A1: APPENDIX 1, LIST OF PERMANENT FABRIC STRUCTURES COMPLETED IN THE UK.

A1:1. STRUCTURES COMPLETED IN 1978.

- Kilmarnock District Council Sports Centre.

A1:2. STRUCTURES COMPLETED IN 1979.

- Bridge of Don Exhibition and Sports Centre.

A1:3. STRUCTURES COMPLETED IN 1981.

- Judy's Pantry, Covent Garden.

A1:4. STRUCTURES COMPLETED IN 1984.

- Regents Park Zoo Canopy.

A1:5. STRUCTURES COMPLETED IN 1985.

- Schlumberger 1, Cambridge

A1:6. STRUCTURES COMPLETED IN 1987.

- Windsor Safari Park Dolphinarium Canopy.
- Blackpool Pleasure Beach Canopy.
- Hooke Park House, Dorset.
- Lords Mound Cricket Stand.

A1:7. STRUCTURES COMPLETED IN 1988.

- Portobello Market Canopy.

A1:8. STRUCTURES COMPLETED IN 1989.

- Hooke Park Training College, Dorset.
- Imagination Headquarters, London.
- All English Lawn Tennis Club, Indoor Tennis Centre, Covered Courts, Wimbledon.

A1:9. STRUCTURES COMPLETED IN 1990.

- Goodwood Grandstand.
- The Players Theatre, Charing Cross.
- Waterside Canopy, Charing Cross.
- Alexandra Palace internal lining canopy, London. .

A1:10. STRUCTURES COMPLETED IN 1991.

- Don Valley Athletics Stadium, Sheffield.
- Cardiff Bay Visitors Centre.
- Express Canopy.
- Landrell Fabric Engineering Premises, Chepstow.

- Haggerston Castle courtyard covering, near Berwick Upon Tweed.
- Project 184. MOMI Hospitality Tent.

A1:11.STRUCTURES COMPLETED IN 1992.

- Schlumberger 2, Cambridge.
- Administration and Amenities Building, Cheriton Passenger Terminal, Folkestone.
- Royal International Eisteddfod Pavilion, Llangollen.
- Garsington Manor Opera Festival Canopy.
- Sainsbury's Plymouth Supermarket, trolley park.

A1:12. STRUCTURES COMPLETED IN 1993.

- Mid Kent Oncology Centre, entrance canopy.
- Phyllis Court Club Grandstand Pavilion, Henley on Thames.
- Covent Garden Swimming Pool, ceiling liner.
- 1st stage of birth 42, Tilbury dock.
- Glyndbourne Opera House, entrance canopy.

A1:13. STRUCTURES COMPLETED IN 1994.

- Sainbury's Coventry Supermarket, portico and garage.
- Birkenhead Park Cricket Club, Merseyside.
- 2nd stage of birth 42, Tilbury Dock.
- The Variety Club Building, Basement Play Area. Great Ormond Street Hospital.
- Amenities Building, Nottingham Inland Revenue.
- Swindon Market Canopy.
- 309 Regent Street, fire stair canopy, London.
- Spiral House Canopy.
- St Anne's Infant School Playground Cover. Tower Hamlets, East London.
- Broadstreet Mall Lilies. Reading.
- Demountable Ticket Office for Buckingham Palace.
- Teachers Stand, Bath Rugby Club.
- Stratford Bus Station. The London Borough of Newman.

NB The list presented here includes only those significant architectural fabric structures which were encountered during the course of this research. These have been supplemented by a large number of temporary fabric structures and smaller scale shading systems.

A2: APPENDIX 2, MEMBRANE MODEL CODE LISTING.

A2:1 FABRIC MEMRANE THERMAL MODEL CONTOL PROCEEDURES.

