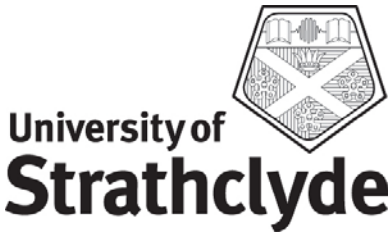
ESRU

Technical Report



CIBSE TM33 Tests for Software Accreditation and Verification: ESP-r Test Results

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Test G1A: Building Material Thermal Property Database

Program: ESP-r Version 11.4, released November 2007

Models
The model is in directory TestG1A/Test_G1A/cfg. There is one configuration file for this test (called test_G1A.cfg).

Simulations
To get results, extract a Quality Assurance (QA) report by setting up the option for databases to "verbose" and then generate the report. This will list the constructions and the materials used for this model together with their thermophysical properties. An example of text taken from the QA report is given here:

```
Multi-layer constructions used:

Details of opaque construction: test_G1A_1st

Layer|Prim|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R    |Descr
     |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext     1   10.0     1.130  2000.  1000. 0.01 0.01    10.  0.01 cast_concrete_CIBSE_GuideA
   2    2   10.0     0.840  1700.   800. 0.01 0.01    10.  0.01 Outer_brick_CIBSE_GuideA
   3    3   10.0     1.150  1800.  1000. 0.01 0.01    10.  0.01 Medium_weight_concrete_BS_EN17
   4    4   10.0     1.650  2000.  1000. 0.01 0.01    10.  0.01 Medium_no2_weight_concrete_BS_
   5    5   10.0     0.035    30.  1000. 0.01 0.01    10.  0.29 Mineral_fibre_CIBSE_GuideA
   6    6   10.0     0.035    25.  1400. 0.01 0.01    10.  0.29 Expanded_polysterene_CIBSE_Gui
   7    7   10.0     0.140   530.  1800. 0.01 0.01    10.  0.07 Plywood_sheathing_CIBSE_GuideA
Int     8   10.0     0.090   300.  1600. 0.01 0.01    10.  0.11 Timber_board_BS_EN1745
```

Results

Table 2.1 (materials of Table 2.2 are also available in the QA report)

Material	Source	Density kg m^{-3}		Thermal conductivity Wm^{-1} K^{-1}		Specific heat $Jkg^{-1}K^{-1}$	
		Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
Outer brick	CIBSE Guide A	1700	**1700**	0.84	**0.84**	800	**800**
Cast concrete	CIBSE Guide A	2000	**2000**	1.13	**1.13**	1000	**1000**
Medium weight concrete	BS EN 1745	1800-2000	**1800 & 2000**	1.15-1.65	**1.15 & 1.65**	1000	**1000**
Mineral fibre	CIBSE Guide A	30	**30**	0.035	**0.035**	1000	**1000**
Expanded polystyrene	CIBSE Guide A	25	**25**	0.035	**0.035**	1400	**1400**
Plywood sheathing	CIBSE Guide A	530	**530**	0.14	**0.14**	1800	**1800**
Timber board	BS EN 1745	300-1000	**300 & 1000**	0.09-0.24	**0.09 & 0.24**	1600	**1600**
Asbestos cement	iSBEM	700	**700**	0.36	**0.36**	1000	**1000**
Brick inner leaf	iSBEM	1700	**1700**	0.56	**0.56**	1000	**1000**
Carpet	iSBEM	20	**20**	0.058	**0.058**	1000	**1000**
EPS insul. (50mm)	iSBEM	15	**15**	0.04	**0.04**	1300	**1300**
Sandstone	iSBEM	2600	**2600**	2.3	**2.3**	1000	**1000**

Conclusion
All thermal properties are correctly reported by ESP-r.

Test G1B: Climate data

Program: ESP-r Version 11.4, released November 2007.

Models

There are 3 ESP-r climate files: London_CIBSE.try, Man_CIBSE.try and Edin_CIBSE.try.

Simulations

Run the climate module for each climate file and extract monthly averages from the "synoptic analysis" and the rest of the data from "table (one day) analysis".

