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# Validation of AGi32 against CIE 171:2006

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## Introduction

The level of sophistication of lighting simulation software has increased dramatically over the last few years, however, until recently the only data available to verify the results obtained from the use of the different software programs was empirical evidence obtained from field measurements for specific scenarios.
The following document describes the performance of AGi32 V 1.94 against the CIE Technical report CIE 171:2006 (Test Cases to Assess the Accuracy of Lighting Computer Programs), this document was prepared by the CIE in order to help program users and developers in assessing the accuracy of lighting computer programs and to identify their weaknesses. An abstract of the document can be found at http://www.cie.co.at/publ/abst/171-06.html

This document provides a brief explanation of each test, in order to save the reader the time and expense of purchasing the CIE 171:2006 document; however, for those readers interested, the complete document can be purchased at http://www.techstreet.com/ciegate.tmpl

The validation approach is based on the concept of testing the different aspects of light propagation separately. A suite of tests was designed and each test addressed a specific aspect of the lighting simulation domain.

## Acknowledgments

The authors would like to thank all who contributed to the preparation of this report. In particular, the team at Lighting Analysts for answering our questions and discussing openly the capabilities and limitations of AGi32; Janani Ramanath who performed many of the calculations and analyses, and Ian Ashdown of Byheart Consultants for his work on the theoretical end, for preparing the Appendix documents and serving as a liaison with the CIE.

## Testing procedures:

Unless otherwise specified, all testing was conducted using the standard settings and features of AGi32 Version 1.94

## Errors and uncertainties:

Ranges presented in the tables of section 4 represent uncertainties of +/- 6.7% in the measured (physical) data and uncertainties of +/- 10.5% in the simulation plus measured data. These uncertainties are due to different factors, for more information on specific error and uncertainties calculations, refer directly to the CIE 171:2006 document.

## Report format:

The report follows the document's recommendation on the presentation of experimental measurements. See below for example.

| | | E (lx) on measurement points | | | |
|---|---|---|---|---|---|
| | | A1 | A2 | A3 | A4 |
| Global error upper limit | | 296 | 574 | 606 | 388 |
| Measurement upper limit | | 278 | 539 | 569 | 364 |
| | Simulation | | | | |
| Measurement lower limit | | 237 | 459 | 484 | 310 |
| Global error lower limit | | 219 | 424 | 448 | 287 |

Table 1: Example of recommended presentation for experimental measurements

# Test cases

## Section 4

### 4.1 Artificial Lighting Scenario – CFL, Grey wall

This scenario was designed to test the ability to measure a set of 4 “lamp only” luminaires in a rectangular room, with grey walls.

**Room geometry**

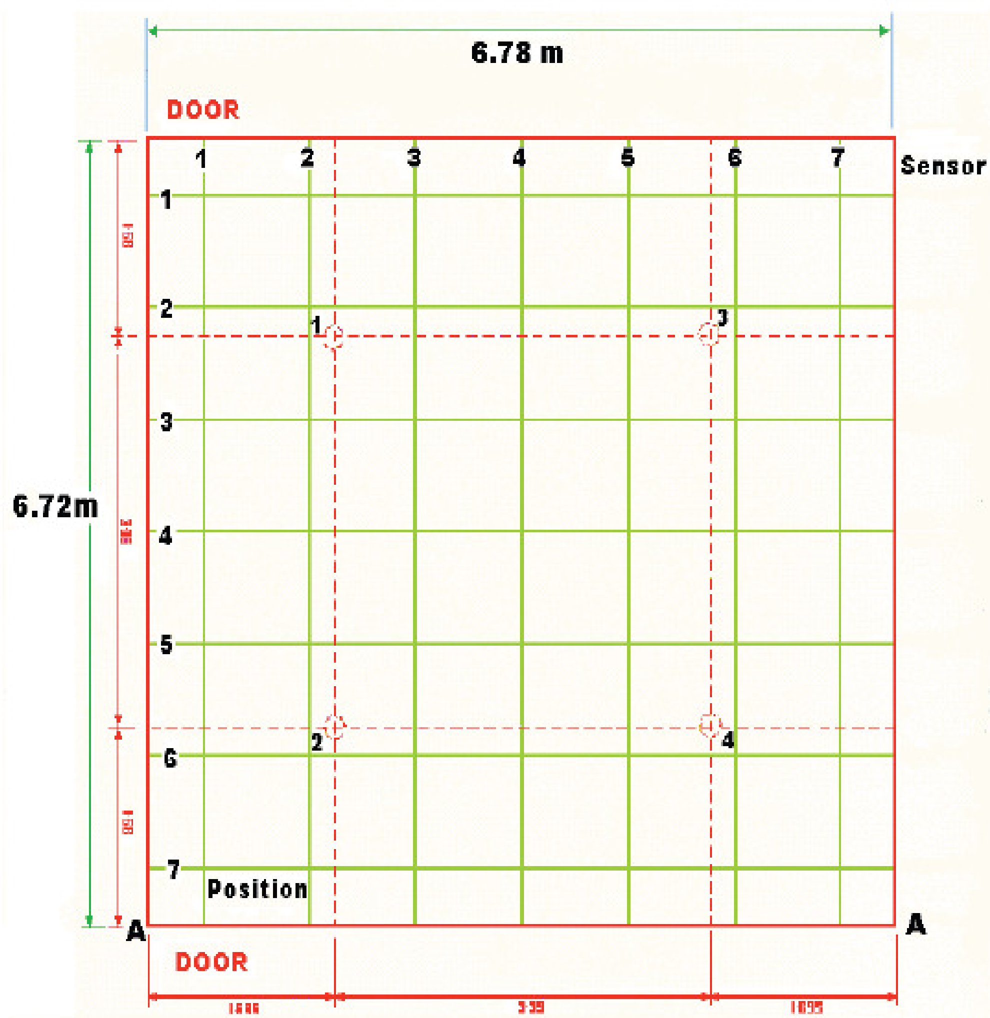
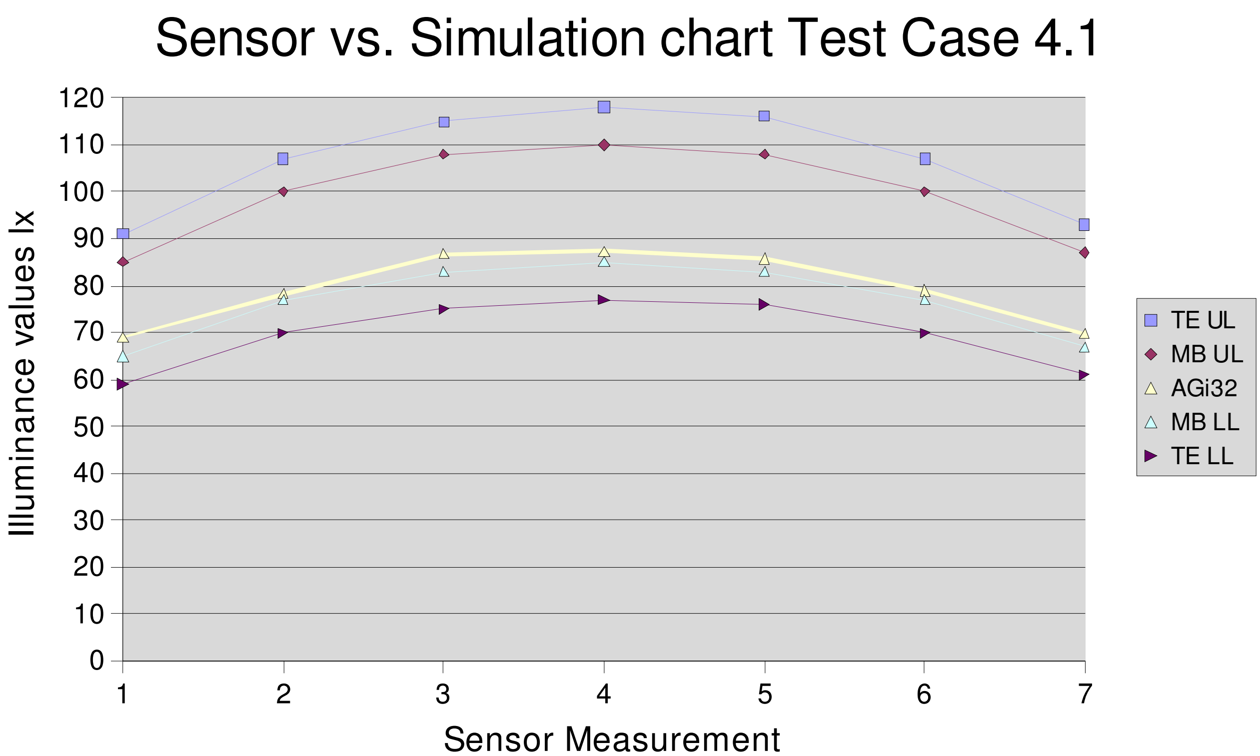


TABLE 1
TEST CASE 4.1

| Position | Sensor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 91 | 107 | 115 | 118 | 116 | 107 | 93 |
| MB UL | 85 | 100 | 108 | 110 | 108 | 100 | 87 |
| AGi32 | 69 | 78.3 | 86.7 | 87.3 | 85.8 | 79 | 69.8 |
| MB LL | 65 | 77 | 83 | 85 | 83 | 77 | 67 |
| TE LL | 59 | 70 | 75 | 77 | 76 | 70 | 61 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 103 | 124 | 130 | 129 | 129 | 124 | 105 |
| MB UL | 96 | 116 | 122 | 120 | 121 | 116 | 98 |
| AGi32 | 80 | 91 | 98.5 | 99.3 | 98.4 | 91.8 | 80.8 |
| MB LL | 74 | 89 | 94 | 93 | 93 | 89 | 75 |
| TE LL | 67 | 81 | 85 | 84 | 84 | 81 | 68 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 112 | 132 | 141 | 141 | 141 | 131 | 113 |
| MB UL | 105 | 123 | 132 | 132 | 132 | 122 | 106 |
| AGi32 | 86.6 | 97.3 | 106 | 108 | 106 | 97.9 | 88.2 |
| MB LL | 81 | 95 | 101 | 102 | 101 | 94 | 81 |
| TE LL | 73 | 86 | 92 | 92 | 92 | 86 | 74 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 115 | 133 | 143 | 146 | 143 | 133 | 116 |
| MB UL | 108 | 124 | 133 | 137 | 133 | 124 | 108 |
| AGi32 | 88.2 | 97.4 | 108 | 109 | 108 | 97.9 | 89.2 |
| MB LL | 83 | 96 | 103 | 105 | 103 | 96 | 83 |
| TE LL | 75 | 87 | 93 | 96 | 93 | 87 | 76 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 113 | 132 | 141 | 140 | 141 | 132 | 112 |
| MB UL | 105 | 124 | 131 | 131 | 131 | 123 | 105 |
| AGi32 | 87.6 | 97.7 | 106 | 109 | 106 | 98 | 87.8 |
| MB LL | 81 | 95 | 101 | 101 | 101 | 95 | 81 |
| TE LL | 74 | 86 | 92 | 92 | 92 | 86 | 73 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 103 | 124 | 130 | 127 | 130 | 123 | 104 |
| MB UL | 97 | 116 | 121 | 119 | 121 | 115 | 97 |
| AGi32 | 80.1 | 91 | 98.5 | 99.2 | 98 | 91.4 | 80.7 |
| MB LL | 74 | 89 | 93 | 92 | 93 | 89 | 75 |
| TE LL | 68 | 81 | 85 | 83 | 85 | 81 | 68 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 92 | 108 | 116 | 117 | 115 | 108 | 92 |
| MB UL | 86 | 100 | 108 | 109 | 107 | 100 | 86 |
| AGi32 | 68.9 | 78.6 | 86.1 | 87.2 | 86.3 | 78.7 | 69.6 |
| MB LL | 66 | 77 | 83 | 84 | 83 | 77 | 66 |
| TE LL | 60 | 70 | 76 | 76 | 75 | 70 | 60 |

Out of range measurement
Out of range global error

**Graphical representation of measurements**




**Results**

The software simulation results all were inside the measurement Upper and Lower limits.

**4.2 Artificial Lighting Scenario – Opal luminaire, Grey wall**

This scenario was designed to test the ability to measure a set of 4 opal luminaires with specific photometric distributions in a rectangular room, with grey walls. The test protocol is similar to 4.1

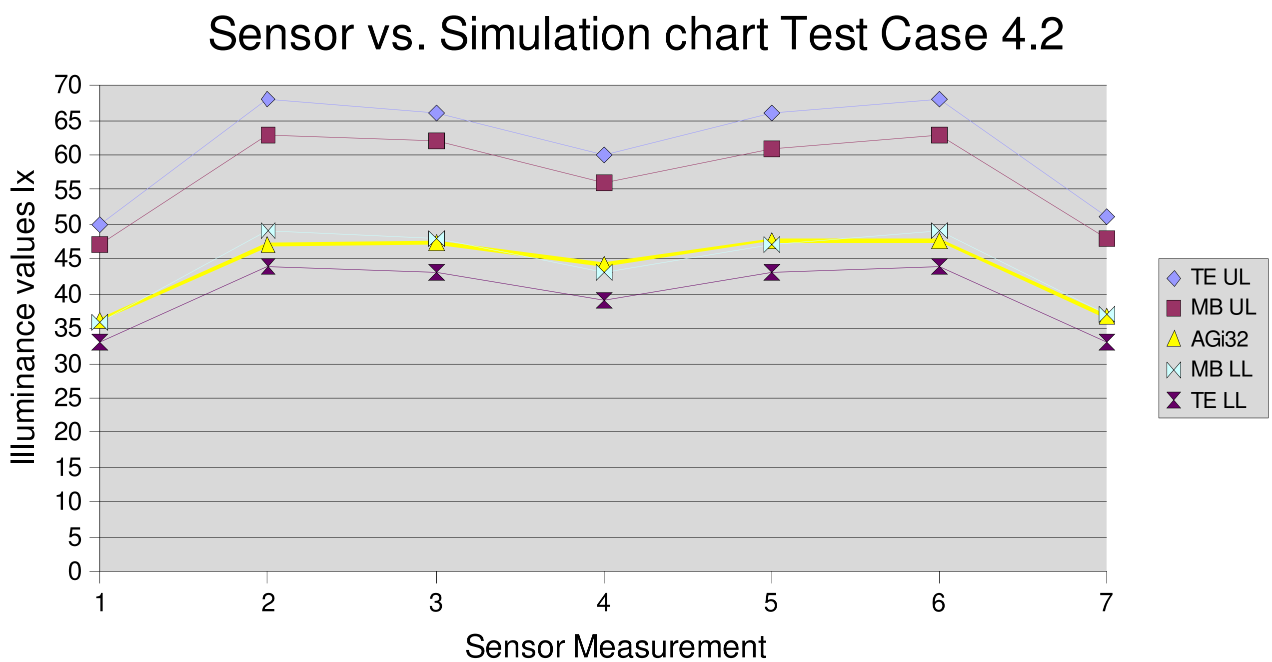
TABLE 2
TEST CASE 4.2

| Position | Sensor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 50 | 68 | 66 | 60 | 66 | 68 | 51 |
| MB UL | 47 | 63 | 62 | 56 | 61 | 63 | 48 |
| AGi32 | 36.3 | 47.2 | 47.4 | 44.3 | 47.8 | 47.8 | 36.8 |
| MB LL | 36 | 49 | 48 | 43 | 47 | 49 | 37 |
| TE LL | 33 | 44 | 43 | 39 | 43 | 44 | 33 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 65 | 93 | 88 | 77 | 87 | 93 | 67 |
| MB UL | 61 | 87 | 83 | 72 | 81 | 87 | 62 |
| AGi32 | 47 | 64.3 | 62.7 | 56 | 63.3 | 65.3 | 47.8 |
| MB LL | 47 | 67 | 64 | 55 | 63 | 67 | 48 |
| TE LL | 43 | 61 | 58 | 50 | 57 | 61 | 44 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 65 | 90 | 87 | 77 | 85 | 90 | 66 |
| MB UL | 61 | 84 | 81 | 72 | 80 | 84 | 62 |
| AGi32 | 47.3 | 62.7 | 62.3 | 57.4 | 63.4 | 64.3 | 48.6 |
| MB LL | 47 | 65 | 62 | 56 | 61 | 65 | 48 |
| TE LL | 42 | 59 | 57 | 50 | 56 | 59 | 43 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 61 | 79 | 77 | 72 | 77 | 79 | 61 |
| MB UL | 57 | 74 | 72 | 67 | 72 | 73 | 57 |
| AGi32 | 44.1 | 56 | 57.3 | 55.5 | 59.3 | 59 | 46.5 |
| MB LL | 44 | 57 | 55 | 52 | 55 | 56 | 44 |
| TE LL | 40 | 52 | 50 | 47 | 50 | 51 | 40 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 66 | 89 | 85 | 75 | 83 | 87 | 64 |
| MB UL | 61 | 83 | 79 | 70 | 78 | 82 | 60 |
| AGi32 | 47.2 | 62.6 | 62.7 | 58.8 | 66.6 | 68.2 | 51.3 |
| MB LL | 47 | 64 | 61 | 54 | 60 | 63 | 46 |
| TE LL | 43 | 58 | 55 | 49 | 54 | 57 | 42 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 65 | 92 | 85 | 74 | 83 | 89 | 63 |
| MB UL | 61 | 86 | 80 | 69 | 78 | 83 | 59 |
| AGi32 | 46.9 | 64.3 | 63.2 | 58.2 | 67.9 | 70.9 | 51.7 |
| MB LL | 47 | 66 | 61 | 53 | 60 | 64 | 46 |
| TE LL | 43 | 60 | 56 | 48 | 54 | 58 | 41 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 50 | 66 | 64 | 57 | 62 | 64 | 48 |
| MB UL | 47 | 62 | 60 | 54 | 58 | 60 | 45 |
| AGi32 | 36.2 | 47.3 | 48.1 | 46.1 | 51.2 | 51.8 | 39.8 |
| MB LL | 36 | 48 | 46 | 41 | 45 | 46 | 35 |
| TE LL | 33 | 43 | 42 | 38 | 41 | 42 | 31 |

Out of range Measurement

Out of range Global error

**Graphical representation of measurements**




**Results**

Some of the software simulation results were outside the measurement lower limit, however, all were within the Global error limits.

