February 2024

# Validation of software
# DL-Light version 15
# On the test series CIE 171:2006

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


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# Introduction

The document CIE 171:2006 published by the International Commission on Illumination « Test Cases to Assess the Accuracy of Lighting Computer Programs» defines a serie of tests and reference results by analytical calculation. The purpose of this document (cf. document CIE): « *The objective of this report is to help lighting program users and developers assess the accuracy of lighting computer programs and to identify their weaknesses. A validation approach is therefore presented based on the concept of separately testing the different aspects of light propagation. To apply this approach, a suite of test cases has been designed where each test case highlights a given aspect of the lighting simulation domain and is associated with the related reference data. Two types of reference data are used: data based on analytical calculation and data based on experimental measurements. The first is associated with theoretical scenarios that avoid uncertainties in the reference values. The second type is obtained through experimental measurements, where the scenario and the protocol are defined in a manner that minimizes the uncertainties associated with the measurements.*»

We calculated this set of tests with DL-Light version 15. This document presents the results of these tests.

# Tests used

DL-Light is a software dedicated to simulations in Daylighting, we therefore selected the tests focusing on natural light.
These are tests 5.9 to 5.14. However tests 5.13 and 5.14 are incorrectly described and cannot be reproduced (For more information see Jake Osborne thesis « Building a comprehensive dataset for the validation of daylight simulation software, using complex "real architecture" », School of Architecture, Victoria University of Wellington» and Ian Ashdown, "*CIE 171-2006, An errata, Getting it right*", available on Internet.). These 2 tests could therefore not be completed.
For the other tests, there are various issues and errors, these are specified for each test.

DL-Light is a simulation software, there may be a small variability in the results. In order to ensure a good comparability of results with the theoretical reference results, each test has been performed 20 times for DL-Light version 15.

For each test we provide the average results for each point and a measurement of the dispersion around the average (standard deviation). The smaller this standard deviation, the closer the results around the average, hence the smaller the variability of results. These results are then compared to the references ones.

# Conclusion

For all the tests that have been conducted, results are very close to the reference ones and the dispersion around the average is small.

DL-Light is therefore able to predict with accuracy the illuminance levels in daylighting.

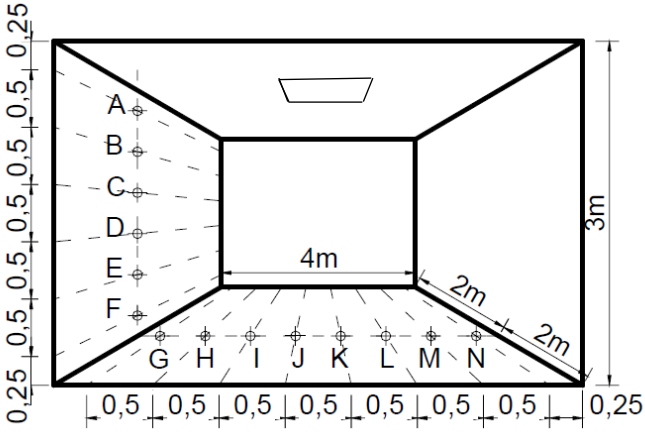
# Test 5.9.3.1

The test 5.9.3.1 defines the geometry that will be used for all the tests.