Results

Table 2.3 Climate data test results

Variable	Basis	**Value for stated climate data set**					
		London		Manchester		Edinburgh	
		Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
Temperature (°C)	January 6; 10:00 a.m.	6.1	**6.1**	-1.3	**-1.3**	6.6	**6.6**
	July 15; 2:00 p.m.	19.1	**19.1**	15.3	**15.3**	14.6	**14.6**
	February average	4.5	**4.5**	4.8	**4.8**	2.7	**2.7**
Wind speed (m/s)	January 6; 10:00 a.m.	5.66	**5.7**	2.06	**2.1**	7.2	**7.2**
	July 15; 2:00 p.m.	4.63	**4.6**	4.63	**4.6**	3.09	**3.1**
	November average	3.46	**3.4**	3.24	**3.2**	4.92	**4.9**
Global solar radiation ($W.m^{-2}$)	January 6; 10:00 a.m.	59	**59**	67	**67**	54	**54**
	July 15; 2:00 p.m.	336	**336**	238	**238**	210	**210**
	July average	212	**211.7**	194	**193.8**	189	**189.5**

Table 2.4 (London Test Reference Year, July 15th)

	Temp / °C		**Solar radiation / $W \cdot m^{-2}$**			
			Global horiz		Diffuse	
Hour	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
1	14	**14.0**	0	**0**	0	**0**
2	13.3	**13.3**	0	**0**	0	**0**
3	12.2	**12.2**	0	**0**	0	**0**
4	11	**11.0**	0	**0**	0	**0**
5	11.5	**11.5**	30	**30**	20	**20**
6	12.1	**12.1**	155	**155**	54	**54**
7	13.2	**13.2**	332	**332**	131	**131**
8	15.1	**15.1**	420	**420**	98	**98**
9	16.9	**16.9**	619	**619**	110	**110**
10	17.8	**17.8**	385	**385**	269	**269**
11	17.5	**17.5**	239	**239**	231	**231**
12	18.3	**18.3**	379	**379**	360	**360**
13	19.2	**19.2**	610	**610**	409	**409**
14	19.1	**19.1**	336	**336**	334	**334**
15	19.4	**19.4**	287	**287**	279	**279**
16	18.9	**18.9**	218	**218**	216	**216**
17	18.8	**18.8**	238	**238**	235	**235**
18	18.8	**18.8**	110	**110**	104	**104**
19	18	**18.0**	35	**35**	35	**35**
20	17	**17.0**	2	**2**	1	**1**
21	13.4	**13.4**	0	**0**	0	**0**
22	13	**13.0**	0	**0**	0	**0**
23	12.9	**12.9**	0	**0**	0	**0**
24	12.8	**12.8**	0	**0**	0	**0**

Conclusion: Results are as specified.

Test G1C: Loads and Schedules

Program
ESP-r version 11.5, released April 2008

Models
There is no model related to this test. This is a test that reports activity values that are read from the SBEM.db1 database or from external files and are used for UK NCM purposes.

Output
To display the data of Tables 2.5 and 2.7, users must first assign zones to the specified activity databases (i.e. link zones to activities in the UK NCM specifications section). A summary of the user choices, including the output needed for these tables, is displayed on the screen when using the "Display information" option. To display the hourly data needed for Table 2.6, users should access the “impose measure/temporal data section”, access the related activity entry (for example the entry for the Airport check in area), select to import UK NCM data and finally select the zone that this activity has been linked to. The data will be then loaded and the hourly values will be displayed on the interface for every hour of the year.

Results

Space/activity	***Occupancy***						
	People / m^2		Metabolic rate / W person^{-1}		Latent heat %		Schedule
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	
Airport Check	0.25	**0.25**	140	**140**	50	**50**	Airport_Check_ Occ_wkdy_Wk1
Court_lecture	0.5	**0.5**	140	**140**	39	**39**	Court_Lecture_ Occ_Wkdy
Uni_CommStaff	0.11	**0.11**	100	**100**	39	**39**	Uni_CommStaff_ Occ_Wkdy
Workshop_ IndProcess	0.02	**0.02**	250	**250**	73	**73**	Workshop_IndPro cess_Occ_Wkdy