**4.3 Artificial Lighting Scenario – Semi-Specular reflector luminaire, Grey wall**

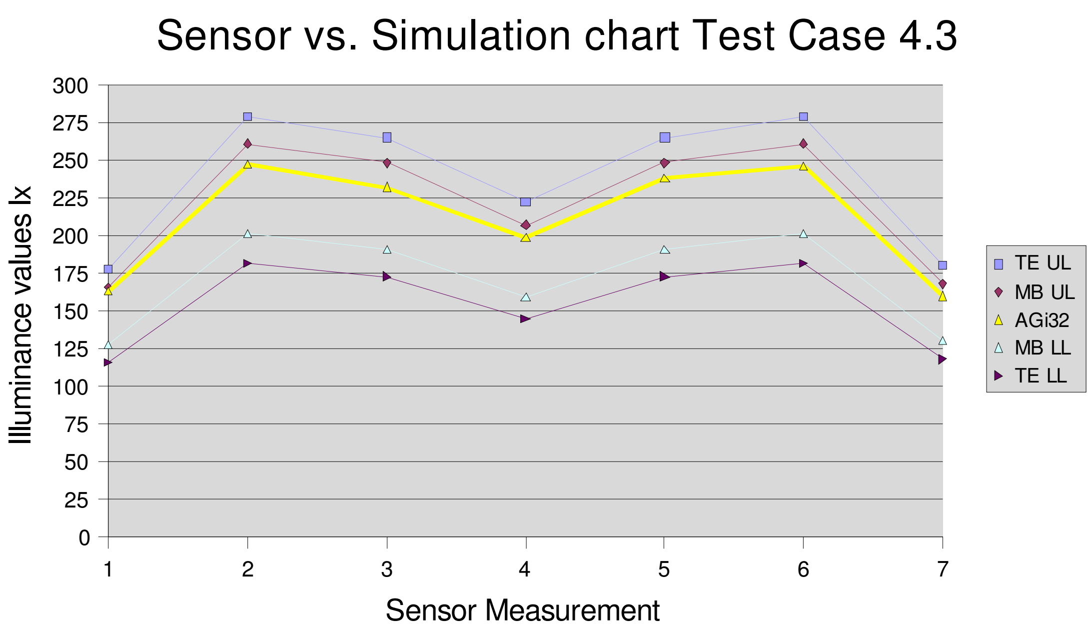
This scenario was designed to test the ability to measure a set of 4 luminaires using semi-specular reflectors with specific photometric distributions in a rectangular room, with grey walls. The test protocol is similar to 4.1

# TABLE 3
## TEST CASE 4.3

| **Position** | **Sensor** | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 178 | 279 | 265 | 222 | 265 | 279 | 180 |
| MB UL | 166 | 261 | 248 | 207 | 248 | 261 | 168 |
| AGi32 | 163 | 247 | 232 | 199 | 238 | 246 | 160 |
| MB LL | 128 | 201 | 191 | 159 | 191 | 201 | 130 |
| TE LL | 116 | 182 | 173 | 145 | 173 | 182 | 118 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 206 | 312 | 305 | 258 | 308 | 317 | 214 |
| MB UL | 192 | 291 | 285 | 241 | 288 | 296 | 200 |
| AGi32 | 177 | 254 | 244 | 216 | 253 | 256 | 177 |
| MB LL | 148 | 224 | 219 | 186 | 222 | 228 | 154 |
| TE LL | 135 | 203 | 199 | 169 | 201 | 207 | 140 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 229 | 353 | 337 | 281 | 342 | 358 | 232 |
| MB UL | 214 | 330 | 315 | 262 | 319 | 334 | 217 |
| AGi32 | 196 | 291 | 281 | 245 | 290 | 295 | 199 |
| MB LL | 165 | 254 | 242 | 202 | 246 | 257 | 167 |
| TE LL | 149 | 230 | 220 | 183 | 223 | 234 | 152 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 209 | 310 | 303 | 265 | 311 | 315 | 207 |
| MB UL | 195 | 290 | 283 | 247 | 290 | 294 | 193 |
| AGi32 | 194 | 285 | 269 | 243 | 280 | 289 | 192 |
| MB LL | 150 | 223 | 218 | 191 | 224 | 227 | 149 |
| TE LL | 136 | 203 | 198 | 173 | 203 | 206 | 135 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 230 | 358 | 345 | 286 | 344 | 356 | 229 |
| MB UL | 215 | 334 | 322 | 267 | 321 | 332 | 214 |
| AGi32 | 205 | 301 | 287 | 249 | 294 | 296 | 196 |
| MB LL | 165 | 257 | 248 | 206 | 247 | 256 | 165 |
| TE LL | 150 | 234 | 225 | 187 | 225 | 232 | 150 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 221 | 329 | 317 | 264 | 312 | 317 | 209 |
| MB UL | 206 | 308 | 296 | 247 | 291 | 296 | 196 |
| AGi32 | 182 | 265 | 255 | 221 | 251 | 253 | 176 |
| MB LL | 159 | 237 | 228 | 190 | 224 | 228 | 151 |
| TE LL | 144 | 215 | 207 | 173 | 204 | 207 | 137 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 188 | 289 | 273 | 229 | 274 | 283 | 180 |
| MB UL | 176 | 270 | 255 | 214 | 255 | 264 | 168 |
| AGi32 | 169 | 255 | 240 | 207 | 244 | 250 | 164 |
| MB LL | 135 | 208 | 196 | 165 | 197 | 204 | 129 |
| TE LL | 123 | 189 | 178 | 150 | 179 | 185 | 117 |

Out of Range Measurement
Out of range Global error

**Graphical representation of measurements**




**Results**

The software simulation results all were inside the measurement Upper and Lower limits.

**4.4 Artificial Lighting Scenario – CFL, Black wall.**

This scenario was designed to test the ability to measure a set of 4 "lamp only" luminaires in a rectangular room, with black walls in order to avoid errors related to inter-reflections. The test protocol is similar to 4.1

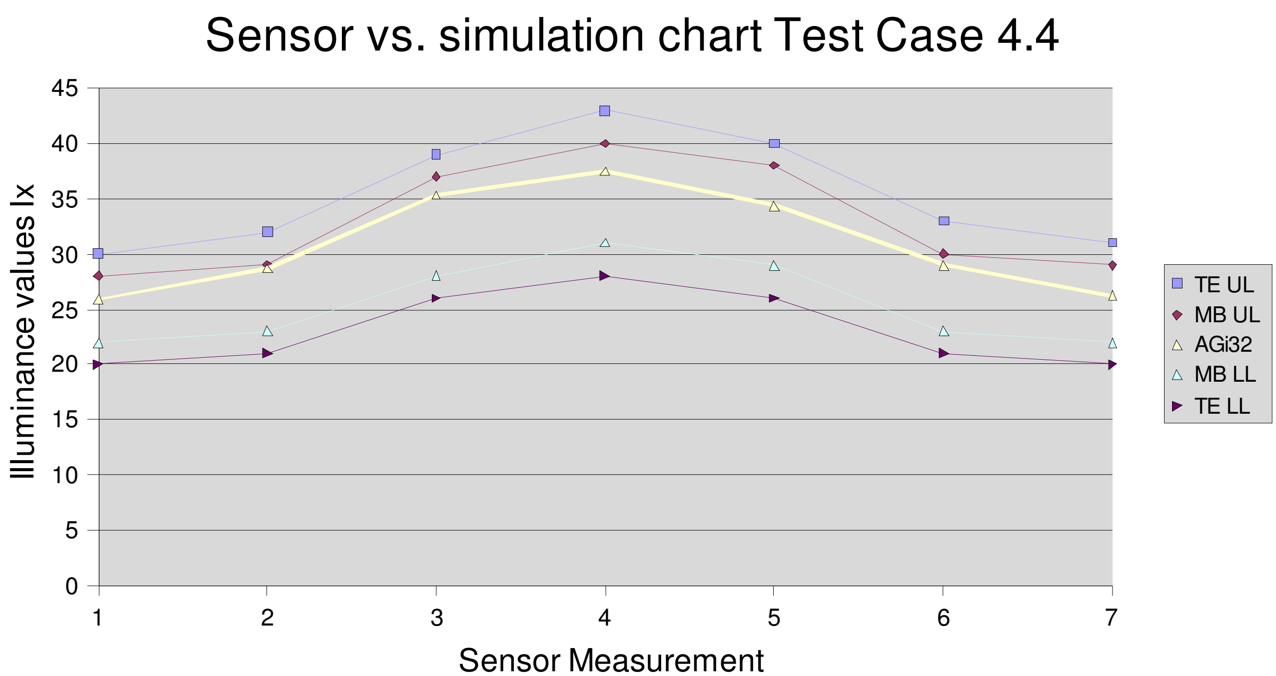
TABLE 4

TEST CASE 4.4

| Position | Sensor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 30 | 32 | 39 | 43 | 40 | 33 | 31 |
| MB UL | 28 | 29 | 37 | 40 | 38 | 30 | 29 |
| 1 | 26 | 28.8 | 35.3 | 37.4 | 34.3 | 28.9 | 26.1 |
| MB LL | 22 | 23 | 28 | 31 | 29 | 23 | 22 |
| TE LL | 20 | 21 | 26 | 28 | 26 | 21 | 20 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 31 | 32 | 39 | 42 | 41 | 33 | 31 |
| MB UL | 28 | 30 | 37 | 39 | 38 | 31 | 29 |
| 2 | 27.9 | 29.3 | 36.1 | 39.1 | 35.7 | 29.5 | 27.9 |
| MB LL | 22 | 23 | 28 | 30 | 29 | 24 | 23 |
| TE LL | 20 | 21 | 26 | 28 | 27 | 21 | 21 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 39 | 41 | 51 | 54 | 51 | 40 | 38 |
| MB UL | 36 | 38 | 48 | 51 | 47 | 38 | 35 |
| 3 | 34.6 | 37.2 | 44.9 | 49.5 | 44.5 | 37.3 | 35.4 |
| MB LL | 28 | 29 | 37 | 39 | 37 | 29 | 27 |
| TE LL | 25 | 27 | 33 | 36 | 33 | 26 | 25 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 43 | 46 | 57 | 62 | 57 | 46 | 43 |
| MB UL | 40 | 43 | 53 | 57 | 53 | 43 | 40 |
| 4 | 37.1 | 41.3 | 50.2 | 52.3 | 49.9 | 41.3 | 37.3 |
| MB LL | 31 | 33 | 41 | 44 | 41 | 33 | 31 |
| TE LL | 28 | 30 | 37 | 40 | 37 | 30 | 28 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 38 | 40 | 51 | 54 | 51 | 41 | 38 |
| MB UL | 35 | 38 | 48 | 51 | 48 | 38 | 36 |
| 5 | 34.8 | 36.8 | 44.4 | 48.9 | 44 | 37 | 34.3 |
| MB LL | 27 | 29 | 37 | 39 | 37 | 29 | 28 |
| TE LL | 25 | 26 | 33 | 35 | 34 | 27 | 25 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 31 | 33 | 41 | 43 | 40 | 33 | 31 |
| MB UL | 29 | 30 | 39 | 40 | 38 | 31 | 29 |
| 6 | 28.2 | 29.8 | 36.6 | 39.5 | 36.3 | 30 | 28.4 |
| MB LL | 23 | 23 | 30 | 31 | 29 | 23 | 23 |
| TE LL | 20 | 21 | 27 | 28 | 26 | 21 | 20 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 31 | 33 | 42 | 44 | 41 | 33 | 32 |
| MB UL | 29 | 31 | 39 | 41 | 38 | 31 | 30 |
| 7 | 26.6 | 29.4 | 35.4 | 38.4 | 35.8 | 29.4 | 26.7 |
| MB LL | 22 | 24 | 30 | 32 | 29 | 24 | 23 |
| TE LL | 20 | 21 | 27 | 29 | 26 | 22 | 21 |

| | |
|---|---|
| (yellow) | Out of range Measurement |
| (red) | Out of range Global error |

**Graphical representation of measurements**




**Results**

Some of the software simulation results were outside the measurement limit, however, all were within the Global error limits.

**4.5 Artificial Lighting Scenario – Opal, Black wall**

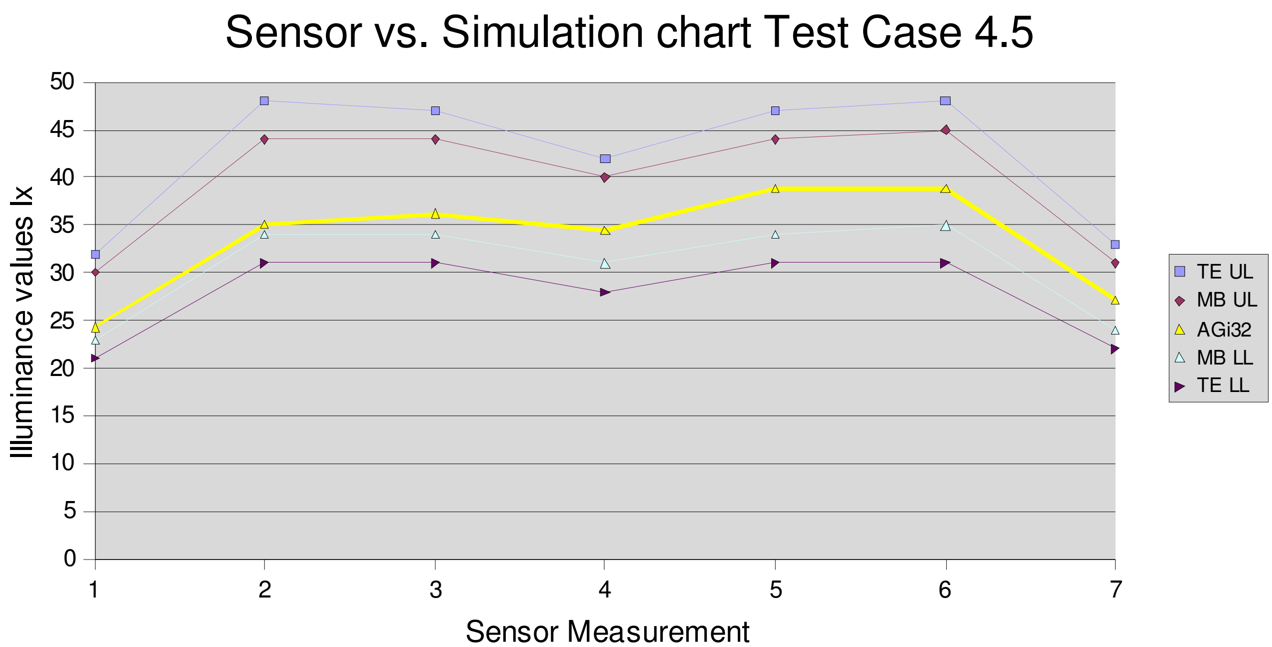
This scenario was designed to test the ability to measure a set of 4 "Opal" luminaires with a specific photometric distribution in a rectangular room, with black walls in order to avoid errors related to inter-reflections. The test protocol is similar to 4.1

# TABLE 5
# TEST CASE 4.5

| Position | Sensor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 32 | 48 | 47 | 42 | 47 | 48 | 33 |
| MB UL | 30 | 44 | 44 | 40 | 44 | 45 | 31 |
| AGi32 | 24.3 | 35.1 | 36.2 | 34.4 | 38.9 | 38.9 | 27.1 |
| MB LL | 23 | 34 | 34 | 31 | 34 | 35 | 24 |
| TE LL | 21 | 31 | 31 | 28 | 31 | 31 | 22 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 46 | 73 | 70 | 60 | 69 | 74 | 48 |
| MB UL | 43 | 68 | 66 | 56 | 64 | 69 | 44 |
| AGi32 | 34.8 | 53.3 | 52.9 | 47.9 | 57.2 | 59.4 | 38.8 |
| MB LL | 33 | 53 | 51 | 43 | 49 | 53 | 34 |
| TE LL | 30 | 48 | 46 | 39 | 45 | 48 | 31 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 47 | 71 | 70 | 61 | 69 | 72 | 48 |
| MB UL | 44 | 66 | 65 | 57 | 65 | 67 | 45 |
| AGi32 | 35.5 | 52.4 | 53.1 | 49.4 | 56.8 | 57.5 | 39 |
| MB LL | 34 | 51 | 50 | 44 | 50 | 52 | 34 |
| TE LL | 30 | 46 | 45 | 40 | 45 | 47 | 31 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 43 | 61 | 62 | 56 | 61 | 61 | 43 |
| MB UL | 40 | 57 | 57 | 53 | 57 | 57 | 40 |
| AGi32 | 32.7 | 46 | 48 | 46.4 | 49.9 | 48.7 | 34.8 |
| MB LL | 31 | 44 | 44 | 40 | 44 | 44 | 31 |
| TE LL | 28 | 40 | 40 | 37 | 40 | 40 | 28 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 47 | 71 | 68 | 60 | 68 | 70 | 47 |
| MB UL | 44 | 66 | 64 | 56 | 63 | 65 | 43 |
| AGi32 | 35.6 | 52.5 | 52.8 | 48 | 53.8 | 53.8 | 36.7 |
| MB LL | 34 | 51 | 49 | 43 | 49 | 50 | 33 |
| TE LL | 31 | 46 | 44 | 39 | 44 | 46 | 30 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 46 | 72 | 68 | 57 | 66 | 71 | 45 |
| MB UL | 43 | 67 | 63 | 54 | 62 | 66 | 42 |
| AGi32 | 34.9 | 53.4 | 52.4 | 46 | 53 | 54.2 | 35.6 |
| MB LL | 33 | 52 | 49 | 41 | 47 | 51 | 33 |
| TE LL | 30 | 47 | 44 | 37 | 43 | 46 | 30 |
| Position | Sensor | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 32 | 47 | 46 | 40 | 45 | 45 | 31 |
| MB UL | 30 | 44 | 43 | 38 | 42 | 42 | 29 |
| AGi32 | 24.4 | 35.1 | 35.7 | 32.9 | 36 | 35.5 | 24.8 |
| MB LL | 23 | 34 | 33 | 29 | 32 | 33 | 23 |
| TE LL | 21 | 30 | 30 | 26 | 29 | 30 | 20 |

| | |
|---|---|
| (yellow) | Out of range Measurement |
| (red) | Out of range Global error |

**Graphical representation of measurements**




**Results**

The software simulation results all were inside the measurement Upper and Lower limits.

**4.6 Artificial Lighting Scenario – semi-specular reflector luminaire, Black wall**

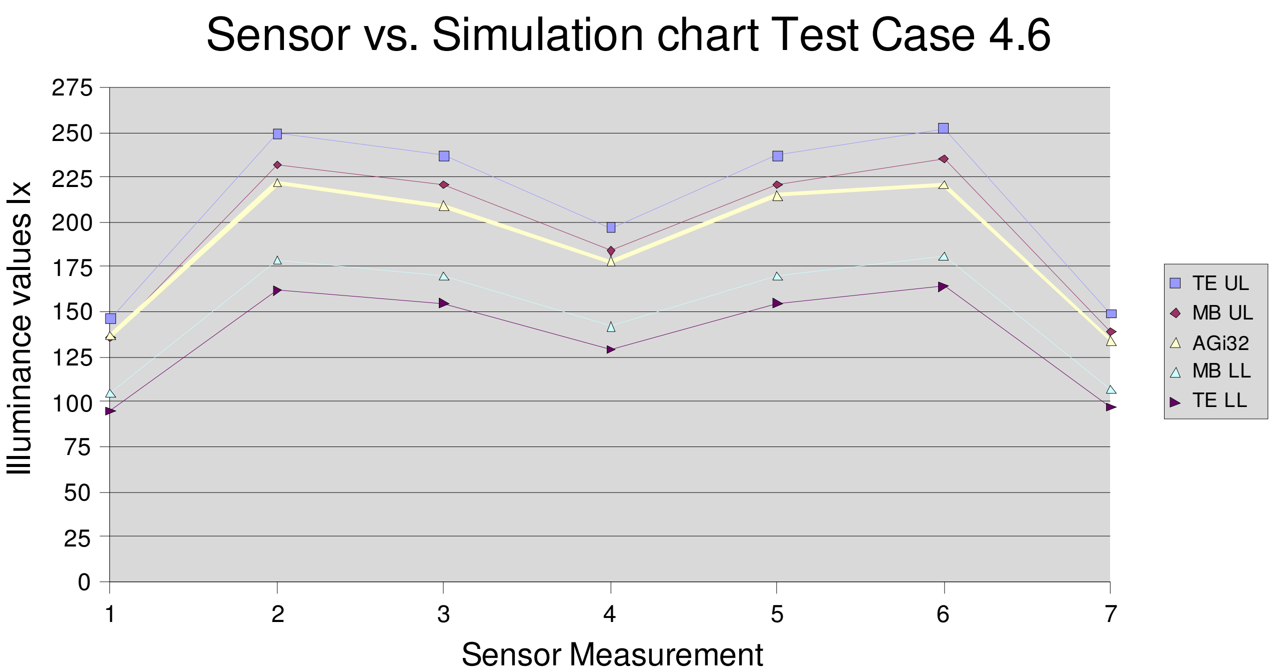
This scenario was designed to test the ability to measure a set of 4 luminaires using semi-specular reflectors with a specific photometric distribution in a rectangular room, with black walls in order to avoid errors related to inter-reflections. The test protocol is similar to 4.1