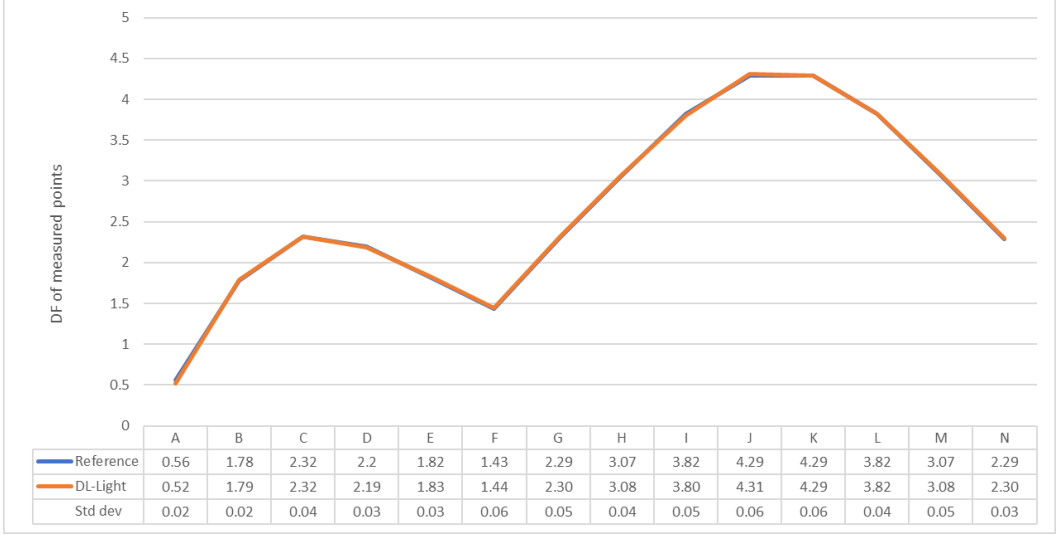
It defines a square room 4*4m and 3m high, with an opening in the ceiling of 1*1m.

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N is calculated and compared to reference results.




Test model 5.9.3.1. Document CIE 171:2006




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 0.56 | 1.78 | 2.32 | 2.2 | 1.82 | 1.43 | 2.29 | 3.07 | 3.82 | 4.29 | 4.29 | 3.82 | 3.07 | 2.29 |
| DL-Light | 0.52 | 1.79 | 2.32 | 2.19 | 1.83 | 1.44 | 2.30 | 3.08 | 3.80 | 4.31 | 4.29 | 3.82 | 3.08 | 2.30 |
| Std dev | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 | 0.06 | 0.05 | 0.04 | 0.05 | 0.06 | 0.06 | 0.04 | 0.05 | 0.03 |

# Conclusion for test 5.9.3.1

DL-Light accurately calculated the expected values for test 5.9.3.1.

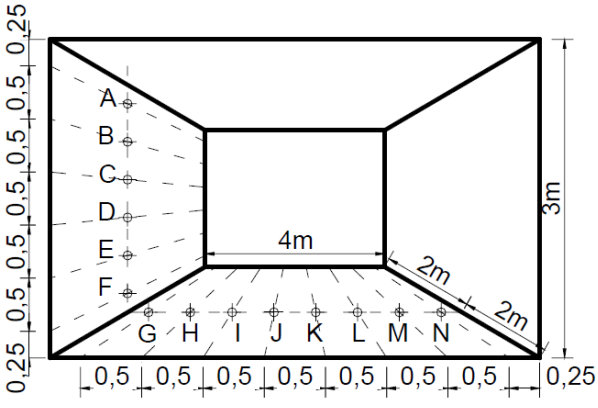
## Test 5.9.3.2

The test 5.9.3.2 uses the geometry defined in the previous test.

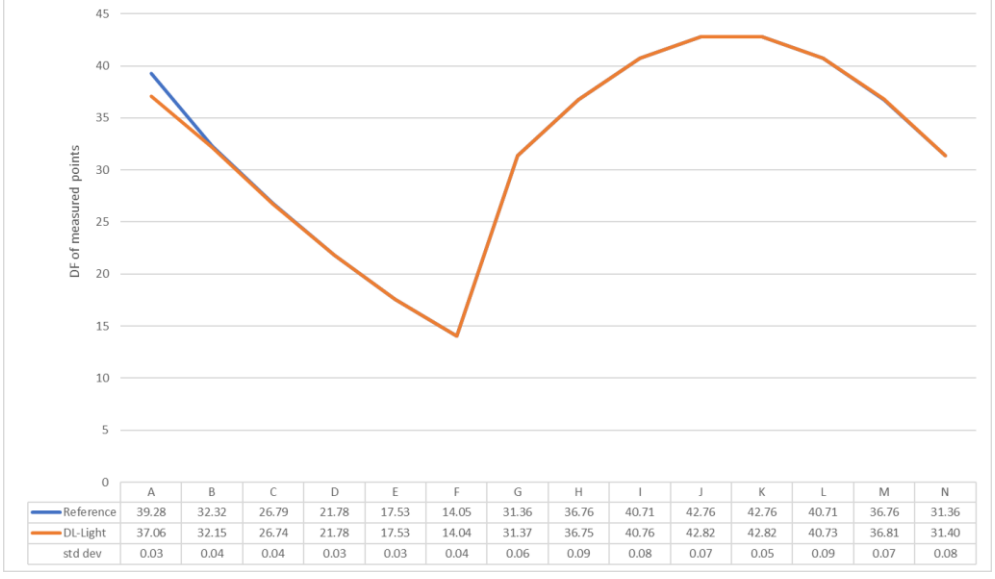
It uses the basic configuration of the square space of 4*4m and 3m high, but the opening in the ceiling is now 4*4m without glazing. The whole ceiling is open.