Table 2.5

Hour	***Fraction of maximum for stated schedule***							
	Airport_Check_Occ_wkdy		Court_Lecture_Occ_Wkdy		Uni_CommStaff_Occ_Wkdy		Workshop_IndProcess_Occ_Wkdy	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
0-1	0.1	**0.1**	0	**0**	0	**0**	0	**0**
1-2	0.1	**0.1**	0	**0**	0	**0**	0	**0**
2-3	0.1	**0.1**	0	**0**	0	**0**	0	**0**
3-4	0.1	**0.1**	0	**0**	0	**0**	0	**0**
4-5	0.25	**0.25**	0	**0**	0	**0**	0	**0**
5-6	0.25	**0.25**	0	**0**	0	**0**	0	**0**
6-7	0.5	**0.5**	0	**0**	0	**0**	0	**0**
7-8	0.5	**0.5**	0	**0**	0.1	**0.1**	0.5	**0.5**
8-9	0.5	**0.5**	0	**0**	0.25	**0.25**	0.75	**0.75**
9-10	0.5	**0.5**	0.25	**0.25**	0.25	**0.25**	1	**1**
10-11	0.5	**0.5**	0.5	**0.5**	0.1	**0.1**	1	**1**
11-12	0.5	**0.5**	0.5	**0.5**	0.1	**0.1**	1	**1**
12-13	0.25	**0.25**	0.25	**0.25**	0.25	**0.25**	0.5	**0.5**
13-14	0.25	**0.25**	0.25	**0.25**	0.25	**0.25**	0.5	**0.5**
14-15	0.25	**0.25**	0.5	**0.5**	0.1	**0.1**	1	**1**
15-16	0.25	**0.25**	0.5	**0.5**	0.1	**0.1**	1	**1**
16-17	0.5	**0.5**	0.5	**0.5**	0.1	**0.1**	1	**1**
17-18	0.5	**0.5**	0	**0**	0.1	**0.1**	0.5	**0.5**
18-19	0.5	**0.5**	0	**0**	0	**0**	0	**0**
19-20	0.5	**0.5**	0	**0**	0	**0**	0	**0**
20-21	0.5	**0.5**	0	**0**	0	**0**	0	**0**
21-22	0.1	**0.1**	0	**0**	0	**0**	0	**0**
22-23	0.1	**0.1**	0	**0**	0	**0**	0	**0**
23-24	0.1	**0.1**	0	**0**	0	**0**	0	**0**

Table 2.6

Space/activity	***Lighting /lux***		***Equipment***				***HVAC Systems***			
			Total / Wm^{-2}		Latent %		Domestic hot water / $L\ day^{-1}\ m^{-2}$		Outside air / $Ls^{-1}\ person^{-1}$	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
DayCtr_FoodPrep	500	**500**	40	**40**	32	**32**	0.33	**0.33**	12	**12**
Office_Openoff	500	**500**	15	**15**	0	**0**	0.33	**0.33**	8	**8**
Theatre Lecture	300	**300**	2	**2**	0	**0**	0.15	**0.15**	8	**8**
Uni_Bed	80	**80**	5	**5**	19	**19**	8	**8**	8	**8**

Table 2.7

Conclusion
The tables show that ESP-r correctly reports the required data.

Test G2: Solar Position

Program
ESP-r version 11.4, released November 2007.

Models
The models are in directory TestG2/simple/cfg. There is a configuration file for each location and date.

Simulations
To get results, run the models with the simulation presets of date, timesteps etc. Turn on the trace in the simulator and select the "solar radiation summary" and output results for timesteps 1 to 48 (includes the pre-simulation day). Extract the solar position from the trace file.

Results

Table 2.8

Time hh/dd /mm	***London*** 51.48N 0.45W				***Manchester*** 53.25N 2.27W				***Edinburgh*** 55.95N 3.35W			
	Azimuth		Altitude		Azimuth		Altitude		Azimuth		Altitude	
	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**
1200/ 22/12	180.0	**179.8**	15.1	**15.1**	178.3	**178.1**	13.3	**13.3**	177.3	**177.1**	10.6	**10.6**
1500/ 27/02	224.1	**224.4**	20.4	**20.7**	221.9	**222.2**	19.9	**20.1**	220.2	**220.5**	18.3	**18.5**
1200/ 21/06	178.4	**178.3**	62.0	**62.0**	175.2	**175.0**	60.1	**60.1**	173.7	**173.5**	57.4	**57.4**
1000/ 20/10	151.1	**151.2**	24.4	**23.9**	149.6	**149.7**	22.3	**21.8**	149.1	**149.1**	19.7	**19.1**

Conclusion
All results obtained by ESP-r are within the tolerance limits.

Test G3.1: Static conduction test

Program
ESP-r, Version 11.4 released November 2007

Model
The model is in directory testg3_1_model/cfg. There is one configuration file for this test (called testG3_1.cfg).