# TABLE 6
## TEST CASE 4.6

| Position | Sensor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 146 | 249 | 237 | 197 | 237 | 252 | 149 |
| MB UL | 136 | 232 | 221 | 184 | 221 | 235 | 139 |
| AGi32 | 137 | 222 | 209 | 178 | 215 | 221 | 134 |
| MB LL | 105 | 179 | 170 | 142 | 170 | 181 | 107 |
| TE LL | 95 | 162 | 155 | 129 | 155 | 164 | 97 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 172 | 288 | 282 | 236 | 284 | 294 | 179 |
| MB UL | 161 | 269 | 263 | 221 | 265 | 275 | 168 |
| AGi32 | 151 | 234 | 226 | 199 | 235 | 237 | 150 |
| MB LL | 124 | 207 | 202 | 170 | 204 | 211 | 129 |
| TE LL | 113 | 188 | 184 | 154 | 185 | 192 | 117 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 195 | 329 | 313 | 258 | 317 | 335 | 196 |
| MB UL | 182 | 307 | 292 | 241 | 296 | 312 | 183 |
| AGi32 | 171 | 272 | 264 | 229 | 272 | 276 | 173 |
| MB LL | 140 | 237 | 225 | 185 | 228 | 241 | 141 |
| TE LL | 127 | 215 | 204 | 168 | 207 | 218 | 128 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 178 | 287 | 278 | 242 | 285 | 290 | 176 |
| MB UL | 166 | 268 | 259 | 226 | 266 | 271 | 164 |
| AGi32 | 171 | 267 | 252 | 226 | 263 | 270 | 169 |
| MB LL | 128 | 206 | 200 | 174 | 205 | 209 | 126 |
| TE LL | 116 | 187 | 181 | 158 | 186 | 190 | 115 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 196 | 334 | 320 | 262 | 319 | 333 | 196 |
| MB UL | 183 | 312 | 299 | 244 | 298 | 311 | 183 |
| AGi32 | 179 | 282 | 270 | 231 | 276 | 277 | 171 |
| MB LL | 141 | 240 | 230 | 188 | 230 | 239 | 141 |
| TE LL | 128 | 218 | 209 | 171 | 208 | 217 | 128 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 186 | 306 | 292 | 242 | 287 | 292 | 175 |
| MB UL | 174 | 286 | 273 | 226 | 268 | 273 | 163 |
| AGi32 | 155 | 245 | 236 | 203 | 232 | 233 | 149 |
| MB LL | 134 | 220 | 210 | 174 | 206 | 210 | 126 |
| TE LL | 122 | 200 | 191 | 158 | 187 | 191 | 114 |
| **Position** | **Sensor** | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| TE UL | 155 | 258 | 241 | 202 | 242 | 251 | 146 |
| MB UL | 145 | 241 | 225 | 189 | 226 | 234 | 136 |
| AGi32 | 141 | 228 | 215 | 183 | 219 | 224 | 137 |
| MB LL | 111 | 186 | 173 | 145 | 174 | 180 | 105 |
| TE LL | 101 | 169 | 157 | 132 | 158 | 164 | 95 |

| | |
|---|---|
| (yellow) | Out of range Measurement |
| (red) | Out of range Global error |

**Graphical representation of measurements**




**Results**

Some of the software simulation results were outside the measurement limit, however, all were within the Global error limits

**Conclusion**

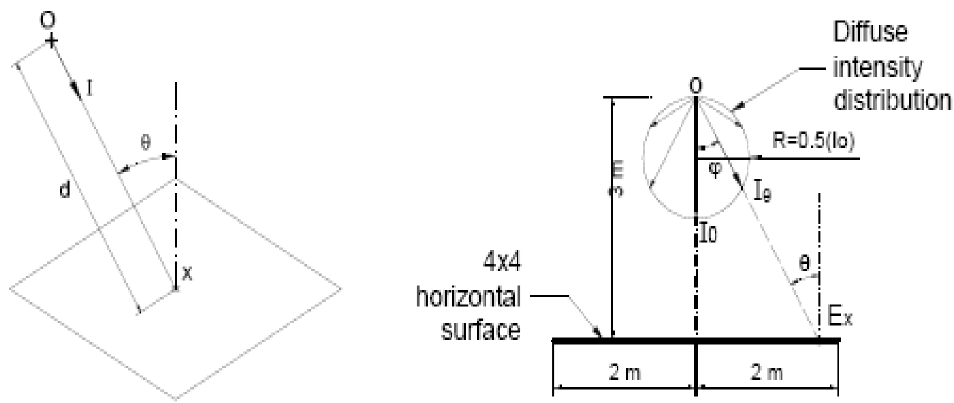
AGi32 performs well within the parameters set by the document and most of the time within the parameters of measurement error.

# Section 5

### 5.2 Simulation of point light sources.

This scenario is designed to test the capabilities of the software to calculate the direct illuminance under a point light source described by a photometric distribution file.

**Test case description**




**Measurement points distribution**

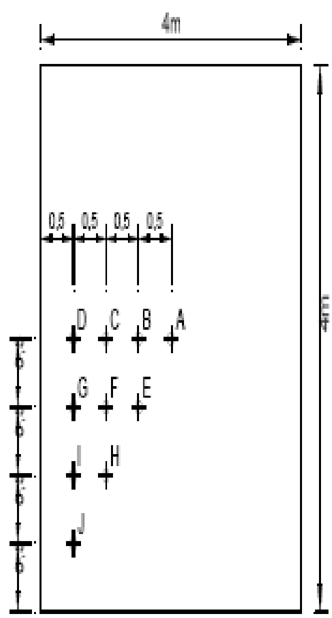
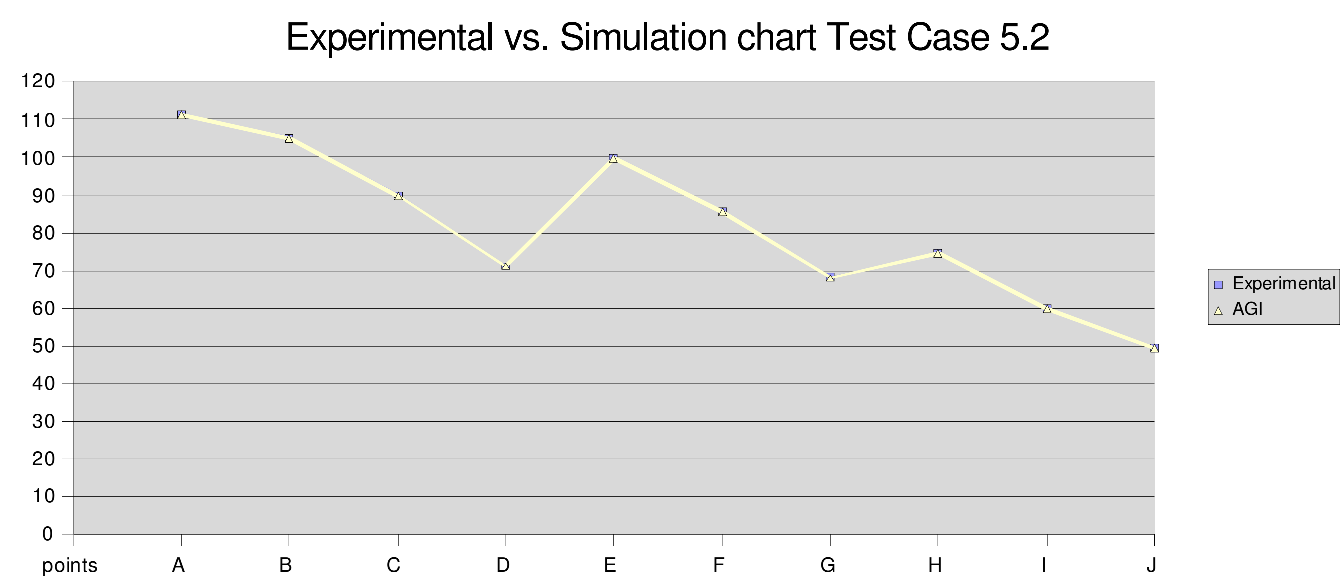
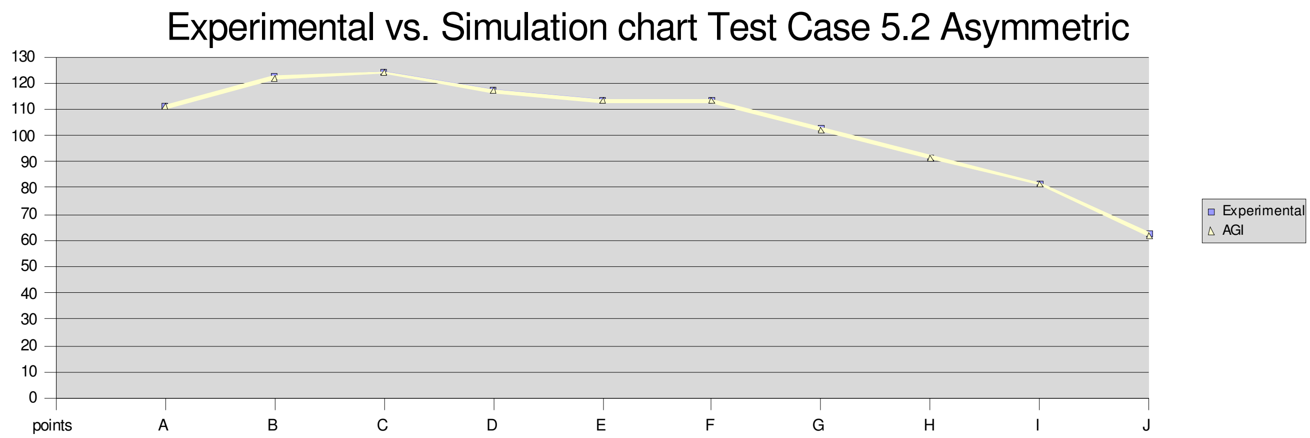


TABLE 7
TEST CASE 5.2

| points | d (m) | incidence (°) | Diffuse photom I (cd) | Experimental E (lx) | AGi32 E (lx) | CIE T9 photometry I (cd) | Experimental E (lx) | AGi32 E (lx) |
|---|---|---|---|---|---|---|---|---|
| A | 3 | 0 | 1000 | 111.11 | 111 | 1000 | 111.11 | 111 |
| B | 3.04 | 9.46 | 986.4 | 105.21 | 105 | 1146.1 | 122.25 | 122 |
| C | 3.16 | 18.43 | 948.7 | 90.02 | 89.9 | 1307.7 | 124.08 | 124 |
| D | 3.35 | 26.57 | 894.4 | 71.11 | 71.1 | 1475.5 | 117.31 | 117 |
| E | 3.08 | 13.26 | 973.3 | 99.73 | 99.6 | 1109.1 | 113.65 | 113 |
| F | 3.2 | 20.44 | 937 | 85.64 | 85.6 | 1240.9 | 113.41 | 113 |
| G | 3.39 | 27.79 | 884.7 | 68.06 | 68 | 1335.4 | 102.74 | 102 |
| H | 3.32 | 25.24 | 904.5 | 74.36 | 74.4 | 1113.8 | 91.57 | 91.6 |
| I | 3.5 | 31 | 857.2 | 59.98 | 59.9 | 1166.8 | 81.65 | 81.5 |
| J | 3.67 | 35.26 | 816.5 | 49.39 | 49.4 | 1027.5 | 62.16 | 62.1 |

**Graphical representation of measurements**





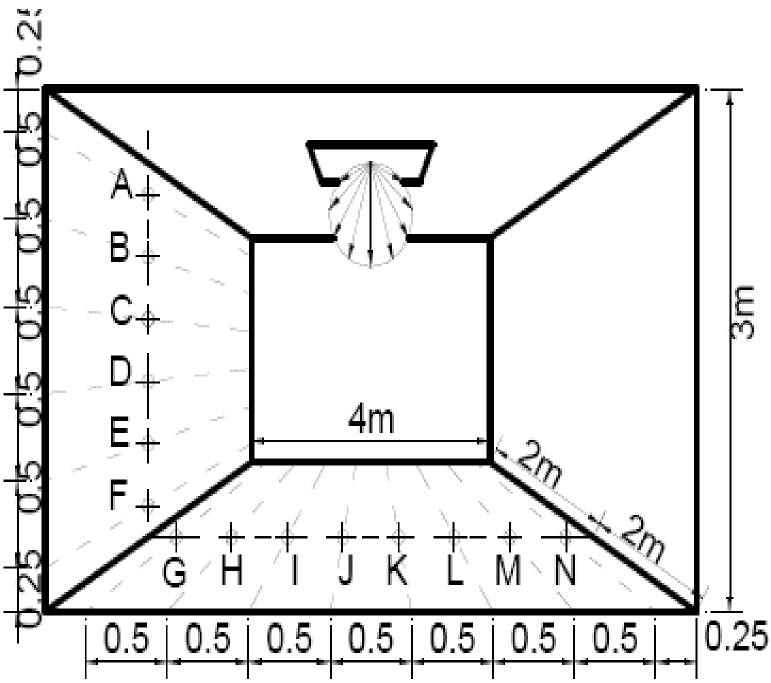

**Results**

The software simulation results all were consistent with the experimental values.

**5.3 Simulation of area light sources.**

This scenario is designed to test the capabilities of the software to calculate the direct illuminance under an area light source.
Note: In this case the advanced settings of AGi32 were used to force luminaire subdivision.

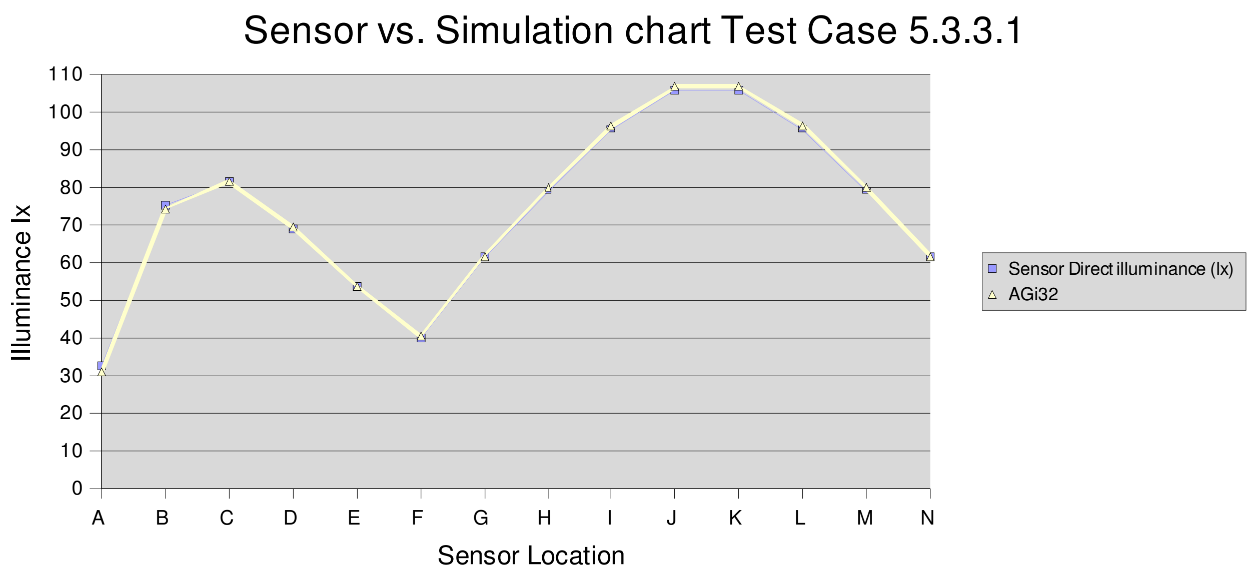
**Test case description**




**Measurement point distribution**

| TABLE 8 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST CASE 5.3.3.1 | | | | | | | | | | | | | | |
| Reference Points | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
| Sensor Direct illuminance (lx) | 32.68 | 75.09 | 81.38 | 69.12 | 53.41 | 39.9 | 61.27 | 79.18 | 95.52 | 105.89 | 105.89 | 95.52 | 79.18 | 61.27 |
| AGi32 | 30.8 | 74.4 | 81.5 | 69.5 | 53.8 | 40.3 | 61.7 | 79.8 | 96.4 | 106.7 | 106.7 | 96.4 | 79.8 | 61.7 |

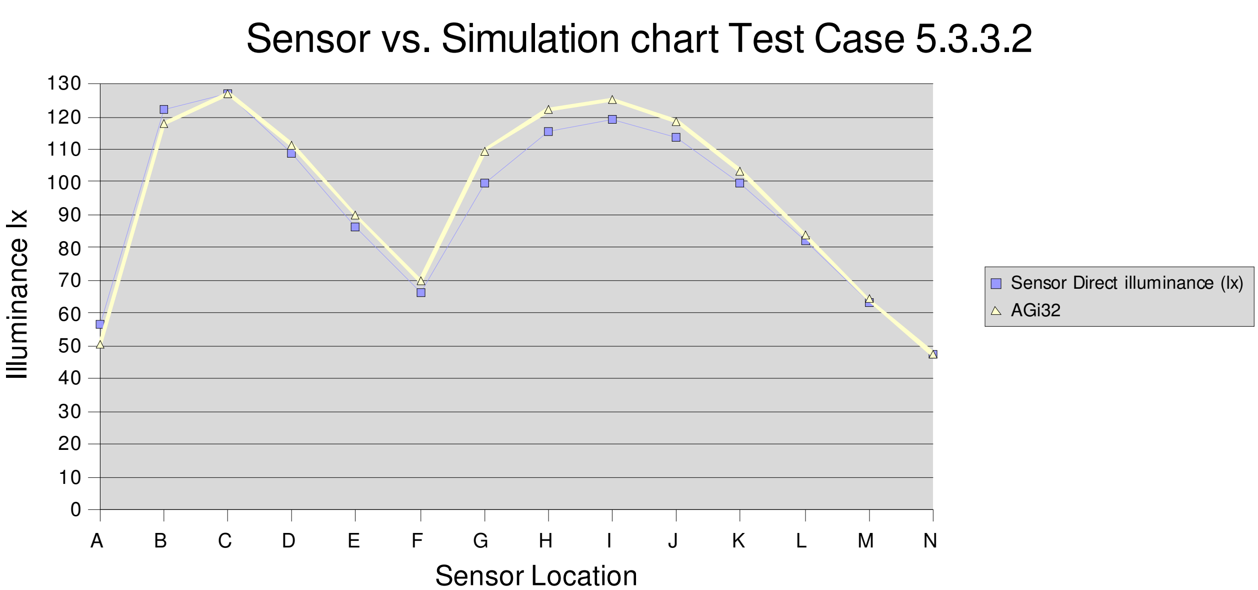
**Graphical Representation of Measurements**




**5.3 Asymmetric**

| TABLE 9 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST CASE 5.3.3.2 | | | | | | | | | | | | | | |
| Reference Points | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
| Sensor Direct illuminance (lx) | 56.73 | 122.1 | 126.95 | 108.61 | 86.13 | 66.07 | 99.62 | 115.53 | 119.34 | 113.8 | 99.97 | 81.98 | 63.3 | 47.39 |
| AGi32 | 50.5 | 117.9 | 127.1 | 111.3 | 89.7 | 70 | 109.6 | 122.1 | 125 | 118.4 | 103.4 | 83.8 | 64.2 | 47.5 |

**Graphical Representation of Measurements**



**5.4 Luminous flux conservation**

**Daylighting scenarios**: There were two different types of daylighting scenarios – one with openings of varying sizes on the ceiling and the other with openings in the wall. Only the scenarios with ceiling openings were considered, since AGi32 has an external virtual ground plane of a certain reflectance that cannot be disabled. This external ground plane would have interfered with the values reported.

