



physically accurate lighting simulation and image rendering system

## Results of CIE TC.3.33 Tests for Inspirer

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### Introduction

This report represents the results of testing of **Inspirer** system (produced by Integra Inc., Japan) by CIE TC.3.33 test suit. Test suit is described in “TC.3.33 List of proposed test cases” F. Maamari, ENTPE (Ecole Nationale des Travaux Publics de l’Etat) – France, issued 18<sup>th</sup> of September 2002 [1].

Most of test cases can be used as benchmarks of daylight simulation in building [2]. We consider here 3 main components of daylight simulation in Inspirer which are tested by CIE TC.3.33 tests, namely

- simulation of primary daylight source (sunlight and skylight);
- simulation of light transport mechanism;
- interrogation of resultant illuminance distribution.

Inspirer provides the daylight model in accordance with IES recommendations [3].

CIE TC.3.33 test methodology is based on the conception of testing separately the different aspects of the light propagation, like the Light source description, the flux entry, the influence of window components or the interreflections [4]. Each test case involves a limited number of parameters and can be used to assess the capability of Inspirer to respect the laws related to these parameters by comparing simulation results to analytical or experimental references.

Test results are performed by **Inspirer** and reference values are collected in *Microsoft Excel* worksheets for the set of tested points. Original templates for these worksheets are included to CIE TC.3.33 test specification. The worksheets also include relative error for each tested particular point.

Inspirer allows a user to simulate illumination with controllable average error [5] and daylight representation accuracy [6]. The simulation control error was set to 1% or less and daylight accuracy was “super” during CIE tests performing. These simulation control specifications provide reasonable calculation time. The accuracy of Inspirer simulation is non-uniformly distributed so the error in particular points can be greater than the average simulation error.

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## Test Cases

### Test 1. Luminous flux penetration through aperture

Opng. type	Analytical	Simulation	error (%)
Roof opng 1x1	70947.26	71324.224	0.53132989
Roof opng 2x2	283789.04	283186.464	0.21233237
Roof opng 3x3	638525.34	637363.936	0.18188847
Roof opng 4x4	1135156.16	1134567.81	0.05183005
Wall opng 2x1	20459.02	20784.504	<b>1.59090709</b>
Wall opng 3x2	61377.06	61761.45	0.62627633
Wall opng 4x3	122754.12	122758.806	0.00381739

### Test 2. Directional transmittance of clear glass

$\theta^\circ$	0	10	20	30	40
Analyt. $t_\theta$	0.8788	0.8796	0.8799	0.8759	0.8661
Simul. $t_\theta$	0.87	0.88	0.88	0.86	0.85
Analyt. $t_\theta/t_0$	1	1.00095	1.00127	0.99669	0.98558
Simul. $t_\theta/t_0$	1.00	1.00	1.01	1.00	0.98
Error (%)	0	0.222788351	0.607728185	0.221031615	0.149150754

$\theta^\circ$	50	60	70	80	90
Analyt. $t_\theta$	0.8476	0.8018	0.6828	0.4233	0.0284
Simul. $t_\theta$	0.84	0.78	0.66	0.43	
Analyt. $T_\theta/t_0$	0.96447	0.91242	0.7769	0.48171	0.03229
Simul. $t_\theta/t_0$	0.97	0.90	0.76	0.51	
Error (%)	0.814540629	0.819249907	1.672416012	<b>5.438334268</b>	-

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### Test 3. Description of luminaries with intensity distribution files

pts	E analyt.	E Simulation	Error (%)
A	111.111	111.110	0.00
B	105.214	105.150	0.06
C	90.020	89.930	<b>0.10</b>
D	71.110	71.070	0.06
E	99.735	99.640	0.09
F	85.636	85.640	0.01
G	68.064	68.010	0.08
H	74.360	74.370	0.01
I	59.981	59.940	0.07
J	49.392	49.380	0.02