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N is calculated and compared to reference results.




Test model 5.9.3.2. Document CIE 171:2006




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| DL-Light | 37.06 | 32.15 | 26.74 | 21.78 | 17.53 | 14.04 | 31.37 | 36.75 | 40.76 | 42.82 | 42.82 | 40.73 | 36.81 | 31.40 |
| std dev | 0.03 | 0.04 | 0.04 | 0.03 | 0.03 | 0.04 | 0.06 | 0.09 | 0.08 | 0.07 | 0.05 | 0.09 | 0.07 | 0.08 |

## Conclusion for test 5.9.3.2

DL-Light accurately calculated the expected values for test 5.9.3.2.

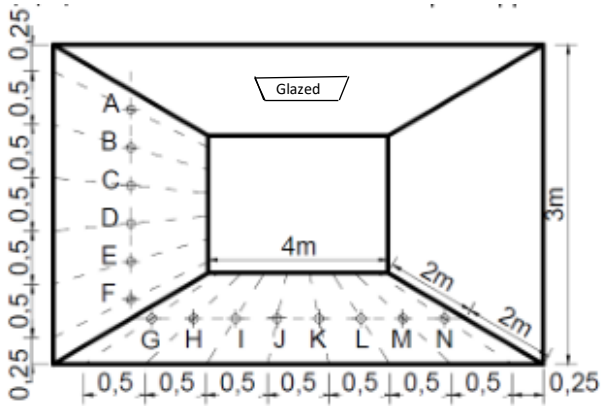
# Test 5.10.1.1.

The test 5.10.1.1 uses the geometry of test 5.9.3.1.

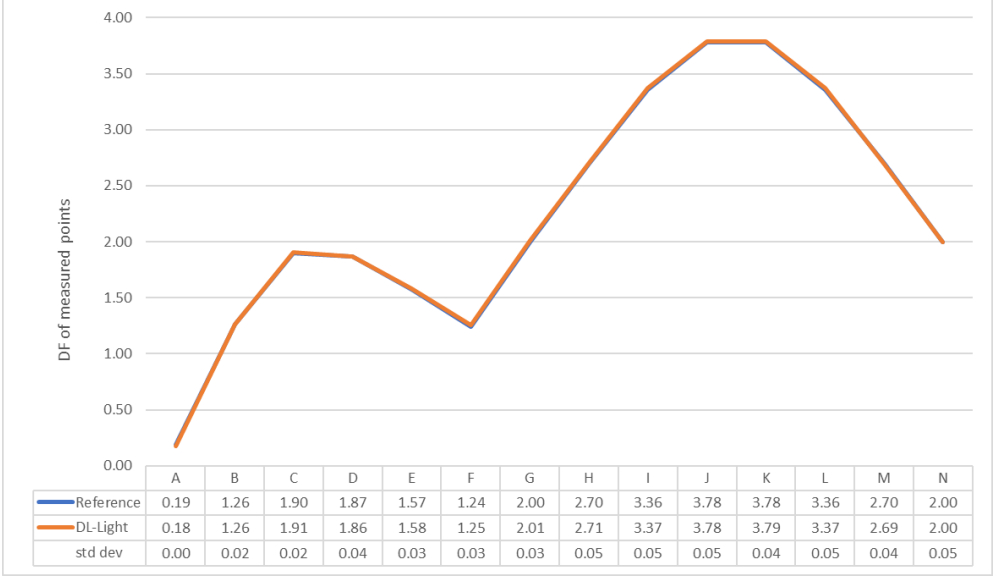
The opening has now a glazing. That glazing is 6mm thick but the transmission factor is not defined. We used 0.88 as transmission factor (common value).