In theory, the flux entering the room through the opening should be equal to the sum of the flux incident on all the surfaces. Upon performing the test though, a small percentage of error was found. There was also a difference observed between different sky types. The values in table 10 below are done using a clear sky while the values for a partly cloudy sky are shown in table 11.

Table 10 Test Case 5.4.2.1

| Scenario | opening size | opening location | Total Wall flux | Opening wall flux | Floor flux | Ceiling Flux | Total flux | Entering Flux | Difference | % error |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1x1 | ceiling | 5,188 | 5159.4 | 109824 | 0 | 120,171 | 116,495 | -3,676 | 3.16 |
| 2 | 2x2 | ceiling | 28,448 | 11404.4 | 439440 | 0 | 479,293 | 470,764 | -8,529 | 1.81 |
| 3 | 3x3 | ceiling | 75,804 | 17769 | 984832 | 0 | 1,078,405 | 1,063,620 | -14,785 | 1.39 |
| 4 | 4x4 | ceiling | 210,732 | 0 | 2E+06 | 0 | 1,955,132 | 1,909,696 | -45,436 | 2.38 |

Table 11 Test Case 5.4.2.1

| Scenario | opening size | opening location | Total Wall flux | Opening wall flux | Floor flux | Ceiling Flux | Total flux | Entering Flux | Difference | % error |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1x1 | ceiling | 15,907 | 12604.8 | 74288 | 0 | 102,800 | 94,538 | -8,262 | 8.74 |
| 2 | 2x2 | ceiling | 84,972 | 27666 | 297648 | 0 | 410,286 | 391,408 | -18,878 | 4.82 |
| 3 | 3x3 | ceiling | 221,964 | 42958.2 | 660128 | 0 | 925,050 | 892,386 | -32,664 | 3.66 |
| 4 | 4x4 | ceiling | 500,088 | 0 | 1E+06 | 0 | 1,661,432 | 1,634,880 | -26,552 | 1.62 |

**Electric lighting scenario**: A luminaire with a downward distribution was used. The flux from the luminaire should be equal to the flux incident on the room surfaces.

Table 12 Test Case 5.4.2.2

| Scenario | Total Wall flux | Floor flux | Ceiling flux | Total flux | Entering flux | Difference | % error |
|---|---|---|---|---|---|---|---|
| AL_1 | 1,249 | 4468.5 | 0 | 5,718 | 5,700 | -18 | 0.31 |

### 5.5 Directional transmittance of clear glass.

The objective of this section was to test if the transmittance of glass varied with the angle of incident light. The test geometry was a room with an opening in the ceiling covered with glass and parallel beams of light incident on the glass at varying angles.

Since incoming light needed to be controlled in terms of its angle, daylight and consequently daylight

transmission glass could not be used for this test. Therefore an array of electric lights with narrow beam spreads were used along with interior glass (Surface type 'Glass').
The directional transmission of glass was determined as the ratio between the total flux in the room with the glass divided by the total flux inside the room without the glass.

The reference table in the CIE document is shown below

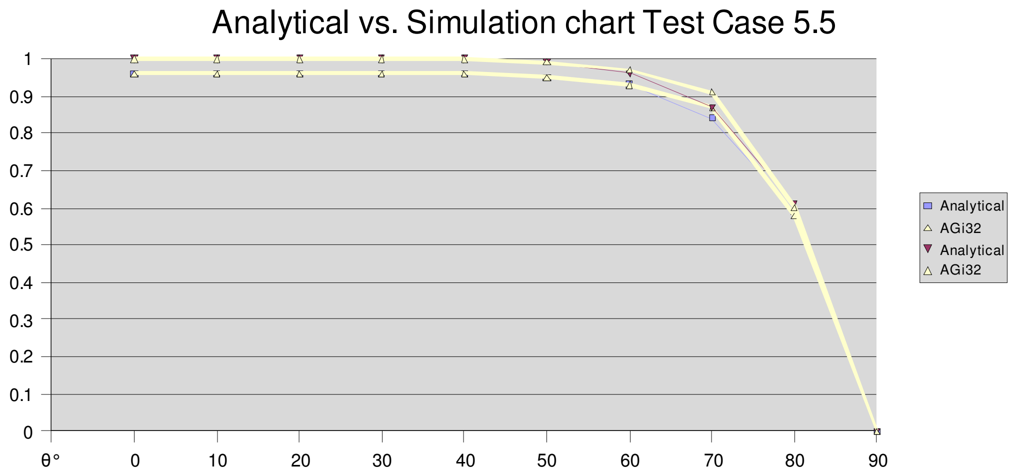
TABLE 13 TEST CASE 5.5

| $\theta°$ | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\tau_\theta$ | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.95 | 0.93 | 0.84 | 0.59 | 0.00 |
| $\tau_\theta/\tau_0$ | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.96 | 0.87 | 0.61 | 0.00 |

Clear glass transmittance variation as a function of the incidence angle

| TABLE 14 TEST CASE 5.5 | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **Total Wall flux** | **Floor flux** | **Total Flux** | **τ ang** | **τang / τ 0** |
| **0** deg | | 2271.7 | 2271.7 | **0.96** | **1.00** |
| 0 deg _no glass | | 2366.4 | 2366.4 | | |
| **10** deg | | 2157.4 | 2157.4 | **0.96** | **1.00** |
| 10 deg _no glass | | 2247.4 | 2247.4 | | |
| **20** deg | | 2114.4 | 2114.4 | **0.96** | **1.00** |
| 20 deg _no glass | | 2202.4 | 2202.4 | | |
| **30** deg | 501.12 | 1671 | 2172.2 | **0.96** | **1.00** |
| 30 deg _no glass | 522.12 | 1740.8 | 2262.9 | | |
| **40** deg | 2361.5 | 40.48 | 2402 | **0.96** | **1.00** |
| 40 deg_no glass | 2461.7 | 42.08 | 2503.8 | | |
| **50** deg | 2101.8 | 0 | 2101.8 | **0.95** | **0.99** |
| 50 deg_no glass | 2202.4 | 0 | 2202.4 | | |
| **60** deg | 1162.1 | 0 | 1162.1 | **0.93** | **0.97** |
| 60 deg_no glass | 1250.2 | 0 | 1250.2 | | |
| **70** deg | 2314.3 | 0 | 2314.3 | **0.87** | **0.91** |
| 70 deg_no glass | 2658.2 | 0 | 2658.2 | | |
| **80** deg | 1415.2 | 0 | 1415.2 | **0.58** | **0.60** |
| 80 deg_no glass | 2460 | 0 | 2460 | | |
| **90** deg | 0 | 0 | 0 | **0.00** | **0.00** |
| 90 deg_no glass | 0 | 0 | 0 | | |

**Graphical Representation of Measurements**




### 5.6 Light reflection over diffuse surfaces

This section is intended to test the ability of the software to calculate light reflection over diffuse surfaces. Incident light from a specified angle hits a diffuse surface of a particular reflectance. Illuminance values are measured on planes perpendicular to this surface and directly above (facing) the surface. Both these planes don't receive direct illuminance from the source. This test is repeated with varying source incident angles, varying sizes of the reflective surface and varying the reflectance of the surface.

Although sunlight would have been the ideal distant source, the inability to separate sunlight and skylight in AGi32 made it impractical to use this as a source. Therefore a very narrow angle source (less than 2 degrees beam spread) was used for the tests. For the first and second test scenarios (0.5mx0.5m surface and 4mx4m surface), an array of these point sources were used to simulate parallel incoming rays. For the 3rd scenario (500m x 500m surface), an array did not yield results close to the reference value, because of the size of the reflective surface. Hence a very large source (140m x 140m) positioned 250 away gave results that were closer to the reference values.

Shown below are the sketches for all 3 scenarios and a sketch showing the measurement points from the CIE report.

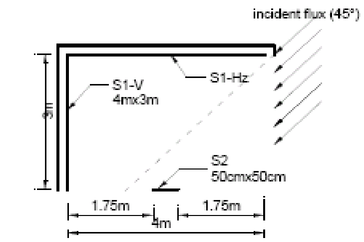



Figure 8: Test case description for $S_2$ of 50cm×50cm

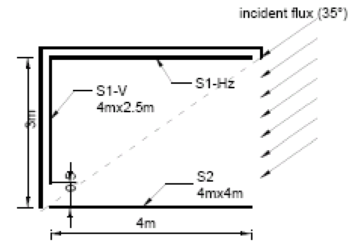



Figure 9: Test case description for $S_2$ of 4mx4m

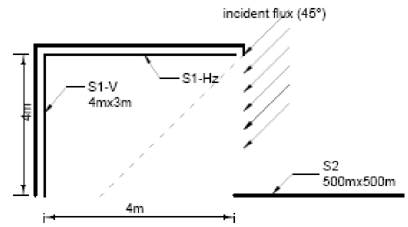



Figure 10: Test case description for $S_2$ of 500m×500m

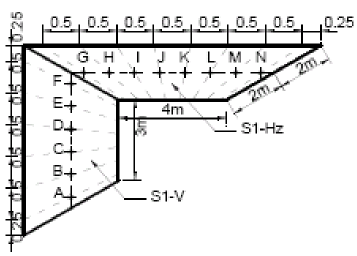



Figure 11: measurement point positions

The table below lists the calculated values for E/ ($E_{hz}$ x ρ) along with the reference values from the CIE for comparison. E represents the illuminance at the different points, $E_{hz}$ is the average horizontal illuminance on the reflective surface and ρ is the reflectance of the surface.

| | TABLE 15 TEST CASE 5.6 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vertical values | | | | | | Horizontal values | | | | | | | |
| Scenario | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
| 50 cm x 50 cm reference | 0.246 | 0.580 | 0.644 | 0.556 | 0.433 | 0.325 | 0.491 | 0.639 | 0.778 | 0.864 | 0.864 | 0.778 | 0.639 | 0.491 |
| 50 cm x 50 cm calculated | 0.245 | 0.578 | 0.645 | 0.556 | 0.434 | 0.323 | 0.500 | 0.634 | 0.778 | 0.867 | 0.856 | 0.767 | 0.634 | 0.478 |
| 4m x 4m reference | | 35.901 | 27.992 | 21.639 | 16.716 | 12.967 | 26.80 | 30.94 | 33.98 | 35.57 | 35.57 | 33.98 | 30.94 | 26.80 |
| 4m x 4m calculated | | 35.810 | 27.902 | 21.516 | 16.592 | 12.862 | 26.38 | 30.44 | 33.42 | 35.21 | 35.21 | 33.42 | 30.44 | 26.41 |
| 500m x 500m reference | 3.080 | 9.097 | 14.718 | 19.767 | 24.161 | 27.896 | 10.95 | 13.26 | 16.21 | 20.00 | 24.80 | 30.77 | 37.87 | 45.84 |
| 500m x 500m calculated | 2.93 | 8.80 | 14.30 | 19.07 | 23.10 | 26.77 | 11.00 | 13.20 | 16.13 | 20.17 | 24.94 | 30.80 | 37.77 | 45.84 |

### 5.7 Diffuse reflections with internal obstructions

The values on the reference table in document 171:2006 are inaccurate, please refer to the appendix for further details.

### 5.8 Internal reflected component for diffuse surfaces

It is our opinion that this test is not conducive to the results expected, please refer to the appendix for further details.

### 5.9 Sky component for roof unglazed opening and CIE general sky types

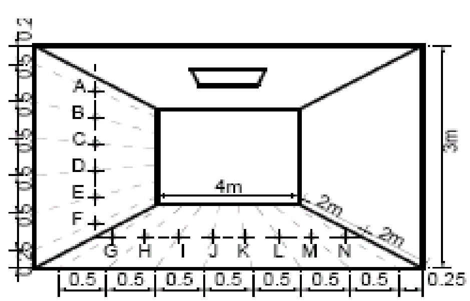



Figure 15: geometry and measurement points description

This section is meant to test the ability of the software to calculate the sky component obtained under different sky conditions. The figure for the test geometry from the CIE report is shown.

Since the sun position is defined as being at 60 degree elevation, a time of 10:10am on March 21, at 0 degree latitude and longitude was used, based on the following website as a reference. http://www.hia-iha.nrc-cnrc.gc.ca/sunrise_e.html. Changing the angle changed results for sky types 2 and 4.

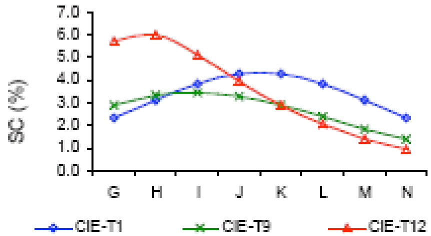
In AGi32, there currently exists no way to separate the direct sun component from the Sky Component(SC) in daylighting . However for CIE sky types 1 to 5 and for CIE type Overcast, there is no direct sun component. So the only illuminance obtained is from the Sky Component.

Daylight Factor (DF) is typically a sum of the external reflected component and sky component. For this test, the test geometry has the opening on the ceiling with no external reflected component. So DF values were used as a measure of the SC values.

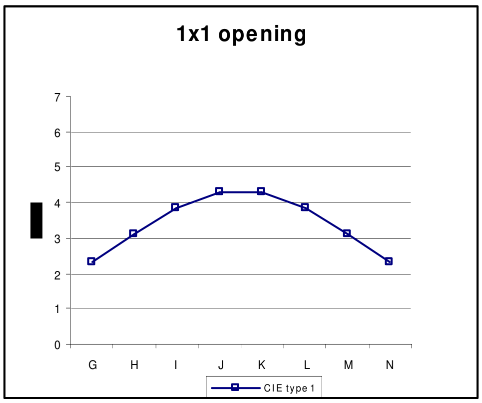
In the current version of AGi32, DF values can be calculated only on a horizontal plane. However, the values for the wall were obtained by dividing the illuminance values by the Daylight Basis (external unobstructed horizontal illuminance) and multiplying this result by 100.

Listed below are the test values along with the reference values for comparison. The values for the DF on the wall for Type 3 do not match with the reference values. However there may be a mistake in the reference values. The reference values appear to have been transposed, with values for point A being listed under F, B under E, C under D and so on.

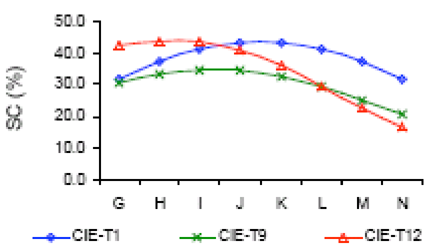
| TABLE 16 TEST CASE 5.9 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Opening** | **CIE sky type** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** |
| 1x1 | Reference | 0.46 | 1.64 | 2.34 | 2.26 | 1.88 | 1.47 | 2.33 | 3.11 | 3.84 | 4.29 | 4.29 | 3.84 | 3.11 | 2.33 |
| | Type 1 | 0.48 | 1.61 | 2.34 | 2.27 | 1.86 | 1.47 | 2.33 | 3.10 | 3.84 | 4.30 | 4.29 | 3.84 | 3.10 | 2.33 |
| | Reference | 0.40 | 1.72 | 2.86 | 3.15 | 2.90 | 2.44 | 4.00 | 5.00 | 5.47 | 5.37 | 4.73 | 3.76 | 2.76 | 1.9 |
| | Type 2 | 0.41 | 1.68 | 2.87 | 3.13 | 2.76 | 2.31 | 3.76 | 4.82 | 5.40 | 5.39 | 4.78 | 3.82 | 2.78 | 1.91 |
| | Reference | 1.36 | 1.78 | 2.22 | 2.46 | 2.05 | 0.79 | 2.13 | 2.80 | 3.42 | 3.81 | 3.81 | 3.42 | 2.80 | 2.13 |
| | Type 3 | 0.80 | 2.02 | 2.47 | 2.23 | 1.76 | 1.36 | 2.12 | 2.78 | 3.41 | 3.80 | 3.79 | 3.41 | 2.78 | 2.12 |
| | Reference | 0.71 | 2.17 | 3.06 | 3.15 | 2.79 | 2.30 | 3.72 | 4.58 | 4.97 | 4.85 | 4.27 | 3.42 | 2.53 | 1.77 |
| | Type 4 | 0.69 | 2.13 | 3.06 | 3.11 | 2.67 | 2.18 | 3.49 | 4.42 | 4.9 | 4.86 | 4.31 | 3.46 | 2.54 | 1.78 |
| | Reference | 1.04 | 2.39 | 2.59 | 2.20 | 1.70 | 1.27 | 1.95 | 2.52 | 3.04 | 3.37 | 3.37 | 3.04 | 2.52 | 1.95 |
| | Type 5 | 1.04 | 2.37 | 2.60 | 2.21 | 1.69 | 1.27 | 1.94 | 2.51 | 3.03 | 3.36 | 3.35 | 3.03 | 2.50 | 1.95 |
| | Reference | 0.56 | 1.78 | 2.32 | 2.20 | 1.82 | 1.43 | 2.29 | 3.07 | 3.82 | 4.29 | 4.29 | 3.82 | 3.07 | 2.29 |
| | CIE overcast | 0.48 | 1.72 | 2.43 | 2.29 | 1.84 | 1.44 | 2.27 | 3 | 3.69 | 4.11 | 4.1 | 3.68 | 2.99 | 2.27 |
| 4x4 | Reference | 37.84 | 31.72 | 26.85 | 22.10 | 17.89 | 14.38 | 31.87 | 37.30 | 41.27 | 43.35 | 43.35 | 41.27 | 37.30 | 31.87 |
| | Type 1 | 36.13 | 31.59 | 26.53 | 22.05 | 17.80 | 14.37 | 31.38 | 37.22 | 41.21 | 43.27 | 43.29 | 41.22 | 37.23 | 31.81 |
| | Reference | 42.03 | 37.03 | 32.75 | 28.13 | 23.70 | 19.79 | 42.01 | 46.99 | 49.85 | 50.08 | 47.76 | 42.89 | 36.40 | 29.02 |
| | Type 2 | 40.39 | 36.73 | 34.18 | 27.77 | 23.29 | 19.43 | 41.51 | 46.58 | 49.46 | 49.86 | 47.73 | 43.12 | 36.58 | 29.27 |
| | Reference | 42.77 | 34.03 | 27.43 | 21.81 | 17.23 | 13.61 | 29.16 | 33.92 | 37.40 | 39.22 | 39.22 | 37.40 | 33.92 | 29.16 |
| | Type 3 | 41.12 | 33.90 | 27.39 | 21.81 | 17.20 | 13.62 | 29.09 | 33.80 | 37.28 | 39.09 | 39.10 | 37.28 | 33.8 | 29.07 |
| | Reference | 46.85 | 39.59 | 33.65 | 28.08 | 23.16 | 19.04 | 39.19 | 43.59 | 46.07 | 46.17 | 43.97 | 39.50 | 33.60 | 26.94 |
| | Type 4 | 44.93 | 39.23 | 33.23 | 27.72 | 24.63 | 18.69 | 38.71 | 43.19 | 45.69 | 45.94 | 43.93 | 39.68 | 33.75 | 27.17 |
| | Reference | 46.74 | 36.05 | 28.05 | 21.67 | 16.73 | 12.98 | 26.80 | 30.95 | 33.99 | 35.58 | 35.58 | 33.99 | 30.95 | 26.8 |
| | Type 5 | 45.12 | 35.90 | 28.03 | 21.68 | 16.73 | 13.00 | 26.75 | 30.86 | 33.89 | 35.47 | 35.49 | 33.90 | 30.86 | 26.73 |
| | Reference | 39.28 | 32.32 | 26.79 | 21.78 | 17.53 | 14.05 | 31.36 | 36.76 | 40.71 | 42.76 | 42.76 | 40.71 | 36.76 | 31.36 |
| | CIE overcast | 37.00 | 32.33 | 27.11 | 22.22 | 17.78 | 14.22 | 31.02 | 36.16 | 39.96 | 41.93 | 41.94 | 39.96 | 36.16 | 30.99 |



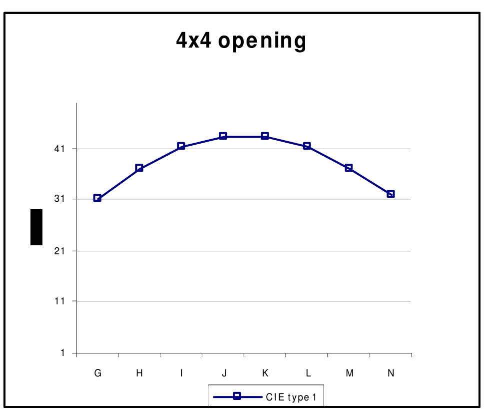

**Reference chart for 1m x 1m opening**




**Calculated chart for 1m x 1m opening**




**Reference chart for 4m x 4m opening**



**Calculated chart for 4mx4m opening**

**5.10 Sky component under a roof glazed opening.**

The objective of this section is to test the ability of the software to calculate the sky component obtained under different sky conditions, under the influence of a glazed opening.