A2:1.1 **Input Information**

cell	**code**	**purpose**	**units**
B31	F21	membrane internal surface start temperature	°c
D31	H24	membrane external surface start temperature	°c
F31	[MEMMOD3.XLW]DATA.XLS!$G$3	external air temperature	°c
H31	[MEMMOD3.XLW]DATA.XLS!$F$3	horizontal global solar radiation	W/m²
J31	[MEMMOD3.XLW]DATA.XLS!$H$3	free stream wind speed	m/s
L31	[MEMMOD3.XLW]DATA.XLS!$I$3	free stream direction	° w of s
B34	[MEMMOD3.XLW]SITE.XLS!$B$3	site longitude (W positive)	°
D34	[MEMMOD3.XLW]SITE.XLS!$B$4	site latitude (N positive)	°
F34	[MEMMOD3.XLW]SITE.XLS!$B$5	site elevation	m
H34	[MEMMOD3.XLW]SITE.XLS!$B$11	obstruction angle	°
J34	[MEMMOD3.XLW]SITE.XLS!$B$6	space internal solar reflectivity.	ratio
L34	[MEMMOD3.XLW]SITE.XLS!$B$7	space internal long wave infra red absoptivity	ratio
B37	[MEMMOD3.XLW]DATA.XLS!$D$3	membrane surface azimuth	° w of s
D37	[MEMMOD3.XLW]DATA.XLS!$C$3	membrane surface inclination	°
F37	[MEMMOD3.XLW]DATA.XLS!$E$3	space internal air temperature	°c
H37	IF(H56=1,(D37/180),0)	membrane panel self facing ?	ratio
I37	[MEMMOD3.XLW]DATA.XLS!$J$3	space internal surface temp	°c
J37	((H37*B31^4)+((1-H37)*[MEMMOD3.XLW]DATA.XLS!$J$3^4))^0.25	space internal equivalent surface temperature	°c
B50	IF(B53>0,B53,INT([MEMMOD3.XLW]DATA.XLS!$B$3))	date	d/m/y
D50	IF(D53>0,D53,([MEMMOD3.XLW]DATA.XLS!$B$3-B50))	time	h:m:s
F50	D50+([MEMMOD3.XLW]DATA.XLS!$I$1/24)+([MEMMOD3.XLW]DATA. XLS!$L$1/(24*60))	GMT	h:m:s
H50	F53-H53	year day number	#
B53	#	false date option	d/m/y
D53	#	false time option	h:m:s
F53	B50	day number	#
H53	[MEMMOD3.XLW]DATA.XLS!$L$1	day number for first of the year	#
J51	IF(F50<0,-1,0)	previous day hour day corrections	#
J52	IF(F50<0,24,0)	previous day hour day corrections	#
K51	IF(OR((D50+([MEMMOD3.XLW]DATA.XLS!$I$1/24))>1,(D50+([MEMMO D3.XLW]DATA.XLS!$I$1/24))=1),1,0)	previous day hour day corrections	#

K52	IF(F50>24,-24,0)	previous day hour day corrections	#
L51	H50+K51+J51	corrected day number	#
L52	F50+J52+K52	corrected GMT	h:m:s
B56	[MEMMOD3.XLW]DATA.XLS!$F$3	night time negative radiation	W/m^2
D56	IF(B56<0,((3.1+B56)/-3.1),1)	night time default cloud cover	ratio
F56	IF(P33<-2,ABS(D56),[MEMMOD3.XLW]DATA.XLS!$S$1)	cloudiness(0 clear, 1 cloudy)	ratio
H56	[MEMMOD3.XLW]SITE.XLS!$B$12	curved envelope?	#
J62	[MEMMOD3.XLW]MEMBRANES.XLS!$B$10	membrane outside surface emmissivity	ratio
L62	[MEMMOD3.XLW]MEMBRANES.XLS!$B$9	membrane inside surface emmissivity	ratio
J65	[MEMMOD3.XLW]MEMBRANES.XLS!$B$11	membrane near normal long wave trans	ratio
L65	((J62+L62)/([MEMMOD3.XLW]MEMBRANES.XLS!$B$9+[MEMMOD3.XLW]MEMBRANES.XLS!$B$10))*J65	membrane hemispherical long wave translucency	ratio
B59	T43	angle of incidence	°
D59	[MEMMOD3.XLW]MEMBRANES.XLS!$B$12	membrane core conductivity	W/m^2°c
B62	[MEMMOD3.XLW]MEMBRANES.XLS!$B$3*(10.2031+(0.0938*B59)-(0.0022*(B59)^2))/10.985	membrane solar translucency	ratio
D62	100-B62-B65	membrane solar absorption	ratio
B65	[MEMMOD3.XLW]MEMBRANES.XLS!$B$5+TAN((B59-(((90-(180/PI())*ATAN(100-[MEMMOD3.XLW]MEMBRANES.XLS!$B$5))/90)*B59))*PI()/180)	membrane solar reflectance	ratio
D65	100-D62-B65-B62	error check	#
F62	[MEMMOD3.XLW]MEMBRANES.XLS!$B$6	membrane diffuse solar translucency	ratio
H62	[MEMMOD3.XLW]MEMBRANES.XLS!$B$7	membrane diffuse solar absorptance	ratio
F65	[MEMMOD3.XLW]MEMBRANES.XLS!$B$8	membrane diffuse solar reflect	ratio
H65	100-H62-F62-F65	error check	%
L37	90-P33	ground incidence	°
D41	[MEMMOD3.XLW]SITE.XLS!$B$14	new concrete view	unitless
D42	[MEMMOD3.XLW]SITE.XLS!$B$15	old concrete view	unitless
D43	[MEMMOD3.XLW]SITE.XLS!$B$16	grass view	unitless
D44	[MEMMOD3.XLW]SITE.XLS!$B$17	crushed rock view	unitless
D45	[MEMMOD3.XLW]SITE.XLS!$B$18	bitumen and gravel roof view	unitless
D46	[MEMMOD3.XLW]SITE.XLS!$B$19	bitumen road surface view	unitless
D47	SUM(D41:D46)	total	unitless
E41	D41/$D$47	new concrete relative view	ratio
E42	D42/$D$47	old concrete relative view	ratio