### Test 4. Shape factor

Illuminance variation at floor level					
Points	1	2	3	4	5
Analytical	341.1	324.1	279.9	223.6	169.1
Simulation	340.3	322.3	279.6	222.9	174.0
Error (%)	0.23	0.54	0.11	0.30	2.90

Illuminance variation at wall level						
Points	6	7	8	9	10	11
Illuminance	109.9	147.4	194.6	242.8	260.6	187.4
Simulation	112.9	147.1	193.2	241.1	255.0	181.6
Error (%)	2.70	0.21	0.74	0.73	2.15	<b>3.12</b>

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**Test 5. Surface reflectance**

**Average Indirect illuminance variation with surface reflectance**

<b>Reflectance</b>	<b>0.00</b>	<b>0.05</b>	<b>0.10</b>	<b>0.20</b>	<b>0.30</b>	<b>0.40</b>	<b>0.50</b>
<b>Anaytical E (lx)</b>	0.00	5.48	11.57	26.04	44.64	69.44	104.17
<b>Simulation</b>	0	5.447	11.48	25.92	44.45	69.1	103.9
<b>Error (%)</b>	-	0.7	<b>0.8</b>	0.5	0.4	0.5	0.3

**Average Indirect illuminance variation with surface reflectance**

<b>Reflectance</b>	<b>0.60</b>	<b>0.70</b>	<b>0.80</b>	<b>0.90</b>	<b>0.95</b>	<b>1.00</b>
<b>Anaytical E (lx)</b>	156.25	243.06	416.67	937.50	1979.2	-
<b>Simulation</b>	155.6	242.4	416	938.11	1975	-
<b>Error (%)</b>	0.4	0.3	0.2	0.1	0.2	-

**Test 6. Sky component with unglazed openings under the CIE general sky type 16 (CIE overcast sky)**

<b>Opening type</b>		<b>Sky component at measurement points</b>										<b>Av. err (%)</b>
		<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>	<b>J</b>	
<b>Roof 1x1</b>	<b>Analytical</b>	3.6	3.4	2.6	1.9	2.8	2.2	1.6	1.8	1.3	1.0	
	<b>Simulation</b>	3.6	3.2	2.5	1.8	2.8	2.3	1.8	1.8	1.4	1.1	
	<b>Error (%)</b>	0.8	<b>6.8</b>	4.3	5.5	1.3	2.8	3.1	0.0	4.9	5.3	<b>3.5</b>
<b>Roof 2x2</b>	<b>Analytical</b>	12.9	11.8	10.5	8.1	10.9	9.6	7.4	7.8	6.1	4.8	
	<b>Simulation</b>	12.9	11.9	9.9	7.6	10.9	9.2	7.1	7.8	6.1	4.9	
	<b>Error (%)</b>	0.3	0.6	5.4	5.6	0.3	4.3	3.8	0.3	0.0	1.5	<b>2.2</b>
<b>Roof 3x3</b>	<b>Analytical</b>	25.1	23.5	20.6	17.6	22.0	19.3	16.5	17.0	14.5	11.7	
	<b>Simulation</b>	25.1	23.5	20.6	16.8	22.1	19.4	15.9	17.2	14.1	11.8	
	<b>Error (%)</b>	0.1	0.1	0.2	4.3	0.4	0.3	3.9	0.9	3.0	0.7	<b>1.4</b>
<b>Roof 4x4</b>	<b>Analytical</b>	37.3	35.6	32.3	27.8	34.0	30.8	26.6	28.0	24.2	21.0	
	<b>Simulation</b>	37.5	35.7	32.4	27.9	34.1	30.9	26.6	28.2	24.3	21.1	
	<b>Error (%)</b>	0.4	0.3	0.3	0.4	0.3	0.4	0.2	0.7	0.4	0.6	<b>0.4</b>