The test geometry and conditions are similar to the one in Section 5.9, except there is meant to be a 6mm thick pane of glass covering the opening on the ceiling. Since AGi32 allows for specifying the transmittance of glass instead of the thickness, a transmittance value of 0.91 was selected for the tests. This was chosen based calculating values for the first case (1mx1m opening, skytype 1), varying the transmittance values and using the value that yielded results closest to the reference values.

The same limitations of measurement as Section 5.9 apply to Section 5.10 as well. Consequently Daylight Factor values are used as a substitute for Sky Component values and DF values for walls were calculated using the Daylight Basis values. The values are restricted to the CIE skytypes 1 to 5 and Overcast. Listed below are the test values and the reference values.

**TABLE 17 TEST CASE 5.10**

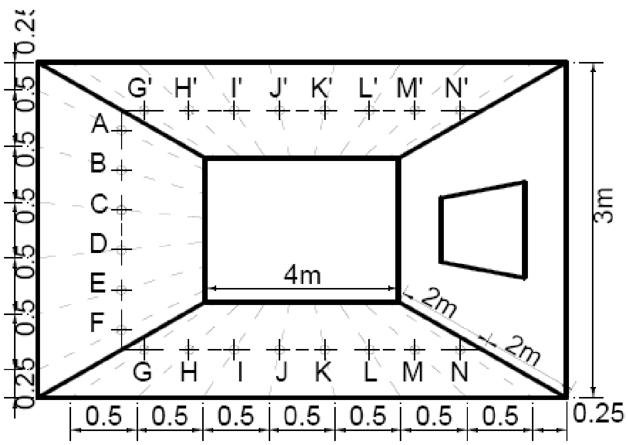
| CIE sky type | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 0.15 | 1.17 | 1.91 | 1.92 | 1.62 | 1.28 | 2.04 | 2.73 | 3.38 | 3.78 | 3.78 | 3.38 | 2.73 | 2.04 |
| Type 1 | 0.21 | 1.26 | 2.00 | 1.98 | 1.62 | 1.28 | 2.03 | 2.71 | 3.35 | 3.75 | 3.74 | 3.35 | 2.71 | 2.04 |
| Reference | 0.13 | 1.22 | 2.34 | 2.68 | 2.50 | 2.12 | 3.50 | 4.39 | 4.81 | 4.72 | 4.16 | 3.31 | 2.42 | 1.67 |
| Type 2 | 0.18 | 1.32 | 2.45 | 2.72 | 2.41 | 2.02 | 3.28 | 4.21 | 4.72 | 4.71 | 4.17 | 3.34 | 2.43 | 1.67 |
| Reference | 0.26 | 1.45 | 2.01 | 1.89 | 1.54 | 1.18 | 1.87 | 2.46 | 3.01 | 3.35 | 3.35 | 3.01 | 2.46 | 1.87 |
| Type 3 | 0.35 | 1.58 | 2.11 | 1.94 | 1.54 | 1.19 | 1.85 | 2.43 | 2.98 | 3.32 | 3.31 | 2.98 | 2.43 | 1.86 |
| Reference | 0.24 | 1.54 | 2.51 | 2.68 | 2.41 | 2.01 | 3.26 | 4.03 | 4.37 | 4.26 | 3.76 | 3.01 | 2.22 | 1.55 |
| Type 4 | 0.30 | 1.66 | 2.62 | 2.71 | 2.33 | 1.91 | 3.05 | 3.86 | 4.28 | 4.25 | 3.77 | 3.02 | 2.22 | 1.55 |
| Reference | 0.35 | 1.69 | 2.12 | 1.87 | 1.47 | 1.11 | 1.71 | 2.22 | 2.68 | 2.96 | 2.96 | 2.68 | 2.22 | 1.71 |
| Type 5 | 0.45 | 1.84 | 2.22 | 1.92 | 1.47 | 1.11 | 1.70 | 2.19 | 2.65 | 2.93 | 2.92 | 2.65 | 2.19 | 1.70 |
| Reference | 0.19 | 1.26 | 1.90 | 1.87 | 1.57 | 1.24 | 2.00 | 2.70 | 3.36 | 3.78 | 3.78 | 3.36 | 2.70 | 2.00 |
| Overcast | 0.22 | 1.39 | 2.14 | 2.06 | 1.66 | 1.30 | 1.98 | 2.62 | 3.22 | 3.59 | 3.58 | 3.22 | 2.61 | 1.98 |
| Reference | 28.64 | 25.36 | 22.25 | 18.71 | 15.34 | 12.43 | 27.88 | 32.69 | 36.22 | 38.07 | 38.07 | 36.22 | 32.69 | 27.88 |
| Type 1 | 28.39 | 26.29 | 22.8 | 19.02 | 15.47 | 12.51 | 27.79 | 32.51 | 36.00 | 37.80 | 37.81 | 36.00 | 32.51 | 27.77 |
| Reference | 32.75 | 30.05 | 27.34 | 23.90 | 20.36 | 17.13 | 36.75 | 41.18 | 43.74 | 43.98 | 41.96 | 37.67 | 31.94 | 25.42 |
| Type 2 | 32.46 | 30.81 | 27.64 | 24.05 | 20.26 | 16.95 | 36.25 | 40.68 | 43.20 | 43.55 | 41.69 | 37.66 | 31.95 | 25.56 |
| Reference | 30.83 | 26.68 | 22.56 | 18.41 | 14.76 | 11.76 | 25.5 | 29.73 | 32.82 | 34.45 | 34.45 | 32.82 | 29.73 | 25.5 |
| Type 3 | 31.23 | 27.91 | 23.25 | 18.79 | 14.95 | 11.83 | 25.39 | 29.52 | 32.56 | 34.14 | 34.15 | 32.57 | 29.52 | 25.38 |
| Reference | 35.03 | 31.59 | 27.90 | 23.79 | 19.87 | 16.46 | 34.27 | 38.19 | 40.42 | 40.55 | 38.63 | 34.69 | 29.48 | 23.59 |
| Type 4 | 35.27 | 32.55 | 28.34 | 23.95 | 19.80 | 16.27 | 33.79 | 37.72 | 39.91 | 40.13 | 38.37 | 34.66 | 29.48 | 23.72 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 32.66 | 27.87 | 22.92 | 18.23 | 14.31 | 11.20 | 23.43 | 27.12 | 29.83 | 31.25 | 31.25 | 29.83 | 27.12 | 23.43 |
| Type 5 | 33.60 | 29.28 | 23.75 | 18.67 | 14.53 | 11.34 | 23.35 | 26.95 | 29.60 | 30.99 | 31.00 | 29.61 | 26.95 | 23.34 |
| Reference | 29.21 | 25.63 | 22.14 | 18.43 | 15.03 | 12.15 | 27.44 | 32.23 | 35.73 | 37.56 | 37.56 | 35.73 | 32.23 | 27.44 |
| Overcast | 29.03 | 26.86 | 23.14 | 19.19 | 15.46 | 12.40 | 27.08 | 31.58 | 34.90 | 36.63 | 36.64 | 34.91 | 31.58 | 27.06 |

### 5.11 Sky Component and External Reflected Component for façade unglazed opening

This section is meant to test the ability of the program to calculate the contribution of reflected daylight from the external ground into a room.

The figure for the test geometry from the CIE report is shown below. The calculations were done for opening sizes of 2mx1m and 4mx3m.




The reference tables list the Sky Component (SC) values on the floor, the SC values + External Reflected Component (ERC) values for the wall and the ERC values on the ceiling.

Since AGi32 (version 1.94) does not allow the separation of the Sky component and the External reflected component, the Daylight Factor (DF) was used as an alternate measure for the wall, since DF = SC+ERC.

For the floor, there is no ERC because of zero reflectances internally and because the floor does not see the external ground. Hence DF should be equal to the SC and was calculated in lieu of SC.

Likewise, for the ceiling, there is no SC because the ceiling does not see the sky and because of zero internal reflectance. Hence DF should be equal to ERC and was calculated in lieu of ERC.

The external ground is specified to be of 30% reflectance. A planar object of 30% reflectance was added to represent the external ground.

Listed below is the table showing the values for the various measurement points. The Daylight Factor for the walls and ceiling were obtained by dividing the illuminance values by the Daylight Basis and multiplying this result by 100.

| TABLE 18A TEST CASE 5.11 WALL CALCULATED VALUES | | | | | | | |
|---|---|---|---|---|---|---|---|
| Size | **CIE sky type** | **A** | **B** | **C** | **D** | **E** | **F** |
| 2mx1m | Type 1 | 0.94 | 1.07 | 1.2 | 1.5 | 1.8 | 1.88 |
| | Type 2 | 0.95 | 1.07 | 1.15 | 1.33 | 1.64 | 1.86 |
| | Type 3 | 0.93 | 1.06 | 1.48 | 2.36 | 2.78 | 2.6 |
| | Type 4 | 0.94 | 1.07 | 1.4 | 2.09 | 2.56 | 2.58 |
| | Type 5 | 0.92 | 1.05 | 1.69 | 3 | 3.53 | 3.17 |
| | Overcast | 0.94 | 1.07 | 1.19 | 1.51 | 1.87 | 2.02 |
| 4mx3m | Type 1 | 4.69 | 5.7 | 6.81 | 7.8 | 8.74 | 9.49 |
| | Type 2 | 4.7 | 5.48 | 6.46 | 7.44 | 8.55 | 9.44 |
| | Type 3 | 5.18 | 7.23 | 9.07 | 10.61 | 11.84 | 12.71 |
| | Type 4 | 5.11 | 6.81 | 8.54 | 10.09 | 11.51 | 12.62 |
| | Type 5 | 5.49 | 8.33 | 10.76 | 12.79 | 14.27 | 15.26 |
| | Overcast | 4.67 | 5.73 | 6.9 | 8.01 | 9.12 | 9.9 |
| REFERENCE VALUES | | | | | | | |
| Size | **CIE sky type** | A | B | C | D | E | F |
| 2mx1m | Type 1 | 0.95 | 1.06 | 1.25 | 1.51 | 1.7 | 1.86 |
| | Type 2 | 0.95 | 1.06 | 1.18 | 1.33 | 1.55 | 1.83 |
| | Type 3 | 0.95 | 1.06 | 1.56 | 2.42 | 2.75 | 2.58 |
| | Type 4 | 0.95 | 1.06 | 1.45 | 2.14 | 2.53 | 2.58 |
| | Type 5 | 0.95 | 1.06 | 1.79 | 3.09 | 3.54 | 3.17 |
| | Overcast | 0.95 | 1.06 | 1.28 | 1.71 | 2.06 | 2.14 |
| 4mx3m | Type 1 | 5.25 | 6.11 | 6.98 | 7.99 | 8.77 | 9.35 |
| | Type 2 | 5.09 | 5.78 | 6.56 | 7.52 | 8.49 | 9.35 |
| | Type 3 | 5.93 | 7.75 | 9.33 | 11.09 | 12.03 | 12.6 |
| | Type 4 | 5.66 | 7.23 | 8.72 | 10.43 | 11.64 | 12.58 |
| | Type 5 | 6.43 | 8.96 | 11.11 | 13.47 | 14.57 | 15.17 |
| | Overcast | 5.29 | 6.46 | 7.67 | 8.88 | 9.73 | 10.29 |

| TABLE 18B TEST CASE 5.11 FLOOR CALCULATED VALUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Size | CIE sky type | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** |
| 2mx1m | Type 1 | 0.87 | 1.29 | 1.99 | 3.21 | 5.05 | 7.58 | 9.31 | 5.11 |
| | Type 2 | 0.92 | 1.41 | 2.24 | 3.87 | 6.49 | 10.43 | 13.25 | 6.3 |
| | Type 3 | 1.08 | 1.54 | 2.25 | 3.4 | 5.1 | 7.3 | 8.6 | 4.59 |
| | Type 4 | 1.15 | 1.69 | 2.56 | 4.15 | 6.64 | 10.2 | 12.45 | 5.77 |
| | Type 5 | 1.26 | 1.75 | 2.48 | 3.59 | 5.18 | 7.11 | 8 | 4.14 |
| | Overcast | 0.93 | 1.37 | 2.09 | 3.32 | 5.14 | 7.57 | 9.13 | 4.93 |
| 4mx3m | Type 1 | 4.31 | 5.96 | 8.35 | 11.82 | 16.83 | 23.78 | 33.02 | 44.1 |
| | Type 2 | 4.75 | 6.77 | 9.74 | 14.16 | 20.66 | 29.59 | 40.75 | 52.91 |
| | Type 3 | 5.13 | 6.87 | 9.35 | 12.87 | 17.86 | 24.68 | 33.63 | 44.32 |
| | Type 4 | 5.63 | 7.77 | 10.86 | 15.35 | 21.81 | 30.56 | 41.36 | 53.08 |
| | Type 5 | 5.8 | 7.64 | 10.2 | 13.78 | 18.75 | 25.47 | 34.18 | 44.51 |
| | Overcast | 4.52 | 6.21 | 8.64 | 12.15 | 17.17 | 24.09 | 33.23 | 44.18 |
| REFERENCE VALUES | | | | | | | | | |
| Size | CIE sky type | G | H | I | J | K | L | M | N |
| 2mx1m | Type 1 | 0.87 | 1.31 | 2.02 | 3.2 | 5.07 | 7.64 | 9.33 | 5.09 |
| | Type 2 | 0.92 | 1.42 | 2.3 | 3.86 | 6.58 | 10.77 | 13.66 | 6.33 |
| | Type 3 | 1.08 | 1.54 | 2.26 | 3.4 | 5.11 | 7.34 | 8.61 | 4.56 |
| | Type 4 | 1.16 | 1.71 | 2.62 | 4.16 | 6.73 | 10.52 | 12.82 | 5.8 |
| | Type 5 | 1.27 | 1.75 | 2.49 | 3.59 | 5.19 | 7.11 | 7.99 | 4.13 |
| | Overcast | 0.95 | 1.38 | 2.07 | 3.19 | 4.97 | 7.42 | 9.11 | 5.04 |
| 4mx3m | Type 1 | 4.27 | 5.92 | 8.33 | 11.82 | 16.84 | 23.83 | 33.05 | 44.06 |
| | Type 2 | 4.7 | 6.71 | 9.75 | 14.3 | 21 | 30.09 | 41.22 | 52.94 |
| | Type 3 | 5.09 | 6.84 | 9.33 | 12.87 | 17.86 | 24.72 | 33.68 | 44.76 |
| | Type 4 | 5.62 | 7.76 | 10.91 | 15.52 | 22.17 | 31.06 | 41.86 | 53.53 |
| | Type 5 | 5.79 | 7.63 | 10.2 | 13.78 | 18.76 | 25.50 | 34.24 | 45.29 |
| | Overcast | 4.5 | 6.15 | 8.53 | 12 | 16.97 | 23.91 | 33.08 | 44.43 |

| Size | TABLE 18C TEST CASE 5.11 CEILING CALCULATED VALUES | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2mx1m | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 0.37 | 0.51 | 0.71 | 1.01 | 1.32 | 1.64 | 1.46 | 0.61 |
| | REFERENCE VALUES | | | | | | | |
| | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 0.38 | 0.53 | 0.75 | 1.08 | 1.56 | 2.14 | 2.4 | 1.24 |
| 4mx3m | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 1.47 | 1.92 | 2.56 | 3.44 | 4.68 | 6.35 | 8.56 | 11.3 |
| | REFERENCE VALUES | | | | | | | |
| | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 1.74 | 2.29 | 3.06 | 4.14 | 5.63 | 7.65 | 10.27 | 13.59 |

## 5.12 Sky Component and External Reflected Component for façade glazed opening

Sky Component and External Reflected Component for façade glazed opening

This section is meant to test the ability of the program to calculate the contribution of reflected daylight from the external ground into a room through a glazed opening. As in Section 5.10, a glass transmission value of 0.91 was assumed in lieu of the 6mm glass thickness. The test geometry and measurements are the same as Section 5.11, except that the openings are covered by glass.