E43	D43/$D$47	grass relative view	ratio
E44	D44/$D$47	crushed rock relative view	ratio
E45	D45/$D$47	bitumen and gravel roof relative view	ratio
E46	D46/$D$47	bitumen road surface relative view	ratio
E47	SUM(E41:E46)	total	ratio
F40	20	ground incidence	ratio
F41	IF($L$37<30,0.31,0)	new concrete angular reflectance	ratio
F42	IF($L$37<30,0.22,0)	old concrete angular reflectance	ratio
F43	IF($L$37<30,0.22,0)	grass angular reflectance	ratio
F44	IF($L$37<30,0.21,0)	crushed rock angular reflectance	ratio
F45	IF($L$37<30,0.14,0)	bitumen and gravel roof angular reflectance	ratio
F46	IF($L$37<30,0.09,0)	bitumen road surface angular reflectance	ratio
F47	IF($L$37<30,1,0)	activate series	ratio
G40	30	ground incidence	ratio
G41	IF(AND($L$37>F$40,$L$37<H$40),0.31,0)	new concrete angular reflectance	ratio
G42	IF(AND($L$37>F$40,$L$37<H$40),0.22,0)	old concrete angular reflectance	ratio
G43	IF(AND($L$37>F$40,$L$37<H$40),0.22,0)	grass angular reflectance	ratio
G44	IF(AND($L$37>F$40,$L$37<H$40),0.21,0)	crushed rock angular reflectance	ratio
G45	IF(AND($L$37>F$40,$L$37<H$40),0.14,0)	bitumen and gravel roof angular reflectance	ratio
G46	IF(AND($L$37>F$40,$L$37<H$40),0.1,0)	bitumen road surface angular reflectance	ratio
G47	IF(AND($L$37>F$40,$L$37<H$40),1,0)	activate series	ratio
H40	40	ground incidence	ratio
H41	IF(AND($L$37>G$40,$L$37<I$40),0.32,0)	new concrete angular reflectance	ratio
H42	IF(AND($L$37>G$40,$L$37<I$40),0.22,0)	old concrete angular reflectance	ratio
H43	IF(AND($L$37>G$40,$L$37<I$40),0.23,0)	grass angular reflectance	ratio
H44	IF(AND($L$37>G$40,$L$37<I$40),0.2,0)	crushed rock angular reflectance	ratio
H45	IF(AND($L$37>G$40,$L$37<I$40),0.14,0)	bitumen and gravel roof angular reflectance	ratio
H46	IF(AND($L$37>G$40,$L$37<I$40),0.1,0)	bitumen road surface angular reflectance	ratio
H47	IF(AND($L$37>G$40,$L$37<I$40),1,0)	activate series	ratio
I40	50	ground incidence	ratio
I41	IF(AND($L$37>H$40,$L$37<J$40),0.32,0)	new concrete angular reflectance	ratio
I42	IF(AND($L$37>H$40,$L$37<J$40),0.23,0)	old concrete angular reflectance	ratio
I43	IF(AND($L$37>H$40,$L$37<J$40),0.25,0)	grass angular reflectance	ratio
I44	IF(AND($L$37>H$40,$L$37<J$40),0.2,0)	crushed rock angular reflectance	ratio
I45	IF(AND($L$37>H$40,$L$37<J$40),0.14,0)	bitumen and gravel roof angular reflectance	ratio
I46	IF(AND($L$37>H$40,$L$37<J$40),0.1,0)	bitumen road surface angular reflectance	ratio

