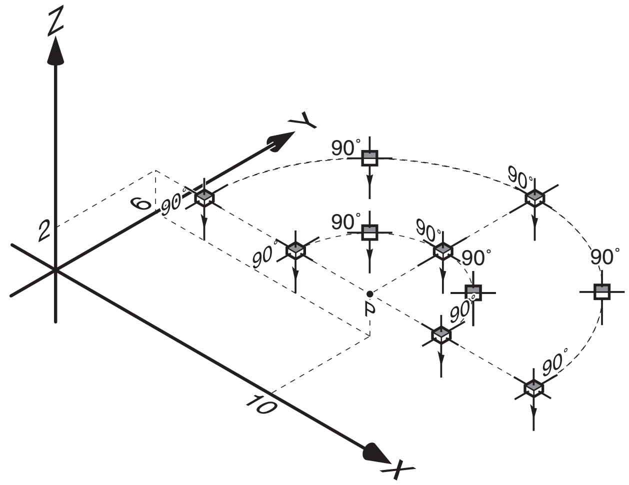
Project Luminaire Type
If a project contains two or more luminaire types, you need to select the required luminaire type. If afterwards a different luminaire type is needed, you can click on the down arrow in the Project Luminaire Type box and make your selection.

Aiming Type
With this parameter you can set the default Aiming Type (choose from either RBA or XYZ), Aiming Angles or Aiming Points for the luminaires in the arrangement.

Example:

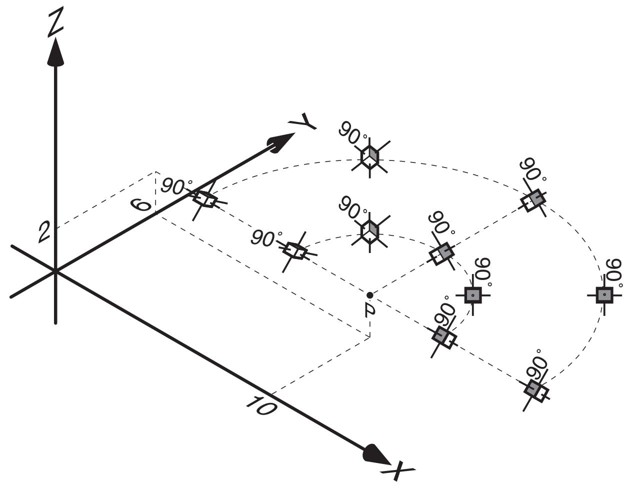
- When the luminaire orientation is set to
  Rot = 90°
  Tilt90 = 0°
  Tilt0 = 0°

This results in the following arrangement:



- When the luminaire orientation is set to
  Rot = 90°
  Tilt90 = 45°
  Tilt0 = 0°

The following arrangement will be created:



Symmetry
If you want to apply symmetry, you can set the default symmetry type for the luminaires in the arrangement.

Number of Same
With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Switching Modes

If switching modes are used, you can select which switching mode you want to apply to the luminaires in the arrangement.

3.6.4 Line Arrangement

In a Line arrangement the luminaires will be arranged in a line.

Arrangement Definition

For the definition of a Line arrangement, the following parameters have to be set:

- Name of the arrangement;
- First and last point of the line;
- Number of luminaires in the line;
- Spacing between the luminaires.

✍ When the line coordinates have been entered, the line orientation is automatically set by the program. Any subsequent alterations to the line coordinates update the orientation.

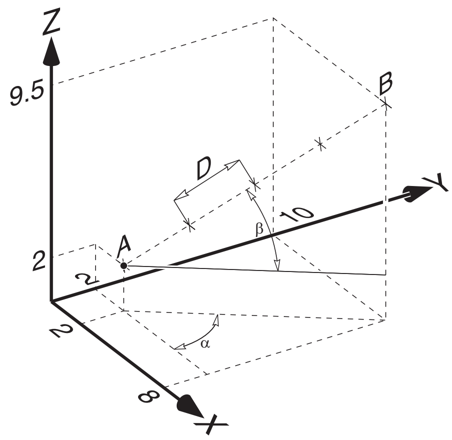
Example:

A = First point (= reference point). The reference point is the position of the first luminaire in the arrangement.

B = Last point

α = Rotation

β = Tilt90



The angle α corresponds with the Rotation of the Line arrangement.
The angle β corresponds with the Tilt90 of the Line arrangement.

When the Line arrangement has been entered, several ways of updating are possible:

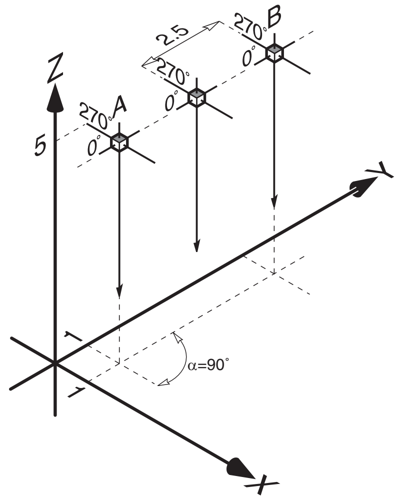
Changing	**Updates**
First point	Last point
Spacing	Last point
Number of Luminaires	Spacing
Last point	Spacing and Orientation
Orientation	Last point

The following Line arrangements have been created to demonstrate the different ways of defining a Line arrangement.
The Line arrangement below has the following settings:

First point = 1.0, 1.0, 5.0
Last point = 1.0, 6.0, 5.0
Number of Luminaires = 3
Spacing = 2.5

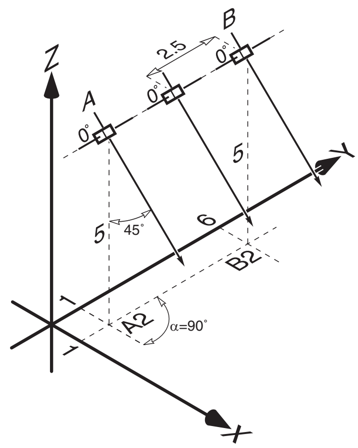
This will create the following *line orientation* automatically:
Rot = 90°
Tilt90 = 0°

The *luminaire orientation* uses the default settings which are set to:
Rot = 0°
Tilt90 = 0°
Tilt0 = 0°



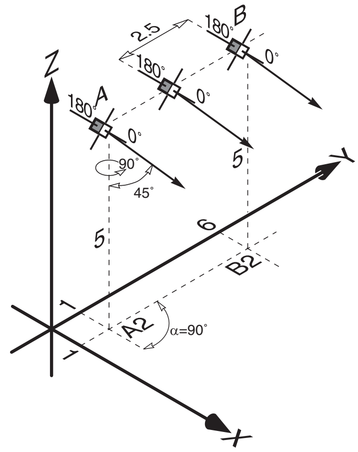
- From the previous illustration, the luminaire orientation is now set to:
  a) Rot = 0°
  Tilt90 = 45° (rotation of 45° around C=0°...C=180° axis)
  Tilt0 = 0°

Which results in the following arrangement:



b) Rot = 90° (rotation of 90°C around the vertical axis)
Tilt90 = 45° (rotation of 45° around C=0°...C=180° axis)
Tilt0 = 0°

Which results in the following arrangement:

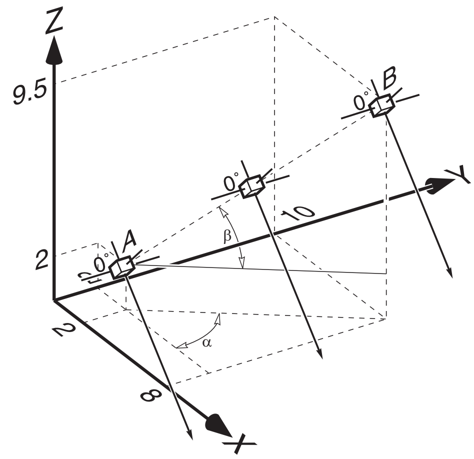


- If a line arrangement is given the following settings:
  First point = 2.0, 2.0, 2.0
  Last point = 8.0,10.0, 9.5
  Number of Luminaires = 3
  Spacing = 6.25 m (calculated automatically by the program)

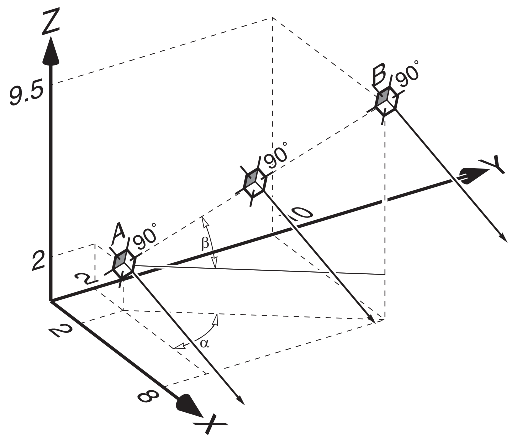
  This will create the following *line orientation* automatically:
  Rot = 53.1° (α)
  Tilt90 = 36.9° (β)

  When the *luminaire orientation* (Aiming Type) is set to:
  Rot = 0°
  Tilt90 = 45° (rotation of 45° around C=0°...C=0° axis)
  Tilt0 = 0°

  The following arrangement will be created:



The luminaire orientation in the above arrangement can now be set with the same values as the line orientation (Rot = 53.1°; Tilt90 = 36.9°), so that the luminaire orientation is 'in line' with the line orientation.



Luminaire Definition

For the definition of the luminaires, the following parameters can be set:

- Project Luminaire Type;
- Aiming Type;
- Symmetry;
- Number of Same;
- Switching Modes.

✍ For each parameter there is a separate Apply button. When settings are changed you can click on the Apply button to carry out the settings for all luminaires in the luminaire list. Selection of different parameter settings for individual luminaires of the arrangement is done in the luminaire list.

Project Luminaire Type

If a project contains two or more luminaire types, you need to select the required luminaire type. If afterwards a different luminaire type is needed, you can click on the down arrow in the Project Luminaire Type box and make your selection.

Aiming Type

With this parameter you can set the default aiming type (choose from either RBA or XYZ), aiming angles or aiming points for the luminaires in the arrangement.

Symmetry

If you want to apply symmetry, you can set the default symmetry type for the luminaires in the arrangement.

Number of Same

With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Switching Modes

If switching modes are used, you can select which switching mode you want to apply to the luminaires in the arrangement.

3.6.5 Point Arrangement

A Point arrangement is a group of luminaires which can be regarded as one point, therefore a point arrangement can be regarded as a point light source.

Arrangement Definition

For the definition of a Point Arrangement, the following parameters have to be set:

- Name of the arrangement;
- Position of the point (pole or mast).

Luminaire Definition

For the definition of the luminaires, the following parameters can be set:

- Project Luminaire Type;
- Aiming Type;
- Symmetry;
- Number of Same;
- Switching Modes.

✍ For each parameter there is a separate Apply button. When settings are changed you can click on the Apply button to carry out the settings for all luminaires in the luminaire list. Selection of different parameter settings for individual luminaires of the arrangement is done in the luminaire list.

Aiming Type
With this parameter you can set the default Aiming Type (choose from either RBA or XYZ), Aiming Angles or Aiming Points for the luminaires in the arrangement.

Warning:
A Point Arrangement normally has a unique aiming pattern. When you click on the Aiming Apply button the settings will be applied to all the luminaires in the luminaire list and the unique aiming pattern will be lost. If you do not want this and it does happen, click on the Cancel button and the action will be undone.

Project Luminaire Type
If a project contains two or more luminaire types, you need to select the required luminaire type. If afterwards a different luminaire type is needed, you can click on the down arrow in the Project Luminaire Type box and make your selection.

Symmetry
If you want to apply symmetry, you can set the default symmetry type for the luminaires in the arrangement.

✍ If symmetry is applied you can generate new logical luminaires by means of the desymmetrize option (see also chapter 'Symmetry', section 'Desymmetrize').

Number of Same
With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Switching Modes
If switching modes are used, you can select which switching mode you want to apply to the luminaires in the arrangement.

3.6.6 Free Arrangement

A Free arrangement is a special arrangement type, where the number of luminaires and their position is not defined by an arrangement rule.

Arrangement Definition

For the definition of a Free Arrangement only the name of the arrangement has to be specified. There is no arrangement rule for defining the number of luminaires and their positions.

✍ The definition of the luminaires and their positions is done in the same way as individual luminaires (see chapter 'Individual Luminaires').

Luminaire Definition

For the definition of the luminaires, the following parameters can be set:

- Project Luminaire Type;
- Aiming Type;
- Symmetry;
- Number of Same;
- Switching Modes.

✍ For each parameter there is a separate Apply button. When settings are changed you can click on the Apply button to carry out the settings for all luminaires in the luminaire list. Selection of different parameter settings for individual luminaires of the arrangement is done in the luminaire list.

Project Luminaire Type
If a project contains two or more luminaire types, you need to select the required luminaire type. If afterwards a different luminaire type is needed, you can click on the down arrow in the Project Luminaire Type box and make your selection.

Aiming Type
With this parameter you can set the default aiming type (choose from either RBA or XYZ), aiming angles or aiming points for the luminaires in the arrangement.

Symmetry
If you want to apply symmetry, you can set the default symmetry type for the luminaires in the arrangement.

Number of Same
With this parameter you can set the number of identical luminaires at a luminaire position (see also chapter 'Luminaire Position and Orientation'; section 'Luminaire Quantity').

Switching Modes
If switching modes are used, you can select which switching mode you want to apply to the luminaires in the arrangement.

3.6.7 Ungrouping a luminaire arrangement

After you have positioned a luminaire arrangement, you may wish to adjust the position of the individual luminaires slightly. When you Ungroup a luminaire arrangement, the luminaires are no longer part of an arrangement but individual luminaires.
It is then possible to, change, delete or replace each luminaire individually.

✍ A similar result (roughly) is obtained when a luminaire arrangement is converted into a Free arrangement.

3.6.8 Convert into a Free Arrangement

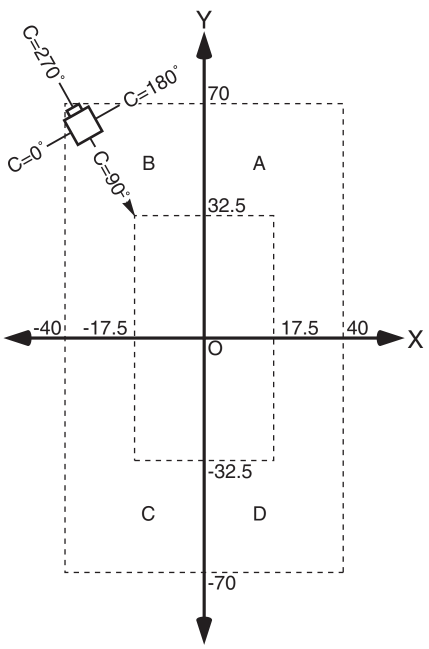
Calculux allows you to convert an existing arrangement or a group of individual luminaires into a Free arrangement. In a Free Arrangement the luminaires are considered as part of an arrangement but there is no arrangement rule for defining the number of luminaires and their positions. Only the name of the arrangement has to be specified.

3.7 Symmetry

3.7.1 General

Symmetry is an optional specification, that can be used to simplify individual luminaire or luminaire arrangement entries when one or more luminaires have a symmetrical orientation and/or position. If applied, the luminaires are duplicated on the opposite side of a line parallel to the X-axis or Y-axis or they are duplicated to all quadrants.

The use of symmetry in luminaire positioning and orientation is explained with the following example:
Assume that you've created an application field of width 80m and length 140m. The centre of the field is located at the origin of the XYZ coordinate system. At (-35, 65, 10) you've positioned a floodlight, orientated towards the centre of the application field (see figure below).



The easiest way to position an identical luminaire at the position at the opposite corner at (35, 65, 10) is to apply X-symmetry to the lighting installation.

If the axis you want to use to apply symmetry is not equal to a central axis (X axis or Y axis) of the application field, you'll have to change the settings of the X-origin and/or Y-origin (placing the plane of symmetry in the middle between the existing and the 'new' luminaire). You can do this in several ways:

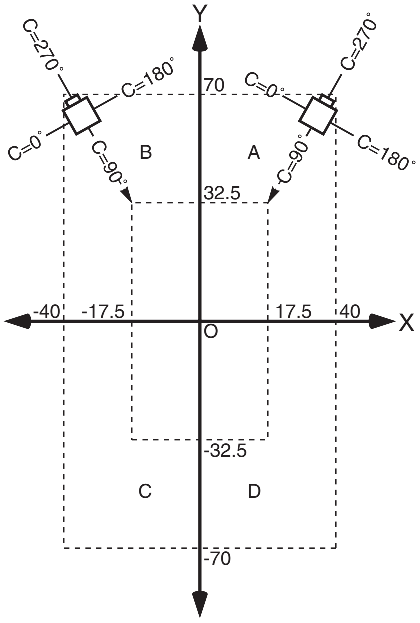
- For all new created luminaires in a project this is done by replacing the settings of the X-origin and/or Y-origin in the Symmetry tab (Project Options).
- For luminaires in a luminaire arrangement this is done by replacing the settings of the X-origin and/or Y-origin in the Luminaire Definition tab (Arranged Luminaires), then clicking on the Apply button.

- For individual luminaires or individual luminaires in an arrangement this is done by replacing the settings of the X-origin and/or Y-origin in the Luminaires tab (Individual Luminaires) or Luminaire List tab (Arranged Luminaires).

✍ When symmetry is applied and the position and/or orientation of a luminaire is changed, the position and/or orientation of all symmetrical luminaires will also change according to the applied symmetry type.

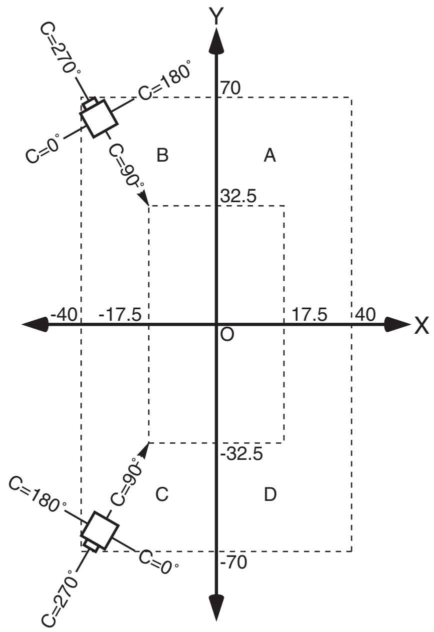
3.7.2 X-Symmetry

If you select X-symmetry the existing luminaire in B quadrant is duplicated to the opposite position in A quadrant with the new coordinates (35, 65, 10). The result of this action will look like this:



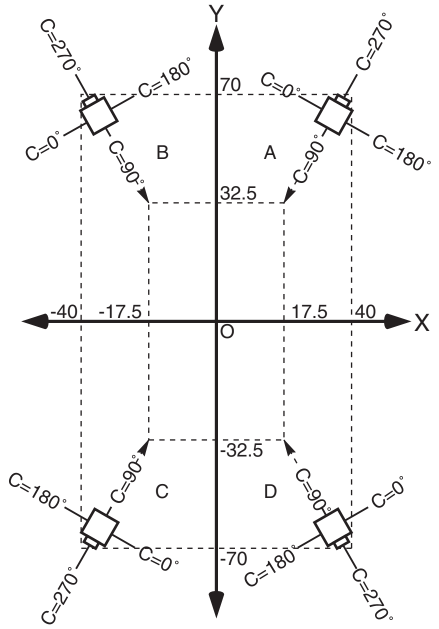
3.7.3 Y-Symmetry

If you select Y-symmetry the existing luminaire in B quadrant is duplicated to the opposite position in C quadrant with the new coordinates (-35, -65, 10). When Y-symmetry is used, the Y-origin field displays the Y coordinate of the XZ plane. The result of this action will look like this:



3.7.4 XY-Symmetry

If you select XY-symmetry the existing luminaire in B quadrant is duplicated to all other corners at the coordinates (-35, -65, 10), (35, 65, 10) and (35, -65, 10).
When X- or XY-symmetry is used, the X-origin field displays the X coordinate of the YZ plane. When Y- or XY symmetry is used, the Y-origin field displays the Y coordinate of the XZ plane. The result of this action will look like this:



Remember that symmetry is not only applied to the position of the luminaire, but also to its orientation: e.g. X-symmetry of a luminaire at coordinates (-35, 65, 10) resulted in a new luminaire on (35, 65, 10) which was rotated automatically so that it's still orientated towards the centre (0, 0, 0).

Applying symmetry about the Y-axis to a lighting design does not automatically imply a symmetric light distribution. This is only the case if the luminaire is symmetric about its C=90°...C=270° plane.

3.7.5 Desymmetrize

This Calculux option can be used to remove the symmetry of luminaires of a Point arrangement. As a result new logical luminaires will be generated. You can only apply desymmetry to Point arrangements with symmetry.

- If the arrangement contains one or more member luminaires with symmetry type XY, 3 new arrangements will be generated (symmetry type NONE).
- If the arrangement contains one or more member luminaires with symmetry type X and symmetry type Y, 2 new arrangement will be generated (symmetry type NONE).
- If the arrangement contains one or more member luminaires with symmetry type X, 1 new arrangement will be generated (symmetry type NONE).
- If the arrangement contains one or more member luminaires with symmetry type Y, 1 new arrangement will be generated (symmetry type NONE).

The Desymmetrize option is very useful when a four corner symmetry Point arrangement
(or mast arrangement) is used with a unique aiming pattern and one mast might have to be moved later on.
By using fixed aiming points, the arrangement can be desymmetrized. Then the mast, which has to be moved, can be moved without changing the aiming points.

3.8 Grids

3.8.1 General

A grid is a plane containing a specific number of points at which lighting calculations are carried out. A grid must always be rectangular in shape and can be in any plane in space (horizontal, vertical or sloping).

It is useful to think of a grid as an invisible surface to which a light meter can be attached. The amount of light measured by the light meter changes as it is moved to different points on the surface. It also changes if the light meter is moved from one side of the surface to the other.

3.8.2 User defined (Free added) grids

Calculux enables you to define your own grids, or to change the specifications of existing grids.

Size and position of a grid: points A, B and C

A grid is defined by specifying the X, Y and Z coordinates of the three reference corners A, B and C. The 4th reference corner is calculated automatically because the grid is a rectangle. Usually point A is considered the bottom left corner of the grid, so when this is the case, the reference corners are as follows:

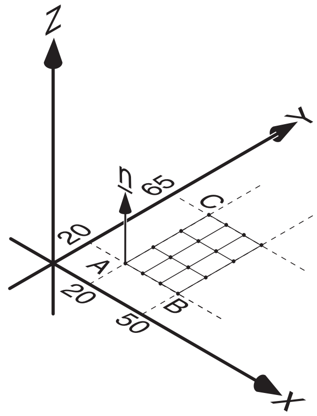
A = The bottom left corner of the grid
B = The bottom right corner of the grid
C = The top left corner of the grid

The following rules apply to grids:

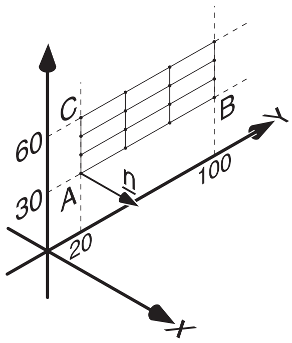
a) The vectors (AB) and (AC) cannot be zero and must be perpendicular.
   A small deviation from perpendicularity is allowed, Calculux will correct this automatically. This is especially useful when a person, using a system with limited accuracy, has to specify the corners of a grid with sides that are not parallel to the axis of the coordinate system.
b) The reference corners A, B and C can not be on one line.

The following illustrations display a horizontal, vertical and sloping grid.

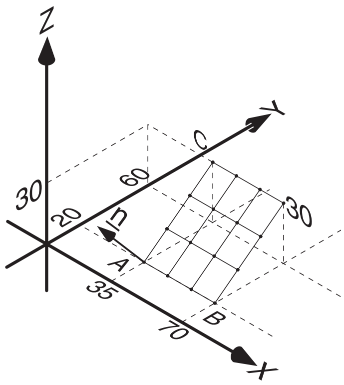
Horizontal grid



Vertical grid



Sloping grid



Calculation points in a grid

The number of calculation points you define in AB and AC direction is used to divide the grid into equal parts. These are the points at which the lighting calculations will be carried out. There is always a calculation point on each corner. For example, if you set both numbers of points in AB and AC direction to 4, the total number of grid points is 4 x 4 = 16, see figure below. The lighting calculations are performed at each of these points.