The reference tables list the Sky Component (SC) values on the floor, the SC values + External Reflected Component (ERC) values for the wall and the ERC values on the ceiling.
As in Section 5.11, the Daylight Factor (DF) was used as an alternate measure for the wall, floor and ceiling, since DF = SC+ERC, there being no SC for the ceiling and no ERC for the floor. The external ground is specified to be of 30% reflectance. A planar object of 30% reflectance was added to represent the external ground. Listed below is the table showing the values for the various measurement points. The Daylight Factor for the walls and ceiling were obtained by dividing the illuminance values by the Daylight Basis and multiplying this result by 100.

| TABLE 19A TEST CASE 5.12 WALL CALCULATED VALUES | | | | | | | |
|---|---|---|---|---|---|---|---|
| Opening | **CIE sky type** | **A** | **B** | **C** | **D** | **E** | **F** |
| 2mx1m | Type 1 | 0.82 | 0.93 | 1.05 | 1.31 | 1.57 | 1.65 |
| | Type 2 | 0.83 | 0.94 | 1.01 | 1.16 | 1.43 | 1.62 |
| | Type 3 | 0.81 | 0.93 | 1.29 | 2.06 | 2.43 | 2.27 |
| | Type 4 | 0.82 | 0.93 | 1.22 | 1.82 | 2.24 | 2.26 |
| | Type 5 | 0.8 | 0.92 | 1.47 | 2.62 | 3.08 | 2.77 |
| | Overcast | 0.82 | 0.93 | 1.04 | 1.32 | 1.63 | 1.76 |
| 4mx3m | Type 1 | 4.09 | 4.98 | 5.94 | 6.81 | 7.63 | 8.27 |
| | Type 2 | 4.11 | 4.78 | 5.65 | 6.48 | 7.44 | 8.27 |
| | Type 3 | 4.51 | 6.3 | 7.94 | 9.28 | 10.35 | 11.12 |
| | Type 4 | 4.46 | 5.94 | 7.49 | 8.79 | 10.09 | 11.01 |
| | Type 5 | 4.82 | 7.25 | 9.41 | 11.17 | 12.47 | 13.33 |
| | Overcast | 4.08 | 4.99 | 6.06 | 7.01 | 7.95 | 8.68 |
| REFERENCE VALUES | | | | | | | |
| Size | **CIE sky type** | A | B | C | D | E | F |
| 2mx1m | Type 1 | 0.84 | 0.94 | 1.1 | 1.33 | 1.5 | 1.63 |
| | Type 2 | 0.84 | 0.94 | 1.04 | 1.17 | 1.36 | 1.61 |
| | Type 3 | 0.84 | 0.94 | 1.38 | 2.13 | 2.42 | 2.27 |
| | Type 4 | 0.84 | 0.94 | 1.27 | 1.88 | 2.23 | 2.27 |
| | Type 5 | 0.84 | 0.94 | 1.58 | 2.72 | 3.12 | 2.79 |
| | Overcast | 0.84 | 0.94 | 1.12 | 1.5 | 1.81 | 1.89 |
| 4mx3m | Type 1 | 4.62 | 5.38 | 6.15 | 7.03 | 7.72 | 8.21 |
| | Type 2 | 4.47 | 5.09 | 5.78 | 6.62 | 7.47 | 8.22 |
| | Type 3 | 5.21 | 6.83 | 8.22 | 9.76 | 10.58 | 11.07 |
| | Type 4 | 4.98 | 6.36 | 7.68 | 9.18 | 10.24 | 11.05 |
| | Type 5 | 5.65 | 7.89 | 9.78 | 11.86 | 12.82 | 13.34 |
| | Overcast | 4.65 | 5.69 | 6.75 | 7.82 | 8.56 | 9.04 |

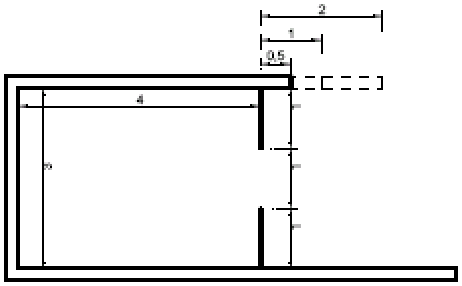
| TABLE 19B TEST CASE 5.12 FLOOR CALCULATED VALUES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Size | CIE sky type | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** |
| 2mx1m | Type 1 | 0.76 | 1.13 | 1.73 | 2.8 | 4.41 | 6.58 | 7.72 | 2.64 |
| | Type 2 | 0.8 | 1.23 | 1.96 | 3.38 | 5.67 | 9.06 | 10.98 | 3.26 |
| | Type 3 | 0.95 | 1.35 | 1.96 | 2.97 | 4.45 | 6.34 | 7.12 | 2.38 |
| | Type 4 | 1.01 | 1.48 | 2.24 | 3.63 | 5.8 | 8.86 | 10.32 | 2.99 |
| | Type 5 | 1.1 | 1.53 | 2.17 | 3.14 | 4.52 | 6.17 | 6.63 | 2.14 |
| | Overcast | 0.81 | 1.2 | 1.83 | 2.9 | 4.49 | 6.58 | 7.56 | 2.55 |
| 4mx3m | Type 1 | 3.77 | 5.21 | 7.29 | 10.3 | 14.61 | 20.4 | 26.81 | 22.52 |
| | Type 2 | 4.15 | 5.91 | 8.5 | 12.34 | 17.93 | 25.34 | 33.03 | 27.03 |
| | Type 3 | 4.48 | 6.01 | 8.16 | 11.23 | 15.52 | 21.21 | 27.37 | 22.66 |
| | Type 4 | 4.92 | 6.79 | 9.48 | 13.38 | 18.94 | 26.2 | 33.58 | 27.14 |
| | Type 5 | 5.07 | 6.67 | 8.91 | 12.02 | 16.3 | 21.91 | 27.86 | 22.79 |
| | Overcast | 3.95 | 5.43 | 7.55 | 10.59 | 14.91 | 20.68 | 27 | 22.58 |
| REFERENCE VALUES | | | | | | | | | |
| Size | CIE sky type | G | H | I | J | K | L | M | N |
| 2mx1m | Type 1 | 0.77 | 1.15 | 1.77 | 2.79 | 4.38 | 6.44 | 7.19 | 2.16 |
| | Type 2 | 0.81 | 1.25 | 2.01 | 3.36 | 5.67 | 9.07 | 10.54 | 2.7 |
| | Type 3 | 0.95 | 1.35 | 1.98 | 2.96 | 4.41 | 6.19 | 6.64 | 1.94 |
| | Type 4 | 1.02 | 1.5 | 2.29 | 3.62 | 5.8 | 8.86 | 9.9 | 2.47 |
| | Type 5 | 1.11 | 1.54 | 2.18 | 3.13 | 4.47 | 6 | 6.17 | 1.75 |
| | Overcast | 0.83 | 1.21 | 1.81 | 2.78 | 4.28 | 6.26 | 7.02 | 2.13 |
| 4mx3m | Type 1 | 3.74 | 5.17 | 7.23 | 10.18 | 14.3 | 19.66 | 25.63 | 30.02 |
| | Type 2 | 4.11 | 5.85 | 8.46 | 12.3 | 17.78 | 24.74 | 31.91 | 36.38 |
| | Type 3 | 4.46 | 5.97 | 8.11 | 11.1 | 15.2 | 20.48 | 26.34 | 31.03 |
| | Type 4 | 4.92 | 6.77 | 9.47 | 13.37 | 18.82 | 25.64 | 32.64 | 37.32 |
| | Type 5 | 5.07 | 6.67 | 8.87 | 11.91 | 16 | 21.21 | 26.96 | 31.84 |
| | Overcast | 3.94 | 5.36 | 7.41 | 10.34 | 14.42 | 19.74 | 25.7 | 30.4 |

| Size | TABLE 19C TEST CASE 5.12 CEILING CALCULATED VALUES | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2mx1m | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 0.32 | 0.44 | 0.62 | 0.88 | 1.15 | 1.43 | 1.21 | 0.32 |
| | REFERENCE VALUES | | | | | | | |
| | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 0.33 | 0.46 | 0.65 | 0.94 | 1.34 | 1.8 | 1.85 | 0.53 |
| 4mx3m | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 1.28 | 1.68 | 2.24 | 3 | 4.07 | 5.46 | 7.05 | 7.22 |
| | REFERENCE VALUES | | | | | | | |
| | **G'** | **H'** | **I'** | **J'** | **K'** | **L'** | **M'** | **N'** |
| | 1.52 | 2 | 2.66 | 3.57 | 4.8 | 6.36 | 8.09 | 9.55 |

**5.13 SC+ ERC for an unglazed façade opening with a continuous external horizontal mask**

This section is meant to test the ability of the software to simulate the effect of a continuous external horizontal mask on interior illuminance from daylighting.

The figure for the test geometry in the CIE report is shown below. The test was done for exterior canopy widths of 0.5m, 1m and 2m respectively.



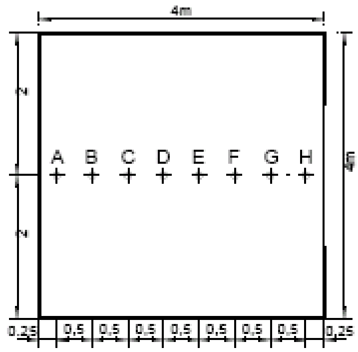



Figure 24: Geometric description for the external horizontal mask test case

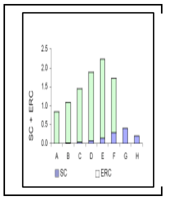
Since this test required an integrated value of SC+ERC, the values for Daylight Factor were used. However the same limitations as in Sections 5.9 and 5.10, allowed values to be calculated only for CIE sky types 1 through 5 and Overcast. As before 10:10am on March 21st for a latitude and longitude of 0 degrees and 0 degrees were used to give a vertical sun angle of 60 degrees.

The canopy reflectance was assumed to be 50% since the values for point H seemed to vary considerably depending on the reflectance.

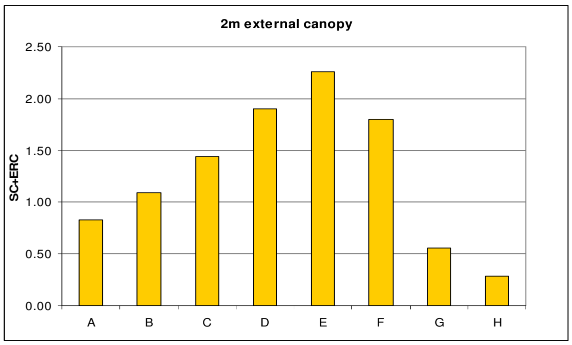
The results of the test are shown in the table below along with the reference values.

| TABLE 20 TEST CASE 5.13 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Canopy width | CIE sky type | A | B | C | D | E | F | G | H |
| 0.5m | Reference | 0.87 | 1.31 | 2.02 | 3.20 | 5.07 | 7.64 | 8.27 | 0.21 |
| | Type 1 | 0.87 | 1.30 | 1.99 | 3.21 | 5.05 | 7.59 | 8.23 | 0.25 |
| | Reference | 0.92 | 1.42 | 2.30 | 3.86 | 6.58 | 10.77 | 12.08 | 0.21 |
| | Type 2 | 0.92 | 1.41 | 2.24 | 3.88 | 6.49 | 10.45 | 11.71 | 0.29 |
| | Reference | 1.08 | 1.54 | 2.26 | 3.40 | 5.11 | 7.34 | 7.65 | 0.21 |
| | Type 3 | 1.08 | 1.54 | 2.25 | 3.41 | 5.10 | 7.31 | 7.62 | 0.22 |
| | Reference | 1.16 | 1.71 | 2.62 | 4.16 | 6.73 | 10.52 | 11.37 | 0.21 |
| | Type 4 | 1.15 | 1.69 | 2.56 | 4.16 | 6.64 | 10.22 | 11.03 | 0.27 |
| | Reference | 1.27 | 1.75 | 2.49 | 3.59 | 5.19 | 7.11 | 7.13 | 0.21 |
| | Type 5 | 1.26 | 1.75 | 2.48 | 3.60 | 5.17 | 7.12 | 7.12 | 0.19 |
| | Reference | 0.95 | 1.38 | 2.07 | 3.19 | 4.97 | 7.42 | 8.07 | 0.21 |
| | CIE overcast | 0.93 | 1.38 | 2.09 | 3.33 | 5.14 | 7.59 | 8.08 | 0.24 |
| 1m | Reference | 0.87 | 1.31 | 2.02 | 3.20 | 4.68 | 5.69 | 4.08 | 0.21 |
| | Type 1 | 0.87 | 1.30 | 1.99 | 3.21 | 4.67 | 5.65 | 4.13 | 0.25 |
| | Reference | 0.92 | 1.42 | 2.30 | 3.86 | 6.00 | 7.72 | 5.78 | 0.21 |
| | Type 2 | 0.92 | 1.41 | 2.24 | 3.88 | 5.95 | 7.56 | 5.71 | 0.30 |
| | Reference | 1.08 | 1.54 | 2.26 | 3.40 | 4.74 | 5.53 | 3.83 | 0.21 |
| | Type 3 | 1.08 | 1.54 | 2.25 | 3.41 | 4.73 | 5.50 | 3.85 | 0.22 |
| | Reference | 1.16 | 1.71 | 2.62 | 4.16 | 6.17 | 7.63 | 5.51 | 0.21 |
| | Type 4 | 1.15 | 1.69 | 2.56 | 4.16 | 6.11 | 7.48 | 5.42 | 0.27 |
| | Reference | 1.27 | 1.75 | 2.49 | 3.59 | 4.82 | 5.42 | 3.63 | 0.21 |
| | Type 5 | 1.26 | 1.75 | 2.48 | 3.60 | 4.81 | 5.41 | 3.63 | 0.19 |
| | Reference | 2.22 | 3.12 | 4.57 | 6.99 | 10.13 | 12.33 | 8.73 | 0.41 |
| | CIE overcast | 0.93 | 1.38 | 2.09 | 3.33 | 4.76 | 5.67 | 4.07 | 0.24 |
| 2m | Reference | 0.83 | 1.09 | 1.44 | 1.88 | 2.22 | 1.72 | 0.40 | 0.21 |
| | Type 1 | 0.83 | 1.09 | 1.44 | 1.90 | 2.26 | 1.80 | 0.56 | 0.29 |
| | Reference | 0.87 | 1.17 | 1.59 | 2.14 | 2.63 | 2.10 | 0.40 | 0.21 |
| | Type 2 | 0.87 | 1.17 | 1.59 | 2.17 | 2.70 | 2.25 | 0.66 | 0.34 |
| | Reference | 1.03 | 1.31 | 1.66 | 2.06 | 2.33 | 1.72 | 0.40 | 0.21 |
| | Type 3 | 1.03 | 1.31 | 1.66 | 2.08 | 2.35 | 1.77 | 0.49 | 0.25 |
| | Reference | 1.10 | 1.42 | 1.86 | 2.39 | 2.81 | 2.14 | 0.40 | 0.21 |
| | Type 4 | 1.10 | 1.42 | 1.85 | 2.40 | 2.84 | 2.24 | 0.59 | 0.31 |
| | Reference | 1.21 | 1.50 | 1.86 | 2.24 | 2.44 | 1.73 | 0.40 | 0.21 |
| | Type 5 | 1.21 | 1.50 | 1.86 | 2.25 | 2.44 | 1.75 | 0.43 | 0.22 |
| | Reference | 0.90 | 1.16 | 1.50 | 1.90 | 2.20 | 1.68 | 0.40 | 0.21 |
| | CIE overcast | 0.88 | 1.16 | 1.52 | 1.99 | 2.33 | 1.81 | 0.53 | 0.28 |

The test results match the reference values closely in every case, except for the Overcast sky scenario with a 1m canopy. **A closer look at the reference values reveals that skytypes 1 and Overcast are similar in nature and should have values that are similar. Hence it appears that the reference values for that scenario (highlighted in yellow) are incorrectly listed in the CIE report.**



**Reference chart for 2m canopy and sky type 1**



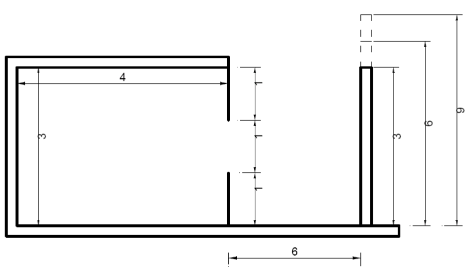

**Calculated chart for 2m canopy and sky type 1**

Although the SC and ERC components cannot be shown individually with AGi32, it can be seen from the chart that the overall values of SC+ERC are very similar.

### 5.14 SC+ ERC for an unglazed façade opening with a continuous external vertical mask

This section is meant to test the ability of the software to simulate the effect of a continuous external vertical mask on interior illuminance from daylighting

The figure for the test geometry from the CIE report is shown below.




External canopy heights of 3m, 6m and 9m are considered for the test scenarios.

As in Section 5.13, the Daylight Factor values are used for the SC+ERC values. Values were calculated for CIE sky types 1 through 5 and Overcast. As before a vertical sun angle of 60 degrees was maintained.

The table below lists the test values along with the reference values for comparison

| TABLE 21 TEST CASE 5.14 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Canopy width | CIE sky type | A | B | C | D | E | F | G | H |
| 3m high | Reference | 0.82 | 1.28 | 2.02 | 3.20 | 5.07 | 7.64 | 9.33 | 5.09 |
| | Type 1 | 0.81 | 1.27 | 1.98 | 3.21 | 5.05 | 7.59 | 9.32 | 5.11 |
| | Reference | 0.86 | 1.39 | 2.30 | 3.86 | 6.58 | 10.77 | 13.66 | 6.33 |
| | Type 2 | 0.85 | 1.38 | 2.24 | 3.88 | 6.49 | 10.45 | 13.26 | 6.30 |
| | Reference | 1.00 | 1.50 | 2.26 | 3.40 | 5.11 | 7.34 | 8.61 | 4.56 |
| | Type 3 | 0.99 | 1.50 | 2.25 | 3.40 | 5.10 | 7.31 | 8.60 | 4.59 |
| | Reference | 1.06 | 1.66 | 2.62 | 4.16 | 6.73 | 10.52 | 12.82 | 5.80 |
| | Type 4 | 1.05 | 1.64 | 2.56 | 4.15 | 6.63 | 10.21 | 12.45 | 5.77 |
| | Reference | 1.15 | 1.70 | 2.49 | 3.59 | 5.19 | 7.11 | 7.99 | 4.13 |
| | Type 5 | 1.14 | 1.70 | 2.48 | 3.59 | 5.17 | 7.12 | 8.01 | 4.14 |
| | Reference | 0.88 | 1.34 | 2.07 | 3.19 | 4.97 | 7.42 | 9.11 | 5.04 |
| | CIE overcast | 0.86 | 1.34 | 2.09 | 3.33 | 5.14 | 7.59 | 9.13 | 4.93 |
| 6m high | Reference | 0.41 | 0.47 | 0.79 | 1.79 | 3.73 | 7.40 | 9.33 | 5.09 |
| | Type 1 | 0.29 | 0.40 | 0.76 | 1.78 | 3.68 | 7.35 | 9.32 | 5.11 |
| | Reference | 0.31 | 0.36 | 0.73 | 2.02 | 4.77 | 10.43 | 13.66 | 6.33 |
| | Type 2 | 0.22 | 0.31 | 0.71 | 2.05 | 4.69 | 10.11 | 13.26 | 6.30 |
| | Reference | 0.47 | 0.53 | 0.88 | 1.88 | 3.73 | 7.11 | 8.61 | 4.56 |
| | Type 3 | 0.32 | 0.45 | 0.83 | 1.85 | 3.68 | 7.07 | 8.60 | 4.59 |
| | Reference | 0.35 | 0.40 | 0.80 | 2.11 | 4.80 | 10.17 | 12.82 | 5.80 |
| | Type 4 | 0.25 | 0.34 | 0.77 | 2.11 | 4.71 | 9.88 | 12.46 | 5.77 |
| | Reference | 0.51 | 0.59 | 0.95 | 1.96 | 3.75 | 6.89 | 7.99 | 4.13 |
| | Type 5 | 0.35 | 0.49 | 0.89 | 1.90 | 3.69 | 6.88 | 8.01 | 4.14 |
| | Reference | 0.42 | 0.48 | 0.81 | 1.78 | 3.65 | 7.19 | 9.11 | 5.04 |
| | CIE overcast | 0.29 | 0.40 | 0.77 | 1.81 | 3.72 | 7.33 | 9.13 | 4.93 |
| 9 m high | Reference | 0.77 | 0.90 | 1.04 | 1.19 | 1.27 | 3.97 | 9.33 | 5.09 |
| | Type 1 | 0.29 | 0.40 | 0.57 | 0.83 | 1.19 | 3.92 | 9.30 | 5.11 |
| | Reference | 0.59 | 0.69 | 0.79 | 0.90 | 0.97 | 5.18 | 13.66 | 6.33 |
| | Type 2 | 0.23 | 0.31 | 0.45 | 0.65 | 0.94 | 5.01 | 13.22 | 6.30 |
| | Reference | 0.88 | 1.02 | 1.19 | 1.35 | 1.45 | 3.93 | 8.61 | 4.56 |
| | Type 3 | 0.32 | 0.45 | 0.64 | 0.93 | 1.34 | 3.86 | 8.58 | 4.59 |
| | Reference | 0.66 | 0.77 | 0.89 | 1.02 | 1.09 | 5.08 | 12.82 | 5.80 |
| | Type 4 | 0.25 | 0.35 | 0.49 | 0.71 | 1.03 | 4.89 | 12.42 | 5.77 |
| | Reference | 0.97 | 1.12 | 1.30 | 1.48 | 1.59 | 3.90 | 7.99 | 4.13 |
| | Type 5 | 0.35 | 0.49 | 0.69 | 1.01 | 1.45 | 3.81 | 7.99 | 4.14 |
| | Reference | 0.80 | 0.93 | 1.08 | 1.23 | 1.32 | 3.93 | 9.11 | 5.04 |
| | CIE overcast | 0.29 | 0.41 | 0.57 | 0.83 | 1.20 | 3.89 | 9.11 | 4.93 |

The reference values and the test values are similar for all points for the 3m high canopy. For the 6m canopy, the test values for points A and B are lower than the reference values. This tends to become more pronounced for the 9m high canopy where the test values for points A, B, C, D and E are lower than the reference values. This disparity in results that increases with the height of canopy suggests that the Sky Component is being partially blocked by the canopy. This blocking may not have been accounted for in the reference values.