I47	IF(AND($L$37>H$40,$L$37<J$40),1,0)	activate series	ratio
J40	60	ground incidence	ratio
J41	IF(AND($L$37>I$40,$L$37<K$40),0.33,0)	new concrete angular reflectance	ratio
J42	IF(AND($L$37>I$40,$L$37<K$40),0.23,0)	old concrete angular reflectance	ratio
J43	IF(AND($L$37>I$40,$L$37<K$40),0.28,0)	grass angular reflectance	ratio
J44	IF(AND($L$37>I$40,$L$37<K$40),0.2,0)	crushed rock angular reflectance	ratio
J45	IF(AND($L$37>I$40,$L$37<K$40),0.14,0)	bitumen and gravel roof angular reflectance	ratio
J46	IF(AND($L$37>I$40,$L$37<K$40),0.11,0)	bitumen road surface angular reflectance	ratio
J47	IF(AND($L$37>I$40,$L$37<K$40),1,0)	ground incidence	ratio
K40	70	new concrete angular reflectance	ratio
K41	IF($L$37>60,0.34,0)	old concrete angular reflectance	ratio
K42	IF($L$37>60,0.25,0)	grass angular reflectance	ratio
K43	IF($L$37>60,0.31,0)	crushed rock angular reflectance	ratio
K44	IF($L$37>60,0.2,0)	bitumen and gravel roof angular reflectance	ratio
K45	IF($L$37>60,0.14,0)	bitumen road surface angular reflectance	ratio
K46	IF($L$37>60,0.12,0)	activate series	ratio
K47	IF($L$37>60,1,0)	total	ratio
L41	E41*SUM(F41:K41)	new concrete selected reflectance	ratio
L42	E42*SUM(F42:K42)	old concrete selected reflectance	ratio
L43	E43*SUM(F43:K43)	grass selected reflectance	ratio
L44	E44*SUM(F44:K44)	crushed rock selected reflectance	ratio
L45	E45*SUM(F45:K45)	bitumen and gravel roof selected reflectance	ratio
L46	E46*SUM(F46:K46)	bitumen road surface selected reflectance	ratio
L47	SUM(L41:L46)/(F47+G47+H47+I47+J47+K47)	ground reflected solar radiation	W/m²
B67	L51	day number	#
B68	0	Jan. Ist	#
B69	31	Jan.	#
B70	59	Feb	#
B71	90	march	#
B72	120	April	#
B73	151	may	#
B74	181	June	#
B74	212	July	#
B76	243	august	#
B77	273	September	#
B78	304	October	#