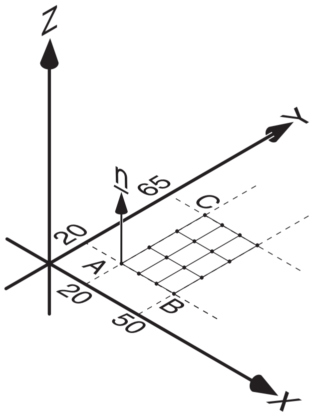
Distance between calculation grid points:

$$D = \frac{\text{Total length of vector}}{(\text{Nr. of grid points along vector}) - 1}$$

The number of divisions along (vector) AB and AC is the number of grid points along that vector - 1.
In the figure below, the distance between the calculation grid points in AB and AC direction is:

$$D_{AB} = \frac{30}{4-1} = 10$$

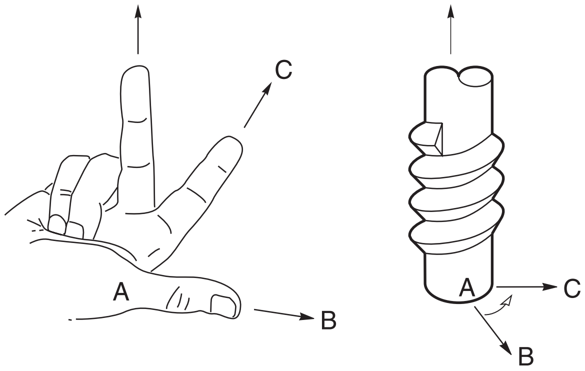
$$D_{AC} = \frac{45}{4-1} = 15$$



Default side

It is usually obvious on which side of the grid (it has two sides) the calculations are to be carried out. However, for some calculations, such as surface illuminance and luminance it is not always obvious and therefore becomes necessary to define the default side of the grid.

The default side of the grid is related to the orientation of A, B and C and is determined using the right hand rule. The direction of the arrow (the normal vector on the grid area) indicates the side of the grid which is the default. This is always the case unless it is specified otherwise.


C
A
B
A
C
B

Grid coupling

Calculux enables you to connect a grid to an application field, (a calculation grid usually lies within an application field) ensuring that any changes made to the field parameters automatically change the grid parameters. You can set a default calculation grid for each application field type in the application field defaults dialogue box. The following example demonstrates these principles:

General field:

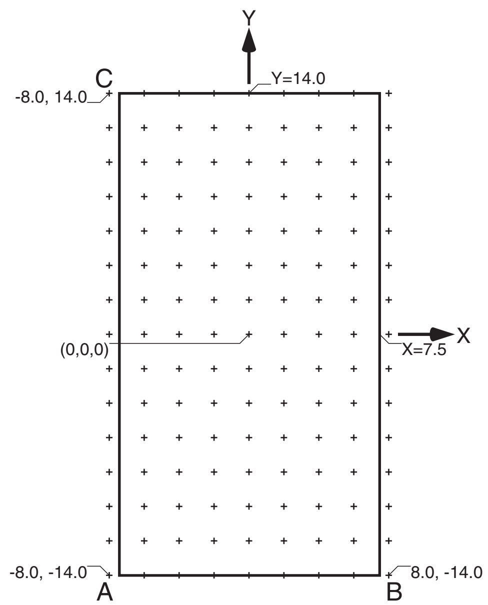
Width = 15 m
Length = 28 m
Centre position = (0.0, 0.0)

Calculation grid:

spacing AB = 2 meters
spacing AC = 2 meters
include Mid Point at Centre Width = yes
include Mid Point at Centre Length = yes

This will give the following grid reference corner coordinates, see figure below:

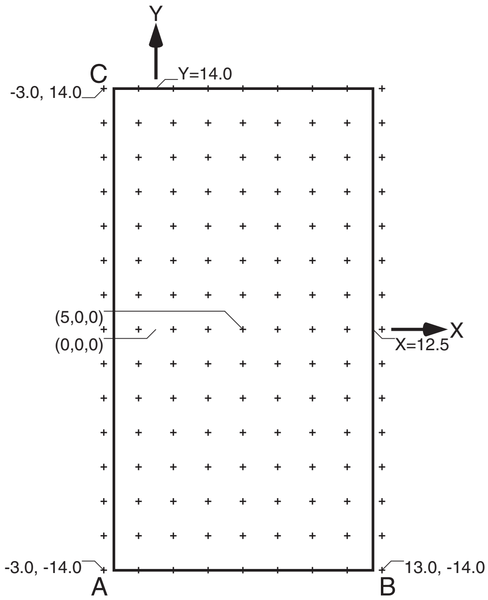
	X	Y	Z
A	-8.0	-14.0	0.0
B	+8.0	-14.0	0.0
C	-8.0	+14.0	0.0



Now moving the centre position of the application field to (5, 0, 0) the grid parameters will automatically change to:

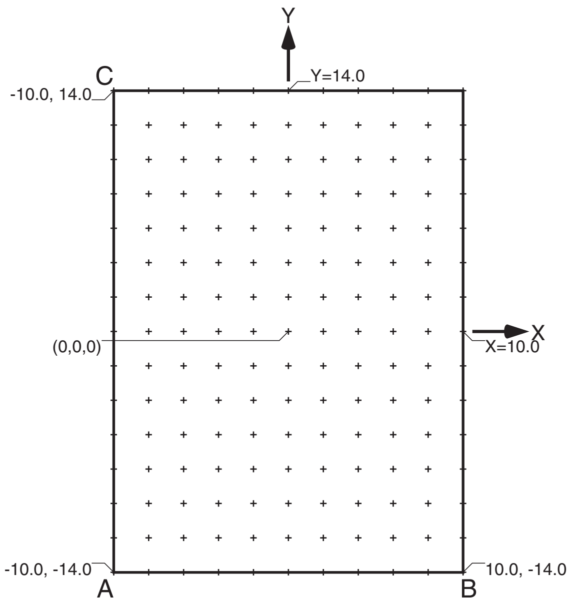
	X	Y	Z
A	-3.0	-14.0	0.0

B	+13.0	-14.0	0.0
C	-3.0	+14.0	0.0



If in the first example the application field width is changed to 20m, the new coordinates will be:

	X	Y	Z
A	-10.0	-14.0	0.0
B	+10.0	-14.0	0.0
C	-10.0	+14.0	0.0

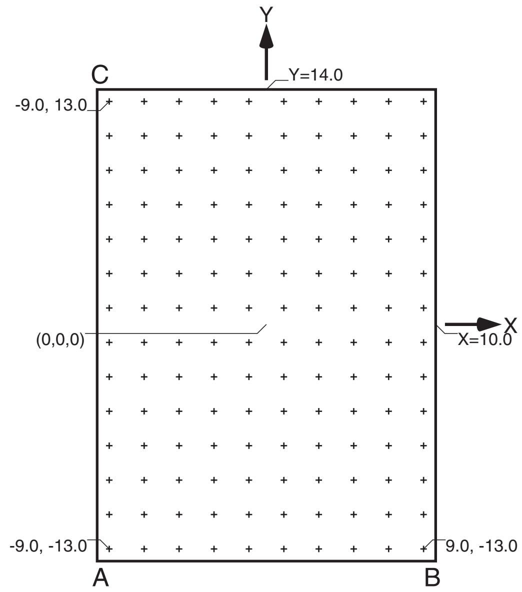


The grid corners can fall outside the application field due to the spacing leading rule, with the centre point of the dimension of the application field being included. See section 'Spacing leading' for a more detailed explanation.

To contain the grid inside the application field it is connected to, exclude
'Mid Point at Centre':
Mid Point at Centre Width = no
Mid Point at Centre Length = no

The grid corner coordinates will change to:

	X	Y	Z
A	-9.0	-13.0	0.0
B	+9.0	-13.0	0.0
C	-9.0	+13.0	0.0



This aspect of Calculux is very user-friendly: you'll begin to appreciate the benefits of grid coupling when you start building your own projects.

For connecting a grid to an application field the following grid point methods are possible:

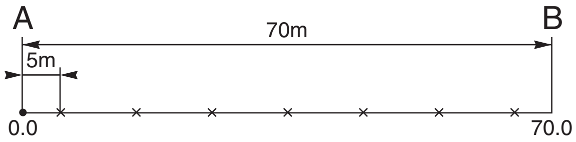
No Rule

When a grid is connected to a application field with 'No Rule', there will be no relation between the definition of the grid and the definition of the field. The grid is defined by the corner points (A, B and C), the number of points in the AB and AC direction, and the direction of the normal vector.
The grid will remain at the same position when the application field is moved and will also be deleted if the application field is deleted.

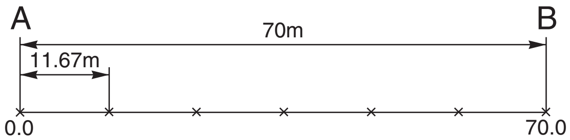
Points Leading

Along each dimension (i.e. length and width of the application field) the number of calculation grid points is defined. These points will be evenly spread over the surface of

the application field starting at the edge or at half spacing from the edge, depending on your selection. Once your selections have been made, Calculux calculates the positions of A, B and C displaying the grid in the view box.
In the following figure the number of calculation grid points along AB is 7, starting at half spacing from the edge. This gives a spacing of 10m. (between calculation points).



In the following figure the number of calculation grid points along AB is 7, starting at the edge (point A). This gives a spacing of 11.67m. (between calculation points).

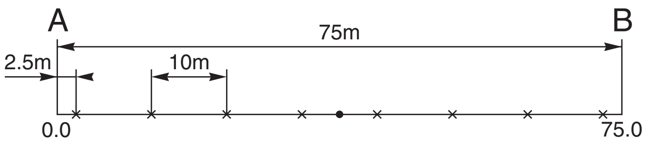


Spacing Leading

Along each dimension (i.e. length and width of the application field) the spacing of the calculation grid points is defined, together with the choice whether or not to include the centre of each dimension in the application field. Once your selections have been made, Calculux calculates the positions of A, B and C displaying the grid in the view box.

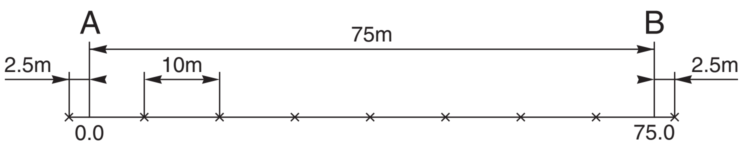
In the following figure the spacing between the calculation grid points along AB is 10m.
The centre point of the dimension of the application field is not included, giving:

- The first point at X = +2.5m;
- The last point at X = +72.5m.



In the following figure the spacing between the calculation grid points along AB is 10m.
The centre point of the dimension of the application field is included, giving:

- The first point at X = -2.5m;
- The last point at X = +77.5m.



The distance between the application area and the border grid point is, at a maximum, half that of the spacing. In case spacing leading is used, the calculation grid can be larger than the application field to which it is connected. To include the grid within the field, switch between 'Mid Point at Centre' included 'Yes' or 'No'.

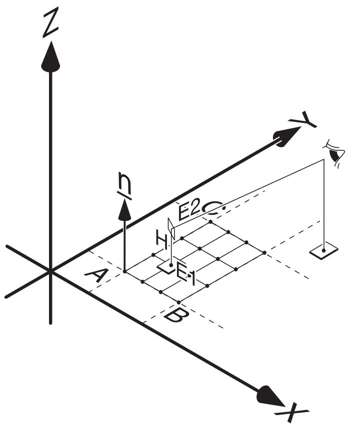
Normal vector of a grid

The normal vector is perpendicular to the plane of the grid and is defined by using the right-handed coordinate system.

Height above a grid

Occasionally, illuminance in the direction of an observer as well as horizontal illuminance has to be calculated for a horizontal grid. In such a case the vertical illuminance towards an observer often has to be 1.5m.
To avoid two grids having to be generated you can define the 'Height above grid' parameter.

This parameter refers to the vertical distance above each generated grid point.
The calculations are carried out at the grid point positions with the 'Height above grid' parameter being added to the Z-coordinate (see figure below).

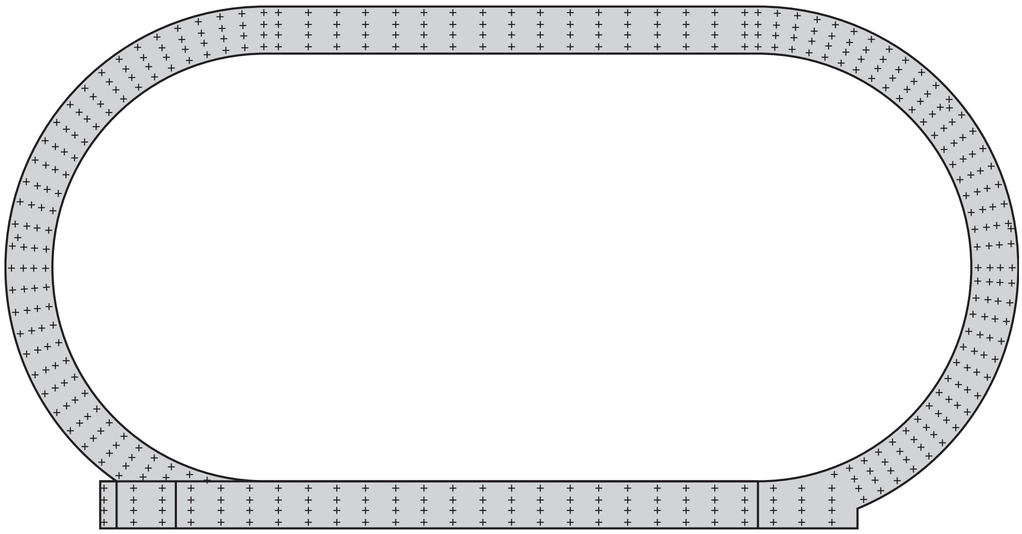


Irregular Grids (not always available; not in Calculux Road)

In addition to the rectangular grid described in the previous sections, Calculux also has the possibility to define irregular grids. An irregular grid is a set of points without any relation. Each point has its own x, y and z position.

Irregular grids can be very useful when local recommendation require calculations to be performed on points of a field that lay outside a rectangular arrangement.
For example, irregular grids can be used to comply with the French recommendations for the lighting of Tennis courts, where the grid points are not all at the same height.

To support the generation of irregular grids, it is also possible to define irregular grid points that lay on a rectangular or circular arrangement.
The figure below shows an example of an Athletic Track with its calculation points defined by irregular grids. Some points are on a rectangular arrangement, some are on a circular arrangement and some are given as individual points.



The definition of calculation points can be time consuming. For this reason it is possible to save the constructed irregular calculation grid for future usage.

✍

- As an irregular grid is just a set of points it not possible to define the Isolux and Mountain plot output type.
- Only the textual and graphical tables are supported.
- The textual table is an X,Y,Z table with the calculated values.
- The graphical table is a projection of all the calculated values on the X-Y plane.

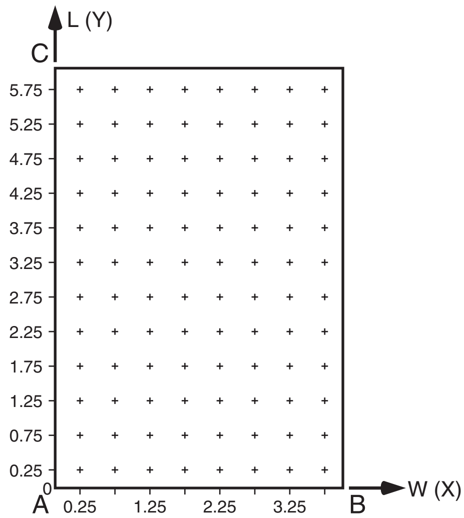
Irregular grid points allow you to perform tailor made calculations.
To avoid unnecessary long output lists or unreadable graphical tables, irregular grids must be applied with care. Also take care that values are not put on top of each other and that the output scale fits.

Presentation of results

When the results of lighting calculations are presented in a textual table, they have a particular format. The calculated results for point A always appear at the bottom left corner of the table, the results for point B at the bottom right corner and the results for C at the top left corner, for example:

A:	x = 0.25	y = 0.25	z = 0.00
B:	x = 3.75	y = 0.25	z = 0.00
C:	x = 0.25	y = 5.75	z = 0.00

If the number of points AB = 8 and AC = 12 and no output rotation is performed, this will give the following format:



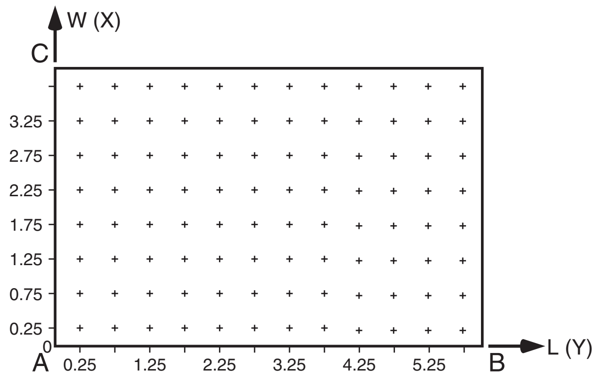
L = Length
W = Width

The '+' represents the calculated result, (you can define points A, B and C to create any layout for the results you require).

A different presentation of the calculated results can be displayed by defining the coordinates of points A, B and C as follows:

A:	x = 0.25	y = 0.25	z = 0.00;
B:	x = 0.25	y = 5.75	z = 0.00;
C:	x = 3.75	y = 0.25	z = 0.00.

If the number of points AB = 8 and AC = 12 and no rotation is applied, this will give the following format:



L = Length
W = Width

3.9 Shapes

A shape is a surface area in the same plane as a grid. Shapes can be used to create a user-defined form on the rectangular grid which is excluded from the calculations. Virtually any kind of form can be created. Shapes are connected to a grid, therefore shapes can only be added after a grid is defined. If multiple shapes are defined for a grid, each shape has an unique name.

In Calculux, shapes can be set active or inactive.

Active and inactive shapes

Each shape can be set active or inactive individually. Only grid points not covered, or covered by inactive shapes will be used for calculation by Calculux.
The shapes on a grid cover a grid point if at least one active shape covers the grid point.

In Calculux shapes can be defined in two ways:
- Pre-defined shapes;
- User-defined shapes.

3.9.1 Pre-defined shapes

In Calculux, some application fields use a connected grid other than the standard rectangle. For these application fields a set of pre-defined shapes is used to create different application field outlines. If the size of the grid is changed, the position and size of the shapes is updated automatically. The user cannot change or delete these pre-defined shapes, but can duplicate or add a shape. A duplicated shape will be a user-defined shape. Each pre-defined shape can be set active or inactive.

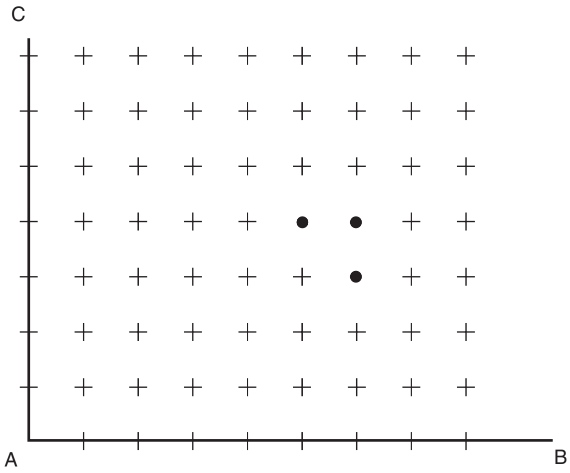
3.9.2 User-defined shapes

On all calculation grids the user can add shapes by specifying the required input parameters. The user can add, change, duplicate or delete shapes. A user-defined shape can be set active or inactive.

In Calculux, the following shape types can be defined by the user:
- Set of points;
- Rectangle;
- Free Grid (extension of polygonal shape);
- Closed polygon;
- Arc.

Set of points

The set of points shape can be used to cover individual grid points. This is especially useful when a few grid points at the edge of an application field or next to a generated shape must be excluded for calculation by Calculux. It only has effect when real grid positions are excluded. A point can be entered between grid points but will have no effect.

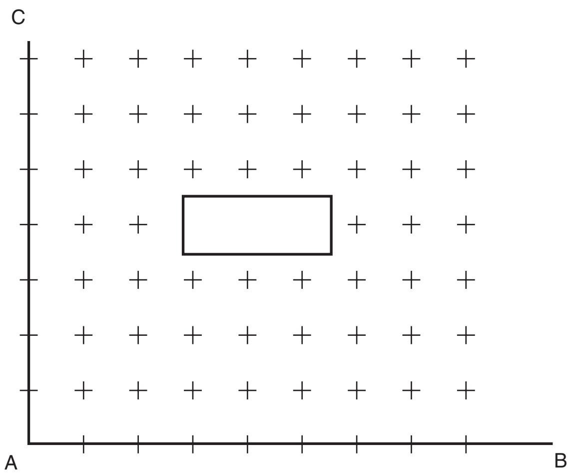


Coordinates can be entered using the dialogue box. However, coordinates which are exactly on a grid point can also be entered simply by mouse-clicking on the grid point in the view box.

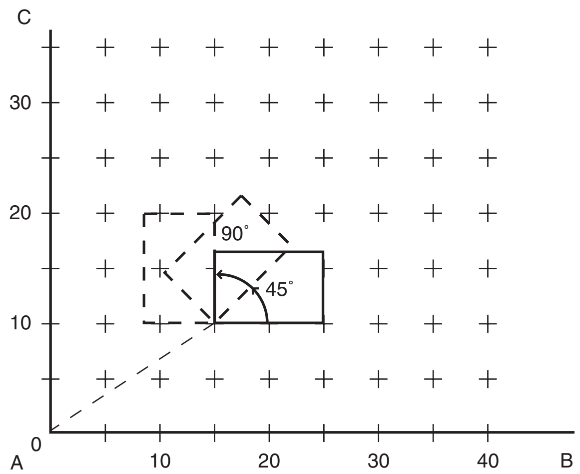
- Points within 5mm from a grid point are taken as that grid point.
- When the number of grid points is changed, it is possible that the selected points are no longer on a calculation point.

Rectangle

The rectangle shape can be used to create rectangular shapes. It is defined by its lower left corner position (relative to point A of the grid), width and length.



Furthermore, rotation around the starting point of the rectangle shape can be specified (see figure below).



If the 'Change Proportionally' function is enabled, the position and size of the shape is changed proportionally with the size of the grid.

Free Grids (not always available; not in Calculux Road)

The free grids function is an extension of the polygonal grids. When defining a polygonal grid, the shapes function enables the possibility to create a form that excludes grid points from the calculation. Because both the grids and the shapes must be defined in a menu by entering the parameters, it is a time consuming and complex exercise.

The free grids function helps the user to define a grid form with some clicks of the mouse. Within the free grids function, the cutout function is used to define an area that excludes grid points from the calculation. This is also done with a few clicks of the mouse.

The example above shows the map of a residential area with its calculation points defined by free grids. The outlines of the roads are followed with the mouse to define the area. With the help of the cutout function, the 'island' in the middle is excluded from the calculation points, also just by following it with the mouse.

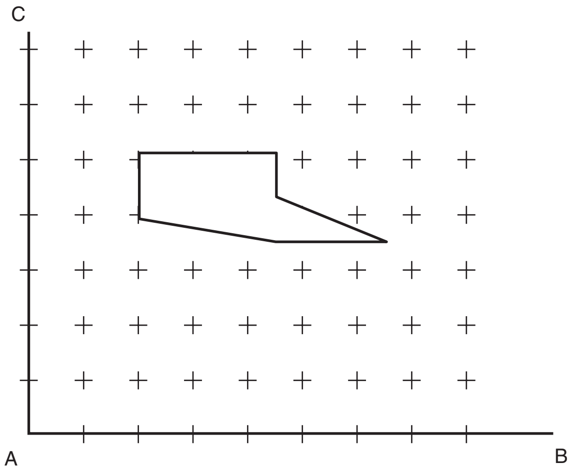
✍ After the free grid is changed with the rectangular grid function, the free grid is converted to a rectangular grid with shapes. From this point it is no longer possible to edit the free grid with the free grid function.

Polygon

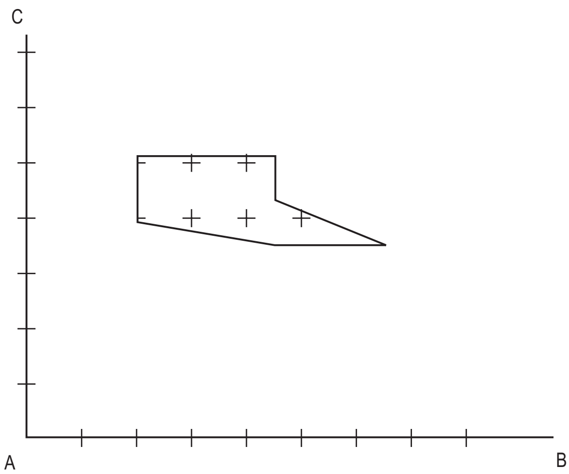
The polygon shape can be used to create irregular shapes consisting of straight lines. At least three coordinates must be entered. The polygon is automatically closed by the program

(first and last point are the same). All coordinates are relative to point A of the calculation grid. Lines within a polygon must not cross each other.
Coordinates can be entered using the dialogue box. However, coordinates which are exactly on a grid point can also be entered simply by mouse-clicking on the grid point in the view box. Polygonal shapes can be set as inbound or outbound.