Simulations
To get results, extract a Quality Assurance (QA) report by setting up the option for databases to "verbose" and optionally toggle to export to file and then generate the report. This will report the thermophysical values for every construction and for different heat flow directions. An example of text taken from the QA report is given here:

```
Details of opaque construction: External

Layer|Prim|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R    |Descr
     |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext    34   55.0     0.990  1800.   850. 0.00 0.80    10.  0.06 Outer layer (zero ext ir)
   2   34   60.0     0.990  1800.   850. 0.00 0.80    10.  0.06 Outer layer (zero ext ir)
   3   22   60.0     0.040    30.   850. 0.01 0.60    10.  1.50 Mineral wool 1
   4   23   30.0     0.790  1600.   850. 0.01 0.60    10.  0.04 Masonry
   5   23   60.0     0.790  1600.   850. 0.01 0.60    10.  0.08 Masonry
   6   23   60.0     0.790  1600.   850. 0.01 0.60    10.  0.08 Masonry
   7   23   25.0     0.790  1600.   850. 0.01 0.60    10.  0.03 Masonry
Int    24   15.0     0.700  1400.   850. 0.90 0.30    10.  0.02 Plaster internal
ISO 6946 U values (horiz/upward/downward heat flow)=  0.493  0.500  0.483 (partition)  0.472
Total area of External is      9.00
```

The surface resistances used in these steady state calculations depend on the heat flow direction. The resistances used are those in Table 2.11. For example, in the construction above, the internal surface resistance is 0.13 m^2K/W and 0.04 m^2K/W respectively.

Results

Table 2.12

Construction	**Transmittance /Wm^{-2} K^{-1}**	
	Ref.	**ESP-r**
External wall	0.49	**0.49**
Internal wall 1	0.35	**0.35**
Internal wall 2	1.68	**1.68**
Floor (upward heat flow)	0.24	**0.24**
Ceiling (downward heat flow)	0.23	**0.24**
Roof 1 (Upward heat flow)	0.44	**0.44**
Window 1	2.94	**2.93**
Window 2	1.72	**1.72**

Conclusion
All results obtained by ESP-r are within the tolerance limits.

Test G3.2: Dynamic conduction test

Program
ESP-r Version 11.4, released November 2007

Models
The model is in directory testg3_2_model/Test_G3.2/cfg. There is a zone for each construction variant in the test combined into a single model configuration file test_G3_2.cfg.

Simulations
To get results, run the model with the 'default' simulation presets. Use the results analysis module and choose 'Timestep reports->performance metrics->temperatures->Zone db T' and then select the option '! List data'. You may want to toggle the option '> Display to screen' to '> Display to file' in order to capture the results.

Results

Table 2.14

Test No.	**Air temperature after specified time**									
	2 hours		6 hours		12 hours		24 hours		120 hours	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
G3.2.1	20.04	**20.06**	21.26	**21.31**	23.48	**23.48**	26.37	**26.37**	30.00	**29.97**
G3.2.2	25.09	**24.95**	29.63	**29.52**	30.00	**29.99**	30.00	**30.00**	30.00	**30.00**
G3.2.3	20.00	**20.00**	20.26	**20.27**	21.67	**21.67**	24.90	**24.86**	29.95	**29.94**
G3.2.4	20.00	**20.00**	20.06	**20.06**	20.25	**20.24**	20.63	**20.62**	23.17	**23.16**

Conclusion
All results obtained by ESP-r are well within the tolerance limits. Note that a 90 day simulation start-up time is used. If 30 days are used, test G3.2.4 results are not so accurate (although still within the tolerance limits) because of the large time constants for this test.

Test G4: Solar shading

Program
ESP-r Version 11.4, released November 2007

Models
The model is in directory testg4_model/cfg. There is a configuration file TM33_g4.cfg which includes each of the shading tests.

Simulations
To get results, run the 'ish' module for each of the zones and export the calculated shading data for each zone. Alternatively, turn on the 'solar trace' in the simulator and select the "solar radiation summary" and output results for timesteps 1 to 48 (includes the pre-simulation day).