B79	334	November	#
B80	365	December	#
D69	IF(AND(B$67>B68,OR(B$67<B69,B$67=B69)),1,0)	select time of year	#
D70	IF(AND(B$67>B69,OR(B$67<B70,B$67=B70)),1,0)	select time of year	#
D71	IF(AND(B$67>B70,OR(B$67<B71,B$67=B71)),1,0)	select time of year	#
D72	IF(AND(B$67>B71,OR(B$67<B72,B$67=B72)),1,0)	select time of year	#
D73	IF(AND(B$67>B72,OR(B$67<B73,B$67=B73)),1,0)	select time of year	#
D74	IF(AND(B$67>B73,OR(B$67<B74,B$67=B74)),1,0)	select time of year	#
D75	IF(AND(B$67>B74,OR(B$67<B75,B$67=B75)),1,0)	select time of year	#
D76	IF(AND(B$67>B75,OR(B$67<B76,B$67=B76)),1,0)	select time of year	#
D77	IF(AND(B$67>B76,OR(B$67<B77,B$67=B77)),1,0)	select time of year	#
D78	IF(AND(B$67>B77,OR(B$67<B78,B$67=B78)),1,0)	select time of year	#
D79	IF(AND(B$67>B78,OR(B$67<B79,B$67=B79)),1,0)	select time of year	#
D80	IF(AND(B$67>B79,OR(B$67<B80,B$67=B80)),1,0)	select time of year	#
E68	[MEMMOD3.XLW]SITE.XLS!$C$1	select bute site	#
E69	4.04*E68*D69	define turbidity for time of year	#
E70	3.77*E68*D70	define turbidity for time of year	#
E71	3.84*E68*D71	define turbidity for time of year	#
E72	4.02*E68*D72	define turbidity for time of year	#
E73	4.1*E68*D73	define turbidity for time of year	#
E74	3.69*E68*D74	define turbidity for time of year	#
E75	3.99*E68*D75	define turbidity for time of year	#
E76	4.53*E68*D76	define turbidity for time of year	#
E77	4.29*E68*D77	define turbidity for time of year	#
E78	3.88*E68*D78	define turbidity for time of year	#
E79	3.67*E68*D79	define turbidity for time of year	#
E80	3.31*E68*D80	define turbidity for time of year	#
F68	[MEMMOD3.XLW]SITE.XLS!$D$1	select wimbledon site	#
F69	4.33*F68*D69	define turbidity for time of year	#
F70	4.35*F68*D70	define turbidity for time of year	#
F71	4.12*F68*D71	define turbidity for time of year	#
F72	4.77*F68*D72	define turbidity for time of year	#
F73	4.47*F68*D73	define turbidity for time of year	#
F74	4.1*F68*D74	define turbidity for time of year	#
F75	4.28*F68*D75	define turbidity for time of year	#
F76	5*F68*D76	define turbidity for time of year	#

F77	4.72*F68*D77	define turbidity for time of year	#
F78	4*F68*D78	define turbidity for time of year	#
F79	3.85*F68*D79	define turbidity for time of year	#
F80	3.34*F68*D80	define turbidity for time of year	#
G68	[MEMMOD3.XLW]SITE.XLS!$E$1	select Eisteddfod site	#
G69	4.18*G68*D69	define turbidity for time of year	#
G70	3.88*G68*D70	define turbidity for time of year	#
G71	3.73*G68*D71	define turbidity for time of year	#
G72	3.87*G68*D72	define turbidity for time of year	#
G73	4.04*G68*D73	define turbidity for time of year	#
G74	3.43*G68*D74	define turbidity for time of year	#
G75	3.79*G68*D75	define turbidity for time of year	#
G76	4.45*G68*D76	define turbidity for time of year	#
G77	4.19*G68*D77	define turbidity for time of year	#
G78	3.8*G68*D78	define turbidity for time of year	#
G79	3.67*G68*D79	define turbidity for time of year	#
G80	3.33*G68*D80	define turbidity for time of year	#
H68	[MEMMOD3.XLW]SITE.XLS!$F$1	select Landrell site	#
H69	4.04*H68*D69	define turbidity for time of year	#
H70	3.77*H68*D70	define turbidity for time of year	#
H71	3.84*H68*D71	define turbidity for time of year	#
H72	4.02*H68*D72	define turbidity for time of year	#
H73	4.1*H68*D73	define turbidity for time of year	#
H74	3.69*H68*D74	define turbidity for time of year	#
H75	3.99*H68*D75	define turbidity for time of year	#
H76	4.53*H68*D76	define turbidity for time of year	#
H77	4.29*H68*D77	define turbidity for time of year	#
H78	3.88*H68*D78	define turbidity for time of year	#
H79	3.67*H68*D79	define turbidity for time of year	#
H80	3.31*H68*D80	define turbidity for time of year	#
I68	[MEMMOD3.XLW]SITE.XLS!$G$1	select Eurotunnel site	#
I69	I68*D69	define turbidity for time of year	#
I70	4.35*I68*D70	define turbidity for time of year	#
I71	4.12*I68*D71	define turbidity for time of year	#
I72	4.77*I68*D72	define turbidity for time of year	#
I73	4.47*I68*D73	define turbidity for time of year	#