Inbound

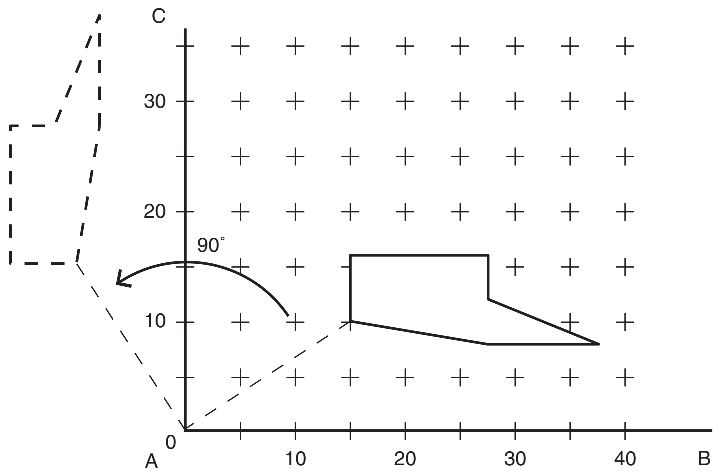


The default setting for the polygon shape is inbound. In this case the area covered by the inbound of the shape will be excluded from the calculations.
Outbound



Choose the Outbound Polygon option to create user-defined application fields that are polygonal shaped. The area covered by the outbound of the shape will be excluded from the calculations.

Rotation
If rotation is applied a polygonal shape is rotated around grid corner A (see figure below).

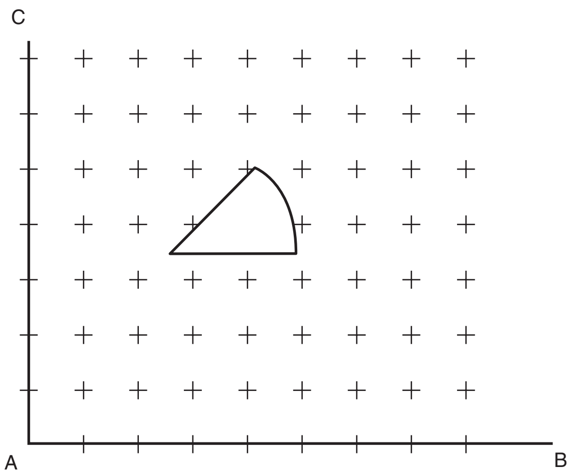


If the 'Change Proportionally' function is enabled, the position and size of the shape is changed proportionally with the size of the grid.

Arc

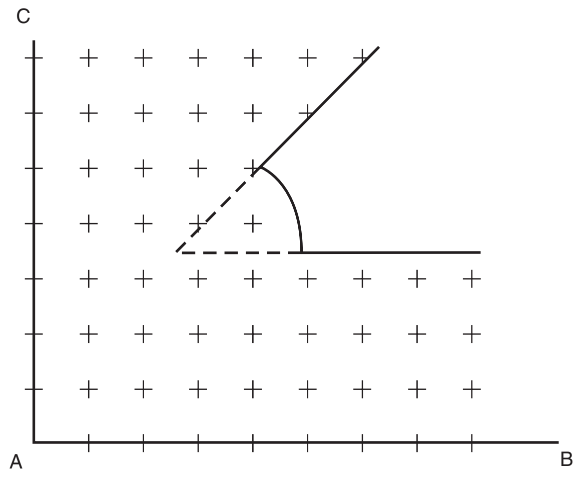
The Arc shape can be used to create circular shapes. The arc shape is defined by its starting position (relative to point A of the grid), radius and angle. The arc shape can be rotated around its starting position. Arc shape coordinates between grid points can only be entered using the dialogue box. The arc shape can be set as inbound or outbound.

Inbound



The default setting for the arc shape is inbound for creating segments up to a full circle. The area covered by the inbound of the shape will be excluded from the calculations.

Outbound



Choose the Outbound Arc option to create rounded corners or edges on user-defined application fields. The area covered by the outbound arc shape will be excluded from the calculations.

3.9.3 Symmetry

Symmetry is an optional specification that can be used to simplify individual shape entry when one or more shapes have a symmetrical orientation and/or position. If applied, the shape is duplicated on the opposite side of a line parallel to the AB axis or the AC axis, or it is duplicated to all quadrants. The user can specify the symmetry type (AB, AC, AB-AC or none) and the AB and AC origin (relative to point A of the grid).

3.10 Lighting control (Switching Modes / Light Regulation Factor)

In many designs the lighting system must be flexible so that the lighting level can be adapted to suit the activities for which the facility is to be used. The Calculux 'Lighting control' feature enables you to dim luminaires or luminaire arrangements.

When using a 'Lighting Control' system you can:

- **Save energy**
  When light sensors are used you can automatically dim luminaires in areas where the amount of daylight increases. By means of movement detectors you can automatically switch of luminaires when an area is not 'occupied'.
  In this way an energy saving of up to 70% can be achieved.

- **Increase the flexibility of the lighting installation**
  When infrared remote control is available, the need for vertical wiring to wall switches is eliminated;

Reduction of the installation costs;
Less costly adaptations to the electrical system, when the furniture layout is changed.

- **Create more comfort for the user**
  When pre-programmed lighting levels are available, the user can switch or regulate the lighting installation to the required lighting level.

In Calculux you can create a 'Lighting Control' system using:

a) Switching Modes
b) Light Regulation Factors

3.10.1 Switching Modes

In many designs the lighting system must be flexible so that the lighting level can be adapted to suit the activities for which the facility is to be used. This requirement calls for a number of switching modes.
A switching mode is a subset of luminaires which are in operation.

For example, for sport lighting the following levels can be used:

- Training;
- Competition;
- Professional competition with facilities for colour television coverage.

The lower the level of play, the less stringent are the quality requirements placed on the lighting.

Less illumination is required in training than in competition resulting in a smaller number of luminaires used in training. As long as training uses a smaller number of luminaires than competition, the luminaires used in training can make up part of the luminaires used in competition.

3.10.2 Light Regulation Factor (LRF)

This option enables you to dim luminaires or luminaire arrangements.
By using this option you can save energy, increase the flexibility of the lighting installation or create more comfort for the user.

The value of the light regulation factor is expressed in % of the lumen output of a luminaire.

✍ There is no linear relation between the value of the light regulation factor and the power consumption of a luminaire. As a result of this, when light regulation factors are used, the power consumption of the luminaire can not be calculated. So in the cost calculation the energy costs will not be given.

3.11 Observers

An observer is a location to be used as an observer's reference point. A television camera is often placed at such a point.
Using a person as an observer enables you to calculate the veiling luminance he experiences upon his eyes. For Road lighting luminance, the observer is the driver of the car. The veiling luminance is the basis upon which the glare calculations are based.
If included in the project, you must specify the xyz coordinates of each observer's position.

✍

- The location of the referred observer is not allowed to coincide with any calculation grid point, on the grid upon which it is being used.
- For veiling luminance and glare calculations, the angle between the vector from the observer to any grid point, and the vector from the observer to any luminaire belonging to this calculation, must always be greater than 1.5 degrees.
- For semi-cylindrical illuminance calculations towards an observer, the location of the observer's reference point must not be above or below any grid point in the calculation grid.
- For veiling luminance calculations, only the location of the observer is a calculation point.

Road luminance calculations

For Road luminance calculations an observer is often positioned in the middle of each traffic lane, facing the direction of the traffic flow. In some situations Calculux automatically places default observers.

✍ For road luminance calculations towards an observer, the angle between the vector from the observer to any grid point of the referenced grid, and its projection on the referenced grid plane, must be between 0.5 and 1.5 degrees. If this is not true, the road reflection table is not applicable.

3.12 AutoCAD Import and Export

Calculux Area allows you to import and export AutoCAD .DXF or .DWG files.

3.12.1 Import

The import function enables you to use an existing AutoCAD drawing as "underlay" in a Calculux project. During import the AutoCAD drawing entities are converted to the basic drawing entities of Calculux (Line, Rectangle, Arc or Text). The AutoCAD drawing is stored in Calculux as a single layer drawing. Editing in Calculux is not possible.

Observe that during import, much of the complexity and detail of the original multi-layered AutoCAD drawing is left out in the flattened, single layer result drawing. Nevertheless, the larger and more complex the import file, the more memory space and processing time the import will require. Therefore:

- Make sure to strip your original drawing from any details and layers which are not relevant for the lighting design.
- Simplify your drawings, as much as possible, to only the relevant two-dimensional line fragments.
- Also, make sure to do this *before* you start the import. As one of the import settings, you can still exclude layers to participate in the result. But they will be processed anyway, thereby extending the processing time.

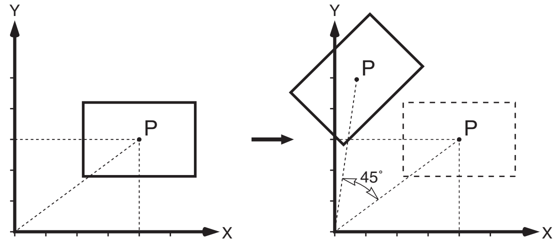
To inspect the AutoCAD drawing, please use world co-ordinates and realise that the Calculux world is from X= ±9999 to Y= ±9999.

In Calculux the following AutoCAD DWG-DXF import properties can be set/selected:

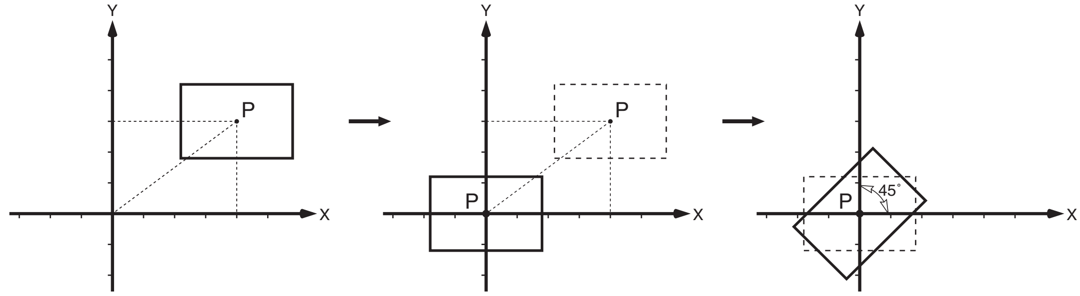
- Layers — includes/excludes layers;
- Unit — unit used for the drawing;
- Scale (%) — scaling of the drawing;
- Rotation — the angle of rotation (counter-clockwise) of the drawing around the centre point (0,0,0) of the XYZ co-ordinate system;
- Translation — moves the XY position of the drawing in relation to centre point of the XYZ co-ordinate system.

Attention must be paid when rotating a drawing, because the position of the drawing in relation to the centre point (0,0,0) of the XYZ co-ordinate system has great influence on the resulting drawing postion.

For example, if a rectangular graph with centre point P=(4,3) is rotated 45°. This will give:



The following example shows the same drawing, but now also translation is applied (-4,-3) when the drawing is rotated 45°. The result of the translation and rotation will be:



3.12.2 Export

The export function enables you to include Calculux calculations in an AutoCAD drawing (.DXF or .DWG format). During export graphical output (lighting installation, aiming arrows, isolux, graphical table and mountain plot) is converted in to an AutoCAD drawing format (.DWG or .DXF). Each graphical output is saved in a separate layer.

For example, assuming your customer has supplied you with an AutoCAD drawing of a sports complex with football fields and some tennis courts. With Calculux you can do the lighting design, then export the lighting design and calculation results as an AutoCAD drawing and import them in the original AutoCAD drawing. The unchanged original AutoCAD drawing, including the lighting design, can than be returned to your customer.

In Calculux the following export properties can be set/selected:

- Graphs to include selects which graphical output of your lighting design is included in the AutoCAD drawing;
- Translation moves the XY position of the graph in relation to centre point of the XYZ co-ordinate system;
- Rotation the angle of rotation (counter-clockwise) of the graph around the centre point (0,0,0) of the XYZ co-ordinate system;
- Export Format selects the format of the export file (.DWG or .DXF);

- Version the version of AutoCAD the export file is compatible with (ACAD 10, ACAD 12, etc.).

✍ The the export file always contains the graphs of the whole installation, so no separate Luminaires per switching mode.

3.13 Drawings

A drawing is a 2-dimensional shape which you can add to your lighting design. A drawing may be a rectangle, arc, line or text. For example, you can place a drawing outside an application field to to illustrate your design (e.g. to represent a nearby construction).

Be aware that if you move the centre coordinates of an application field, the drawing you've added will not move. Drawings appear on screen and in your printed reports if selected, but do not affect your calculations or scaling.

The name and dimensions must be entered before a drawing can be included in a project. The exception is the text option. For this drawing, entering the name, the XYZ coordinates of where the centre of the text should be and the actual text is all that is required.

✍ A drawing does not affect the scaling of project overviews, calculation result views and the results of calculations.

3.14 Obstacles

3.14.1 General

Obstacles are objects which can obstruct light sources.

Obstacles affect all direct light (light from a luminaire to a calculation point) hitting any surface of the obstacle. The amount of light that passes through an obstacle is solely determined by the transparency factor, not by the distance the light travels through the obstacle. A beam of light which passes through several obstacles is modified by the product of the transparency factors of these obstacles.

Obstacles are positioned and oriented in the 3-D XYZ coordinate system. Position and orientation conventions are the same as used for luminaire positioning and orientation, including the use of symmetry. For the definition of an obstacle, the following parameters have to be set:

- Name of the obstacle;
- Obstacle position;
- Obstacle size;
- Obstacle orientation;
- Use of symmetry (if applicable, refer to section Symmetry in this chapter).

✍ When the height of an obstacle is set to zero, a light obstructing area in a certain plane can be created.

Calculation

The following conditions are assumed for obstacles:

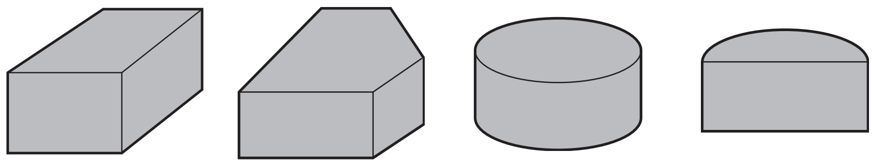
- An obstacle obstructs light from a luminaire to a calculation point. The calculation point can be part of a calculation grid or can be an observer's eye for the calculation of the veiling luminance.
- Obstacles are massive, i.e. when both light source and calculation point are inside the obstacle, the obstacle still obstructs light between this light source and the calculation point. A luminaire can consist of multiple light sources (luminaire split-up).
- When for a calculation the (il)luminance in the direction of an observer is needed, it doesn't matter whether this observer is hidden behind an obstacle or not. The observer is only used to determine the direction of the infinite small plane on which the calculation is performed.

3.14.2 Obstacle definition

In Calculux an Obstacle can be defined and placed on a plane in the 3D world.
The position of the obstacle can obstruct the luminaire, in which case the calculation in Calculux will be affected.

The following four obstacle types can be distinguished:

- Block obstacle;
- Poly block obstacle;
- Pillar obstacle;
- Half pillar obstacle.



Block Poly block Pillar Half pillar

To simplify the definition of an obstacle you should first define an obstacle type without orientation (rotation or tilt) and afterwards apply rotation and/or tilt.

Block obstacle

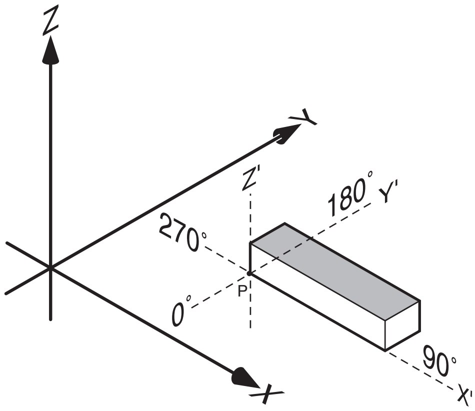
For the definition of a Block obstacle, the following parameters have to be set:

- Obstacle name (max. 24 characters);
- Transparency Factor (if applicable);
- Reference point P (P is the bottom left corner of the Block obstacle if no rotation and tilt is applied);
- Dimensions (Width, Lenght and Height);
- Orientation (Rot, Tilt90 or Tilt0);
- Symmetry (if applicable, refer to section Symmetry).

Example:
A Block obstacle is defined using the parameters given below:

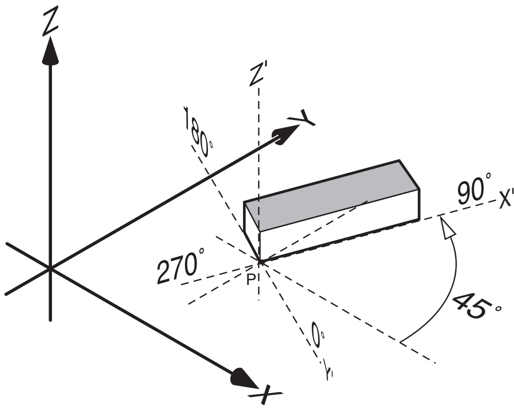
Reference point (P):	Dimensions:	Orientation:
X = 9.00 m	Width = 12.00 m	Rot = 0.00°
Y = 6.00 m	Length = 4.00 m	Tilt90 = 0.00°
Z = 0.00 m	Height = 2.50 m	Tilt0 = 0.00°

This will result in the following view:

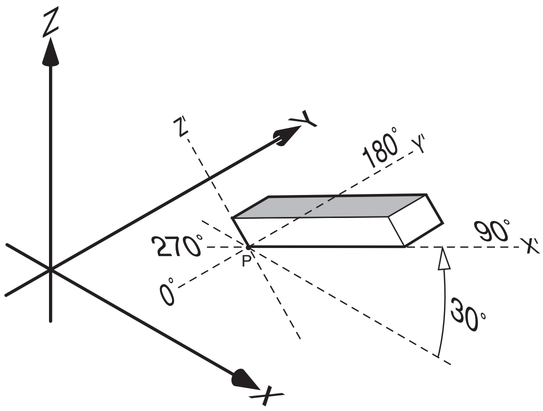


Now the Block obstacle is generated, you can apply rotation.

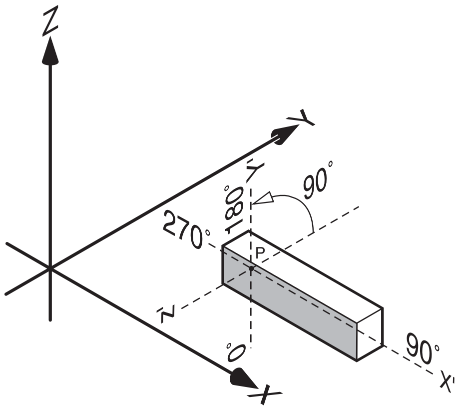
Rotation = 45°:
The Block obstacle is rotated 45° anti clockwise around the Z'-axis.



Tilt90 = 30° (Rot = 0° and Tilt0 = 0°):
The Block obstacle is rotated 30° around the Y'-axis towards the positive Z'-axis.



Tilt0 = -90° (Rot = 0° and Tilt90 = 0°):
The Block obstacle is rotated 90° around the X'-axis towards the positive Z'-axis.



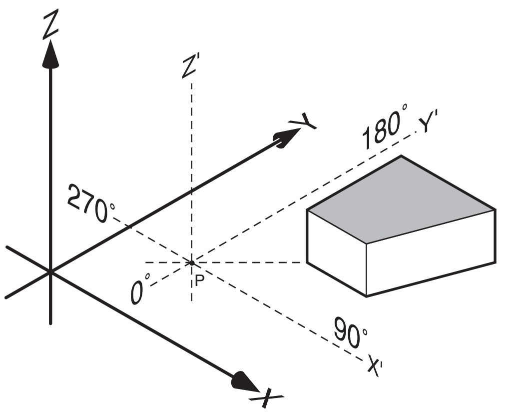
Poly block obstacle

- Obstacle name (max. 24 charcters);
- Transparency Factor (if applicable);
- Reference point P;
- Heigth of the obstacle;
- The Polyline coordinates (Note that all X, Y coordinates of the polyline are relative to reference point P);
- Orientation (Rot, Tilt90 or Tilt0);
- Symmetry (if applicable, refer to section Symmetry).

Example:
A Poly block obstacle is defined using the below parameters:

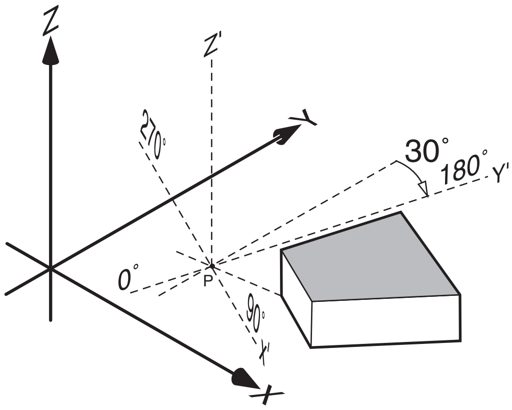
Reference point (P):		X, Y coordinates:	Orientation:	
X	= 5.00 m	5.00, 5.00	Rot	= 0.00°
Y	= 5.00 m	10.00, 5.00	Tilt90	= 0.00°
Z	= 0.00 m	14.00, 15.00	Tilt0	= 0.00°
Height	= 3.00 m	5.00, 15.00		

This will result in the following view:

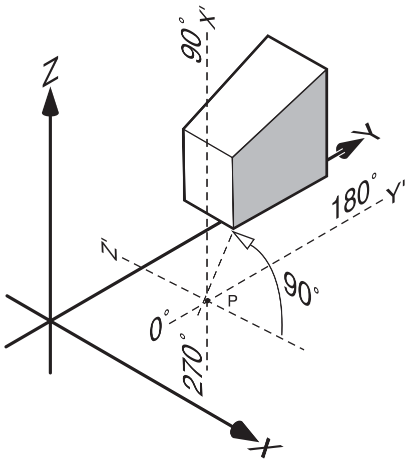


Now the Poly block obstacle is generated, you can apply rotation.

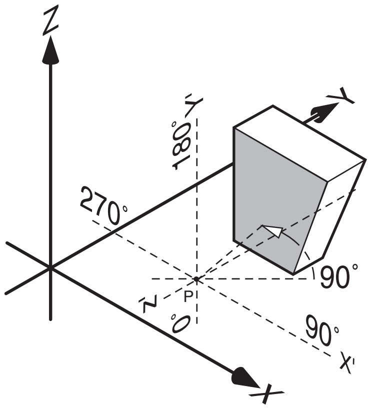
Rotation = -30°
The Poly block obstacle is rotated 30° clockwise around the Z'-axis.



Tilt90 = 90° (Rot = 0° and Tilt0 = 0°):
The Poly block obstacle is rotated 90° around the Y'-axis towards the positive Z'-axis.



Tilt0 = -90° (Rot = 0° and Tilt90 = 0°):
The Poly block obstacle is rotated 90° around the X'-axis towards the positive Z'-axis.


Z
Y
Y'
180°
270°
90°
P
Z'
0°
90°
X'
X

Pillar obstacle

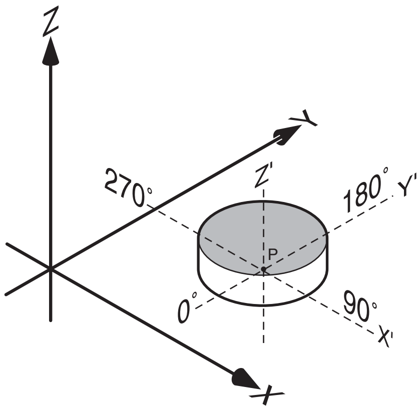
For the definition of a Pillar obstacle, the following parameters have to be set:

- Obstacle name (max. 24 characters);
- Transparency Factor (if applicable);
- Reference point P (P is the center point of the bottom plane of the Pillar obstacle if no tilt is applied);
- Size (Height and Radius);
- Orientation (Tilt90 or Tilt0);
- Symmetry (if applicable, refer to section Symmetry).