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N is calculated and compared to reference results.




Test model 5.10.1.1. Document CIE 171:2006




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| DL-Light | 0.18 | 1.26 | 1.91 | 1.86 | 1.58 | 1.25 | 2.01 | 2.71 | 3.37 | 3.78 | 3.79 | 3.37 | 2.69 | 2.00 |
| std dev | 0.00 | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.04 | 0.05 |

# Conclusion for test 5.10.1.1

DL-Light accurately calculated the expected values for test 5.10.1.1.

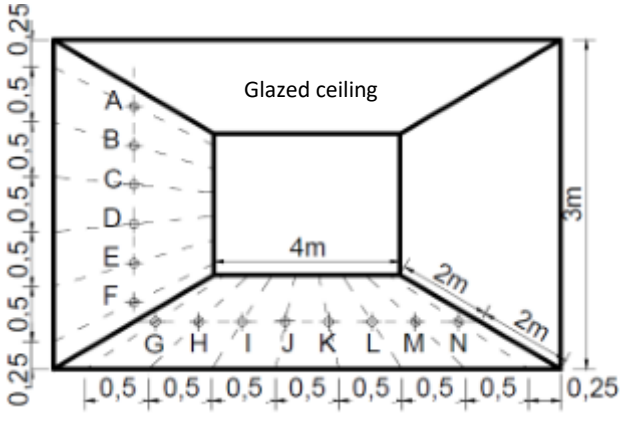
# Test 5.10.1.2.

The test 5.10.1.2 uses the geometry defined in test 5.10.1.1.

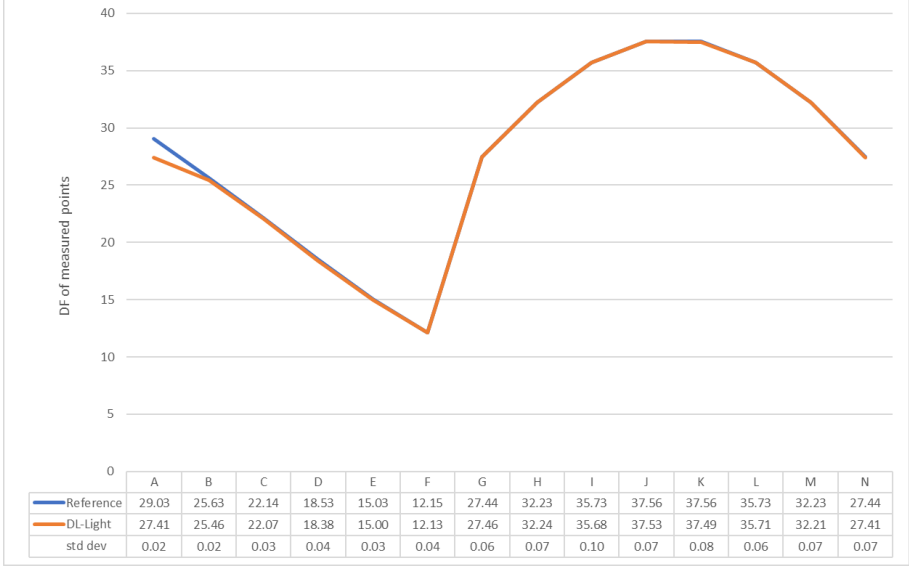
The test add a glazing on the whole ceiling opening. That glazing is 6mm thick but the transmission factor is not defined. We used 0.88 as transmission factor (common value).

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N is calculated and compared to reference results.




Test model 5.10.1.2. Document CIE 171:2006




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 29.03 | 25.63 | 22.14 | 18.53 | 15.03 | 12.15 | 27.44 | 32.23 | 35.73 | 37.56 | 37.56 | 35.73 | 32.23 | 27.44 |
| DL-Light | 27.41 | 25.46 | 22.07 | 18.38 | 15.00 | 12.13 | 27.46 | 32.24 | 35.68 | 37.53 | 37.49 | 35.71 | 32.21 | 27.41 |
| std dev | 0.02 | 0.02 | 0.03 | 0.04 | 0.03 | 0.04 | 0.06 | 0.07 | 0.10 | 0.07 | 0.08 | 0.06 | 0.07 | 0.07 |

# Conclusion for test 5.10.1.2

DL-Light accurately calculated the expected values for test 5.10.1.2.