Results

Table 2.15

Time	Test 1		Test 2		Test 3		Test 4		Test 5		Test 6	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
07:00	1.00	**1.00**	1.00	**1.00**	1.00	**1.00**	1.00	**1.00**	0.00	**0.00**	1.00	**1.00**
07:30	0.32		0.68		1.00		0.00		0.04		1.00	
08:00	0.44	**0.43**	0.56	**0.57**	1.00	**1.00**	0.00	**0.00**	0.10	**0.10**	1.00	**1.00**
08:30	0.58		0.42		1.00		0.00		0.17		1.00	
09:00	0.72	**0.71**	0.27	**0.26**	0.99	**0.99**	0.00	**0.00**	0.26	**0.25**	0.98	**1.00**
09:30	0.74		0.14		0.88		0.00		0.38		0.74	
10:00	0.72	**0.69**	0.04	**0.04**	0.76	**0.73**	0.04	**0.08**	0.55	**0.55**	0.40	**0.40**
10:30	0.67		0.00		0.67		0.17		0.82		0.00	
11:00	0.63	**0.60**	0.00	**0.00**	0.63	**0.60**	0.24	**0.25**	0.96	**0.96**	0.00	**0.00**
11:30	0.61		0.00		0.61		0.28		0.96		0.00	
12:00	0.60	**0.60**	0.00	**0.00**	0.60	**0.60**	0.30	**0.30**	0.95	**0.95**	0.00	**0.00**
12:30	0.60		0.00		0.60		0.29		1.00		1.00	
13:00	0.62	**0.60**	0.00	**0.00**	0.62	**0.60**	0.26	**0.30**	1.00	**1.00**	1.00	**1.00**

Conclusion
All results obtained by ESP-r are within the tolerance limits.

Test G5: Glazing Properties

Program
ESP-r Version 11.4, released November 2007

Models
The model is testg5_model/cfg/G5.cfg

Testing
To get results, choose database maintenance from main ESP-r menu, then choose multi-layered construction database and choose to "browse or edit" this database. The ten glazing systems are contained in this multi-layered construction database. Choose option to view g-value and choose required glazing system. The U-value will be displayed in the text feedback area of ESP-r interface (along with other construction information). Choose additional pane properties from the menu or provide your own. Upon exiting from this menu the system g-value will be displayed.

If running in a UNIX environment, run the shell script testg5_model/cfg/show_gval.sh from the command line to display g-values. Note that construction U-values have been set in accordance with the results table and hence these are predefined to be exact.

Note that ESP-r does not use g-value or U-value, as it calculates time-varying convective and radiative fluxes at the inside and outside surfaces. However, these values can be reported based on standard surface coefficients.

Results

System (outside to inside)	***g-value***				***U-value***			
	Air		Argon		Air		Argon	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
Clear/clear	0.72	**0.71**	0.72	**0.72**	2.83	**2.83**	2.68	**2.68**
Clear/low emissivity	0.68	**0.68**	0.68	**0.69**	1.92	**1.92**	1.64	**1.64**
Absorbing/low emissivity	0.44	**0.43**	0.44	**0.43**	1.92	**1.92**	1.64	**1.64**
High performance/low emissivity	0.37	**0.37**	0.37	**0.37**	1.58	**1.58**	1.24	**1.24**
Clear/clear/clear	0.64	**0.64**	0.64	**0.64**	1.88	**1.88**	1.74	**1.74**

Conclusion
All results obtained by ESP-r are within the tolerance limits.

Test G6: Steady State Heat Loss from Rooms

Program
ESP-r Version 11.4, released November 2007

Models
The models are in directory TestG6/Test_G6/cfg. There are four configuration files for this test corresponding to tests A1, A2, B1 and B2.

In the models, the internal long-wave radiation is calculated by ESP-r. The internal convective coefficients and the external radiative and convective coefficients are fixed as prescribed.

Simulations
To get results, use the scripts run_A1 etc. Results are presented directly. Note that the heating load is presented in kW, but the infiltration is in -W. Alternatively, the models can be run with the simulation pre-sets of period, timesteps etc. Surface temperatures, air temperatures, heating load and infiltration can be displayed graphically or as timestep listings.