Example:
A Pillar obstacle is defined using the parameters given below:

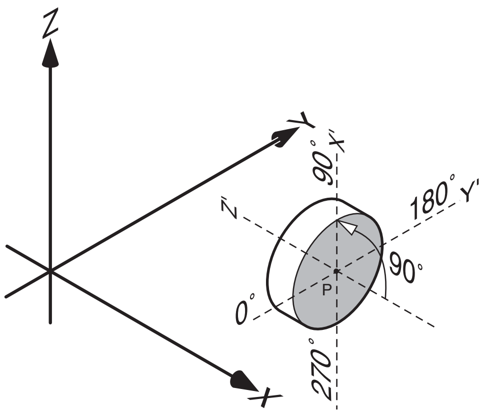
Reference point (P):	Size:	Orientation:
X = 15.00 m	Height = 3.00 m	Tilt90 = 0.00°
Y = 15.00 m	Radius = 6.00 m	Tilt0 = 0.00°
Z = 0.00 m		

This will result in the following view:

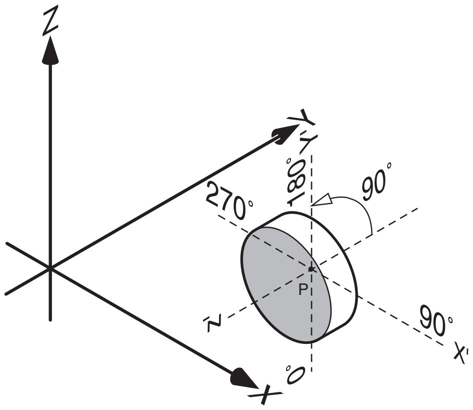


Now the Pillar obstacle is generated, you can change the orientation.

Tilt90 = 90° (Rot = 0° and Tilt0 = 0°)
The Pillar obstacle is rotated 90° around the Y'-axis towards the positive Z'-axis.



Tilt0 = -90° (Rot = 0° and Tilt90 = 0°)
The Pillar obstacle is rotated 90° around the X'-axis towards the negative Z'-axis.



Half pillar obstacle

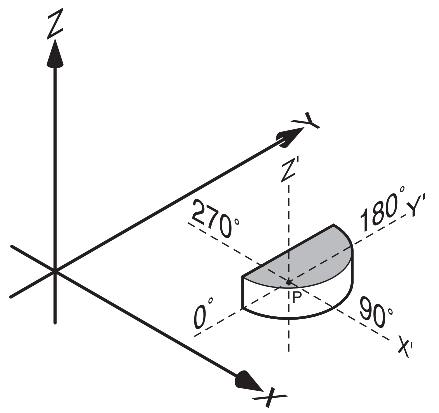
For the definition of a Half pillar obstacle, the following parameters have to be set:

- Obstacle name (max. 24 characters);
- Transparency Factor (if applicable);
- Reference point P (P is the center point of the bottom plane of the Half pillar obstacle if no tilt is applied);
- Size (Height and Radius);
- Orientation (Tilt90 or Tilt0);
- Symmetry (if applicable, refer to section Symmetry).

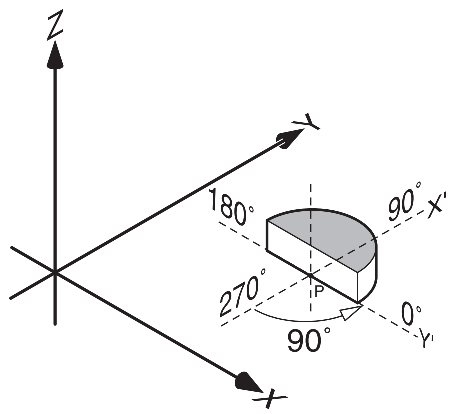
Example:
A Half pillar obstacle is defined using the parameters given below:

Reference point (P):	Size:	Orientation:
X = 15.00 m	Height = 3.00 m	Rot = 0.00°
Y = 15.00 m	Radius = 6.00 m	Tilt90 = 0.00°
Z = 0.00 m		Tilt0 = 0.00°

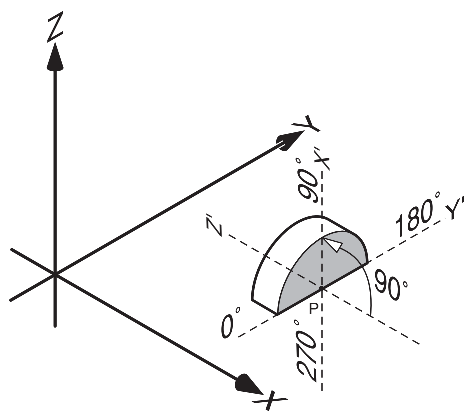
This will result in the following view:



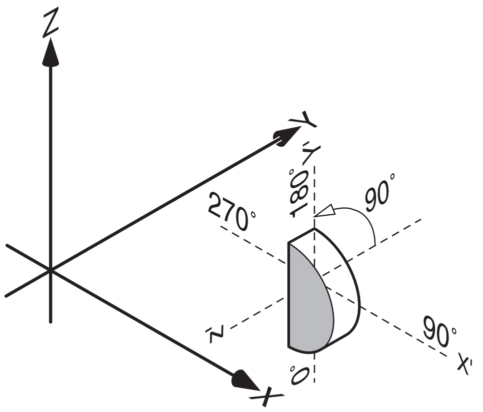
Now the Half pillar obstacle is generated, you can change the rotation.
Rotation = 90°
The Half pillar obstacle is rotated 90° anti clockwise around the Z'-axis.



Tilt90 = 90° (Rot = 0° and Tilt0 = 0°)
The Half pillar obstacle is rotated 90° around the Y'-axis towards the positive Z'-axis.



Tilt0 = -90° (Rot = 0° and Tilt90 = 0°)
The Half pillar obstacle is rotated 90° around the X'-axis towards the positive Z'-axis.

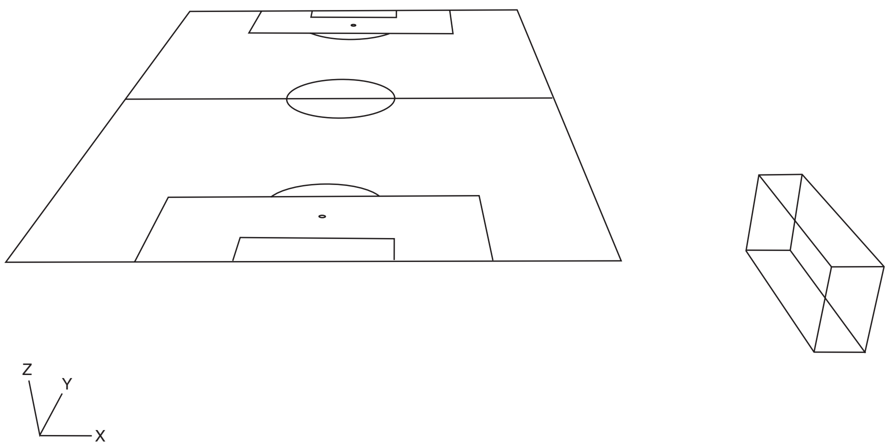


Placing and manipulating obstacles

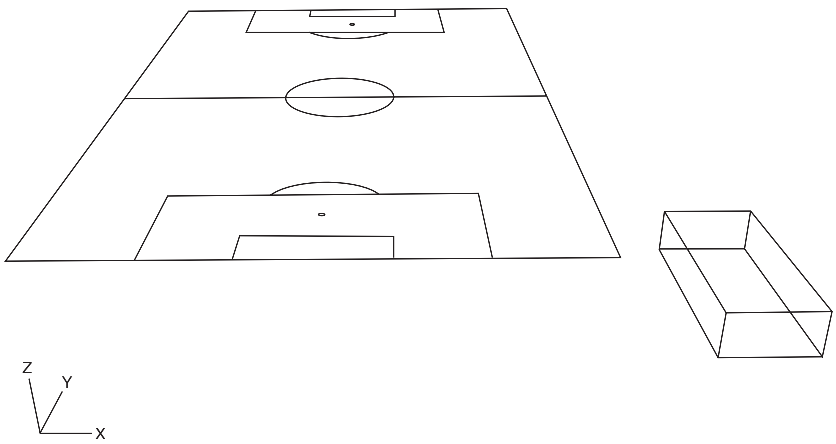
In Calculux obstacles can be used to create objects (e.g. a house or a row of houses) on or next to an application field.
Example below shows how to create a row of houses next to a football field, using a Block obstacle and a Half pillar obstacle.

- First a Block obstacle is defined using the parameters given below:

Reference point (P):	Dimensions:	Orientation:
X = 50.00 m	Width = 5.00 m	Rot = 0.00°
Y = -70.00 m	Length = 4.00 m	Tilt90 = 0.00°
Z = 0.00 m	Height = 2.50 m	Tilt0 = 0.00°



- Now a Tilt90 = 90° is applied to the previously defined Block obstacle:

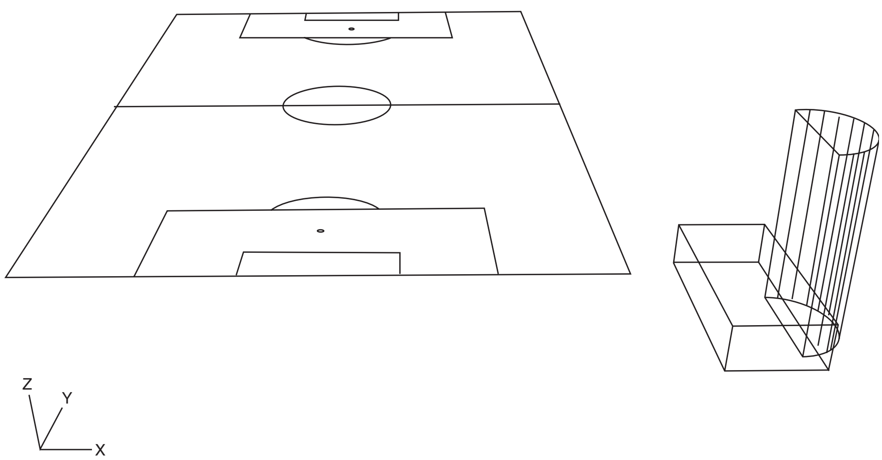


To explain the function of tilting and rotating, a different type of obstacle is added to construct a more realistic building.

- A Half pillar obstacle is defined using the parameters given below:

Reference point (P):	Size:	Orientation:
X = 45.00 m	Height = 20.00 m	Rot = 0.00°
Y = -70.00 m	Radius = 5.00 m	Tilt90 = 0.00°
Z = 5.00 m		Tilt0 = 0.00°

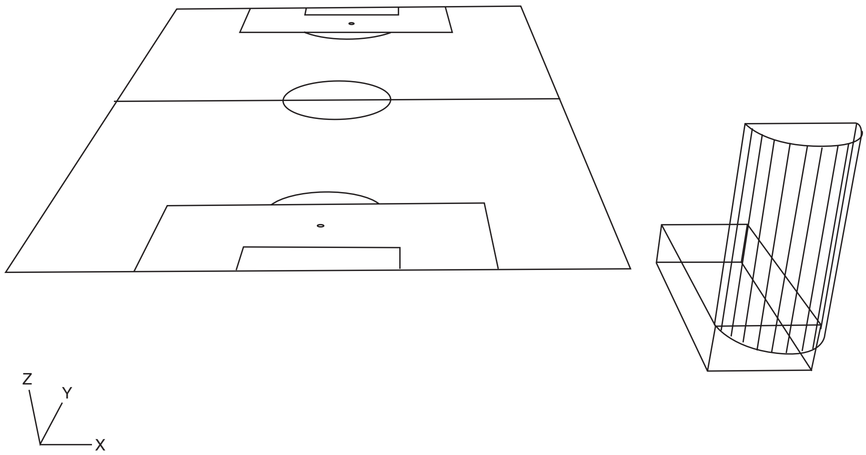
which results in the following:



For the Half Pillar obstacle in the previous illustration, the *orientation* is now set to:

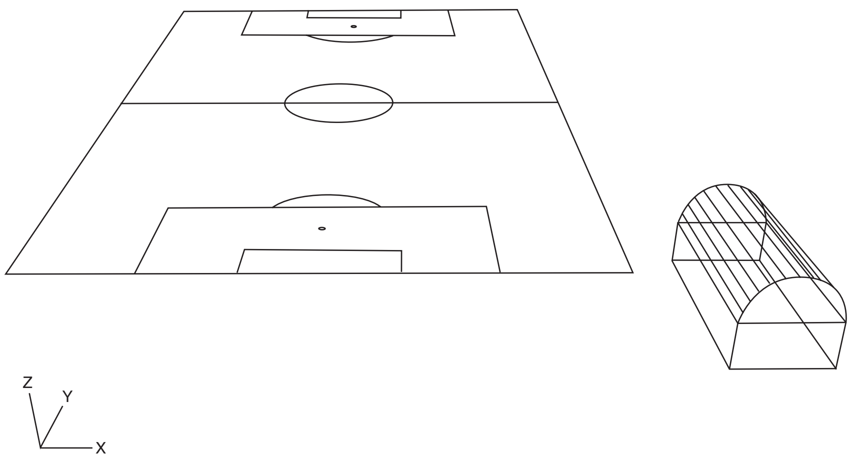
a) Rot = -90° (rotation of 90° anti clockwise around the vertical axis)
   Tilt90 = 0°
   Tilt0 = 0°

which results in the following arrangement:



b) Rot = -90°
Tilt90 = 90°
Tilt0 = 0°

which results in the following arrangement:



3.14.3 Symmetry

Obstacles can be placed symmetrically on the application field. The user decides whether to use symmetry or not. The use of X-symmetry implies that the obstacle will be placed symmetrically on the X-axis. The use of Y-symmetry implies that the obstacle will be

placed symmetrically on the Y-axis. XY-symmetry causes obstacle placement in both directions.

3.15 Light-technical Calculations

Calculux Area currently supports the following calculation types:

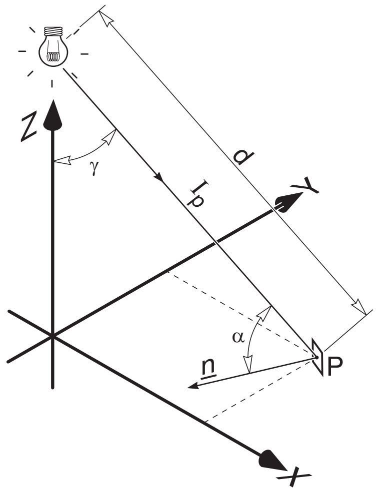
- Plane Illuminance;
- Semi Cylindrical Illuminance;
- Semi Spherical Illuminance;
- Road Luminance;
- Veiling Luminance;
- Glare Rating;
- Illuminance Uniformity on vertical planes;
- Gradient Calculations;
- Obtrusive light.

3.15.1 Plane Illuminance

This is the ratio of the luminous flux incident on an infinitely small flat surface to the area of that surface.
The surface can have any orientation. The orientation is defined by the normal vector on the surface.

The plane illuminance (from one light source) at point P on the calculation grid is given by:

$$E_p = \frac{I_p}{d^2} \cos\alpha$$



Variables: | **Meaning:**

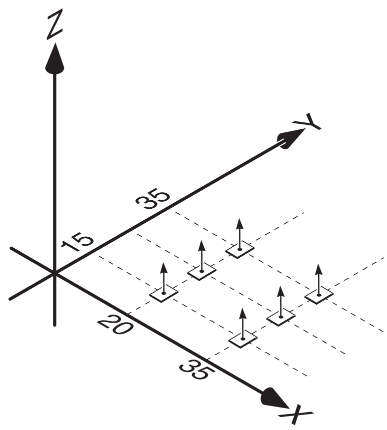
Variables:	**Meaning:**
E_p	plane illuminance at point P (Lx);
I_p	luminous intensity from the light source in the direction of point P (cd);
d	distance from the source to point P (m);
α	angle between the normal $\underline{n}$ and the light incidence (deg).

This formula assumes that the luminaire is a point source. For fluorescent luminaires, of which the distance between the luminaire and the point P is short in comparison with the dimensions of the luminaire, the above formula is not valid. Calculux has a built-in feature (luminaire splitup) which overcomes this problem. When the luminaire splitup feature is activated, the luminaire is considered to be made up of a number of smaller luminaires with the same light distribution but proportionally smaller lumen output.

The following types of surface orientation information relating to each point on the grid are recognised by Calculux.

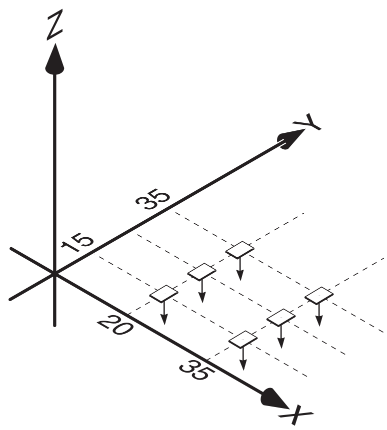
a) The surface orientation of each point on the grid can be in one of the main directions of the XYZ coordinate system:

Hor +Z
Horizontal +Z grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the positive Z direction.

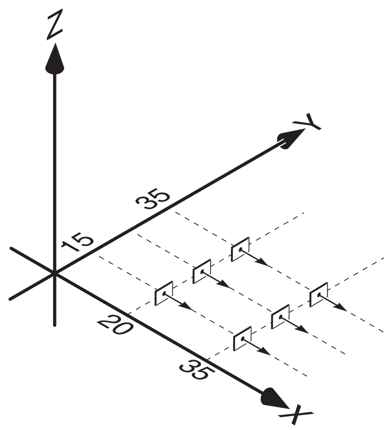


The surfaces are infinitely small planes (one in each grid point) on which the light calculations will be performed.

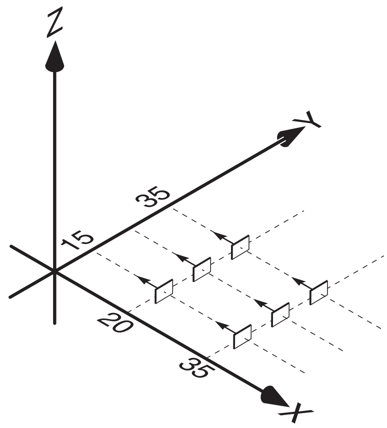
Hor -Z
Horizontal -Z grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the negative Z direction.



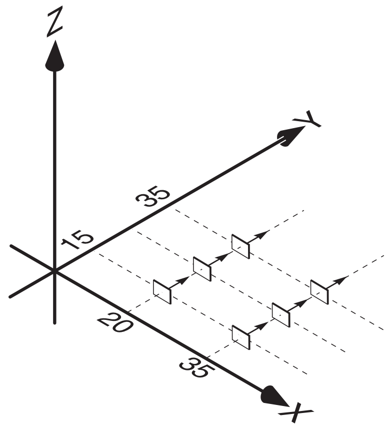
Vert +X
Vertical +X grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the positive X direction.



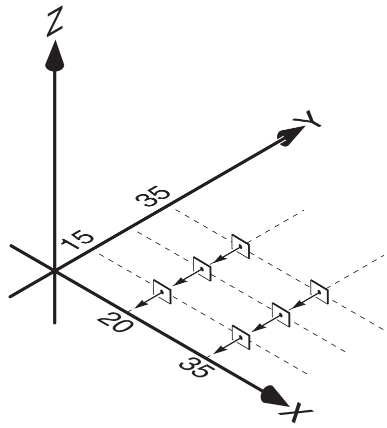
Vert -X
Vertical -X grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the negative X direction.



Vert +Y
Vertical +Y grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the positive Y direction.

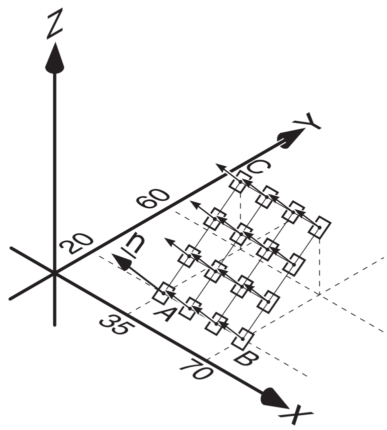


Vert -Y
Vertical -Y grid point.
The surfaces in the grid points, used in the calculation, are orientated towards the negative Y direction.

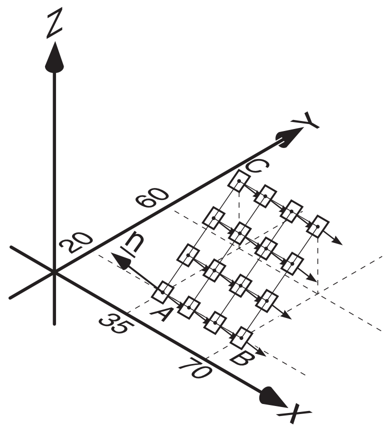


b) The surface orientation is parallel to the plane that passes through the grid points. This enables the illuminance to be calculated on two sides of the plane through the grid points:

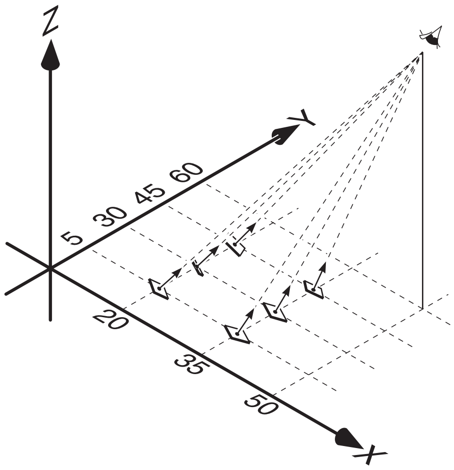
Surface +N
Surface +N grid point.
The surfaces in the grid points, used in the calculation, are orientated parallel to the plane which passes through the grid points in positive N direction.



Surface -N
Surface -N grid point.
The surfaces in the grid points, used in the calculation, are orientated parallel to the plane which passes through the grid points in negative N direction.



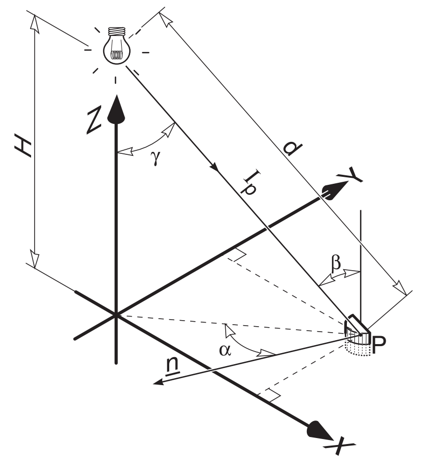
c) The surface orientation is in the direction of an observer. The normal vector of the surfaces, used in the calculation is orientated towards the observer. In each grid point, the orientation of the surface is different.



3.15.2 Semi Cylindrical Illuminance

This is the ratio of the luminous flux incident on a rounded part of an infinitely small semi cylinder to the area of the rounded part of that semi cylinder.

The base of the semi cylinder always remains parallel to the XY plane. The rounded surface of the semi cylinder, however, can have any orientation.



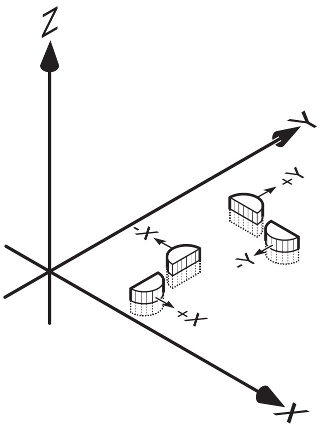
The semi cylindrical illuminance (from a single light source) at point P on the calculation grid is given by:

$$E_{sc} = \frac{I_p}{\pi d^2}(1 + \cos\alpha)\sin\beta$$

Variables:	**Meaning:**
E_{sc}	semi cylindrical illuminance at point P (Lx);
I_p	luminous intensity of the source in the direction of point P (cd);
α	angle between the direction of the projected light incidence and normal $\underline{n}$ (= direction of observation) (deg);
β	angle between the direction of light incidence and the normal on the flat part of the semi cylinder (deg);
d	distance between the light source and point P (m).

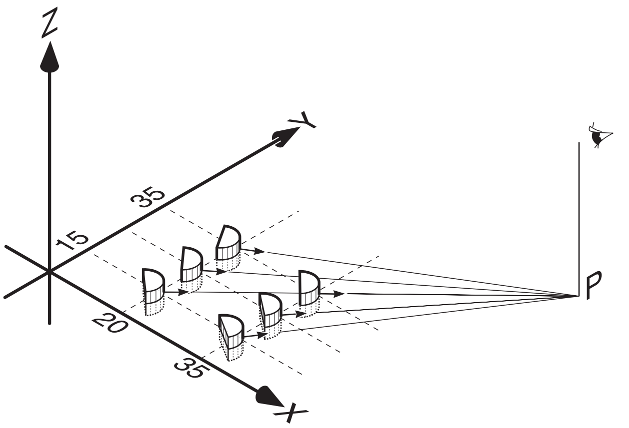
The following orientation information of the rounded surface is recognised by Calculux:

a) The surface orientation of the infinitely small cylindrical surfaces is in one of the main directions of the XYZ coordinate system:
   - Vertical +X;
   - Vertical -X;
   - Vertical +Y;
   - Vertical -Y.