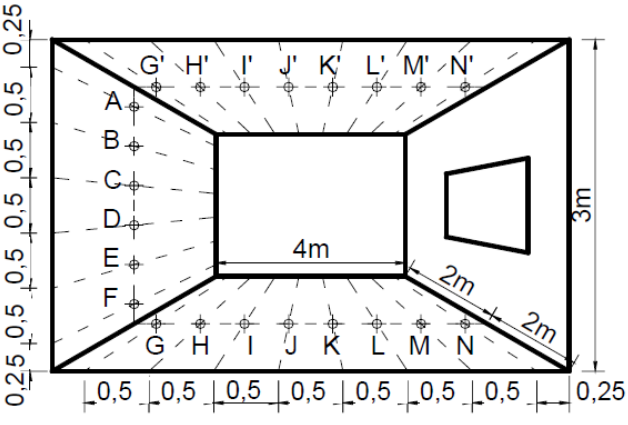
## Test 5.11.3.1.

The test 5.11.3.1 studies the capacity of the software to take into account reflexions from the exterior ground which is illuminated by the sky and sun.

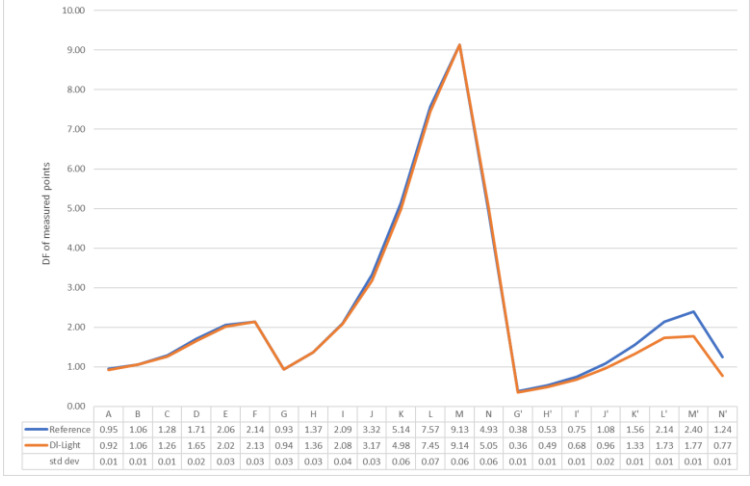
The geometry is as for the other tests with a opening on a vertical facade.

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N' is calculated and compared to reference results.




Test model 5.11.3.1. Document CIE 171:2006




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | G' | H' | I' | J' | K' | L' | M' | N' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 0.95 | 1.06 | 1.28 | 1.71 | 2.06 | 2.14 | 0.93 | 1.37 | 2.09 | 3.32 | 5.14 | 7.57 | 9.13 | 4.93 | 0.38 | 0.53 | 0.75 | 1.08 | 1.56 | 2.14 | 2.40 | 1.24 |
| DI-Light | 0.92 | 1.06 | 1.26 | 1.65 | 2.02 | 2.13 | 0.94 | 1.36 | 2.08 | 3.17 | 4.98 | 7.45 | 9.14 | 5.05 | 0.36 | 0.49 | 0.68 | 0.96 | 1.33 | 1.73 | 1.77 | 0.77 |
| std dev | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.06 | 0.07 | 0.06 | 0.06 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |

## Conclusion for test 5.11.3.1

In this test, we can see differences for the wall in its upper part and for the points on the ceiling.

This comes from the fact that **the hypotheses on this test are false**. The test suppose an exterior surface with a uniform illuminance and that does not take into account the shadow projected by the building itself. Therefore, the analytical results overestimate the close outside illuminance that is bounced on the ceiling and upper part of the wall. Hence, it overestimates the results. This issue is clearly explained in Ian Ashdown, "*CIE 171-2006, An errata, Getting it right*", available on Internet.). *Unfortunately, this test case is flawed in that "the external ground illuminance is assumed to be uniform." This assumption fails to take into consideration shadowing of the ground by the building.*

DL-Light accurately calculated the expected values for test 5.11.3.1 for those that could be calculated, that is when the influence of the ground is negligible.