Results

Table 2.21: Predicted temperatures

Test		**Temperature of Stated Surface (deg C)**							**Air temp (deg C)**
		1	**2**	**3**	**4**	**5**	**6**	**7**	
A1	Ref	20.5	20.6	20.5	19.4	20.9	20.2	11.1	22.2
	ESP-r	**20.6**	**20.7**	**20.6**	**19.4**	**20.9**	**20.1**	**11.0**	**22.2**
A2	Ref	20.8	21.0	20.8	19.7	20.9	20.8	11.2	21.3
	ESP-r	**20.7**	**20.9**	**20.7**	**19.6**	**20.8**	**20.6**	**11.1**	**21.2**
B1	Ref	20.2	19.0	19.0	19.2	20.8	19.7	11.0	22.8
	ESP-r	**20.3**	**19.0**	**19.0**	**19.2**	**20.8**	**19.7**	**10.8**	**22.9**
B2	Ref	20.9	19.6	19.5	19.8	21.0	20.9	11.3	21.2
	ESP-r	**21.0**	**19.7**	**19.6**	**19.9**	**21.1**	**20.9**	**11.3**	**21.3**

Table 2.22: Predicted heat loss

Test		**Heat loss (W)**			**Test**		**Heat loss (W)**		
		Fabric	Infilt	Total			Fabric	Infilt	Total
A1	Ref	542	121	663	B1	Ref	831	496	1327
	ESP-r	**550**	**120**	**670**		**ESP-r**	**829**	**491**	**1320**
A2	Ref	556	117	673	B2	Ref	862	465	1327
	ESP-r	**555**	**115**	**670**		**ESP-r**	**867**	**463**	**1330**

Conclusion
All temperatures are within +/- 0.2degC and predicted heat losses are within +/-2.5% as required.

Test G7: Annual Cooling and Heating Demand

Program
ESP-r Version 11.4, released November 2007.

Models
The models are in directory TestG7/Test_G7/cfg.

All tests are included in one model. Two zones are created for each case, labelled T7a* and T7b*

Simulations
To get results, run a simulation with the given simulation presets for annual simulation. Results can be obtained from the results analysis module by listing the energy delivered. The total heating and cooling for each case are found by adding the two zones together for each case.

Results

Table 2.28: Predicted heating and cooling loads

Test	Heating Demand (kWh)		Cooling Demand (kWh)	
	Ref	**ESP-r**	Ref	**ESP-r**
Case G7.1	2592	**2500**	1025	**1003**
Case G7.2	3257	**3170**	449	**461**
Case G7.3	2653	**2516**	1236	**1168**
Case G7.4	3155	**3051**	474	**485**

Conclusion
All heating loads are within +/-8% and all cooling loads are within +/-12% as required.

Test G8: Overheating Risk

Program
ESP-r Version 11.4, released November 2007.

Models
The models are in directory TestG8/Test_G8/cfg.

All tests are included in one model. The model is same as for test G7, except design summer year climate is used, model is free floating, and infiltration rate is increased to 1ac/h.

Simulations
To get results, run a simulation with the given simulation presets for annual simulation. Results can be obtained from the results analysis module by selecting frequency table, then selecting both the "a" and "b" zones for each case in turn. Then select temperatures and resultant temperature and set the bins: choose 27 to 40 with 13 bins to cover all cases. Simple processing gives the data tabulated below. Alternatively choose "hours above a value" and set each temperature limit in turn to list the required data.

Results

Table listing results given in Figure 2.4.

Test	**Case G8.1**		**Case G8.2**		**Case G8.3**		**Case G8.4**	
	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**	Ref	**ESP-r**
Hours >27			>600	**937**				
Hours >28			340-600	**513**			500-~650	**625**
Hours >29			170-350	**241**			300-440	**375**
Hours >30	510-~700	**677**	100-200	**151**			160-270	**212**
Hours >31	300-430	**364**	20-110	**50**	525-600	**561**	80-150	**117**
Hours >32	150-270	**183**	0-50	**0**	350-420	**380**	40-80	**50**
Hours >33	75-150	**106**	0-20	**0**	200-300	**230**	15-40	**20**
Hours >34	20-75	**24**	0	**0**	120-175	**125**	0-20	**0**
Hours >35	0-30	**0**			50-110	**65**	0-10	**0**
Hours >36	0-15	**0**			20-70	**25**	0	**0**
Hours >37	0	**0**			0-25	**9**		
Hours >38					0-20	**0**		
Hours >39					0	**0**		

Conclusion
All resultant temperatures are within the specified limits.

Test G9: Infiltration and Ventilation

Program
ESP-r Version 11.4, released November 2007.

Models
The model is in directory TestG9/Test_G9/cfg. There is one configuration file for this test (called CIBSE_flow.cfg).