✍ The base of each semi cylinder, and thus normal $\underline{n}$ (→), is always parallel to the XY plane.

b) The surface orientation of the infinitely small cylindrical surfaces is in the direction of an observer.

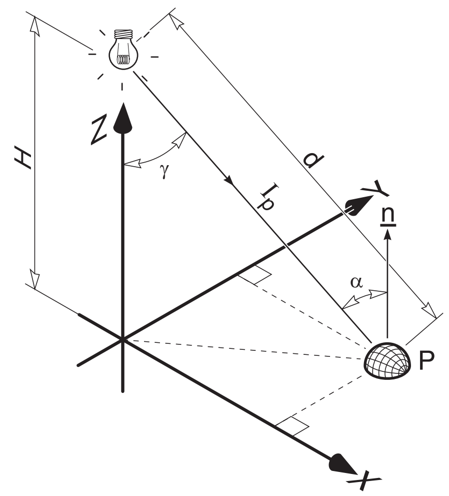


✍ As the base of the semi cylinder is always parallel to the XY plane only the X and Y coordinates of the observer need to be specified.

3.15.3 Semi Spherical Illuminance

This is the ratio of the luminous flux incident on an infinitely small semi sphere to the area of that semi sphere.

The semi sphere can have any orientation. The orientation is defined by the normal vector on the surface.



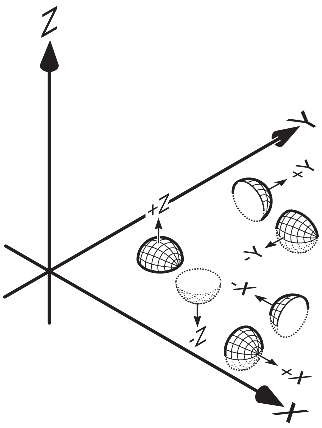
The semi spherical illuminance (from a singular light source) at point P on the calculation grid is given by:

$$E_{sph} = \frac{I_p}{4d^2}(1 + \cos\alpha)$$

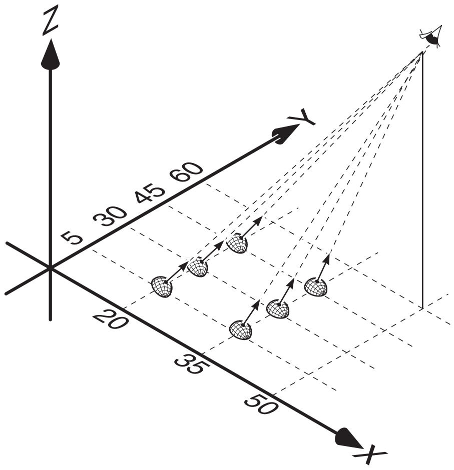
Variables:	Meaning:
E_{sph}	semi spherical illuminance at point P (Lx);
I_p	luminous intensity of the source in the direction of the point P (cd);
α	angle between the direction of light incidence and the normal $\underline{n}$ (deg);
d	distance between the light source and the point P (m).

The following orientation information for the semi sphere is recognised by Calculux:

a) Surface orientation of the semi sphere in one of the main directions of the XYZ coordinate system:
   - Vertical +X;
   - Vertical -X;
   - Vertical +Y;
   - Vertical -Y;
   - Horizontal +Z;
   - Horizontal -Z.

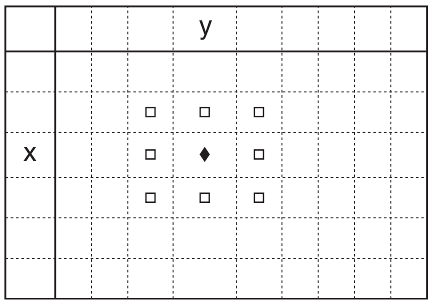


b) The surface orientation of the infinitely small spherical surfaces is in the direction of an observer. In this case, all semi spheres within the calculation grid will have their normal vector in the direction of the observer.



3.15.4 Gradient Calculations (not always available)

Gradient calculations give an insight in the change of illuminance values on an area of interest (the grid). For each grid point the illuminance is compared with the illuminance of the adjacent grid points. The gradient in a grid point X is defined as the maximum of
$|E_{ij} - E_{xy}| / E_{xy}$ for the eight surrounding points of grid point X (see figure below).



The gradient is given by:

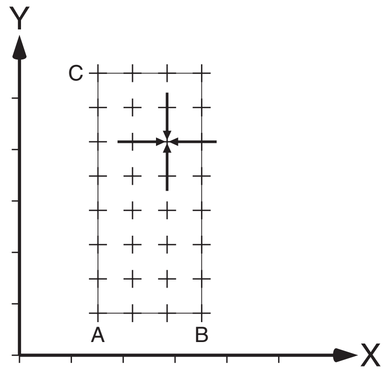
$$U = MAX_{-1\le i\le 1, -1\le j\le 1 (i,j)\ne(0,0)} \frac{\left|\left(E_{x+i,y+j} - E_{x,y}\right) * \left(d_{step}/d\left((x,y),(x+i,y+j)\right)\right)\right|}{E_{xy}} * 100\%$$

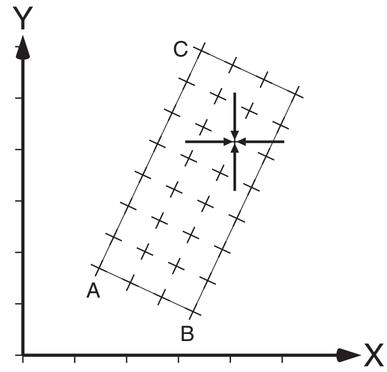
d is the distance between point (x,y) and (x+i, y+i).

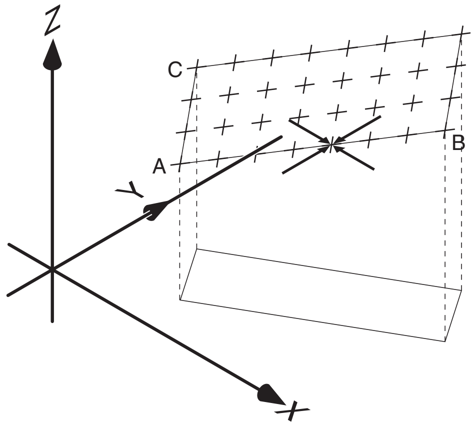
- The gradient is connected to an illuminance calculation (plane, semi spherical or semi cylindrical). The values will only be presented in a textual or graphical table. If no textual or graphical table is included for the connected calculation, no output will be generated.
- The step-size for which the gradient is calculated can be defined in the input.
  A threshold value can be defined. All values below the threshold will not be presented.

3.15.5 Illuminance uniformity on vertical planes

The Illuminance uniformity on vertical planes calculated in each grid point in a grid. The vertical illuminance is calculated in four directions, all parallel to the original co-ordinate axes and perpendicular to the Z-axis (see the figures below).







The uniformity in each point is given by:

$$U = \frac{E_{\text{vertical min}}}{E_{\text{vertical max}}}$$

Variables:	**Meaning:**
$E_{\text{vertical min}}$	minimum (E_{-x}, E_{+x}, E_{-y}, E_{+y});
$E_{\text{vertical max}}$	maximum (E_{-x}, E_{+x}, E_{-y}, E_{+y});
E_{-x}, E_{+x}, E_{-y}, E_{+y}	the illuminances measured from the four directions perpendicular to the Z-axis.

3.15.6 Luminance

In Calculux it is possible to calculate the luminance of a plane through the grid points, assuming that the plane reflects light in a perfectly random way (diffuse reflection) with reflection factor ρ.

The luminance is given by the formula:

$$L_p = \rho \frac{E_p}{\pi}$$

Variables:	**Meaning:**
L_p	luminance in point p;
E_p	plane illuminance at point p;
ρ	reflection factor of the plane through the grid points;
π	3.141593.

3.15.7 Road Luminance

In order to calculate the surface luminance of a road surface, the reflective properties of the surface must be known.

Luminance Coefficient

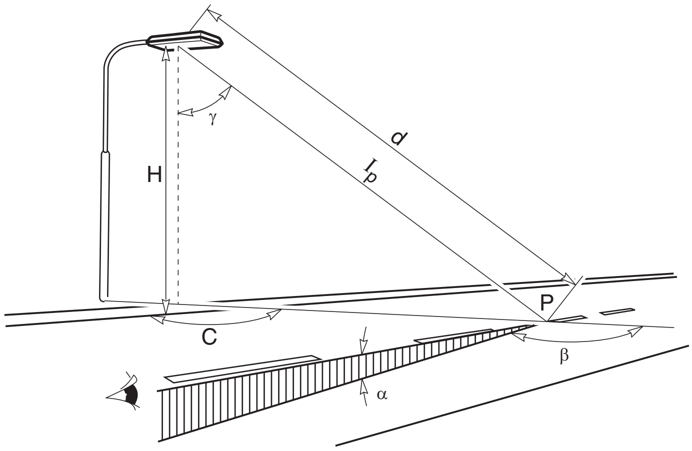
The reflective properties of a surface can be indicated by means of luminance coefficient q. This coefficient is defined as the ratio of the luminance at a point to the horizontal illuminance at the same point (as obtained from a single luminaire):

$$q = \frac{L}{E_h} \quad \text{and} \quad L = q * E_h$$

Variables:	**Meaning:**
q	luminance coefficient;
L	luminances at a point P (cd/m^2);
E_h	horizontal illuminance at point P (Lx).

The luminance coefficient depends on the position of the observer and the light source relative to the point on the road surface under consideration.

This relation can be described by the angles illustrated in the following figure:



$$q = q(\alpha, \beta, \gamma)$$

To a car driver the area in front of a car (60-160 m ahead) is very important. In this area α only varies between 0.5 and 1.5 degrees. Measurements have shown that, within this α-range, the α-dependency of q can be neglected.

Road Reflection Table
The luminance coefficient of a road surface thus dependents on the values of the angles β and γ. The reflection properties of a surface can therefore be specified in a table in which, for each relevant β and γ combination, the q value is given.

Calculux contains a number of Road reflection tables (which are included in the Appendix of this binder).
However, additional tables can be added, provided they have the correct format.

3.15.8 Glare

Glare is the condition of vision in which there is a reduction in the ability to see details or objects due to an unsuitable distribution or range of luminance, or to extreme contrasts.

Glare can occur in one of two possible forms:

- Disability glare glare that impairs the vision;
- Discomfort glare glare that induces a feeling of discomfort.

For outdoor sports and area lighting situations a measure for *disability glare* is 'Glare Rating'. In road lighting applications it is the 'Relative Threshold Increment'. For both, an important measure is the 'Veiling Luminance'.

For road Lighting another measure for *discomfort glare* is the 'Glare Control Mark (G)'.

The above measures are described in the following sections.

Veiling Luminance

Veiling luminance is the loss of visibility performance as a result of glare. The light from glare sources scattered in the direction of the retina will cause a bright veil to be superimposed on the sharp image of the scene in front of the observer.

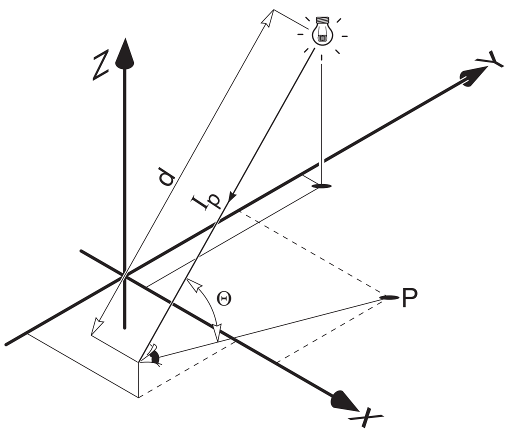
Veiling Luminance can be caused by the luminaires as well as by the environment.

The equivalent veiling luminance L_{vl} (the light produced by the luminaires which is directly incident on the eye) is defined by the following formula:

$$L_{vl} = k \sum_{i=1}^{n} \frac{Eeye_i}{\Theta_i^2}$$

Variables:	**Meaning:**
L_{vl}	equivalent veiling luminance (cd/m^2);
E_{eyei}	illuminance on the observer's eye (in a plane perpendicular to the line of sight) caused by the glare source (Lx);
Θ_i	angle between the viewing direction and light incidence of the glare source on the eye (deg);
k	age factor (for calculation purposes set to 10);
n	total number of light sources.

For veiling luminance calculations, Θ_i must be more than 1.5 degrees. If this angle is less than 1.5 degrees, the veiling luminance calculations are not valid. Also luminaires with
$\Theta_i > 60$ degrees are not taken into account.



✍ For veiling luminance calculations, only the observer location is a calculation point.

Glare Rating

Glare rating is a measure for the amount of disability glare in a sports lighting installation.
A lower glare rating results in a better glare restriction. The range of the glare assessment scale is from 10 (unnoticeable) to 90 (unbearable).

Glare	Glare rating
Unbearable	90
	80
Disturbing	70
	60
Just admissible	50
	40
Noticeable	30
	20
Unnoticeable	10

For glare rating calculations the following formula is used:

$$GR = 27 + 24\log\left(\frac{L_{vl}}{L_{ve}^{0.9}}\right)$$

Variables:	**Meaning:**
GR	glare rating;
L_{vl}	equivalent veiling luminance produced by the luminaires. It relates to the light of the luminaires which is directly incident on the eye of an observer;
L_{ve}	veiling luminance produced by the environment; This is the light reflected towards the eye from the area in front of the observer.

For sports lighting, the equivalent veiling luminance L_{ve} produced by the environment is approximated from the average luminance L_{av} of the horizontal area being observed, using the formula:

$$L_{ve} = 0.035 * L_{av}$$

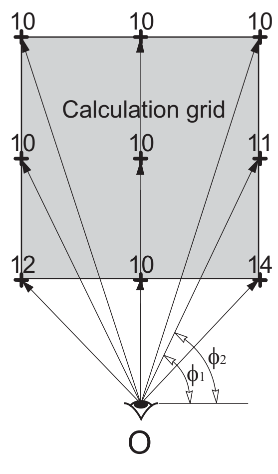
The average luminance L_{av}(in) is approximated by:

$$L_{av} = \frac{\rho}{\pi} E_{hor_{av}}$$

Variables:	Meaning:
E_{horav}	average horizontal area illuminance (Lx);
ρ	average reflectance of the area considered (most often grass);
π	3.141593.

For glare rating on a grid or individual grid point you can define the angle of Θ ($1.5 \leq \Theta \leq 60$ degrees).
In Calculux there are three methods for calculation of the Glare rating:

a) A given observer is looking at each point of a calculation grid.
The glare is calculated for a single observer looking in the different directions of each of the grid points.

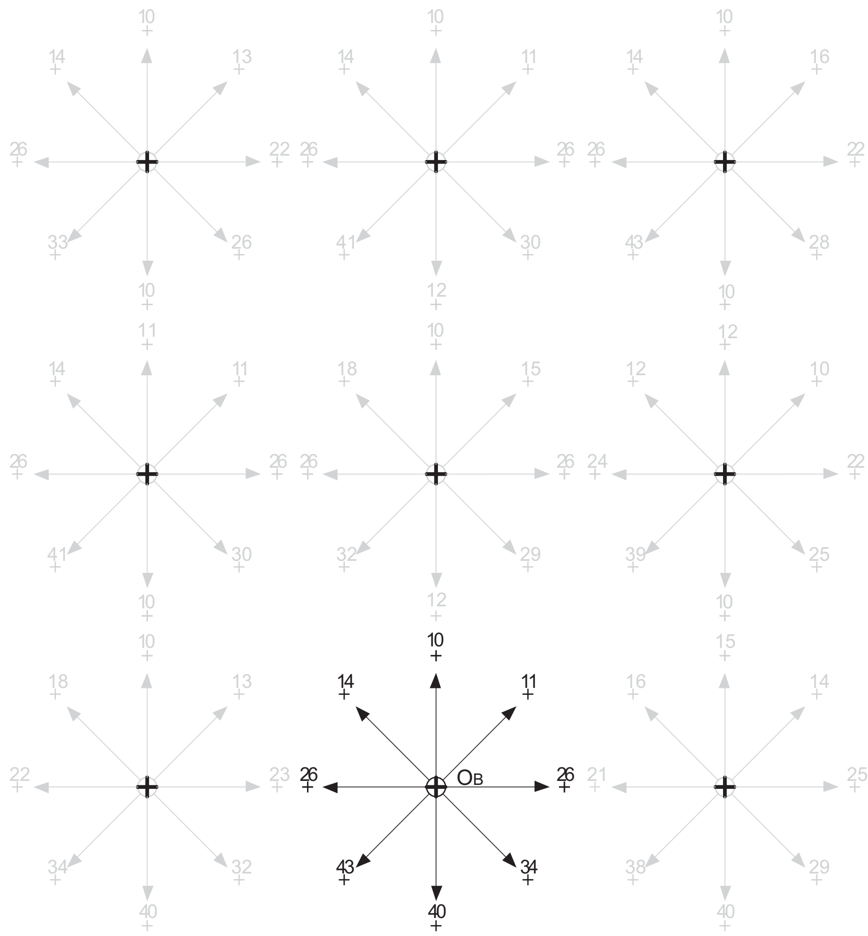


✍

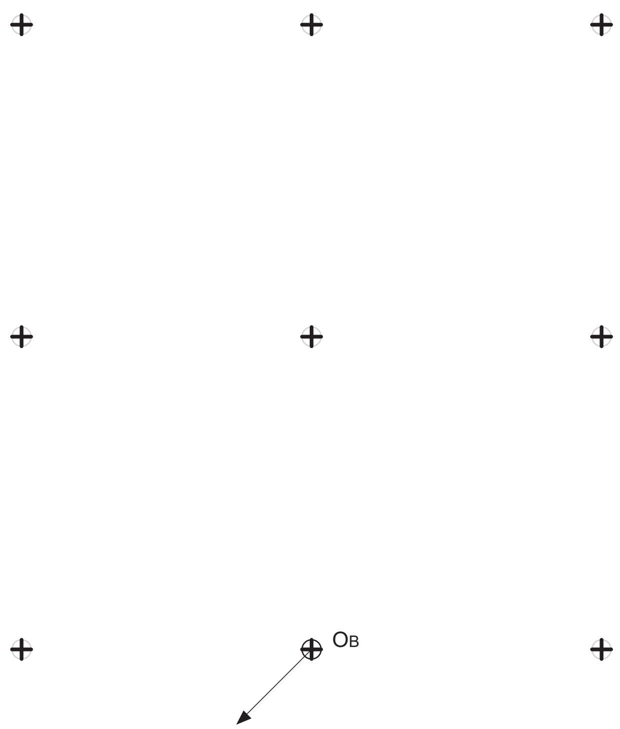
- The background luminance is the average illuminance on the calculation grid where the observer is looking at.
- It is not allowed to position the observer on one of the grid points.
- For each point the horizontal and vertical viewing angles are different.

b) Each point in a grid is an observer.
In this case you can calculate a number of glare values for each grid point, each with its own direction. It is also possible to present the maximum value and its direction.

The figure below shows an example of a calculation grid with 9 grid points. The delta angle for the glare calculations is 45°. The angle is measured counter clockwise from the AB-axis (normally this is the X-axis).



For Observer O_B the maximum value is 43 for an angle of 225° (see next figure).



In this case you have to define a calculation area for the background luminance and to select an appropriate reflection factor. For the presentation of the results, only a textual and graphical table are possible.

c) The user defines a point and direction (not always available).
   In this case you define a point and a direction. Calculux calculates the Glare rating in the given point looking in the given direction.
   For the background luminance, you have to define a calculation area and to select an appropriate reflection factor. For the presentation of the results, only a textual is possible.

Reflectance for Glare Rating

Every surface, be it grass, pavement etc. reflects a certain amount of light. The ratio of $light_{in}$ and $light_{out}$ is known as reflectance.
The reflected light defines, amongst other things, the background illuminance and therefore also the glare experienced by people looking at the surface in question.

In Calculux the reflectance is a value, set by the user between 0.0 and 0.95, which is used in the glare rating calculations. A higher surface reflectance will result in a lower glare value.

Even though grass is the most common used surface for sports fields,
it can be helpful to keep a list of reflection factors. For instance tennis courts can be clay covered.

✍ For glare rating calculations, the glare rating of the given observer looking in the direction of each grid point is given.

Relative Threshold Increment (TI)

This is the measure for the amount of disability glare in a road lighting installation. TI (Threshold Increment) expressed as a percentage is calculated, using the following formula:

$$TI = \frac{(65 * MF^{0.8} * L_{vl})}{L_{av}^{0.8}} \quad \text{for } L_{av} \leq 5$$

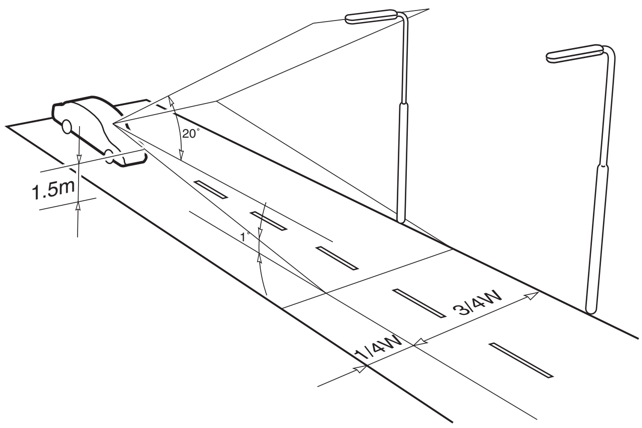
$$TI = \frac{(95 * MF^{1.05} * L_{vl})}{L_{av}^{1.05}} \quad \text{for } L_{av} > 5$$

Variables:	**Meaning:**
L_{vl}	equivalent veiling luminance produced directly by the luminaires. (The value is calculated under 'new' conditions);
L_{av}	average maintained road luminance;
MF	general maintenance factor used to calculate the average luminance.

✍ TI is a quality figure of a Road Lighting installation.

Since the position of the driver (observer) relative to the luminaires of the road lighting installation is changing continuously, the Threshold Increment will vary. When the value of the variation is not too high, the variation itself will cause no disturbance. It is therefore sufficient to specify a top limit for the Threshold Increment.

The longitudinal position of the observer at which the Threshold Increment will be a maximum, is dependent upon the screening angle of the vehicle's roof.



This angle has been standardised by the CEN (for the purpose of glare evaluation in road lighting design) at 20 degrees above the horizontal. The TI is only calculated for luminaries within this limit.

The TI calculation is repeated with the observer moved forwards in increments that are same in number and distance as the longitudinal spacing of the grid points.
Each line of luminaires (parallel to the road) is extended to 500 meter in front of the observer. For each luminaire in the (extended)line, that is in front of the observer and contributes more than 2% of the sum of all previous ones in that line, the contribution is taken into account. Individual luminaries are also taken in to account.

The lower the level of Threshold Increment, the better the visibility.
The following scale provides an insight into the practical meaning of differences in Threshold Increment.

Threshold Increment (%)	Assessment
>20	Bad
10	Moderate
<10	Good

Calculux Road only:
In Calculux Road the initial position of the observer for TI is automatically calculated by the Schemes editor. The observer is placed on the street in such way that the first luminaire is seen under a screening angle of 20 degrees.

Calculux Area only:
In Calculux Area the initial position of the observer for TI is the same as for the Road Luminance.

Glare Control Mark (G))

Glare Control Mark is a measure of discomfort glare in Road Lighting designs. It is calculated from certain luminaire and installation characteristics. The higher the value of G, the less will be the glare, resulting in a higher visual comfort for the road user.

The Glare Control Mark is given by the formula:

Variables:	**Meaning:**
SLI	specific luminaire index;;
L_{av}	average maintained road luminance;
h"	luminaire height minus eye height;
p	number of luminaires per kilometer.

The SLI is a luminaire characteristic and is given by:

$$SLI = 13.84 + 3.31 Log I_{80} + 1.3(Log\left(\frac{I_{80}}{I_{88}}\right))**0.5 - 0.08 Log\left(\frac{I_{80}}{I_{88}}\right) + 1.29 \log F + C$$

Variables:	Meaning:
I_{80}	luminous intensity at an elevation angle of 80 degrees in the C=0 plane of the luminaire. This is the new value, so no maintenance factors are taken into account;
I_{80}/I_{88}	ratio of the luminous intensity at an elevation angle of 80 degrees and 88 degrees in the C=0 plane;
F	flashed area of the luminaire (m^2);
C	colour factor (dependent on the lamp type).