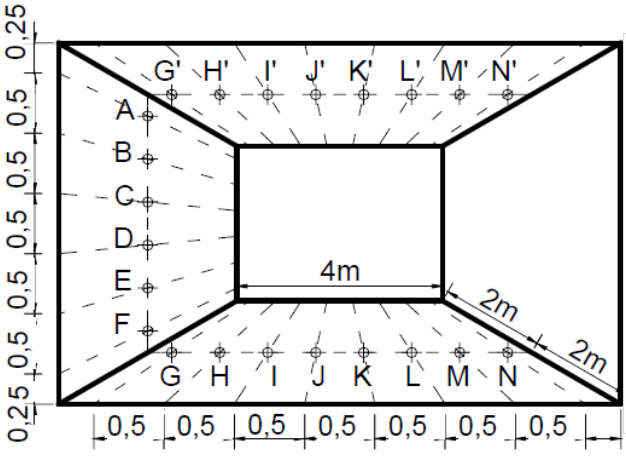
## Test 5.11.3.2.

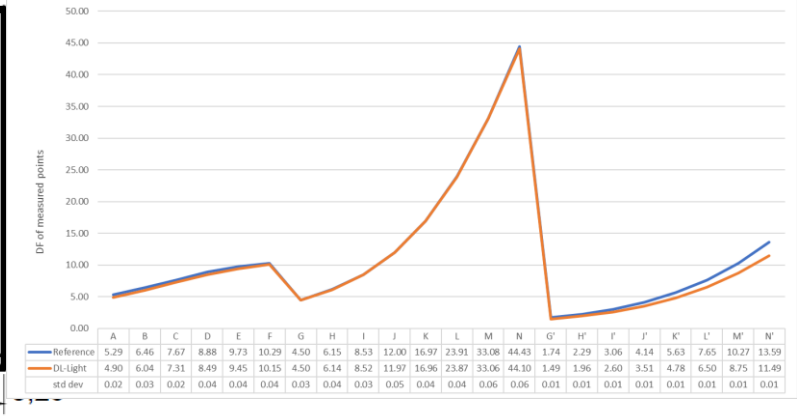
The test 5.11.3.2 studies the capacity of the software to take into account reflexions from the exterior ground which is illuminated by the sky and sun.

The geometry is as for the other tests with a completely open vertical facade.

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N' is calculated and compared to reference results.




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | G' | H' | I' | J' | K' | L' | M' | N' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 5.29 | 6.46 | 7.67 | 8.88 | 9.73 | 10.29 | 4.50 | 6.15 | 8.53 | 12.00 | 16.97 | 23.91 | 33.08 | 44.43 | 1.74 | 2.29 | 3.06 | 4.14 | 5.63 | 7.65 | 10.27 | 13.59 |
| DL-Light | 4.90 | 6.04 | 7.31 | 8.49 | 9.45 | 10.15 | 4.50 | 6.14 | 8.52 | 11.97 | 16.96 | 23.87 | 33.06 | 44.10 | 1.49 | 1.96 | 2.60 | 3.51 | 4.78 | 6.50 | 8.75 | 11.49 |
| std dev | 0.02 | 0.03 | 0.02 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.05 | 0.04 | 0.04 | 0.06 | 0.06 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

Test model 5.11.3.2. Document CIE 171:2006

## Conclusion for test 5.11.3.2

In this test, we can see differences for the wall in its upper part and for the points on the ceiling.

This comes from the fact that **the hypotheses on this test are false**. The test suppose an exterior surface with a uniform illuminance and that does not take into account the shadow projected by the building itself. Therefore, the analytical results overestimate the close outside illuminance that is bounced on the ceiling and upper part of the wall. Hence, it overestimates the results. This issue is clearly explained in Ian Ashdown, "*CIE 171-2006, An errata, Getting it right*", available on Internet.). *Unfortunately, this test case is flawed in that "the external ground illuminance is assumed to be uniform." This assumption fails to take into consideration shadowing of the ground by the building.*

DL-Light accurately calculated the expected values for test 5.11.3.2 for those that could be calculated, that is when the influence of the ground is negligible.