Simulations
To get results, simulate the models with the simulation pre-sets of date, timesteps etc. Run the results analysis, select timestep reports, performance metrics and then "Network air/water flow". Open the flow results (CIBSE_flow.mfr), select the results to be displayed in a file (instead of the screen), select the volume flow rate option and display results for all the individual connections. Close results analysis and open the file with the volume flow rate results (default name: data.grt). In this file results are displayed in m^3/s. Results for Test 1 can be taken between the hours 1-6, results for test 2 can be taken between the hours 7-12, results for test 3 can be taken between the hours 13-18 and results for test 4 can be taken between the hours 19-24.

Results

Table 2.32

Connection	**Air flow rate/L·s^{-1}**							
	Test 1		Test 2		Test 3		Test 4	
	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**	Ref.	**ESP-r**
Entering room 1 via B1	-11.6	**-11.6**	-20.6	**-20.6**	-36.0	**-36.0**	-20.4	**-20.4**
Entering room 1 via B2	16.6	**16.6**	17.1	**17.2**	29.9	**29.9**	28.7	**28.7**
Entering room 1 via D1	-5.5	**-5.5**	3.4	**3.4**	6.0	**6.0**	-9.2	**-9.2**
Entering room 2 via B6	26.4	**26.4**	11.6	**11.6**	13.6	**13.7**	39.4	**39.4**
Entering room 2 via R1	-27.3	**-27.3**	-11.7	**-11.7**	-14.0	**-13.9**	-40.7	**-40.7**
Entering room 3 via B3	13.8	**13.8**	5.3	**5.3**	9.0	**8.9**	23.4	**23.4**
Entering room 3 via B4	-7.2	**-7.2**	10.5	**10.6**	18.0	**17.9**	-17.4	**-17.3**
Entering room 3 via D2	-12.7	**-12.7**	-12.8	**-12.8**	-21.4	**-21.5**	-16.2	**-16.1**
Entering room 4 via R2	-21.1	**-21.2**	-23.4	**-23.4**	-38.7	**-38.7**	-23.7	**-23.8**
Entering room 4 via B5	8.3	**8.3**	10.6	**10.6**	17.2	**17.2**	7.2	**7.2**

Conclusion
All results obtained by ESP-r are within the tolerance limits.

Test G10: Air Handling Unit Test

Program
ESP-r version 11.5, released April 2008.

Models
The models are in directory TestG10/Test_G10/cfg. There are three configuration files for this test (called G10-1.cfg, G10-2.cfg and G10-3.cfg) corresponding to the three different system configurations set out in the test specifications: AHU 1, AHU2 and AHU3

Simulations
To get results for system AHU 1, run the script "script-1", the results from the simulation will be placed in two files test_G1.dat and energy-G1.dat. To get the results for system AHU 2 run the script "script-2", the results will be places in two files test_G2.dat and energy_G2.dat. Finally, to get the results for system AHU 3 run the script "script-3". Again results will be placed in the files test_G3.dat and energy_G3.dat. Specific results for temperatures will be placed in file <date_time>_T.dat and humidities will be placed in file <date_time>_g.dat.

Results

Table 2.33

AHU 1	**Energy Demand kWh**		
Component	Ref.	**ESP-r**	%Error
Cooling Coil	12348	**12601**	2.0
Heating Coil	5461	**5499**	0.7
Fans	1132	**1132**	0
Humidifier	0	**0**	0

Table 2.34

AHU 2	**Energy Demand kWh**		
Component	Ref.	**ESP-r**	%Error
Cooling Coil	11744	**11682**	0.5
Heating Coil	5579	**5544**	0.6
Fans	1698	**1698**	0
Humidifier	0	**0**	0

Table 2.35a

AHU 3	**Energy Demand kWh**		
Component	Ref.	**ESP-r**	%Error
Cooling Coil	0	**0**	0
Heating Coil	10914	**10854**	0.5
Fans	1698	**1698**	0
Humidifier	4083	**4084**	0

Table 2.35b

AHU 3	**Temperatures and Humidities (g/kg)** **Conditions at selected nodes (to be within +/- 0.2)**			
	Date & time 5/1 06:00			
Component	Ref. Temp	**ESP-r Temp**	Ref. Hum	**ESP-r Hum.**
inlet duct	-2.1	**-2.1**	3.1	**3.1**
heat exch. outlet	14.4	**14.4**	6.7	**6.7**
supply fan outlet	25.9	**25.9**	6.7	**6.7**
humidifier outlet	26.2	**26.2**	8.5	**8.5**
return fan outlet	21.5	**21.5**	9.1	**9.1**
heat exch. exit	5.0	**5.2**	5.5	**5.5**