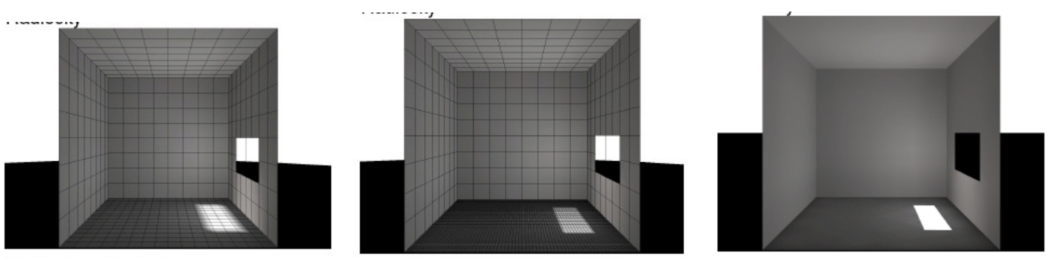
# Section 6

**It is important to note on this section that these tests are only proposed in order to cover additional aspects of lighting simulation, some of these tests are not completely defined in the CIE document. The authors created the scenarios that were possible in the current version of AGi32 following as closely as possible the descriptions presented.**

### 6.1 Sun patches

This test verifies the ability of the program to create a sun patch on the floor of a room from a rectangular opening on the wall. The report specifies that the area surrounding the sunpatch should have an illuminance value of zero, while the sun patch itself should have some analytically calculated value.

When the test was performed, depending on the mesh size, the sun patch appeared more or less defined. Regardless of mesh size though, there was a defined sun patch in the rendering once a raytrace was performed.



Radiosity with wireframe Radiosity with wireframe Raytrace

There was a considerable difference in the illuminance values between the sun patch and surrounding areas. However because of the presence of skylight, the surrounding areas did not have zero illuminance.

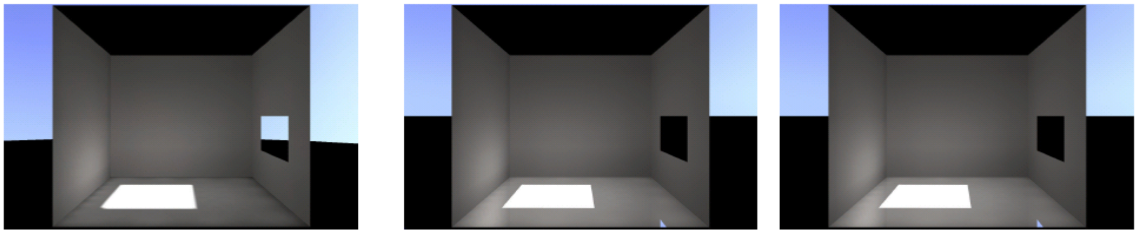
### 6.2 Specular reflections

This test is meant to verify the ability of the program to simulate specular surfaces.

Directional sunlight incident on a specular room floor should create a sun patch on the wall.

AGi32 primarily works through the use of radiosity and assumes that all surfaces are diffuse. After the initial calculation, there is a raytracing option that can be applied to get a rendering that includes specular surfaces. However while the specular surface itself looks like a mirror and has reflections of surrounding objects on its surface, it does not behave like a mirror and reflect the light rays (in this case the sun patch) on to adjoining surfaces.

Regardless of the raytracing options chosen and changing parameters such as the number of bounces, AGi32 was not able to simulate the sun patch on the wall reflected from a specular floor.



Radiosity Raytrace - 4 bounces Raytrace - 8 bounces

Both raytrace images with direct illumination option enabled.

**6.3 Simulating an ideal diffuse glass material**

Not possible in the current version of AGi32

**6.4 Light transmission through bi-directional glazing**

This test is not possible, since a bidirectional glazing surface cannot be defined in the current version of AGi32

**6.5 Light reflection on bidirectional surfaces**

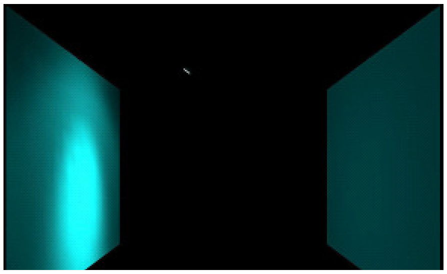
This test is not possible, since a bidirectional glazing surface cannot be defined in the current version of AGi32

**6.6 Spectral calculation**

This test is meant to verify the ability of the program to simulate the spectral properties of internal surfaces.

Scenario A: A light source of a given spectrum when illuminating an ideal diffuse surface of certain absorption, should reflect light of a certain color, as determined by the spectrum of the reflected light.

Although AGi32 currently does not allow users to specify the exact spectral properties of the light, it does allow for color adjustments based on an RGB scale. Therefore a white light (SRE =1) illuminating a blue-green surface reflects blue-green light onto the opposite wall, which appears bluish green even though it is a neutral grey. Hence the absorptive qualities of the surface and spectral qualities of the reflected light are consistent with what they should be.



Render Image - View Name : Render

ctrum when illuminating a surface with an opposite absorption should

*Scenario B*

Again in this case, although exact spectral composition of the light and the surface cannot be defined, the same model as in Scenario A was used. Instead of white light, saturated red coloured light (SRE = 0.21) illuminates a blue green surface. As a result all the red is absorbed and the surface appears black (surface luminance = zero). Hence this test was verified.

**6.7 External illuminance variation**

AGi32 can calculate the variations in external illuminance caused by different sky types, differing sun angles and differing zenith luminances. However this section was not tested since it's not quite clear from the document what the test measures and what is used as a reference.

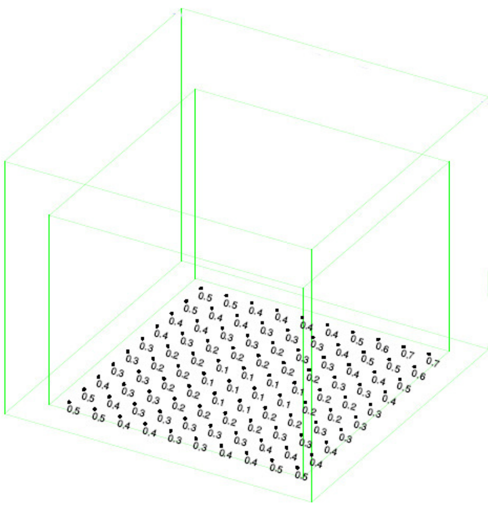
**6.8 Daily and monthly variation of external illuminance**

Again, although AGi32 can calculate daily and monthly variations in external illuminance bases on the geographical location and the sun angles, the test and the references are not clearly defined. Hence this test was not done.

**6.9 Light Leaks into enclosed areas**

This section is meant to verify if light leaks are present when sunlight illuminates a closed box on a horizontal surface.

An outer envelope of daylight transition opening surfaces was built around a box made of double-sided surfaces. Light leaks were present, but minimal and illuminance values of 0.1fc and 0.2fc were seen on the floor.



Agi32 further minimizes light leaks by allowing the user to select different surface types, a surface that is not defined as a Daylight surface will not allow Daylight to penetrate the plane. This type of leak would only occur on nested rooms, which is discouraged by the software developers.

**6.10 Room surface symmetry**

An isoradiant source when placed in the centre of a 4m x 4m x 4m room, should give equal illuminance values on all the surfaces, when measured on a 10 x10 grid. This test is done with 2 surface reflectances – 0% and 50%.

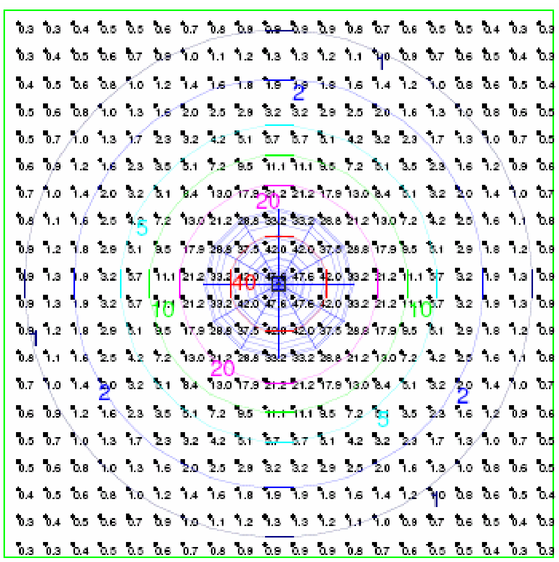

Section 6.10
Centre of source at 2m,2m,2m, Room refl -0%


Section 6.10
Centre of source at 2m,2m,2m Room refl -50%

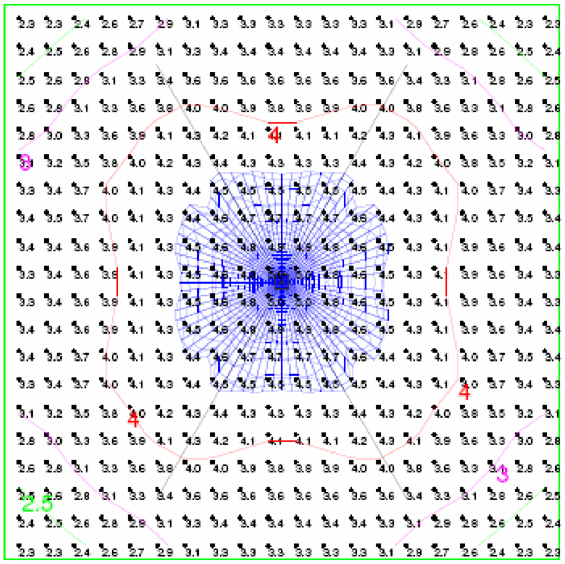
### 6.11 Light source symmetry

This test is meant to verify the ability of the program to process a source with symmetric distribution. The model is a 4m x 4m x 3m room with a light source placed in the centre of the ceiling, and wall reflectances of zero. The floor has an illuminance grid of 20 x 20 and the points should reflect the symmetrical distribution of the source. This test is performed with an axially symmetric source, a source with quadrilateral symmetry and a source with bilateral symmetry.

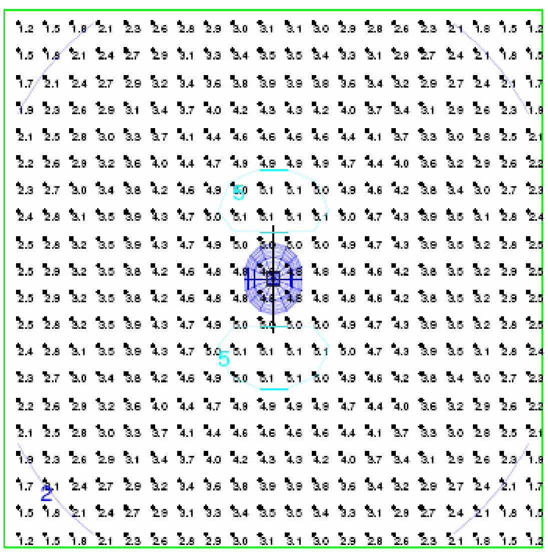
The figures below show the calculation grids on the floor using AGi32 for the axial source, the quadrilateral source and the bilateral source. In all cases, the symmetry of pattern on the floor matches the symmetry of the photometric distribution. Hence this test is verified.



Floor
Section 6.11
Room reflectance = 0
Axially symmetric souce
Isolines shown for 1fc, 2fc, 5fc, 10fc, 20fc and 40fc.



Floor
Section 6.11
Room reflectance = 0
Quadrilaterally symmetric souce
Isolines shown for 2.5fc, 3fc and 4fc

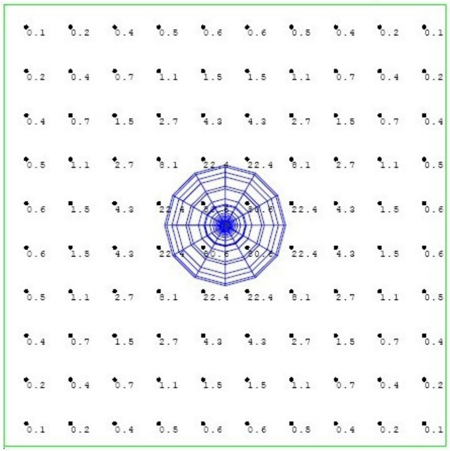


Floor
Section 6.11
Room reflectance = 0
Bilateral symmetric souce
Isolines shown for 1fc, 2fc, 5fc, 10fc, 20fc and 40fc.

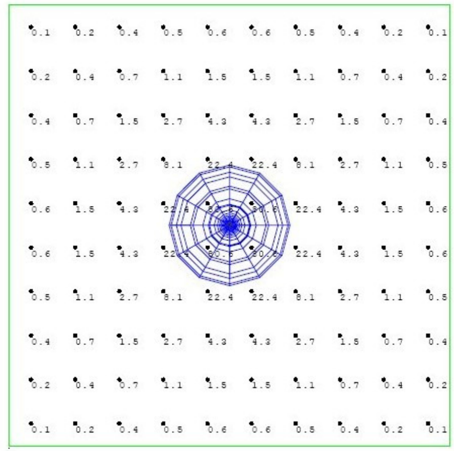
**6.12 Light source aiming**

A light source with a lower hemisphere only distribution located in the centre of a 4m x 4m x 4m room of zero reflectance, when aimed at different surfaces in the room should give the same illuminance value on the aimed surface in each case, as measured on a 10 x 10 grid.

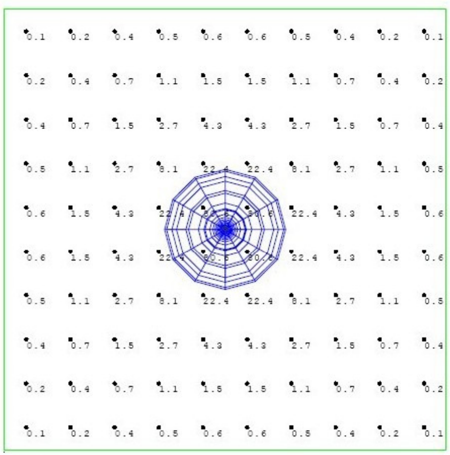
This test was performed with AGi32 and the illuminance grids on each surface at which the luminaire was aimed are of equal illuminance as can be seen from the figures below.



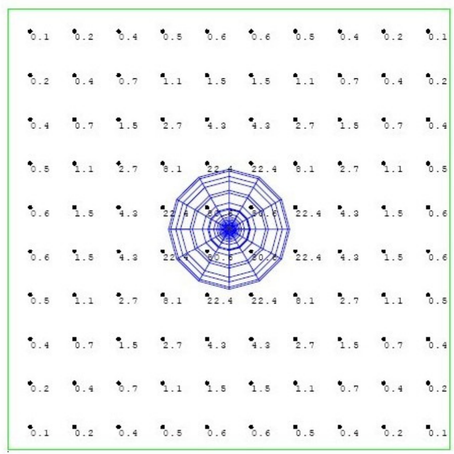
Floor



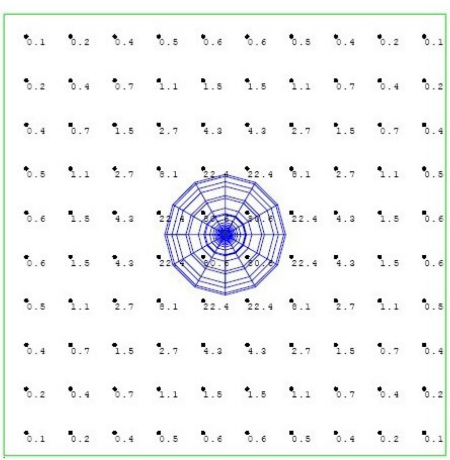
Wall_1



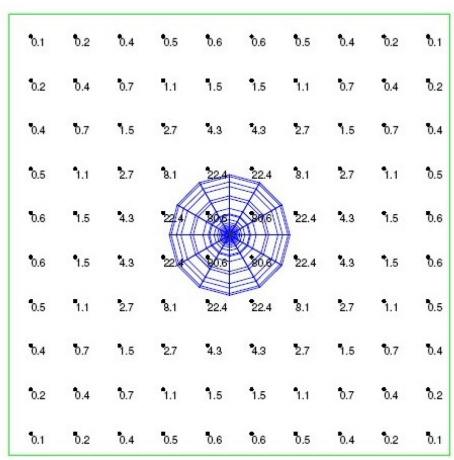
Wall_2



Wall_3



Wall_4

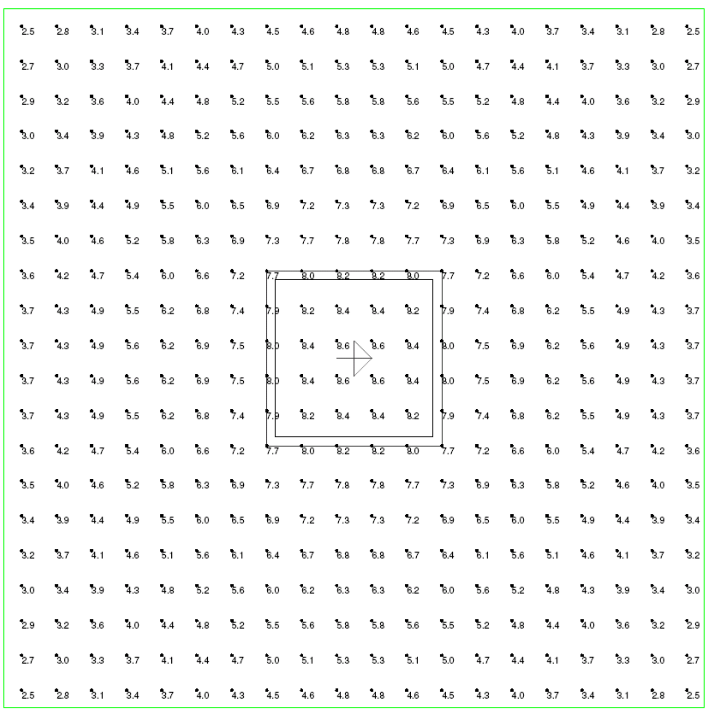


Ceiling

**6.13 Internal shadows**

A 1m x 1m luminaire when placed in the centre of the ceiling of a 4m x 4m x 3m room of zero reflectance, gives a certain illuminance on the floor. However if half the luminaire were masked by a surface, there should be illuminance seen on only half of the room.

In AGi32, in order to keep with the principles of far-field photometry, area luminaries are usually subdivided into smaller sources, each with a distribution pattern similar to the overall distribution.
Therefore for the purposes of this test, this subdivision had to be turned off, by specifying the minimum luminaire segment to be greater than 1m. Once this was done, the luminaire behaved as desired and gave zero illuminance values across half the room when masked.




2.5 2.8 3.1 3.4 3.7 4.0 4.3 4.5 4.6 4.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2.7 3.0 3.3 3.7 4.1 4.4 4.7 5.0 5.1 5.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2.9 3.2 3.6 4.0 4.4 4.8 5.2 5.5 5.6 5.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3.0 3.4 3.9 4.3 4.8 5.2 5.6 6.0 6.2 6.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
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3.4 3.9 4.4 4.9 5.5 6.0 6.5 6.9 7.2 7.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3.5 4.0 4.6 5.2 5.8 6.3 6.9 7.3 7.7 7.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
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3.5 4.0 4.6 5.2 5.8 6.3 6.9 7.3 7.7 7.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3.4 3.9 4.4 4.9 5.5 6.0 6.5 6.9 7.2 7.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3.2 3.7 4.1 4.6 5.1 5.6 6.1 6.4 6.7 6.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3.0 3.4 3.9 4.3 4.8 5.2 5.6 6.0 6.2 6.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2.9 3.2 3.6 4.0 4.4 4.8 5.2 5.5 5.6 5.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2.7 3.0 3.3 3.7 4.1 4.4 4.7 5.0 5.1 5.3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2.5 2.8 3.1 3.4 3.7 4.0 4.3 4.5 4.6 4.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

# APPENDIX

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March 24th, 2007

# Analysis of Test Case 5.7

## CIE 171:2006

## Test Cases to Assess the Accuracy of Lighting Computer Programs

The objective of Test Case 5.7, "Diffuse reflections with internal obstructions," is to "verify the capability of a program to simulate the influence of an obstruction to diffuse illumination."