✍ Calculux will only calculate the Glare Control Mark if the following conditions are met:

- Road Luminance is the selected calculation type.
- Luminaires are placed in straight and continuous rows (≥ 300 meters), all with the same spacing and height above the road. Per row, the orientation must be:
  ⇒ The same for all luminaires in that row.
  ⇒ Perpendicular to the road axis (The C=90°..C=270° plane of the luminaire is perpendicular to the road surface). No luminaire tilt in the C=0°..C=180° plane is allowed.
- Only one luminaire type is used.
- If more than one row of luminaires is used the luminaires must be symmetric around the C=90°..C=270° plane. The maximum number of rows possible is 2.
- $0.3 \leq L_{av} \leq 7$
- $5 \leq h'' \leq 20$
- $20 \leq p \leq 100$
- SLI > 0

The following restrictions apply to the calculation of SLI:

- $50 \leq I_{80} \leq 7000$
- $1 \leq I_{80}/I_{88} \leq 50$
- $0.007 \leq F \leq 0.4$

Typical values of G are shown in the following table:

G	Assessment
< 3	Bad
5	Moderate
> 7	Good

✍ The Glare Control Mark is not used very much any more.

3.15.9 Obtrusive Light Calculations

Obtrusive light is light that causes annoyance, discomfort, distraction or reduction in the ability to see essential information, e.g. signal lights. Obtrusive light can be a result of quantitative, directional or spectral attributes in a specific situation, e.g. spill light of a lighting installation.

Spill light (stray light) is light emitted by a lighting installation on areas outside the boundaries of the property where the installation is situated.

Lighting installations can be evaluated for obtrusive light by using the following quality figures:

- Illuminance on environmental zones close to the lighting installation;
- Luminance on environmental zones close to the lighting installation;
- Upward Light Ratio (ULR) for a single luminaire and/or complete lighting installation;
- Threshold increment on traffic areas close to the installation;
- Maximum intensity towards specified observers;
- Maximum luminance towards specified observers.

With Calculux you can calculate each of the above quality figures. However, Calculux does not give any guidelines for quantitative values or where the quality figures should be applied.

Luminance and Illuminance on environmental zones close to lighting installations

The luminance and illuminance on environmental zones close to a lighting installation are a measure for *spill light*. In Calculux you can use the calculated luminance and illuminance measuring values.

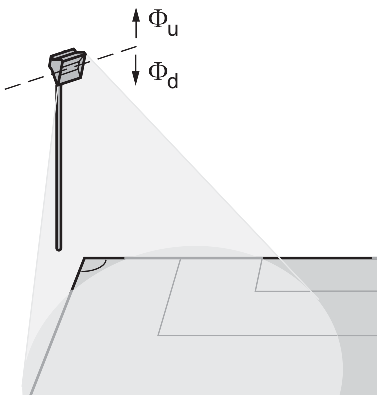
✍ For the luminance the designer has to specify the reflectance of the area considered.

Upward Light Ratio (ULR)

Calculux allows you to calculate the Upward Light Ratio for both a single luminaire and a complete lighting installation.

Upward Light Ratio for a luminaire

For a single luminaire the Upward Light Ratio is the proportion of the flux that is emitted above the horizontal axis when the luminaire is **installed** (see figure below).



$$ULR_{luminaire} = \frac{\Phi_u}{\Phi_u + \Phi_d}$$

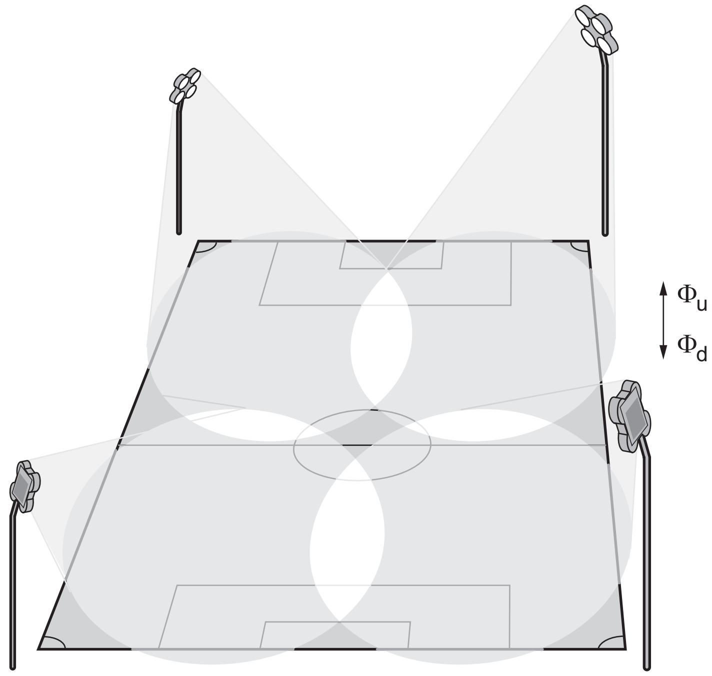
Variables:	**Meaning:**
$ULR_{luminaire}$	Upward Light Ratio of the luminaire.
Φ_u	Upward flux of the luminaire in its installed position.
Φ_d	Downward flux of the luminaire in its installed position.

Upward Light Output Ratio (ULOR)

This is the proportion of the lamp flux of a luminaire that is emitted above the horizontal axis when the luminaire's light emitting area is aimed downwards.

Upward Light Ratio for a lighting installation

The Upward Light Ratio (ULR) for a lighting installation is the sum of the upward flux contribution of each luminaire in the installation, divided by the sum of the upward flux + downward flux of all luminaires (see figure below).



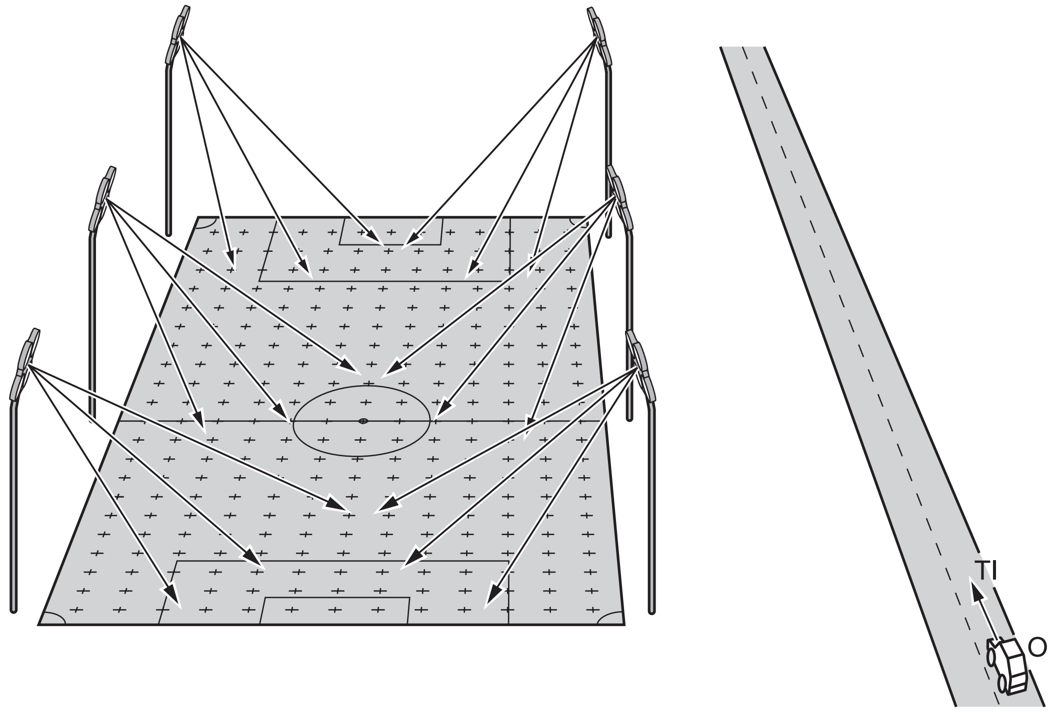
$$ULR_{installation} = \frac{\Sigma\Phi_{u(luminaires)}}{\Sigma\Phi_{u(luminaires)} + \Sigma\Phi_{d(luminaires)}}$$

Variables:	**Meaning:**
$ULR_{installation}$	Upward Light Ratio of the lighting installation.
Φ_u	Sum of the upward flux of all luminaires in the lighting installation.
Φ_d	Sum of the downward flux of all luminaires in the lighting installation.

Threshold increment on traffic areas close to a lighting installation

In Calculux it is possible to calculate the threshold increment (measure of the amount of disability glare in a road lighting installation) on areas close to a lighting installation. To do so you should define a traffic area (single or dual carriage way) and an observer alongside the lighting installation (see figure next page). For calculation of the threshold increment also the background luminance (adaptation luminance) must be given. The viewing direction of the observer is parallel to the direction of the carriage way.

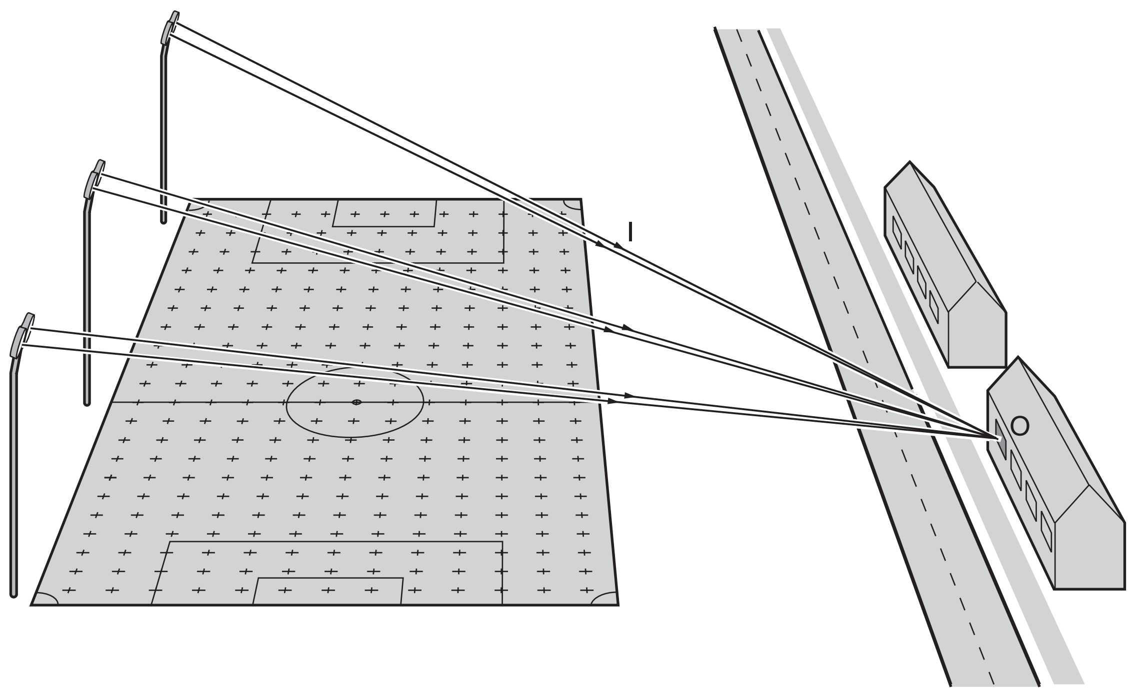
A screening angle of 20° is taken into account. The observer is looking under 1° parallel to the road.



O Observer in a car.
TI Threshold increment in the viewing direction of the observer.

Maximum intensity towards observers

Calculux allows you to calculate the intensity (I) for each luminaire in the direction of an observer, and in addition, the maximum (I_{max}) of these intensity values. For each specified observer you can set a limit for the calculated intensity values. Calculux will then show you which of the luminaires (if any) exceeds the limit.



O Observer in one of the houses.
I Intensity towards the observer.

Maximum luminance towards observers

For each luminaire in the direction of an observer, Calculux allows you to calculate the luminance (L_p) and limit luminance (L_{limit}). In addition, Calculux determines the maximum (L_{max}) of the calculated luminance values.

Calculux will show you which of the luminaires (if any) exceeds the limit luminance for this observer. For a more detailed overview, you can let Calculux create a table with all relevant values used in these calculations.

For the calculations, the following formulas are used:

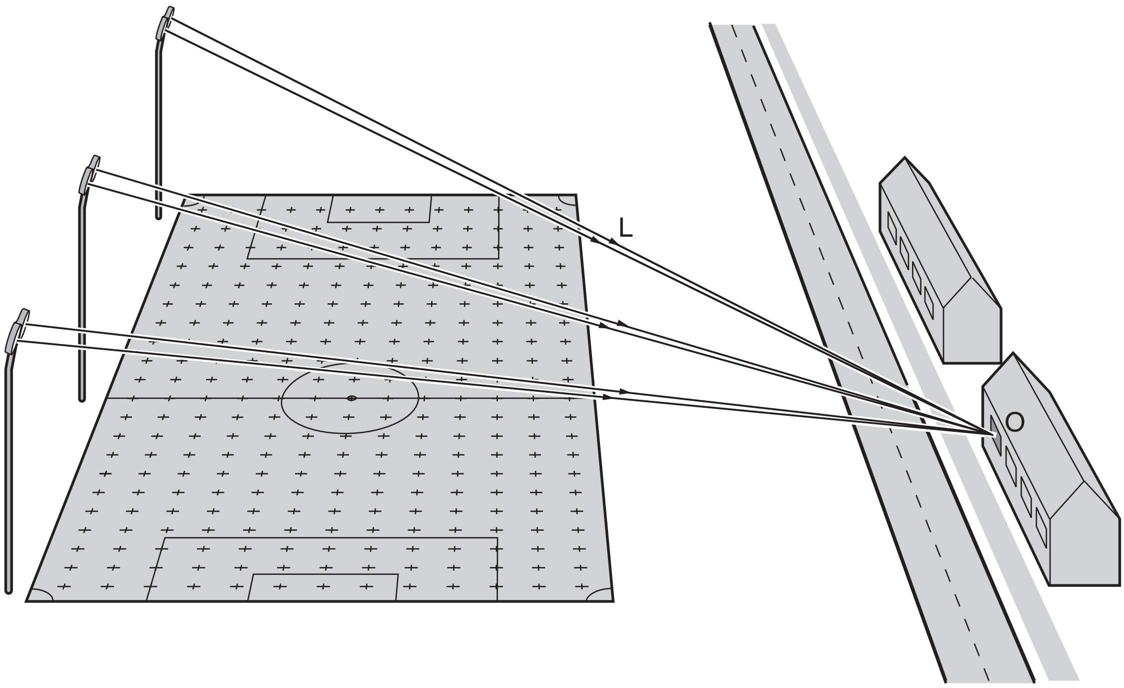
Luminance: $\mathrm{L_p} = \dfrac{I_\mathrm{p}}{A_\mathrm{p}}$

Variables:	**Meaning:**
L_p	The luminance of the luminaire towards the observer position p.
I_p	The intensity of the luminaire towards the observer position p.
A_p	The projected area of the luminaire for observer position p.

Limit luminance: $\mathrm{L_{limit}} = kR\sqrt{\dfrac{L_\mathrm{u}}{A_\mathrm{p}}}$

Variables:	**Meaning:**
L_u	The luminance of the surroundings (a real value with $0.1 \le L_\mathrm{u} \le 10$), given by the lighting designer.
k	The area-specific k-factor (a positive integer value), given by the lighting designer. (In general, the k-factor is higher for an industrial area than for a residential area.)
R	The distance from the observer to the luminaire.

✍ In contrast with the maximum intensity calculation (see the previous section), the maximum allowed luminance depends also on the luminance of the surroundings, because the limit value depends on it.



O Observer in one of the houses.
L Luminance towards the observer.

3.15.10 Quality Figures

Calculux allows you to show the quality figures of the calculations. Depending on the settings of the Quality Figure tab (see Calculation menu, Presentation...) the following quality figures can be displayed:

Average value calculation

The average value for a grid is worked out by adding the calculated values of each point and dividing it by the number of grid points (grid dimensions; AB, AC).

$$\text{Average} = \frac{\sum \text{calculated values for all individual points}}{(\text{Points AB}) * (\text{Points AC})}$$

Minimum

This is the minimum calculated value.

Maximum

This is the maximum calculated value.

Minimum/maximum

This is the minimum calculated value divided by the maximum calculated value.

Minimum/average

This is the minimum calculated value divided by the average calculated value.

3.16 Report Setup

A very useful feature of Calculux is the report facility. When you have completed a lighting project you can create attractive reports to present the results of the calculations to your customers. By means of the Report Setup you can simply specify the layout of the report and components you wish to include.
For example, you can include, a table of contents, 2-D and 3-D project overviews, a summary, luminaire information (including Polar or Cartesian diagram) and/or financial data.
For detailed information about your calculation results you can include the following presentation formats:

- Textual Table;
- Graphical Table;
- Iso Contour;
- Filled Iso Contour;
- Mountain Plot.

You can also include a summary of your findings and recommendations about the best lighting solutions. If you wish, you can produce reports in several languages.

✍ The order of the calculation results can be altered (see Calculation Presentations dialogue box). However, the order of the presentation formats is governed by Calculux and cannot be altered.

Calculux enables you also to print a report in portrait or landscape format with the 2D result views rotated 90°. This option (Report menu, Print Setup, Layout tab) can be very useful. For instance, when a report which has to be printed in portrait format contains a landscape formatted 2D result view which looks relatively small. By selecting 'Rotate presentation for Portrait Printing', the 2D result views will be rotated 90°. Because of the rotation the view can be enlarged.

3.17 Cost Calculations

Calculux allows you to calculate the annual energy, investment, lamp and maintenance costs for the lighting installation in your project. You can view and/or enter the data for calculating the 'annual costs' and the 'total investment' costs of the project.

3.17.1 Total Investment

The Total Investment is the cost of the luminaires, lamps and the installation of the entire lighting project. The Total Investment costs are calculated according to the following formula:

$$\text{Total\_Investment} = \Sigma_{\text{lumtype}}\left(\text{NT} * \left(\text{LPR} + \text{INSTC} + \left(\text{LAPR} * \text{NL}\right)\right)\right)$$

Variables:	**Meaning:**
INSTC	Installation costs of the particular luminaire type;
LAPR	Lamp price for the particular luminaire type;
LPR	Price of the particular luminaire type;
NL	Number of lamps for the particular luminaire;
NT	Number of luminaires of the particular type;
Σ_{lumtype}	Sum for all luminaires types.

3.17.2 Annual costs

The total annual costs are calculated according to the following formula:

Total Annual Cost = EN + AI + LC + MC

Variables:	**Meaning:**
EN:	Energy costs per year;
AI:	Annual investments costs for the particular luminaire type;
LC:	Lamp replacement costs per year;
MC:	Maintenance costs per year.

The formulas for these costs are:

$$EN = \frac{KWHPR}{1000} * \Sigma_{swimod}\{\{\Sigma_{lumtype}(NT_{swimod} * LWATT)\} * BRNH_{swimod}\}$$

$$AI = AF * \Sigma_{lumtype}\{NT * (LPR + INSTC)\}$$

$$AF = \frac{R/100}{1 - \{1/[1 + R/100]\}^{**N}}$$

$$LC = \frac{\Sigma_{lumtype}\{NT * NL * LAPR\}}{RP}$$

$$MC = \frac{\Sigma_{lumtype}\{NT * MCL\}}{RP}$$

Variables:	**Meaning:**
AF	the annuity factor;
$BRNH_{swimod}$	the burning hours per year of the switching mode;
INSTC	the installation cost per luminaire for a particular luminaire type;
KWHPR	the kilowatt-hour price;
LAPR	the lamp price for a particular luminaire type;
LPR	the price per luminaire for a particular luminaire type;
LWATT	the total watts per luminaire for a particular luminaire type;
MCL	the maintenance cost per luminaire for a particular luminaire type;
N	the amortization period (years);
NT	the number of luminaires of a particular type;
NT_{swimod}	the number of luminaires of a particular type per switching mode;
NL	the number of lamps per luminaire for a particular luminaire type;
R	the interest rate (%);
RP	the relamping period (years) for a particular luminaire type;
$\Sigma_{lumtype}$	the sum for all luminaire types.

Cost calculations and light regulation factors

There is no linear relation between the value of the light regulation factor and the power consumption of a luminaire. As a result of this, when light regulation factors are used, the power consumption of the luminaire cannot be calculated. So in the cost calculation the energy costs will not be given.

3.18 Maintenance Factor/New Value Factor

The Maintenance Factor is the ratio of the average illuminance on the plane under investigation after a specified period of use of the lighting installation, to the average illuminance obtained under the same conditions for a new installation. It is always equal or less than 1 and is used as a multiplier for calculations, based on luminaire light distribution tables.

In some countries the **New Value Factor** (or Inverse Maintenance Factor) is used. Calculux allows you to use new value factors instead of maintenance factors.
The 'Inverse Maintenance Factor' is always more than or equal to 1.

The following maintenance factors are specified:

- General Project Maintenance Factor;
- Luminaire Type Maintenance Factor;
- Lamp Maintenance Factor.

3.18.1 General Project Maintenance Factor

This maintenance factor takes into account a general factor with which all calculation results are multiplied. It acts as a safeguarding factor and must reflect the overall conditions of the installation. The value of the 'Project Maintenance Factor' is always equal or less than 1.

3.18.2 Luminaire Type Maintenance Factor

This maintenance factor takes into account the reduction of light output caused by dirt deposited on or in a luminaire. The rate at which the dirt is deposited depends on the construction of the luminaire and the extent of what dirt is present in the environment.
The value of the 'Luminaire Type Maintenance Factor' is always equal or less than 1.

3.18.3 Lamp Maintenance Factor

The Lamp Maintenance Factor value is always equal or less than 1 and consists of two elements:

a) Lamp Survival Factor;
b) Lamp Lumen Depreciation Factor.

a) Lamp Survival Factor

This maintenance factor takes into account the percentage of the lamp failures during a specific number of operation hours. It is only applicable when a group replacement is to be carried out. The 'Lamp Survival Factor' is based on the assumptions about the switching cycle, supply voltage and control gear.

b) Lamp Lumen Depreciation Factor.

This maintenance factor takes into account the fact that the luminous output of all lamps decreases with use.

Appendix 1

Road Reflection Tables

Road Reflection TABLES

R-Tables are tables which give the Reflection Characteristics of the roads. They are needed to calculate the Road luminance.

The following R-tables are supplied with the Calculux package:

✍ All R-table files are in ASCII format. If new R-tables are added they must have the extension RTB.

File name	Name in User Interface	S1	Q0
RTAB1.RTB	Concrete CIE C1	0.244	0.100
RTAB2.RTB	Asphalt CIE C2	0.967	0.070
RTAB3.RTB	Asphalt CIE R3	1.109	0.070
RTAB4.RTB	Asphalt (dark) CIE R4	1.549	0.080
RTAB5.RTB	Wetsurface W1	3.152	0.110
RTAB6.RTB	Wetsurface W2	5.722	0.150
RTAB7.RTB	Wetsurface W3	8.633	0.200
RTAB8.RTB	Wetsurface W4	10.842	0.250
RTAB9.RTB	CIE CLASS R1	0.247	0.100
RTAB10.RTB	Concrete CIE R2	0.582	0.070
RTAB11.RTB	N1 very diffuse	0.180	0.100
RTAB12.RTB	N2 concrete	0.409	0.070
RTAB13.RTB	N3 asphalt	0.881	0.070
RTAB14.RTB	N4 glossy asphalt	1.607	0.080
RTAB15.RTB	ZOAB (Dutch Porous)	0.689	0.100
RTAB16.RTB	Porous Asphalt (UK)	0.582	0.050

Tables 1-14 are according to the following CIE publications:

- Publication Nr. 66 1984
  Road Surfaces and Lighting
  Joint technical report CIE/PIARC
- Publication Nr. 47 1979
  Road Lighting for Wet conditions

Table 15 is measured by the KEMA for the Dutch Road Authorities (Rijkswaterstaat). The table represents the properties of dry Porous Asphalt.

Table 16 is recommended by the UK Highways Agency when Porous Asphalt is to be used. The reflection properties are the same as Concrete CIE R2, the only difference is the Q0 value which is 0.05.

✍ It might be that in your Calculux version not all tables are supplied, or that additional tables are supplied. Tables which are not needed can be deleted so they will not show up in the different dialogues.
For more details contact the supplier of your package.