Table 2.35c

AHU 3	**Temperatures and Humidities (g/kg)** **Conditions at selected nodes (to be within +/- 0.2)**			
	Date & time 6/1 04:00			
Component	Ref. Temp	**ESP-r Temp**	Ref. Hum	**ESP-r Hum.**
inlet duct	6.2	**6.2**	5.1	**5.1**
heat exch. outlet	16.9	**16.9**	7.5	**7.5**
supply fan outlet	25.9	**25.9**	7.5	**7.5**
humidifier outlet	26.1	**26.1**	8.5	**8.5**
return fan outlet	21.5	**21.5**	9.1	**9.1**
heat exch. exit	10.8	**10.9**	6.7	**6.7**

Table 2.35d

AHU 3	**Temperatures and Humidities (g/kg)** Conditions at selected nodes (to be within +/- 0.2)			
	Date & time 10/1 14:00			
Component	Ref. Temp	**ESP-r Temp**	Ref. Hum	**ESP-r Hum.**
inlet duct	3.3	**3.3**	4.1	**4.1**
heat exch. outlet	16.0	**16.0**	7.1	**7.1**
supply fan outlet	25.9	**25.9**	7.1	**7.1**
humidifier outlet	26.2	**26.1**	8.5	**8.5**
return fan outlet	21.5	**21.5**	9.1	**9.1**
heat exch. exit	8.7	**8.9**	6.1	**6.1**

Conclusion

All results obtained by ESP-r are within the specified tolerance limits.

TM33: Empirical Validation Test

Program
ESP-r Version 11.5, released April 2008.

Models
The models are in directories emptest_AC/cfg (there are two configuration files corresponding to case E1A and case E1C), emptest_B/cfg, emptest_DF/cfg (there are two configuration files corresponding to case E1D and case E1F), and emptest_E/cfg.

Simulations
To get results, run the models with simulation presets of start-up days, timesteps and simulation period. For cases E1A, E1B and E1C, internal convective heat transfer coefficient was set to be default. This is due to the facts that there is no heating control for the three cases and the ESP-r default internal convective coefficient is used for calculating convection which is driven primarily by buoyancy. External convective coefficient was chosen to be CIBSE Guide coefficient. For cases E1D, E1E and E1F, both internal and external convective coefficients were set to be CIBSE Guide coefficients.

For cases E1D, E1E and E1F, the heating system was modelled by using PID control. Both zone-side and plant-side time steps were set to be 60 per hour. Note that test results are sensitive to time steps and PID parameters. With different time steps, the test results presented in the following table would be slightly changed.

Results
Table1 Predicted heating energy consumption, plus average hourly max and min temperatures.

Test	Parameter	Measured value	**ESP-r**	Tolerance
Case E1A	Energy (kWh)	0.0	**0.0**	± 0.0
	Max. temp.(C)	31.0	**32.1**	± 2.5
	Min. temp. (C)	12.2	**13.2**	± 2.5
Case E1B	Energy (kWh)	0.0	**0.0**	± 0.0
	Max. temp.(C)	16.8	**17.6**	± 1.5
	Min. temp. (C)	9.2	**9.5**	± 1.5
Case E1C	Energy (kWh)	0.0	**0.0**	± 0.0
	Max. temp.(C)	32.6	**32.4**	± 2.5
	Min. temp. (C)	12.1	**12**	± 2.5
Case E1D	Energy (kWh)	24.8	**21.1**	± 15%
	Max. temp.(C)	37.8	**38.5**	± 2.5
	Min. temp. (C)	11.9	**11.6**	± 2.5
Case E1E	Energy (kWh)	32.5	**30.2**	± 15%

Test	Parameter	Measured value	**ESP-r**	Tolerance
	Max. temp.(C)	29.8	**30.4**	± 1.0
	Min. temp. (C)	14.6	**12.6**	± 2.5
Case E1F	Energy (kWh)	25.0	**24.1**	± 15%
	Max. temp.(C)	37.0	**37.9**	± 2.5
	Min. temp. (C)	9.1	**9.9**	± 2.5

Conclusion
All results obtained by ESP-r are within the tolerance limits.