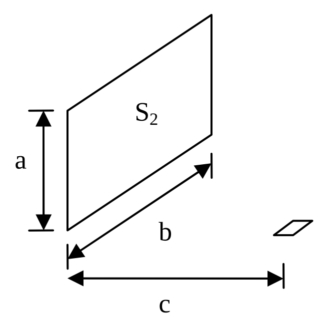
The derivation of Table 19 is not explained in CIE !71, but it was presumably determined using form factor analysis. The following independent analysis indicates that the values presented in Table 19 are incorrect.

### 1. Analytical Reference

As noted in Section 5.7.3, "To enable comparison between the simulation results and the analytical reference independently from the illuminance value over $S_2$ or from its surface reflectance, the reference values are presented under the form of $E/E_v \cdot \rho$ (see Table 19). This is equal to the configuration factor between the measurement point and the unobstructed portion of $S_2$.

### 2. Table 19 Analysis

To validate the values presented in Table 19, it is necessary to calculate the configuration factors between the measurement point and the unobstructed portion of $S_2$. For the horizontal surface $S_{1\text{-hz}}$ measurements, these are given by:



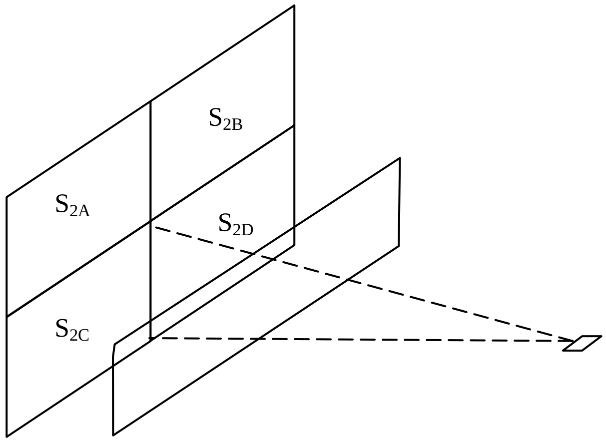

where:

$X = a/b$

$Y = c/b$

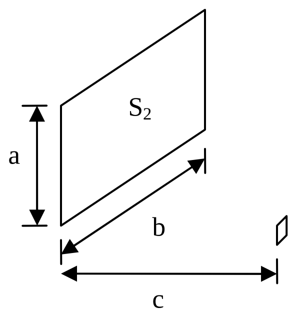
$$C = \frac{1}{2\pi}\left(\arctan\left(\frac{1}{Y}\right) - \frac{Y}{\sqrt{X^2+Y^2}}\arctan\left(\frac{1}{\sqrt{X^2+Y^2}}\right)\right)$$

We can then use form factor algebra to determine:




where $C = C(S_{2A+2C}) + C(S_{2B+2D}) - C(S_{2C}) - C(S_{2D})$.

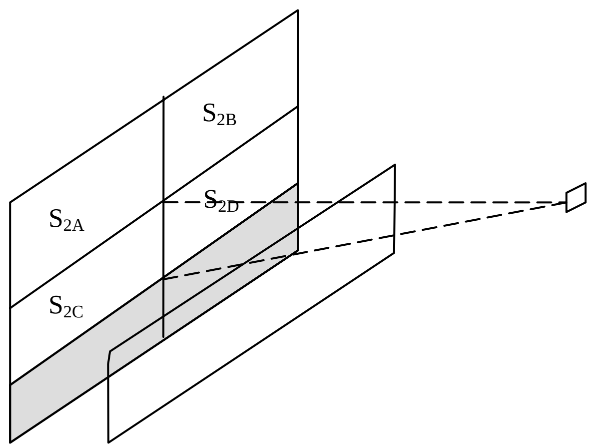
For the vertical surface $S_{1\text{-}v}$ measurements, the configuration factors are given by:




where:

$$X = a/c$$
$$Y = b/c$$
$$C = \frac{1}{2\pi}\left(\frac{X}{\sqrt{1+X^2}}\arctan\left(\frac{Y}{\sqrt{1+X^2}}\right) + \frac{Y}{\sqrt{1+Y^2}}\arctan\left(\frac{X}{\sqrt{1+Y^2}}\right)\right)$$

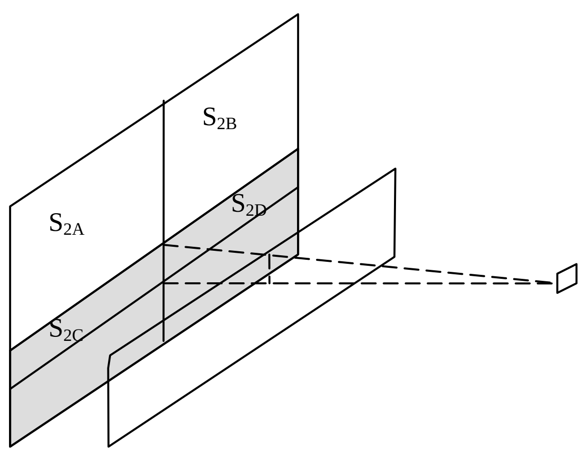
We can again use form factor algebra to determine:




where:

$$C = C(S_{2A}) + C(S_{2B}) + C(S_{2C}) + C(S_{2D})$$

for measurement points A through D, and:




$$C = C(S_{2A+2C}) + C(S_{2B+2D}) - C(S_{2C}) - C(S_{2D})$$

for measurement points E and F.

Table 19 then becomes:

| **Points of measurement for $S_{1\text{-}v}$** | | | | | | |
|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** |
| $E/(E_v \cdot \rho)$(%) | 17.38 | 13.08 | 9.80 | 9.60 | 12.62 | 12.44 |

| **Points of measurement for $S_{1\text{-}hz}$** | | | | | |
|---|---|---|---|---|---|
| | **G** | **H** | **I** | **J** | **K** |
| $E/(E_v \cdot \rho)$(%) | 3.38 | 3.62 | 3.02 | 0.00 | 0.00 |

## 3. Conclusion

Table 19 of CIE 171:2006 is incorrect, likely because incorrect geometry was used for the calculations.

**Worksheet**

**Horizontal Points (G – K)**

b = 2.0

| Point | c | a | X | Y | s | $C(S_{2C})$, $C(S_{2D})$ |
|---|---|---|---|---|---|---|
| G | 3.75 | 1.6667 | 0.8333 | 1.8750 | 2.0518 | 0.0120 |
| H | 3.25 | 1.8751 | 0.9286 | 1.6250 | 1.8716 | 0.0200 |
| I | 2.75 | 2.2000 | 1.1000 | 1.3750 | 1.7609 | 0.0359 |
| J | 2.25 | 3.0000 | 1.5000 | 1.1250 | 1.8750 | 0.0689 |
| K | 1.75 | - | - | - | - | - |

| Point | c | a | X | Y | s | $C(S_{2A+2C})$, $C(S_{2B+2D})$ |
|---|---|---|---|---|---|---|
| G | 3.75 | 3.0000 | 1.5000 | 1.8750 | 2.4012 | 0.0289 |
| H | 3.25 | 3.0000 | 1.5000 | 1.6250 | 2.2115 | 0.0381 |
| I | 2.75 | 3.0000 | 1.5000 | 1.3750 | 2.0349 | 0.0510 |
| J | 2.25 | 3.0000 | 1.5000 | 1.1250 | 1.8750 | 0.0689 |
| K | 1.75 | - | - | - | - | - |

| Point | C |
|---|---|
| G | 0.0338 |
| H | 0.0362 |
| I | 0.0302 |
| J | 0.0000 |
| K | - |

**Vertical Points (A – D)**

b = 2.0
c = 4.0
Y = 0.5
sx = sqrt(1 + $X^2$)
sy = sqrt(1 + $Y^2$) = 1.1180

| Point | a | X | sx | $C(S_{2A})$, $C(S_{2B})$ |
|---|---|---|---|---|
| A | 0.25 | 0.0625 | 1.0019 | 0.0011 |
| B | 0.75 | 0.1875 | 1.0174 | 0.0098 |
| C | 1.25 | 0.3125 | 1.0476 | 0.0254 |
| D | 1.75 | 0.4375 | 1.0915 | 0.0451 |

| Point | a | X | sx | $C(S_{2C})$, $C(S_{2D})$ |
|---|---|---|---|---|
| A | 2.75 | 0.6875 | 1.2135 | 0.0858 |
| B | 2.00 | 0.5000 | 1.1180 | 0.0556 |
| C | 1.20 | 0.3000 | 1.0440 | 0.0236 |
| D | 0.40 | 0.1000 | 1.0049 | 0.0029 |

| Point | C |
|---|---|
| A | 0.1738 |
| B | 0.1308 |
| C | 0.0980 |
| D | 0.0960 |

**Vertical Points (E – F)**

b = 2.0

c = 4.0
Y = 0.5
sx = sqrt(1 + $X^2$)
sy = sqrt(1 + $Y^2$) = 1.1180

| **Point** | **a** | **X** | **sx** | **$C(S_{2A+2C})$, $C(S_{2B+2D})$** |
|---|---|---|---|---|
| E | 2.25 | 0.5625 | 1.1473 | 0.0660 |
| F | 2.75 | 0.6875 | 1.2135 | 0.0858 |

| **Point** | **a** | **X** | **sx** | **$C(S_{2C})$, $C(S_{2D})$** |
|---|---|---|---|---|
| E | 0.40 | 0.1000 | 1.0049 | 0.0029 |
| F | 1.20 | 0.3000 | 1.0440 | 0.0236 |

| **Point** | **C** |
|---|---|
| E | 0.1262 |
| F | 0.1244 |

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# Analysis of Test Case 5.8

## CIE 171:2006

## Test Cases to Assess the Accuracy of Lighting Computer Programs

The objective of Test Case 5.8, "Internal reflected component calculation for diffuse surfaces," is to "assess the accuracy of the diffuse inter-reflections inside a room."

The approach consists of analytically calculating the indirect illuminance of a closed sphere by an isotopic point light source and using this as the "approximate average indirect illuminance" of a square room.

### 1. General Approach Commentary

To quote from CIE 171:2006:

> *The test case geometry is a square room of dimensions 4 m x 4 m x 4 m ($S_T$ = 96 m$^2$), with all surfaces being uniform diffusers and spectrally neutral. An isotropic point light source is positioned at the centre of the room with an output flux ($\phi$) of 10000 lm.*
>
> *The reflectance $\rho$ is the same for all interior surfaces and varies from 0% to 95%.*

It is understandable that CIE 171:2006 specifies a square room rather than a tessellated sphere, as some older programs (such as Lighting Technologies' *Lumen Micro*) are incapable of supporting arbitrarily oriented surface elements. However, this presents a problem in that the interreflections between surface elements at the room corners result in significantly lower illuminances for these elements than for those elements in the middle of the room surfaces. This problem is exacerbated by low surface reflectances[1]. (See Figure 1 for an example).

This problem is compounded by the choice of surface discretization. A coarse mesh will tend to smooth the illuminance distribution, but it will also mask errors[2]. Without specifying a mesh resolution or how to average the results, it is difficult to compare the results from different lighting design programs such as *AGi32* that use the radiosity method. It is even more difficult to compare results from ray-tracing programs such as *Radiance*, as the results depend on the number of stochastically traced rays.

[1] In general, the luminance distribution of a non-convex object is determined not only by external illumination but also by interreflections between its surfaces. This issue has been extensively studied in the field of computer vision and image understanding. See for example M. S. Langer, "When Shadows Become Interreflections," International Journal of Computer Vision. 34 (2/3):193-204, 1999 (available from http://www.cim.mcgill.ca/~langer/research-interreflections.html).

[2] A presentation by DIAL recommends that the isotopic point source be replaced with a non-isotopic point source that results in a uniform direct illumination distribution of the room surfaces. Unfortunately, this proposed solution is flawed in that the interreflections will still result in a non-uniform indirect illuminance distribution. The presentation uses a coarse grid with *DIALux*, which results in a deceivingly smooth luminance distribution and an unsubstantiated assumption of compliance with Test 5.8. (It is likely however that *DIALux* would comply with the revised test recommended herein.)

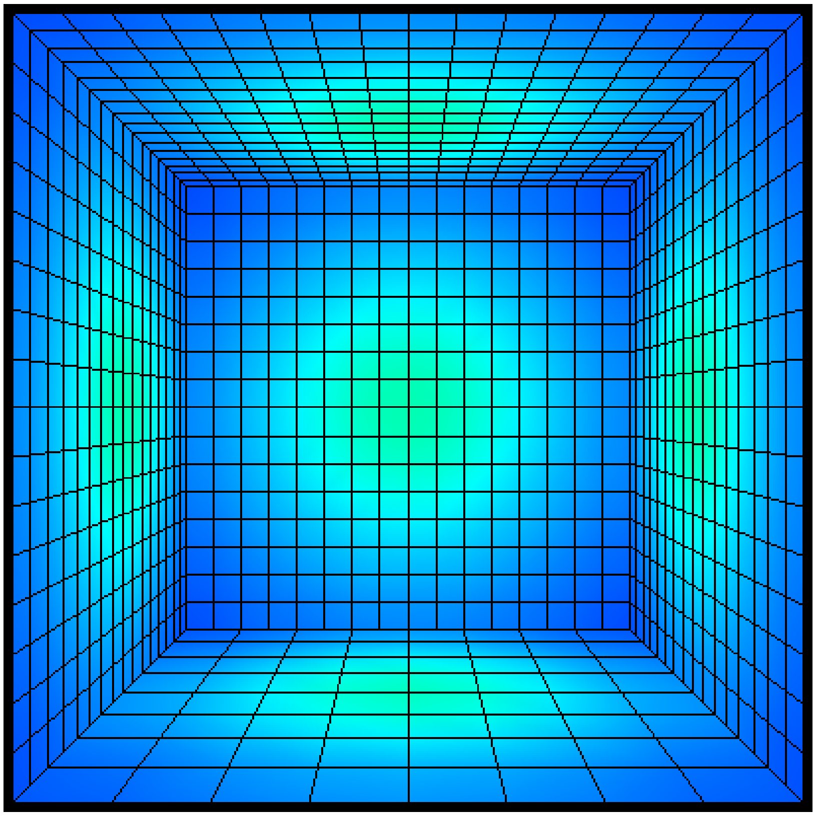

**Figure 1.** Example room with 10% surface reflectance. Illuminance values range from 48 cd / m$^2$ in room corners to 209 cd / m$^2$ in center of room surfaces. (Table 1 predicts 115 cd / m$^2$.)

## 2. Analytical Solution Commentary

To quote from CIE 171:2006:

*Analytically, in the case of a closed sphere with diffuse internal surfaces, the indirect flux* $\phi_i$ *incident upon an internal point of the sphere is given by the equation:*

$$\phi_i = \rho\phi + \rho^2\phi + \rho^3\phi + \ldots = \frac{\rho \cdot \phi}{1 - \rho} \qquad (14)$$

*where:*

$\phi$ *= direct luminous flux entering the sphere.*

*The indirect illuminance at any internal point of the sphere is given by the equation:*

$$E = \frac{1}{S_T} \cdot \frac{\rho \cdot \phi}{1 - \rho} \qquad (15)$$

*where:*

*E = indirect illuminance (lx);*

$S_T$ *= sphere internal surface (m$^2$);*

$\rho$ *= sphere internal surface reflectance;*

$\phi$ *= direct luminous flux entering the sphere (lm)*

The problem with this approach is that most lighting design programs do not separately report direct and indirect illuminance. It is therefore necessary to relate total illuminance to its indirect component for the special case of an integrating sphere.

The luminance $L$ at any internal point of the sphere due to indirect *and direct* illuminance is:

$$L = \frac{\phi}{\pi S_T} \cdot \frac{\rho}{1-\rho}$$

Given that the sphere surface is an ideal diffuse reflector, the luminous exitance $M$ at any point is:

$$M = \pi L = \frac{1}{S_T} \cdot \frac{\rho \cdot \phi}{1-\rho}$$

and so the illuminance $E$ at any point is:

$$E = \frac{M}{\rho} = \frac{1}{S_T} \cdot \frac{\phi}{1-\rho}$$

The direct illuminance $E_D$ at any point is:

$$E_D = \frac{\phi}{S_T}$$

and so its indirect illuminance $E_I$ is:

$$E_I = \frac{\phi}{S_T} \cdot \left( \frac{1}{1-\rho} - \frac{1-\rho}{1-\rho} \right) = \frac{\phi}{S_T} \cdot \frac{\rho}{1-\rho} = \rho E$$

and so:

$$E = \frac{E_I}{\rho}$$

Dividing each entry of Table 20 by $\rho$ gives:

| $\rho$ | 0.00 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 0.95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *E* | 0.00 | 109 | 115 | 130 | 148 | 173 | 208 | 260 | 347 | 520 | 1041 | 2083 |

**Table 1.** Illuminance variation with reflectance.

### 3. *AGi32* Analysis

To test the compliance of *AGi32* Version 1.9 to these revised analytical results, a recursively subdivided octahedron with 256 elements was used to approximate a sphere, where each element consists of an identical equiangular triangle (Figure 2). The sphere has a diameter of 5.528 meters, giving a surface area of 96 $m^2$. An isotropic point source emitter with an intensity of 10000 lm / $4\pi$ = 795.8 cd and a surface area of 25 $mm^2$ was inserted at the geometric center of the sphere.

Allowing the convergence to proceed to 0.01 gave the following average illuminance values:

| $\rho$ | 0.00 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 0.95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{theoretical}$ | 0.00 | 109 | 115 | 130 | 148 | 173 | 208 | 260 | 347 | 520 | 1041 | 2083 |
| $E_{average}$ | 0.00 | 109 | 115 | 130 | 148 | 173 | 209 | 261 | 347 | 522 | 1044 | 2092 |
| *% Error* | +0.0 | +0.0 | +0.0 | +0.0 | +0.0 | +0.0 | +0.5 | +0.4 | +0.0 | +0.4 | +0.3 | +0.4 |
| *Steps* | 4 | 390 | 454 | 493 | 534 | 704 | 919 | 1177 | 1647 | 2558 | 5279 | 10692 |

**Table 2.** Calculated average illuminance variation with reflectance (*AGi32*).

For the case of an integrating sphere, the maximum error is 0.5 percent.

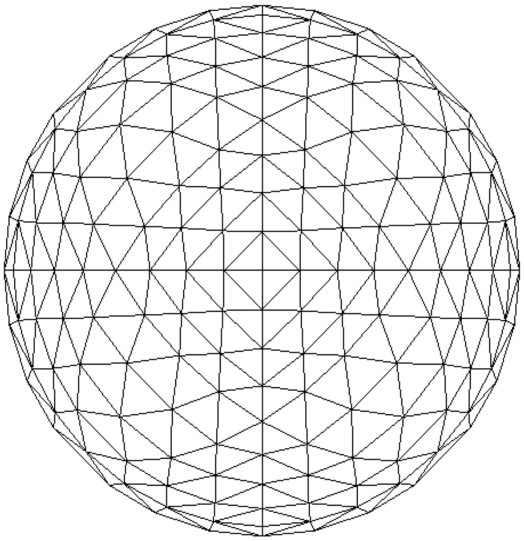

**Figure 2.** Recursively subdivided octahedron with 256 elements.

## 4. Conclusions

*AGi32* complies with the intent of CIE 171:2006 Test Case 5.8 to within 0.5%. However, the specified test case geometry of a square room does not lend itself to meaningful and unambiguous results.

In view of the above, it is recommended that:

1. The test case geometry be amended to consist of a sphere rather than a square room; and
2. The test case analytical reference be amended to specify total illuminance rather than indirect illuminance.