**Results of CIE TC.3.33 Tests for Inspirer**

Opening type		Sky component at measurement points								Av. err (%)
		A	B	C	D	E	F	G	H	
Wall 2x1	Analytical	0.8	1.2	1.8	2.7	4.2	6.1	6.9	2.4	
	Simulation	0.8	1.1	1.7	2.6	4.1	6.0	7.4	4.1	
	Error (%)	3.8	5.6	5.6	3.0	3.1	0.9	7.8	70.4	12.5
Wall 3x2	Analytical	2.2	3.2	4.6	6.7	9.9	14.3	18.3	10.2	
	Simulation	2.1	3.0	4.4	6.4	9.7	14.3	19.5	14.9	
	Error (%)	4.0	6.4	5.4	4.1	2.1	0.1	6.5	46.4	9.4
Wall 4x3	Analytical	3.9	5.3	7.4	10.2	14.3	19.6	25.7	30.5	
	Simulation	3.7	5.1	7.1	9.9	14.1	19.8	27.4	36.7	
	Error (%)	4.7	3.8	4.6	2.8	1.6	0.9	6.7	20.3	5.7

**Test 7. Direct illuminance with roof openings under CIE general sky type 5 (Uniform sky)**

**1m x 1m opening**

	Floor measurement points						Wall measurement points						
	A	B	C	D	E	av. err	F	G	H	I	J	K	av. err
Analyt. E	762	724	625	500	378		246	329	435	543	582	419	
Simul. E	747	718	620	497	403		256	325	432	541	560	391	
error (%)	1.99	0.82	0.87	0.64	6.53	2.17	4.03	1.39	0.62	0.26	3.90	6.73	2.82

**2m x 2m opening**

	Floor measurement points						Wall measurement points						
	A	B	C	D	E	av. err	F	G	H	I	J	K	av. err
Analyt. E	2756	2642	2336	1922	1494		903	1207	1608	2076	2407	1950	
Simul. E	2729	2608	2298	1908	1576		952	1208	1617	2068	2317	1801	
error (%)	0.97	1.30	1.65	0.74	5.51	2.03	5.53	0.05	0.54	0.38	3.73	7.63	2.98

**3m x 3m opening**

	Floor measurement points						Wall measurement points						
	A	B	C	D	E	av. err	F	G	H	I	J	K	av. err
Analyt. E	5351	5184	4714	4031	3259		1759	2322	3084	4071	5155	5282	
Simul. E	5299	5122	4684	4009	3419		1829	2320	3108	4086	5063	4866	
error (%)	0.97	1.19	0.63	0.55	4.92	1.65	4.00	0.08	0.78	0.37	1.78	7.87	2.48

**4m x 4m opening**

	Floor measurement points						Wall measurement points						
	A	B	C	D	E	av. err	F	G	H	I	J	K	av. err
Analyt. E	7993	7814	7290	6475	5469		2559	3288	4249	5502	7096	9025	
Simul. E	7938	7740	7262	6442	5665		2668	3289	4284	5540	7087	9037	
error (%)	0.69	0.94	0.38	0.51	3.59	1.22	4.28	0.05	0.83	0.68	0.13	0.14	1.02

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**Test 8. Sky component with glazed roof openings under the CIE general sky type 16 (CIE overcast sky)**

**1m x 1m opening**

Points	A	B	C	D	E	F	Average error (%)
Analytical SC	1.8	2.6	3.1	1.4	2.0	1.0	
Simulation SC	1.8	2.5	3.1	1.3	2.0	1.1	
error (%)	0.6	4.6	0.3	6.4	0.5	<b>9.0</b>	3.6

**2m x 2m opening**

Points	A	B	C	D	E	F	Average error (%)
Analytical SC	7.3	9.6	11.2	6.3	8.9	4.6	
Simulation SC	7.1	9.7	11.2	6.2	8.6	4.6	
error (%)	3.0	1.0	0.2	1.3	2.9	0.9	1.5

**3m x 3m opening**

Points	A	B	C	D	E	F	Average error (%)
Analytical SC	15.9	19.3	21.8	14.1	17.2	10.9	
Simulation SC	15.5	19.6	21.3	13.7	17.0	10.9	
error (%)	2.7	1.8	2.1	3.0	1.2	0.4	1.9