Table A1 RTAB1.RTB

Name = Concrete CIE C1 Q0 = 0.100 s1=0.244

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700	7700 7700
0.2	7100 7020	7080 7080	7030 6980	7100 7020	7120 7040	7100 7140	7080 7080	7080 7240	7070 7190	7040 7230
0.5	5860 5480	5820 5410	5870 5310	5810 5440	5810 5460	5760 5620	5700 5660	5670 5870	5640 5810	5560 5890
0.8	4680 3890	4670 3830	4650 3730	4550 3840	4570 3910	4460 4120	4300 4190	4200 4370	4100 4380	3990 4450
1.0	3780 2630	3720 2600	3730 2500	3630 2650	3470 2780	3310 2950	3140 3050	2990 3180	2850 3230	2730 3290
1.2	3080 1790	3040 1730	3050 1730	2850 1830	2700 1940	2440 2070	2180 2240	2030 2370	1930 2380	1850 2450
1.5	2580 1240	2540 1200	2510 1200	2290 1320	2030 1400	1780 1550	1570 1630	1430 1770	1340 1790	1280 1840
1.8	2170 870	2140 840	2050 880	1820 980	1530 1030	1290 1160	1100 1230	1000 1340	950 1370	900 1380
2.0	1880 620	1810 640	1740 640	1420 720	1160 780	950 880	800 950	730 1050	690 1080	640 1090
2.5	1450 360	1360 360	1210 390	900 440	660 500	530 550	460 600	410 660	390 690	370 710
3.0	1180 220	1080 230	870 250	570 280	410 310	320 370	280 410	260 450	250 470	230 510
3.5	970 150	870 160	640 170	390 190	260 230	200 270	180 300	170 330	160 350	150 370
4.0	800 110	690 110	500 130	290 150	170 170	140 190	130 220	120 260	110 270	110 290
4.5	700 80	580 90	370 100	210 120	130 140	100 160	90 170	80 200	80 210	80 220
5.0	600 60	510 70	290 70	150 90	90 100	70 120	70 140	60 170	60 170	60 180
5.5	520 0	410 0	230 0	120 0	70 0	60 0	60 0	60 0	50 0	40 0
6.0	480 0	360 0	190 0	80 0	60 0	50 0	50 0	50 0	50 0	0 0
6.5	440 0	320 0	170 0	70 0	60 0	50 0	50 0	50 0	0 0	0 0
7.0	410 0	280 0	140 0	60 0	50 0	40 0	40 0	40 0	0 0	0 0
7.5	370 0	260 0	120 0	60 0	40 0	30 0	30 0	0 0	0 0	0 0
8.0	340 0	230 0	110 0	50 0	40 0	30 0	30 0	0 0	0 0	0 0
8.5	320 0	210 0	90 0	50 0	40 0	30 0	30 0	0 0	0 0	0 0
9.0	290 0	190 0	80 0	40 0	30 0	30 0	0 0	0 0	0 0	0 0
9.5	270 0	170 0	70 0	40 0	30 0	30 0	0 0	0 0	0 0	0 0
10.0	260 0	160 0	60 0	30 0	30 0	30 0	0 0	0 0	0 0	0 0
10.5	250 0	160 0	60 0	30 0	20 0	10 0	0 0	0 0	0 0	0 0
11.0	230 0	150 0	60 0	30 0	20 0	10 0	0 0	0 0	0 0	0 0
11.5	220 0	140 0	60 0	30 0	20 0	0 0	0 0	0 0	0 0	0 0
12.0	210 0	140 0	50 0	30 0	20 0	0 0	0 0	0 0	0 0	0 0

Table A2 RTAB2.RTB

Name = Asphalt CIE C2 Q0 = 0.070 s1=0.967

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	4700	4700	4700	4700	4700	4700	4700	4700	4700	4700
	4700	4700	4700	4700	4700	4700	4700	4700	4700	4700
0.2	5171	5114	5300	5200	5300	5271	5171	5100	5014	4986
	4971	4857	4686	4457	4271	4200	4257	4114	4171	4014
0.5	5414	5257	5357	5329	5243	5129	5000	4857	4686	4529
	4371	4000	3800	3557	3386	3386	3300	3300	3243	3357
0.8	5429	5357	5400	5214	5014	4771	4500	4214	3929	3657
	3414	3114	2829	2543	2500	2514	2514	2414	2500	2514
1.0	5314	5357	5314	5057	4500	3957	3471	3157	2929	2743
	2586	2171	1914	1857	1786	1771	1786	1843	1829	1829
1.2	5357	5329	5029	4543	3786	3157	2700	2371	2143	1943
	1786	1529	1300	1329	1300	1300	1257	1343	1386	1386
1.5	5057	5029	4800	3871	3043	2429	2000	1729	1557	1386
	1243	1086	957	929	943	943	957	971	1014	1014
1.8	4757	4671	4314	3171	2371	1843	1486	1286	1071	971
	900	757	729	700	700	671	743	729	757	771
2.0	4543	4429	3800	2571	1729	1286	1071	886	771	714
	686	571	571	543	543	543	586	586	614	643
2.5	3829	3743	2929	1700	1029	714	586	514	471	414
	371	357	329	343	357	343	371	386	414	400
3.0	3243	3100	2100	1057	600	414	357	329	300	271
	257	229	229	243	257	243	271	300	300	329
3.5	2771	2400	1514	671	429	314	243	200	186	171
	171	157	143	157	171	186	214	200	214	200
4.0	2400	1943	1086	486	271	200	186	157	143	143
	143	114	114	129	143	129	157	171	157	186
4.5	2014	1586	771	300	200	157	129	114	114	114
	114	100	100	114	114	114	114	143	143	157
5.0	1800	1286	614	243	143	114	114	100	86	86
	100	86	100	86	86	100	114	114	114	129
5.5	1529	1129	457	171	114	100	100	100	86	71
	0	0	0	0	0	0	0	0	0	0
6.0	1343	929	371	143	100	86	86	86	71	0
	0	0	0	0	0	0	0	0	0	0
6.5	1229	800	300	114	100	86	71	71	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	1114	714	243	100	71	71	71	71	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	1000	586	200	100	57	43	57	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	900	529	157	71	57	57	57	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	857	529	143	71	57	57	57	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	800	457	129	71	57	43	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	757	400	129	57	57	57	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	743	386	100	71	57	43	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	643	329	100	57	43	43	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	614	314	100	43	43	43	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	757	314	100	43	43	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	600	286	100	57	43	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A3 RTAB3.RTB

Name = Asphalt CIE R3   Q0 = 0.070   S1=1.109

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
Tan(Gamma)										
0.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
0.2	4657	4657	4585	4585	4528	4457	4400	4400	4328	4257
	4200	4000	3871	3742	3685	3614	3557	3485	3428	3428
0.5	4914	4914	4842	4842	4657	4528	4400	4257	4128	3942
	3742	3357	3100	2914	2842	2842	2842	2842	2771	2771
0.8	5100	5042	5042	4842	4585	4328	4071	3814	3485	3171
	2914	2514	2257	2128	2128	2128	2071	1942	1942	2000
1.0	5171	5171	5028	4657	3942	3557	3228	2914	2585	2257
	2000	1685	1485	1428	1428	1428	1428	1428	1428	1428
1.2	5100	5100	4971	4257	3485	2971	2514	2200	1942	1685
	1485	1185	1042	1000	1014	1057	1100	1100	1100	1114
1.5	5042	4971	4657	3814	3100	2514	2071	1671	1428	1228
	1114	1028	857	814	828	857	857	857	871	885
1.8	4842	4785	4328	3300	2457	1814	1485	1271	1128	1000
	885	728	642	628	642	657	642	642	657	671
2.0	4657	4585	4000	2714	1942	1428	1171	1014	885	771
	685	557	485	485	485	500	514	514	528	542
2.5	4128	4000	3171	1814	1228	928	771	628	542	485
	357	328	314	328	342	342	342	342	342	357
3.0	3614	3357	2328	1214	757	542	442	357	328	285
	257	214	214	200	214	214	228	228	242	242
3.5	3100	2771	1742	857	500	357	314	271	228	214
	185	142	128	128	142	157	157	171	171	185
4.0	2714	2328	1285	614	371	285	228	200	171	142
	128	100	100	100	114	114	128	128	128	142
4.5	2328	1942	1042	442	285	214	171	142	128	114
	114	71	71	71	71	85	100	114	114	128
5.0	2071	1557	857	342	228	171	128	114	114	100
	85	57	42	42	57	57	71	100	100	100
5.5	1814	1342	671	257	200	142	114	100	85	85
	0	0	0	0	0	0	0	0	0	0
6.0	1614	1100	514	214	157	128	114	100	71	0
	0	0	0	0	0	0	0	0	0	0
6.5	1485	971	428	157	114	85	71	57	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	1357	857	342	128	100	71	57	42	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	1242	757	300	100	71	57	57	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	1185	671	242	85	57	57	42	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	1114	600	214	71	57	42	42	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	1042	542	171	57	42	28	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	985	485	142	57	57	28	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	928	457	128	42	28	28	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	885	414	114	42	28	28	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	842	371	100	42	28	28	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	800	342	85	28	28	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	757	314	85	28	28	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A4 RTAB4.RTB

Name = Asphalt (dark) CIE R4 Q0 = 0.080 S1=1.549

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	3300	3300	3300	3300	3300	3300	3300	3300	3300	3300
	3300	3300	3300	3300	3300	3300	3300	3300	3300	3300
0.2	3712	3962	3962	3962	3962	3875	3800	3625	3550	3462
	3387	3050	2887	2800	2800	2725	2725	2637	2637	2637
0.5	4125	4287	4287	4287	4125	3875	3712	3550	3462	3300
	3137	2725	2475	2312	2225	2150	2150	2062	2062	2062
0.8	4700	4787	4625	4375	4125	3800	3462	3137	2887	2637
	2475	2062	1737	1650	1650	1562	1562	1562	1487	1487
1.0	4950	4950	4950	4125	3625	3137	2725	2475	2312	2062
	1812	1400	1075	1075	1075	1075	1075	1087	1087	1087
1.2	5037	5112	4625	3875	3137	2637	2225	1900	1650	1437
	1287	962	825	812	812	787	812	825	837	850
1.5	5112	4950	4450	3550	2725	2150	1737	1437	1250	1100
	987	762	625	625	625	625	650	687	687	687
1.8	5112	4950	4287	3137	2225	1737	1350	1100	937	825
	737	550	462	462	462	475	500	512	525	562
2.0	5112	4787	3962	2800	1812	1325	1075	887	737	662
	562	412	362	362	362	375	400	412	425	462
2.5	4950	4450	3300	1900	1250	912	687	562	462	400
	350	262	250	250	250	262	275	300	312	325
3.0	4625	3800	2637	1187	787	550	375	312	262	212
	200	162	150	150	162	162	187	200	212	237
3.5	4287	3387	2062	787	500	325	237	187	162	150
	137	125	112	112	112	112	137	150	162	187
4.0	3962	2975	1650	562	300	200	162	137	125	112
	100	100	87	87	100	100	112	112	137	150
4.5	3712	2637	1325	412	212	137	112	100	87	87
	75	75	75	75	87	87	87	100	112	125
5.0	3462	2312	987	300	162	100	87	75	75	62
	62	62	62	62	75	75	75	75	87	100
5.5	3212	2012	737	237	125	87	75	62	62	50
	0	0	0	0	0	0	0	0	0	0
6.0	3050	1750	575	162	100	75	62	50	50	0
	0	0	0	0	0	0	0	0	0	0
6.5	2887	1525	462	137	75	62	50	37	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	2725	1325	400	112	62	50	37	37	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	2562	1175	325	100	50	37	37	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	2412	1025	275	75	50	37	25	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	2300	925	237	62	37	37	25	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	2175	825	200	62	37	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	2112	737	162	50	37	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	2050	662	150	50	25	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	1975	612	137	37	25	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	1912	562	125	37	25	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	1862	512	100	37	25	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	1812	462	100	37	25	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A5 RTAB5.RTB

Name = Wet surface W1 Q0 = 0.110 S1=3.152

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	3456	3456	3456	3456	3456	3456	3456	3456	3456	3456
	3456	3456	3456	3456	3456	3456	3456	3456	3456	3456
0.2	3736	3736	3736	3728	3710	3666	3622	3587	3552	3491
	3429	3307	3184	3114	3079	3070	3052	3070	3070	3087
0.5	4394	4377	4333	4219	4026	3815	3614	3412	3219	3035
	2859	2561	2386	2333	2315	2368	2394	2447	2473	2491
0.8	5683	5622	5455	5052	4491	3894	3377	2973	2614	2342
	2096	1737	1605	1605	1640	1710	1754	1833	1859	1894
1.0	7306	7175	6780	5710	4587	3605	2833	2298	1859	1605
	1386	1123	1061	1088	1140	1210	1272	1333	1368	1395
1.2	8823	8560	7736	5929	4245	3008	2123	1640	1272	1061
	895	737	710	746	798	860	921	982	1009	1026
1.5	9981	9508	8157	5561	3526	2324	1535	1131	833	693
	579	491	491	526	570	631	675	728	754	772
1.8	10683	10008	8201	4859	2780	1702	1044	763	553	465
	395	342	342	386	421	465	509	553	570	588
2.0	10893	10025	7692	4035	2131	1245	728	526	377	325
	272	246	254	281	316	360	395	421	447	465
2.5	10385	9139	6104	2570	1210	658	360	263	193	167
	149	140	149	175	193	228	246	272	298	307
3.0	9271	7683	4324	1561	649	351	193	149	114	96
	88	88	96	114	132	149	167	193	202	210
3.5	8017	6227	2982	921	360	202	114	88	70	61
	61	61	70	79	96	105	123	140	149	158
4.0	6754	4806	2017	570	193	114	70	61	53	44
	44	44	53	61	70	79	96	105	114	114
4.5	5499	3605	1368	351	123	79	53	44	35	35
	35	35	35	44	53	61	70	79	88	96
5.0	4456	2763	956	228	79	53	35	35	26	26
	26	26	35	35	44	53	61	61	70	79
5.5	3631	2105	658	149	53	44	35	26	26	18
	0	0	0	0	0	0	0	0	0	0
6.0	2956	1640	474	105	44	35	26	18	18	0
	0	0	0	0	0	0	0	0	0	0
6.5	2438	1298	342	79	35	26	18	18	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	2052	1044	272	61	26	18	18	18	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	1745	860	210	53	26	18	18	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	1491	702	167	35	26	18	18	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	1272	579	132	35	18	18	18	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	1105	491	114	26	18	18	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	974	421	96	26	18	18	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	860	368	79	18	18	9	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	763	325	61	18	18	9	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	684	298	61	18	18	9	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	623	263	53	18	18	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	570	246	44	18	9	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A6 RTAB6.RTB

Name = Wet surface W2 Q0 = 0.150 S1=5.722

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	2273	2273	2273	2273	2273	2273	2273	2273	2273	2273
	2273	2273	2273	2273	2273	2273	2273	2273	2273	2273
0.2	2439	2433	2433	2413	2406	2373	2346	2320	2293	2260
	2220	2140	2060	2034	2007	2021	2027	2047	2040	2047
0.5	2891	2871	2838	2772	2665	2519	2379	2233	2094	1987
	1881	1682	1549	1542	1549	1582	1602	1642	1648	1668
0.8	4127	4108	3995	3649	3184	2718	2313	1994	1715	1529
	1363	1137	1070	1077	1097	1143	1176	1230	1243	1263
1.0	5995	5989	5636	4699	3589	2645	1947	1529	1196	1017
	864	731	711	738	764	811	844	891	911	931
1.2	8295	8149	7378	5244	3529	2273	1462	1057	764	651
	552	479	472	505	532	572	605	651	665	678
1.5	10342	9943	8361	5231	2951	1715	990	705	498	425
	359	319	326	352	379	419	445	479	492	512
1.8	11950	11226	8793	4633	2340	1263	678	472	326	279
	239	226	233	259	279	306	332	359	372	385
2.0	13007	11911	8547	3835	1728	877	445	312	226	193
	173	160	173	186	206	239	253	279	292	299
2.5	13758	11711	7211	2499	851	432	219	160	120	106
	93	93	100	113	126	146	160	179	186	193
3.0	13313	10568	5357	1436	432	213	106	86	66	60
	60	60	66	73	86	100	106	120	126	133
3.5	12077	8906	3755	831	226	120	60	47	40	33
	33	40	40	53	60	73	80	86	93	100
4.0	10482	7225	2546	472	133	73	40	33	27	27
	27	27	33	40	40	53	60	66	73	73
4.5	8753	5583	1615	266	80	47	27	20	20	20
	20	20	27	27	33	40	47	53	60	60
5.0	7198	4287	1070	166	53	33	20	20	13	13
	13	20	20	20	27	33	33	40	47	47
5.5	5889	3250	731	106	33	27	20	13	13	7
	0	0	0	0	0	0	0	0	0	0
6.0	4898	2539	512	73	27	20	13	13	13	0
	0	0	0	0	0	0	0	0	0	0
6.5	4101	2001	366	53	20	13	13	13	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	3423	1589	266	40	20	13	13	7	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	2871	1269	206	27	13	13	13	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	2439	1030	160	27	13	13	7	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	2074	831	120	20	13	7	7	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	1775	685	93	20	13	7	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	1529	578	73	13	7	7	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	1316	485	66	13	7	7	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	1150	419	53	13	7	7	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	1017	366	47	13	7	7	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	904	326	40	7	7	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	818	292	33	7	7	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A7 RTAB7.RTB

Name = Wet surface W3 Q0 = 0.200 S1=8.633

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576	1576 1576
0.2	1658 1530	1663 1485	1658 1449	1653 1439	1643 1428	1622 1439	1602 1434	1587 1444	1566 1444	1551 1449
0.5	2046 1280	2051 1153	2025 1107	1959 1107	1888 1107	1755 1133	1632 1143	1530 1173	1434 1173	1357 1184
0.8	3183 913	3173 801	3051 770	2729 781	2362 796	1964 826	1638 847	1367 877	1143 888	1020 903
1.0	5071 582	4979 520	4714 515	3836 536	2780 556	1918 587	1326 607	1025 638	791 648	679 658
1.2	7525 372	7336 347	6489 347	4596 372	2734 388	1612 418	949 434	679 464	490 474	423 485
1.5	9871 240	9387 235	7805 240	4561 260	2255 281	1153 301	587 316	418 342	301 352	265 362
1.8	11938 158	11402 163	8525 173	4035 189	1673 204	801 224	383 235	270 255	194 265	179 270
2.0	13606 117	12427 117	8520 128	3362 138	1158 153	520 168	235 184	173 199	133 204	122 214
2.5	15550 66	13075 71	7035 77	1990 82	556 92	245 102	107 117	87 128	71 133	71 138
3.0	15708 41	12152 46	5285 46	1122 56	265 61	117 71	51 77	51 87	46 92	46 97
3.5	14830 31	10382 31	3699 31	592 41	143 46	71 51	36 56	31 61	26 66	31 71
4.0	13458 20	8606 20	2510 26	332 31	71 31	41 36	26 41	20 46	20 51	20 51
4.5	11535 15	6821 15	1597 20	184 20	46 26	31 31	20 31	15 36	15 41	15 41
5.0	9805 10	5270 10	1036 15	112 15	31 20	20 20	15 26	10 31	10 31	10 36
5.5	8076 0	4040 0	673 0	71 0	20 0	15 0	15 0	10 0	10 0	10 0
6.0	6709 0	3209 0	469 0	51 0	15 0	15 0	10 0	10 0	10 0	0 0
6.5	5612 0	2571 0	337 0	36 0	15 0	10 0	10 0	10 0	0 0	0 0
7.0	4785 0	2076 0	245 0	31 0	10 0	10 0	10 0	10 0	0 0	0 0
7.5	4071 0	1663 0	184 0	20 0	10 0	10 0	10 0	0 0	0 0	0 0
8.0	3479 0	1357 0	143 0	20 0	10 0	10 0	10 0	0 0	0 0	0 0
8.5	2969 0	1102 0	107 0	15 0	10 0	10 0	10 0	0 0	0 0	0 0
9.0	2551 0	898 0	87 0	15 0	10 0	10 0	0 0	0 0	0 0	0 0
9.5	2183 0	750 0	66 0	10 0	5 0	5 0	0 0	0 0	0 0	0 0
10.0	1888 0	633 0	56 0	10 0	5 0	5 0	0 0	0 0	0 0	0 0
10.5	1648 0	541 0	51 0	10 0	5 0	5 0	0 0	0 0	0 0	0 0
11.0	1449 0	464 0	41 0	10 0	5 0	5 0	0 0	0 0	0 0	0 0
11.5	1280 0	413 0	36 0	10 0	5 0	0 0	0 0	0 0	0 0	0 0
12.0	1153 0	367 0	31 0	10 0	5 0	0 0	0 0	0 0	0 0	0 0

Table A8 RTAB8.RTB

Name = Wet surface W4 Q0 = 0.250 S1=10.842

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149	1149 1149
0.2	1117 1097	1117 1085	1117 1064	1121 1060	1129 1056	1125 1069	1117 1073	1113 1077	1113 1081	1105 1081
0.5	1206 882	1218 850	1206 818	1170 826	1154 830	1089 854	1028 862	988 878	947 886	915 890
0.8	1777 631	1769 587	1769 575	1692 587	1429 599	1145 619	915 635	809 656	712 668	672 676
1.0	3262 405	3193 385	2971 389	2339 405	1623 417	1077 441	712 449	583 478	474 486	437 494
1.2	5545 263	5262 259	4327 263	2777 275	1457 291	830 312	474 324	376 344	300 352	279 364
1.5	8103 174	7399 174	5379 182	2789 198	1137 206	583 223	295 235	243 251	198 259	186 267
1.8	10523 121	9212 121	6144 125	2615 142	854 150	405 166	190 174	158 190	134 194	125 202
2.0	12458 85	10799 89	6472 93	2117 105	652 113	279 125	121 134	109 146	97 150	89 158
2.5	15785 49	12223 53	5525 53	1113 65	267 69	134 77	69 85	61 93	53 97	49 101
3.0	16991 32	12045 32	4270 36	611 40	105 45	61 53	36 57	32 65	32 69	32 73
3.5	17084 24	10969 24	2926 24	291 28	57 32	32 36	20 40	20 49	16 49	20 53
4.0	16639 16	9621 16	2028 16	146 20	32 24	20 28	16 32	12 36	12 36	12 40
4.5	15028 12	7852 12	1311 12	77 16	24 20	16 24	12 24	12 28	12 28	12 32
5.0	13296 12	6306 12	765 12	49 12	16 16	12 20	8 20	8 24	8 24	8 28
5.5	11495 0	4978 0	506 0	28 0	12 0	12 0	12 0	8 0	8 0	8 0
6.0	10111 0	3910 0	304 0	20 0	12 0	12 0	12 0	8 0	8 0	0 0
6.5	8949 0	3088 0	206 0	16 0	8 0	8 0	8 0	8 0	0 0	0 0
7.0	7630 0	2424 0	142 0	16 0	8 0	8 0	8 0	8 0	0 0	0 0
7.5	6601 0	1906 0	101 0	12 0	8 0	8 0	8 0	0 0	0 0	0 0
8.0	5658 0	1506 0	81 0	12 0	8 0	8 0	8 0	0 0	0 0	0 0
8.5	4812 0	1214 0	61 0	8 0	8 0	8 0	8 0	0 0	0 0	0 0
9.0	4145 0	1008 0	49 0	8 0	8 0	8 0	0 0	0 0	0 0	0 0
9.5	3606 0	850 0	40 0	8 0	4 0	4 0	0 0	0 0	0 0	0 0
10.0	3173 0	712 0	32 0	8 0	4 0	4 0	0 0	0 0	0 0	0 0
10.5	2777 0	611 0	28 0	8 0	4 0	4 0	0 0	0 0	0 0	0 0
11.0	2424 0	530 0	24 0	8 0	4 0	4 0	0 0	0 0	0 0	0 0
11.5	2153 0	465 0	20 0	8 0	4 0	0 0	0 0	0 0	0 0	0 0
12.0	1939 0	417 0	20 0	8 0	4 0	0 0	0 0	0 0	0 0	0 0