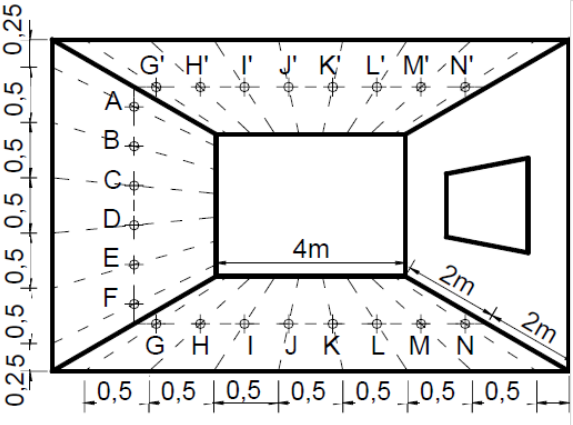
## Test 5.12.3.1.

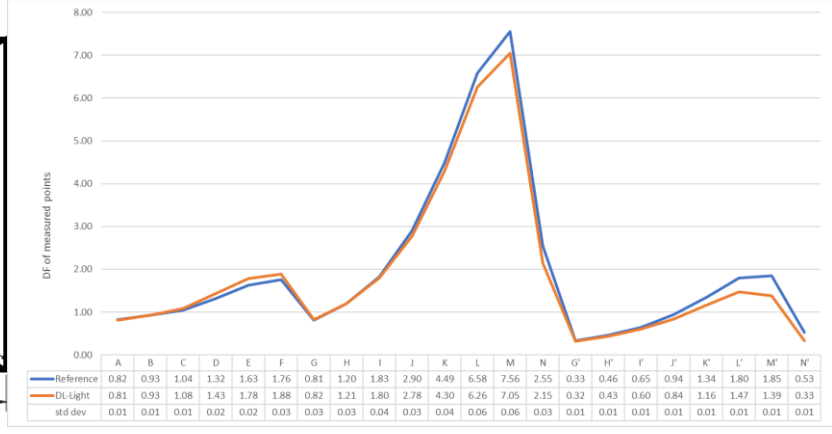
The test 5.12.3.1 studies the capacity of the software to take into account reflexions from the exterior ground which is illuminated by the sky and sun.

The geometry is as for the other tests with a opening on a vertical facade. That glazing is 6mm thick but the transmission factor is not defined. We used 0.88 as transmission factor (common value).

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N' is calculated and compared to reference results.




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | G' | H' | I' | J' | K' | L' | M' | N' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 0.82 | 0.93 | 1.04 | 1.32 | 1.63 | 1.76 | 0.81 | 1.20 | 1.83 | 2.90 | 4.49 | 6.58 | 7.56 | 2.55 | 0.33 | 0.46 | 0.65 | 0.94 | 1.34 | 1.80 | 1.85 | 0.53 |
| DL-Light | 0.81 | 0.93 | 1.08 | 1.43 | 1.78 | 1.88 | 0.82 | 1.21 | 1.80 | 2.78 | 4.30 | 6.26 | 7.05 | 2.15 | 0.32 | 0.43 | 0.60 | 0.84 | 1.16 | 1.47 | 1.39 | 0.33 |
| std dev | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 | 0.06 | 0.06 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

Test model 5.12.3.1. Document CIE 171:2006

## Conclusion for test 5.12.3.1

In this test, we can see differences for the wall in its upper part and for the points on the ceiling.

This comes from the fact that **the hypotheses on this test are false**. The test suppose an exterior surface with a uniform illuminance and that does not take into account the shadow projected by the building itself. Therefore, the analytical results overestimate the close outside illuminance that is bounced on the ceiling and upper part of the wall. Hence, it overestimates the results. This issue is clearly explained in Ian Ashdown, "*CIE 171-2006, An errata, Getting it right*", available on Internet.). *Unfortunately, this test case is flawed in that "the external ground illuminance is assumed to be uniform." This assumption fails to take into consideration shadowing of the ground by the building.*

DL-Light accurately calculated the expected values for test 5.12.3.1 for those that could be calculated, that is when the influence of the ground is negligible.