I74	4.1*I68*D74	define turbidity for time of year	#
I75	4.28*I68*D75	define turbidity for time of year	#
I76	5*I68*D76	define turbidity for time of year	#
I77	4.72*I68*D77	define turbidity for time of year	#
I78	4*I68*D78	define turbidity for time of year	#
I79	3.85*I68*D79	define turbidity for time of year	#
I80	3.34*I68*D80	define turbidity for time of year	#
K69	SUM(E69:I69)	define selected turbidity for time of year	#
K70	SUM(E70:I70)	define selected turbidity for time of year	#
K71	SUM(E71:I71)	define selected turbidity for time of year	#
K72	SUM(E72:I72)	define selected turbidity for time of year	#
K73	SUM(E73:I73)	define selected turbidity for time of year	#
K74	SUM(E74:I74)	define selected turbidity for time of year	#
K75	SUM(E75:I75)	define selected turbidity for time of year	#
K76	SUM(E76:I76)	define selected turbidity for time of year	#
K77	SUM(E77:I77)	define selected turbidity for time of year	#
K78	SUM(E78:I78)	define selected turbidity for time of year	#
K79	SUM(E79:I79)	define selected turbidity for time of year	#
K80	SUM(E80:I80)	define selected turbidity for time of year	#
K81	SUM(K69:K80)	atmospheric turbidity	#

A2:1.2 **Convergence Display.**

cell	**code**	**purpose**	**units**
D2	0	inner iterations = 0	#
E2	L3+1	inner iterations plus 1	#
L5	#	current inner iterations	#
I3	#	artificial stop time	h:m:s
I5	IF(I3>0,I3,MAX([MEMMOD3.XLW]DATA.XLS!$B:$B))	data series stop time	h:m:s
J5	[MEMMOD3.XLW]DATA.XLS!$B$3	current time	h:m:s
K5	(I5-J5)*60*24	remaining time	h:m:s
L5	(D24-B24)/B24	remaining residual	W/m²
J2	[MEMMOD3.XLW]MEMBRANES.XLS!$B$1	membrane type	#
J3	[MEMMOD3.XLW]SITE.XLS!$B$1	Site	#
B21	0.0001	termination residual	W/m²
B18	B21*D18	user multiplier residual	#

D18	1/(B21/5)	auto residual multiplier	#
F18	X23*D18	internal surface residual	#
H18	X13*D18	external surface residual	#
J18	ABS(H18)+ABS(F18)	total residual	#
L18	J18/D18	total net heat transfer	W/m^2
L21	#	previous internal surface net heat transfer	W/m^2
J21	#	previous internal surface temperature	°c
F21	#	current internal surface temperature	°c
D21	IF(OR(F21-J21=0,L18-L24=0),J21,F21-(L18*(F21-J21)/(L18-L24)))	projected internal surface temperature	°c
L24	#	previous external surface net heat transfer	W/m^2
J24	#	previous external surface temperature	°c
H24	#	current external surface temperature	°c
F24	IF(OR(H24-J24=0,L18-L21=0),J24,H24-(L18*(H24-J24)/(L18-L21)))	projected external surface temperature	°c
D24	#	projected external surface temperature record	°c
B23	O10+O7-[MEMMOD3.XLW]DATA.XLS!$K$3	predicted incident solar radiation error	W/m^2
B24	IF(F15=0,0,-F15+F21)	predicted internal surface temperature error	°c

A2:1.3 **Control Programme.**

line	**code**	**purpose**	**units**
1	Record1 (k)	run macro	#
2	ACTIVATE("[MEMMOD3.XLW]MEMMOD3.XLS")	activate calculation spread sheet	#
3	ARRANGE.ALL(4)	arrange workbook	#
4	ACTIVATE("[MEMMOD3.XLW]MEMBRANES.XLS")	activate membrane data base	#
5	IF([MEMMOD3.XLW]MEMBRANES.XLS!$C$1=0,GOTO(A10))	check if membrane type () has been selected	#
6	SELECT("R2C3")	select membrane name	#
7	COPY()	copy membrane name	#
8	SELECT("R1C2")	select membrane name cell	#
9	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
10	IF([MEMMOD3.XLW]MEMBRANES.XLS!$D$1=0,GOTO(A15))	check if membrane type () has been selected	#
11	SELECT("R2C4")	select membrane name	#
12	COPY()	copy membrane name	#
13	SELECT("R1C2")	select membrane name cell	#
14	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
15	IF([MEMMOD3.XLW]MEMBRANES.XLS!$E$1=0,GOTO(A20))	check if membrane type () has been selected	#