Table A9 RTAB9.RTB

Name = CIE CLASS R1 Q0 = 0.100 S1=0.247

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	6550	6550	6550	6550	6550	6550	6550	6550	6550	6550
	6550	6550	6550	6550	6550	6550	6550	6550	6550	6550
0.2	6190	6190	6190	6190	6100	6100	6100	6100	6100	6100
	6100	6100	6100	6010	6010	6010	6010	6010	6010	6010
0.5	5390	5390	5390	5390	5390	5390	5210	5210	5210	5210
	5210	5030	5030	5030	5030	5030	5030	5030	5030	5030
0.8	4310	4310	4310	4310	4310	4310	4310	4310	4310	4310
	3950	3860	3710	3710	3710	3710	3710	3860	3950	3950
1.0	3410	3410	3410	3410	3230	3230	3050	2960	2870	2870
	2780	2690	2690	2690	2690	2690	2690	2780	2780	2780
1.2	2690	2690	2690	2600	2510	2420	2240	2070	1980	1890
	1890	1800	1800	1800	1800	1800	1890	1980	2070	2240
1.5	2240	2240	2240	2150	1980	1800	1710	1620	1530	1480
	1440	1440	1390	1390	1390	1440	1480	1530	1620	1800
1.8	1890	1890	1890	1710	1530	1390	1300	1210	1170	1120
	1080	1030	990	990	1030	1080	1120	1210	1300	1390
2.0	1620	1620	1570	1350	1170	1080	990	940	900	850
	850	830	840	840	860	900	940	990	1030	1110
2.5	1210	1210	1170	950	790	660	600	570	540	520
	510	500	510	520	540	580	610	650	690	750
3.0	940	940	860	660	490	410	380	360	340	330
	320	310	310	330	350	380	400	430	470	510
3.5	810	800	660	460	330	280	250	230	220	220
	210	210	220	220	240	270	290	310	340	380
4.0	710	690	550	320	230	200	180	160	150	140
	140	140	150	170	190	200	220	230	250	270
4.5	630	590	430	240	170	140	130	120	120	110
	110	110	120	130	140	140	160	170	190	210
5.0	570	520	360	190	140	120	100	90	90	90
	90	90	90	100	110	130	140	150	160	160
5.5	510	470	310	150	110	90	80	80	80	80
	0	0	0	0	0	0	0	0	0	0
6.0	470	420	250	120	90	70	70	60	60	0
	0	0	0	0	0	0	0	0	0	0
6.5	430	380	220	100	70	60	50	50	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	400	340	180	80	60	50	40	40	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	370	310	150	70	50	40	40	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	350	280	140	60	40	40	30	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	330	250	120	50	40	30	30	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	310	230	100	40	30	30	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	300	220	90	40	30	30	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	290	200	80	30	20	20	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	280	180	70	30	20	20	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	270	160	70	30	20	20	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	260	150	60	20	20	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	250	140	60	20	20	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A10 RTAB10.RTB

Name = Concrete CIE R2 Q0 = 0.070 S1=0.582

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571	5571 5571
0.2	5871 5414	5871 5257	5871 5100	5871 5100	5871 4942	5871 4942	5871 4942	5871 4785	5871 4785	5871 4785
0.5	5871 4642	5871 4328	5871 4014	5871 4014	5757 3871	5757 3871	5485 3871	5414 3714	5285 3714	4942 3714
0.8	5414 3400	5414 3085	5414 2942	5257 2942	5100 2942	4942 2942	4642 2942	4328 2942	4014 2942	3714 2942
1.0	4785 2471	4785 2171	4785 2171	4642 2171	4171 2171	4157 2171	3714 2014	3400 2014	3085 2014	2785 2014
1.2	4328 1542	4328 1428	4171 1471	3871 1514	3400 1542	2942 1542	2628 1628	2171 1628	1857 1700	1700 1700
1.5	3871 1142	3871 1085	3714 1085	3242 1142	2557 1200	2171 1242	2014 1271	1700 1300	1542 1328	1328 1357
1.8	3557 871	3400 742	3242 771	2785 828	2171 900	1771 957	1514 985	1300 1014	1114 1042	957 1057
2.0	3242 642	3085 571	2785 585	2171 642	1671 700	1357 742	1142 771	957 800	871 814	742 828
2.5	2785 385	2714 342	2085 371	1571 400	1057 428	828 471	685 500	571 542	500 571	428 585
3.0	2285 228	2214 228	1642 242	957 242	614 257	471 300	371 314	300 342	257 371	242 385
3.5	2085 157	1871 157	1242 157	585 157	357 171	257 200	214 214	185 242	171 257	157 300
4.0	1885 114	1614 114	957 114	385 128	214 142	171 157	142 171	128 185	128 214	114 242
4.5	1685 85	1357 85	714 85	285 85	171 100	128 114	100 142	100 171	85 185	85 200
5.0	1514 71	1157 57	542 71	200 71	114 85	85 100	71 128	71 142	71 142	71 157
5.5	1371 0	985 0	414 0	157 0	85 0	71 0	57 0	57 0	57 0	57 0
6.0	1242 0	828 0	314 0	114 0	71 0	57 0	57 0	42 0	42 0	0 0
6.5	1114 0	714 0	242 0	85 0	57 0	42 0	42 0	42 0	0 0	0 0
7.0	1014 0	614 0	200 0	71 0	42 0	42 0	28 0	28 0	0 0	0 0
7.5	957 0	542 0	171 0	57 0	42 0	28 0	28 0	0 0	0 0	0 0
8.0	900 0	471 0	142 0	42 0	28 0	28 0	28 0	0 0	0 0	0 0
8.5	828 0	400 0	128 0	42 0	28 0	28 0	28 0	0 0	0 0	0 0
9.0	785 0	357 0	100 0	42 0	28 0	14 0	0 0	0 0	0 0	0 0
9.5	742 0	328 0	100 0	28 0	28 0	14 0	0 0	0 0	0 0	0 0
10.0	700 0	300 0	85 0	28 0	14 0	14 0	0 0	0 0	0 0	0 0
10.5	671 0	257 0	71 0	28 0	14 0	14 0	0 0	0 0	0 0	0 0
11.0	628 0	228 0	57 0	28 0	14 0	14 0	0 0	0 0	0 0	0 0
11.5	600 0	200 0	57 0	28 0	14 0	0 0	0 0	0 0	0 0	0 0
12.0	585 0	185 0	57 0	14 0	14 0	0 0	0 0	0 0	0 0	0 0

Table A11 RTAB11.RTB

Name = N1 very diffuse Q0 = 0.100 S1=0.180

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680	7680 7680
0.2	6940 6950	6940 6990	6940 7020	6940 7140	6940 7200	6930 7340	6930 7410	6930 7510	6930 7530	6930 7570
0.5	5570 5430	5570 5420	5570 5470	5550 5640	5540 5770	5500 6000	5460 6150	5440 6330	5440 6400	5430 6460
0.8	4240 3780	4240 3810	4240 3880	4170 4070	4150 4250	4060 4500	3970 4690	3920 4890	3880 4970	3820 5050
1.0	3230 2570	3220 2590	3210 2660	3100 2840	3020 3030	2890 3280	2780 3460	2710 3680	2660 3750	2610 3810
1.2	2520 1730	2500 1750	2470 1830	2340 2000	2200 2160	2060 2370	1930 2540	1860 2710	1800 2790	1760 2850
1.5	2020 1190	1980 1220	1930 1290	1770 1420	1600 1570	1470 1750	1350 1890	1280 2040	1240 2120	1210 2160
1.8	1640 840	1620 860	1540 930	1340 1040	1170 1160	1040 1310	940 1440	890 1550	870 1620	840 1660
2.0	1380 610	1360 630	1260 690	1040 780	880 880	760 1010	690 1110	650 1210	630 1270	610 1310
2.5	1030 350	1000 370	860 410	640 480	510 550	430 640	380 710	360 790	350 840	350 860
3.0	800 210	750 230	610 260	410 310	310 360	260 420	240 480	220 550	210 580	210 600
3.5	650 150	600 180	450 180	280 210	210 250	170 310	150 350	150 390	150 420	150 440
4.0	550 100	480 120	340 130	200 160	140 190	120 230	110 260	100 300	100 320	100 340
4.5	470 80	400 80	260 100	140 120	110 150	80 180	80 200	80 230	80 250	80 270
5.0	400 60	340 60	200 80	110 100	80 120	60 140	60 180	50 180	50 210	50 210
5.5	350 0	280 0	150 0	80 0	60 0	50 0	50 0	50 0	50 0	50 0
6.0	310 0	250 0	130 0	70 0	50 0	40 0	40 0	40 0	40 0	0 0
6.5	280 0	210 0	110 0	50 0	40 0	30 0	30 0	30 0	0 0	0 0
7.0	250 0	190 0	90 0	50 0	30 0	30 0	30 0	30 0	0 0	0 0
7.5	230 0	170 0	80 0	40 0	30 0	30 0	30 0	0 0	0 0	0 0
8.0	210 0	150 0	70 0	40 0	30 0	20 0	20 0	0 0	0 0	0 0
8.5	190 0	140 0	60 0	30 0	20 0	20 0	20 0	0 0	0 0	0 0
9.0	180 0	130 0	50 0	30 0	20 0	20 0	0 0	0 0	0 0	0 0
9.5	170 0	120 0	50 0	20 0	20 0	20 0	0 0	0 0	0 0	0 0
10.0	160 0	110 0	40 0	20 0	20 0	20 0	0 0	0 0	0 0	0 0
10.5	150 0	100 0	40 0	20 0	20 0	10 0	0 0	0 0	0 0	0 0
11.0	150 0	90 0	40 0	20 0	20 0	10 0	0 0	0 0	0 0	0 0
11.5	140 0	90 0	30 0	20 0	20 0	0 0	0 0	0 0	0 0	0 0
12.0	140 0	80 0	30 0	20 0	20 0	0 0	0 0	0 0	0 0	0 0

Table A12 RTAB12.RTB

Name = N2 concrete Q0 = 0.070 S1=0.409

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	6771	6771	6771	6771	6771	6771	6771	6771	6771	6771
	6771	6771	6771	6771	6771	6771	6771	6771	6771	6771
0.2	6743	6729	6729	6714	6714	6686	6657	6629	6614	6557
	6429	6429	6329	6271	6235	6200	6200	6214	6229	6229
0.5	6100	6086	6086	6029	5971	5900	5829	5700	5571	5457
	5357	5129	4957	4900	4871	4914	4971	5029	5043	5086
0.8	5343	5314	5286	5157	4986	4800	4586	4414	4243	4071
	3929	3643	3500	3486	3500	3614	3657	3743	3786	3829
1.0	4657	4614	4557	4329	4057	3757	3471	3243	3043	2886
	2757	2529	2429	2429	2486	2571	2657	2743	2800	2843
1.2	4057	4014	3929	3586	3200	2829	2514	2300	2129	1986
	1886	1729	1671	1700	1757	1843	1929	2014	2071	2100
1.5	3557	3514	3357	2900	2457	2086	1814	1614	1486	1386
	1314	1200	1186	1214	1271	1343	1414	1500	1543	1571
1.8	3129	3086	2871	2314	1843	1514	1300	1157	1043	971
	914	857	843	886	929	1000	1057	1129	1171	1200
2.0	2771	2714	2443	1829	1386	1114	929	814	757	686
	657	629	629	657	700	757	814	871	914	929
2.5	2243	2143	1771	1171	814	629	529	457	429	400
	386	371	371	400	429	471	529	571	600	614
3.0	1857	1714	1286	743	500	371	314	271	257	243
	243	229	243	257	286	314	343	386	400	414
3.5	1571	1400	929	486	314	229	200	186	171	157
	157	157	157	171	200	229	257	271	300	300
4.0	1343	1143	686	329	214	157	129	129	114	114
	114	114	114	129	143	171	186	214	229	229
4.5	1143	929	514	243	143	114	100	86	86	86
	86	86	86	100	114	129	143	157	171	186
5.0	1000	786	400	171	114	86	71	71	57	57
	57	57	71	71	86	100	114	129	143	143
5.5	871	657	314	129	86	57	57	43	43	43
	0	0	0	0	0	0	0	0	0	0
6.0	771	557	257	100	71	57	43	43	43	0
	0	0	0	0	0	0	0	0	0	0
6.5	686	486	200	86	57	43	29	29	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	614	429	171	71	43	29	29	29	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	557	386	143	57	29	29	29	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	514	329	129	43	29	29	14	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	471	300	100	43	29	14	14	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	429	257	86	29	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	400	243	71	29	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	371	229	71	29	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	357	200	57	14	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	329	186	57	14	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	314	171	43	14	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	300	171	43	14	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A13 RTAB13.RTB

Name = N3 asphalt Q0 = 0.070 S1=0.881

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	5057	5057	5057	5057	5057	5057	5057	5057	5057	5057
	5057	5057	5057	5057	5057	5057	5057	5057	5057	5057
0.2	5586	5586	5571	5557	5543	5500	5443	5400	5329	5271
	5214	5014	4829	4686	4557	4471	4400	4371	4343	4343
0.5	5800	5771	5757	5671	5571	5414	5229	5071	4900	4714
	4543	4157	3829	3657	3529	3457	3429	3429	3429	3429
0.8	5786	5757	5700	5486	5214	4886	4557	4257	3971	3714
	3486	3043	2743	2600	2514	2500	2500	2514	2529	2529
1.0	5657	5600	5486	5100	4600	4100	3629	3257	2957	2700
	2500	2100	1900	1800	1771	1757	1786	1814	1843	1857
1.2	5471	5343	5143	4529	3843	3243	2757	2400	2129	1914
	1757	1471	1329	1271	1243	1271	1300	1343	1357	1371
1.5	5143	5014	4686	3857	3071	2457	2014	1700	1500	1343
	1229	1029	943	900	900	914	957	986	1014	1029
1.8	4786	4643	4200	3200	2357	1814	1457	1229	1071	957
	871	743	671	657	671	686	714	743	771	786
2.0	4457	4257	3700	2600	1800	1343	1071	900	800	714
	643	543	500	500	500	529	543	571	600	614
2.5	3857	3571	2843	1714	1086	757	614	500	457	400
	371	329	314	300	314	329	343	386	400	400
3.0	3329	2943	2114	1114	657	443	371	300	271	257
	243	214	200	200	214	229	243	257	271	286
3.5	2886	2443	1557	729	414	286	243	200	186	171
	157	143	143	143	157	157	171	186	200	214
4.0	2529	2029	1171	500	286	186	157	143	129	129
	114	100	100	100	114	114	129	143	157	157
4.5	2214	1686	871	343	200	143	114	100	100	86
	86	71	71	86	86	86	100	114	129	129
5.0	1957	1429	671	257	143	100	86	86	71	71
	71	57	57	71	71	71	86	86	100	100
5.5	1729	1200	529	186	114	86	71	57	57	57
	0	0	0	0	0	0	0	0	0	0
6.0	1543	1029	414	157	86	71	57	57	57	0
	0	0	0	0	0	0	0	0	0	0
6.5	1386	886	343	129	71	57	57	43	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	1271	786	286	100	57	43	43	29	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	1157	700	243	86	57	43	43	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	1057	614	214	71	43	29	29	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	971	543	171	57	43	29	29	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	900	486	157	57	29	29	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	829	443	129	43	29	29	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	771	400	114	43	29	29	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	729	371	100	43	29	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	686	343	86	29	29	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	643	314	86	29	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	614	300	71	29	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A14 RTAB14.RTB

Name = N4 glossy asphalt Q0 = 0.080 s1=01.607

Beta	0.0	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
Tan(Gamma)	45.0	60.0	75.0	90.0	105.0	120.0	135.0	150.0	165.0	180.0
0.0	3525	3525	3525	3525	3525	3525	3525	3525	3525	3525
	3525	3525	3525	3525	3525	3525	3525	3525	3525	3525
0.2	4150	4150	4138	4100	4100	4050	3988	3938	3888	3788
	3688	3500	3275	3163	3088	3013	2963	2888	2875	2850
0.5	4688	4675	4663	4588	4475	4313	4138	3975	3813	3588
	3388	3025	2613	2450	2363	2300	2250	2213	2200	2188
0.8	5150	5138	5075	4850	4513	4213	3925	3550	3200	2938
	2725	2275	1913	1775	1725	1688	1650	1625	1625	1625
1.0	5513	5475	5325	4813	4263	3675	3138	2750	2450	2175
	1950	1575	1325	1213	1175	1175	1163	1175	1175	1188
1.2	5738	5663	5375	4563	3738	3038	2475	2100	1825	1600
	1438	1138	950	888	850	863	863	875	888	900
1.5	5825	5700	5213	4075	3075	2363	1863	1525	1313	1150
	1038	838	700	663	650	650	663	675	688	688
1.8	5800	5613	4900	3550	2488	1825	1425	1150	988	863
	788	625	525	500	488	500	513	525	538	550
2.0	5663	5388	4450	2925	1913	1350	1063	863	750	650
	575	463	400	375	375	375	388	400	413	425
2.5	5313	4838	3538	1900	1163	800	625	513	450	388
	350	288	250	238	238	238	250	263	288	288
3.0	4813	4163	2638	1225	713	475	375	313	275	238
	213	175	163	150	150	163	175	175	188	200
3.5	4363	3575	1975	825	463	313	250	213	188	163
	150	125	113	100	113	113	125	125	150	150
4.0	3950	3063	1463	588	338	225	175	150	138	125
	113	88	75	75	75	88	100	100	113	113
4.5	3575	2588	1100	413	250	175	138	113	100	88
	88	75	75	63	63	75	75	88	88	100
5.0	3250	2188	863	300	188	125	100	88	75	75
	63	63	63	50	50	63	63	63	75	75
5.5	2963	1838	675	238	150	100	75	75	63	63
	0	0	0	0	0	0	0	0	0	0
6.0	2713	2025	538	188	113	75	63	63	50	0
	0	0	0	0	0	0	0	0	0	0
6.5	2475	1350	438	150	88	63	63	50	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	2300	1188	350	113	75	63	50	25	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	2113	1063	288	100	63	50	38	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	1975	938	250	88	50	38	38	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	1850	850	213	75	50	38	38	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	1725	763	175	63	38	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	1638	688	150	50	38	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	1575	625	138	50	25	25	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	1475	575	125	38	25	13	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	1375	525	100	38	25	13	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	1288	488	100	38	25	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	1225	450	88	25	25	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Table A15 RTAB15.RTB

Name = Dutch DOT porous Q0 = 0.100 s1=0.689

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300	5300 5300
0.2	5550 5210	5540 5090	5590 4910	5530 4790	5480 4680	5450 4580	5420 4570	5340 4550	5260 4510	5230 4540
0.5	6020 4380	5930 4010	5540 3760	5300 3600	5160 3510	5020 3510	4890 3480	4720 3520	4560 3430	4460 3510
0.8	5010 3190	4930 2840	5020 2690	4790 2560	4610 2490	4390 2490	4140 2540	3680 2570	3590 2570	3370 2610
1.0	4680 2240	4640 1960	4630 1800	4260 1770	3870 1740	3480 1800	3120 1790	2820 1880	2580 1860	2390 1900
1.2	4420 1550	4400 1360	4180 1260	3690 1220	3160 1210	2670 1270	2260 1310	1990 1350	1800 1390	1660 1390
1.5	4140 1080	4030 930	3760 890	3040 880	2490 900	1990 930	1600 970	1370 1010	1240 1050	1140 1070
1.8	3950 760	3790 660	3380 660	2500 640	1880 650	1460 710	1170 720	980 750	880 750	810 810
2.0	3650 540	3560 480	2790 490	2010 470	1400 500	1050 520	830 550	710 590	640 630	580 620
2.5	3220 310	2940 280	2250 270	1230 290	810 300	580 310	470 340	390 380	350 390	320 400
3.0	2840 170	2440 170	1640 170	820 180	470 200	320 230	270 240	240 270	230 290	200 280
3.5	2470 120	2090 110	1230 120	510 120	300 140	210 150	170 180	150 200	150 200	130 210
4.0	2150 90	1730 80	900 80	340 90	200 100	130 110	110 130	100 140	100 150	90 160
4.5	1900 60	1450 60	670 60	230 70	140 70	100 90	90 100	70 110	60 120	60 120
5.0	1650 50	1190 40	500 50	170 50	90 60	60 70	60 80	50 90	50 90	50 100
5.5	1450 0	960 0	370 0	130 0	70 0	50 0	50 0	50 0	40 0	30 0
6.0	1270 0	800 0	290 0	100 0	60 0	40 0	40 0	40 0	30 0	0 0
6.5	1170 0	710 0	230 0	70 0	50 0	40 0	30 0	30 0	0 0	0 0
7.0	1090 0	600 0	180 0	60 0	40 0	30 0	30 0	30 0	0 0	0 0
7.5	980 0	520 0	170 0	50 0	30 0	20 0	20 0	0 0	0 0	0 0
8.0	900 0	460 0	140 0	40 0	20 0	20 0	20 0	0 0	0 0	0 0
8.5	830 0	420 0	110 0	30 0	20 0	20 0	20 0	0 0	0 0	0 0
9.0	740 0	370 0	90 0	30 0	20 0	10 0	0 0	0 0	0 0	0 0
9.5	710 0	320 0	80 0	30 0	10 0	10 0	0 0	0 0	0 0	0 0
10.0	650 0	290 0	70 0	20 0	10 0	10 0	0 0	0 0	0 0	0 0
10.5	620 0	270 0	60 0	20 0	10 0	0 0	0 0	0 0	0 0	0 0
11.0	580 0	250 0	60 0	20 0	10 0	0 0	0 0	0 0	0 0	0 0
11.5	540 0	230 0	50 0	20 0	10 0	0 0	0 0	0 0	0 0	0 0
12.0	510 0	220 0	40 0	20 0	10 0	0 0	0 0	0 0	0 0	0 0

Table A16 RTAB16.RTB

Name = Porous Asphalt (UK) Q0 = 0.050 S1=0.582

Beta Tan(Gamma)	0.0 45.0	2.0 60.0	5.0 75.0	10.0 90.0	15.0 105.0	20.0 120.0	25.0 135.0	30.0 150.0	35.0 165.0	40.0 180.0
0.0	5571	5571	5571	5571	5571	5571	5571	5571	5571	5571
	5571	5571	5571	5571	5571	5571	5571	5571	5571	5571
0.2	5871	5871	5871	5871	5871	5871	5871	5871	5871	5871
	5414	5257	5100	5100	4942	4942	4942	4785	4785	4785
0.5	5871	5871	5871	5871	5757	5757	5485	5414	5285	4942
	4642	4328	4014	4014	3871	3871	3871	3714	3714	3714
0.8	5414	5414	5414	5257	5100	4942	4642	4328	4014	3714
	3400	3085	2942	2942	2942	2942	2942	2942	2942	2942
1.0	4785	4785	4785	4642	4171	4157	3714	3400	3085	2785
	2471	2171	2171	2171	2171	2171	2014	2014	2014	2014
1.2	4328	4328	4171	3871	3400	2942	2628	2171	1857	1700
	1542	1428	1471	1514	1542	1542	1628	1628	1700	1700
1.5	3871	3871	3714	3242	2557	2171	2014	1700	1542	1328
	1142	1085	1085	1142	1200	1242	1271	1300	1328	1357
1.8	3557	3400	3242	2785	2171	1771	1514	1300	1114	957
	871	742	771	828	900	957	985	1014	1042	1057
2.0	3242	3085	2785	2171	1671	1357	1142	957	871	742
	642	571	585	642	700	742	771	800	814	828
2.5	2785	2714	2085	1571	1057	828	685	571	500	428
	385	342	371	400	428	471	500	542	571	585
3.0	2285	2214	1642	957	614	471	371	300	257	242
	228	228	242	242	257	300	314	342	371	385
3.5	2085	1871	1242	585	357	257	214	185	171	157
	157	157	157	157	171	200	214	242	257	300
4.0	1885	1614	957	385	214	171	142	128	128	114
	114	114	114	128	142	157	171	185	214	242
4.5	1685	1357	714	285	171	128	100	100	85	85
	85	85	85	85	100	114	142	171	185	200
5.0	1514	1157	542	200	114	85	71	71	71	71
	71	57	71	71	85	100	128	142	142	157
5.5	1371	985	414	157	85	71	57	57	57	57
	0	0	0	0	0	0	0	0	0	0
6.0	1242	828	314	114	71	57	57	42	42	0
	0	0	0	0	0	0	0	0	0	0
6.5	1114	714	242	85	57	42	42	42	0	0
	0	0	0	0	0	0	0	0	0	0
7.0	1014	614	200	71	42	42	28	28	0	0
	0	0	0	0	0	0	0	0	0	0
7.5	957	542	171	57	42	28	28	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.0	900	471	142	42	28	28	28	0	0	0
	0	0	0	0	0	0	0	0	0	0
8.5	828	400	128	42	28	28	28	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.0	785	357	100	42	28	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
9.5	742	328	100	28	28	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.0	700	300	85	28	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
10.5	671	257	71	28	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.0	628	228	57	28	14	14	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
11.5	600	200	57	28	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
12.0	585	185	57	14	14	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

Appendix 2

Index

Page

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

Q

R

S

X

Y

LiDAC International
Lighting Design and Application Centre
P.O. Box 80020
5600 JM Eindhoven
The Netherlands

http://www.lightingsoftware.philips.com