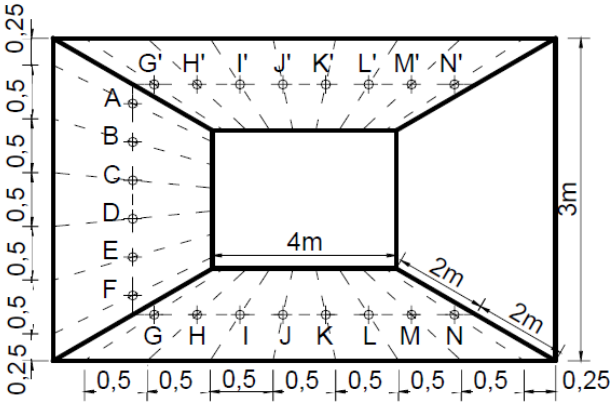
## Test 5.12.3.2.

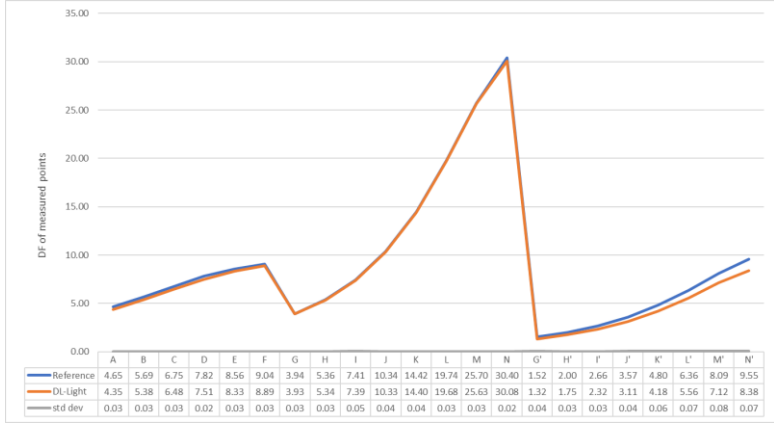
The test 5.12.3.2 studies the capacity of the software to take into account reflexions from the exterior ground which is illuminated by the sky and sun.

The geometry is as for the other tests with a opening on the whole vertical facade. That glazing is 6mm thick but the transmission factor is not defined. We used 0.88 as transmission factor (common value).

The tests uses black surfaces to avoid inter-reflexions.

The illuminance for points A to N' is calculated and compared to reference results.




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | G' | H' | I' | J' | K' | L' | M' | N' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | 4.65 | 5.69 | 6.75 | 7.82 | 8.56 | 9.04 | 3.94 | 5.36 | 7.41 | 10.34 | 14.42 | 19.74 | 25.70 | 30.40 | 1.52 | 2.00 | 2.66 | 3.57 | 4.80 | 6.36 | 8.09 | 9.55 |
| DL-Light | 4.35 | 5.38 | 6.48 | 7.51 | 8.33 | 8.89 | 3.93 | 5.34 | 7.39 | 10.33 | 14.40 | 19.68 | 25.63 | 30.08 | 1.32 | 1.75 | 2.32 | 3.11 | 4.18 | 5.56 | 7.12 | 8.38 |
| std dev | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.03 | 0.04 | 0.06 | 0.07 | 0.08 | 0.07 |

Test model 5.12.3.2. Document CIE 171:2006

## Conclusion for test 5.12.3.2

In this test, we can see differences for the wall in its upper part and for the points on the ceiling.

This comes from the fact that **the hypotheses on this test are false**. The test suppose an exterior surface with a uniform illuminance and that does not take into account the shadow projected by the building itself. Therefore, the analytical results overestimate the close outside illuminance that is bounced on the ceiling and upper part of the wall. Hence, it overestimates the results. This issue is clearly explained in Ian Ashdown, "*CIE 171-2006, An errata, Getting it right*", available on Internet.). *Unfortunately, this test case is flawed in that "the external ground illuminance is assumed to be uniform." This assumption fails to take into consideration shadowing of the ground by the building.*

DL-Light accurately calculated the expected values for test 5.12.3.2 for those that could be calculated, that is when the influence of the ground is negligible.