16	SELECT("R2C5")	select membrane name	#
17	COPY()	copy membrane name	#
18	SELECT("R1C2")	select membrane name cell	#
19	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
20	IF([MEMMOD3.XLW]MEMBRANES.XLS!$F$1=0,GOTO(A25))	check if membrane type () has been selected	#
21	SELECT("R2C6")	select membrane name	#
22	COPY()	copy membrane name	#
23	SELECT("R1C2")	select membrane name cell	#
24	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
25	IF([MEMMOD3.XLW]MEMBRANES.XLS!$G$1=0,GOTO(A30))	check if membrane type () has been selected	#
26	SELECT("R2C7")	select membrane name	#
27	COPY()	copy membrane name	#
28	SELECT("R1C2")	select membrane name cell	#
29	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
30	IF([MEMMOD3.XLW]MEMBRANES.XLS!$H$1=0,GOTO(A35))	check if membrane type () has been selected	#
31	SELECT("R2C8")	select membrane name	#
32	COPY()	copy membrane name	#
33	SELECT("R1C2")	select membrane name cell	#
34	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
35	IF([MEMMOD3.XLW]MEMBRANES.XLS!$I$1=0,GOTO(A40))	check if membrane type () has been selected	#
36	SELECT("R2C9")	select membrane name	#
37	COPY()	copy membrane name	#
38	SELECT("R1C2")	select membrane name cell	#
39	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
40	IF([MEMMOD3.XLW]MEMBRANES.XLS!$J$1=0,GOTO(A45))	check if membrane type () has been selected	#
41	SELECT("R2C10")	select membrane name	#
42	COPY()	copy membrane name	#
43	SELECT("R1C2")	select membrane name cell	#
44	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste membrane name in membrane name cell	#
45	ACTIVATE("[MEMMOD3.XLW]MEMMOD3.XLS")	activate calculation spread sheet	#
46	ARRANGE.ALL(4)	arrange workbook	#
47	ACTIVATE("[MEMMOD3.XLW]SITE.XLS")	activate site data base	#
48	IF([MEMMOD3.XLW]SITE.XLS!$C$1=0,GOTO(A53))	check if site () has been selected	#
49	SELECT("R2C3")	select site name	#
50	COPY()	copy site name	#
51	SELECT("R1C2")	select site name cell	#

52	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste site name in site name cell	#
53	IF([MEMMOD3.XLW]SITE.XLS!$D$1=0,GOTO(A58))	check if site () has been selected	#
54	SELECT("R2C4")	select site name	#
55	COPY()	copy site name	#
56	SELECT("R1C2")	select site name cell	#
57	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste site name in site name cell	#
58	IF([MEMMOD3.XLW]SITE.XLS!$E$1=0,GOTO(A63))	check if site () has been selected	#
59	SELECT("R2C5")	select site name	#
60	COPY()	copy site name	#
61	SELECT("R1C2")	select site name cell	#
62	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste site name in site name cell	#
63	IF([MEMMOD3.XLW]SITE.XLS!$F$1=0,GOTO(A68))	check if site () has been selected	#
64	SELECT("R2C6")	select site name	#
65	COPY()	copy site name	#
66	SELECT("R1C2")	select site name cell	#
67	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste site name in site name cell	#
68	IF([MEMMOD3.XLW]SITE.XLS!$G$1=0,GOTO(A73))	check if site () has been selected	#
69	SELECT("R2C7")	select site name	#
70	COPY()	copy site name	#
71	SELECT("R1C2")	select site name cell	#
72	PASTE.SPECIAL(2,1,FALSE,FALSE)	paste site name in site name cell	#
73	ACTIVATE("[MEMMOD3.XLW]MEMMOD3.XLS")	activate calculation spread sheet	#
74	SELECT("R21C10")	select membrane internal surface start temp	#
75	FORMULA("18")	set to 18	#
76	SELECT("R24C10")	select membrane external surface start temp	#
77	FORMULA("18")	set to 18	#
78	ACTIVATE("[MEMMOD3.XLW]MEMMOD3.XLS")	select calculation spread sheet	#
79	SELECT("R1C1")	orientate display	#
80	SELECT("R2C4")	select inner iteration zero value	#
81	COPY()	copy	#
82	SELECT("R3C12")	select inner iteration number cell	#
83	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste value zero on for inner iteration number	#
84	GOAL.SEEK("R18C8",0,"R24C8")	goal.seek a (external surface temperature)	#
85	SELECT("R18C12")	select ext power exchange	#
86	COPY()	copy	#
87	SELECT("R21C12")	select ext power exchange record cell	#