**4m x 4m opening**

Points	A	B	C	D	E	F	Average error (%)
Analytical SC	24.9	29.8	32.5	22.9	27.3	19.2	
Simulation SC	24.7	30.1	33.0	23.0	27.6	19.1	
error (%)	0.9	0.9	1.7	0.6	1.0	0.4	0.9

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**Test 9. Direct illuminance with unglazed wall openings under CIE general sky type 5**

2m x 1m opening

	Floor points				average error(%)
	A	B	C	D	
Calculated E	216.81	193.08	93.76	46.67	
Simulation E	216.675	192.467	100.535	47.937	
error %	0.06	0.32	7.22	2.72	2.58

	Roof points				average error(%)
	L	M	N	O	
Calculated E	14.00	28.13	57.93	65.04	
Simulation E	13.695	28.774	57.331	65.688	
error %	2.18	2.29	1.03	0.99	1.62

	Wall points							average error(%)
	E	F	G	H	I	J	K	
Calculated E	105.93	115.42	97.03	77.26	56.35	34.63	31.78	
Simulation E	107.81	116.583	95.348	74.912	55.445	33.403	31.51	
Error %	1.77	1.01	1.73	3.04	1.61	3.53	0.85	1.93

4m x 3m opening

	Floor points				average error(%)
	A	B	C	D	
Calculated E	1230.2	686.8	371.7	208.3	
Simulation E	1212.869	693.456	374.531	223.961	
error %	1.41	0.96	0.75	7.50	2.66

	Roof points				average error(%)
	L	M	N	O	
Calculated E	369.1	206.1	111.5	62.5	
Simulation E	366.935	204.452	110.151	62.134	
error %	0.57	0.78	1.23	0.59	0.79

	Wall points							average error(%)
	E	F	G	H	I	J	K	
Calculated E	472.6	438.5	415.4	388.0	356.4	320.8	239.1	
Simulation E	471.18	439.661	413.435	391.937	350.214	316.508	234.484	
error %	0.30	0.26	0.47	1.01	1.74	1.33	1.92	1.00

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### Test 10. Direct illuminance with glazed wall openings under CIE general sky type 16

#### 2m x 1m opening

	Floor points								Av. err (%)
	A	B	C	D	E	F	G	H	
<b>Calculated DF</b>	0.8	1.2	1.8	2.7	4.2	6.1	6.9	2.4	
<b>Calculated E</b>	19.547	29.321	43.982	65.973	102.624	149.049	168.597	58.642	
<b>Simulation E</b>	20.782	30.56	45.749	70.252	108.147	156.161	172.599	44.873	
<b>error %</b>	6.32	4.23	4.02	6.49	5.38	4.77	2.37	<b>23.48</b>	7.13

#### 4m x 3m opening

	Floor points								Av. err (%)
	A	B	C	D	E	F	G	H	
<b>Calculated DF</b>	3.92	5.34	7.37	10.26	14.30	19.61	25.72	30.58	
<b>Calculated E</b>	95.782	130.479	180.081	250.696	349.410	479.157	628.450	747.201	
<b>Simulation E</b>	100.006	136.822	188.416	262.452	366.457	498.473	643.262	740.097	
<b>error %</b>	4.41	4.86	4.63	4.69	<b>4.88</b>	4.03	2.36	0.95	3.85

## Conclusion

The total number of CIE tests is 227 combined in 10 test sets. Inspirer system demonstrates the following accuracy:

Error between CIE data and simulation results	Number of passed tests	Per cent from total tests number
less than 1%	119	52
less than 3%	163	72
less than 5%	197	87
less than 10%	223	98
more than 10%	4	2

## References

- [1] "TC.3.33 List of proposed test cases" F. Maamari, ENTRE – France, Ecole Nationale des Travaux Publics de l'Etat (ENTRE), Laboratory of Building sciences (LASH), Department of Civil Engineering and Building(DGCB), URA CNRS 1652, issued 18<sup>th</sup> of September 2002
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