88	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste residual	#
89	SELECT("R24C8")	select solved ext start temp	#
90	COPY()	copy	#
91	SELECT("R24C10")	select previous start temp cell	#
92	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste solved temp	#
93	GOAL.SEEK("R18C6",0,"R21C6")	goal.seek b (internal surface temperature)	#
94	SELECT("R18C12")	select int power exchange	#
95	COPY()	copy	#
96	SELECT("R24C12")	select int power exchange record cell	#
97	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste residual	#
98	SELECT("R21C6")	select solved int start temp	#
99	COPY()	copy	#
100	SELECT("R21C10")	select previous start temp cell	#
101	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste solved temp	#
102	SELECT("R2C5")	select new inner iteration number	#
103	COPY()	copy value	#
104	SELECT("R3C12")	select inner iteration number cell	#
105	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste value	#
106	GOAL.SEEK("R18C8",0,"R24C8")	goal.seek a (external surface temperature)	#
107	IF([MEMMOD3.XLW]MEMMOD3.XLS!$L$18-[MEMMOD3.XLW]MEMMOD3.XLS!$L$21=0,GOTO(A112),GOTO(A108))	check if difference between new and old residuals = 0	#
108	SELECT("R24C6")	select projected equilibriums temp	#
109	COPY()	copy	#
110	SELECT("R24C4")	select ext projection record cell	#
111	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste	#
112	GOAL.SEEK("R18C6",0,"R21C6")	goal.seek b (internal surface temperature)	#
113	IF([MEMMOD3.XLW]MEMMOD3.XLS!$L$18-[MEMMOD3.XLW]MEMMOD3.XLS!$L$24=0,GOTO(A122),GOTO(A114))	check if difference between new and old residuals = 0	#
114	SELECT("R21C4")	select projected equilibrium int temp	#
115	COPY()	copy	#
116	SELECT("R21C6")	select start temp cell	#
117	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste projection	#
118	SELECT("R24C4")	select external surface projection record	#
119	COPY()	copy	#

120	SELECT("R24C8")	select external surface start temp cell	#
121	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste projection	#
122	IF([MEMMOD3.XLW]MEMMOD3.XLS!$L$18>[MEMMOD3.XLW]MEMMOD3.XLS!$B$21,GOTO(A84),GOTO(A123))	check for termination residual	#
123	IF([MEMMOD3.XLW]MEMMOD3.XLS!$K$5>0,GOTO(A124),GOTO(A137))	check for end time	#
124	ACTIVATE("[MEMMOD3.XLW]DATA.XLS")	goto data series	#
125	SELECT("R3C2:R4C22")	select completed time step	#
126	COPY()	copy completed time step	#
127	SELECT("R1C2")	home	#
128	SELECT.END(4)	goto end of data series	#
129	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste completed time step	#
130	SELECT("R4C2:R4C12")	select next time step	#
131	COPY()	copy next time step	#
132	SELECT("R3C2")	select beginning of data series	#
133	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste next time step	#
134	SELECT("R4C2:R4C22")	select duplicated data	#
135	EDIT.DELETE(2)	delete duplicated data	#
136	GOTO(A78)	repeat	#
137	WORKBOOK.ACTIVATE(,FALSE)	put final run at end and delete extra row	#
138	WORKBOOK.SELECT("[MEMMOD3.XLW]DATA.XLS","[MEMMOD3.XLW]DATA.XLS")	goto workbook menu	#
139	WORKBOOK.ACTIVATE("[MEMMOD3.XLW]DATA.XLS",FALSE)	activate data sheet	#
140	SELECT("R3C2:R3C22")	select last time series	#
141	COPY()	copy	#
142	SELECT("R3C2")	home	#
143	SELECT.END(4)	end	#
144	PASTE.SPECIAL(3,1,FALSE,FALSE)	paste last data series	#
145	CANCEL.COPY()	cancel	#
146	SELECT("R1C1")	home	#
147	HALT()	end	#

A2:2 SOLAR MODEL.

A2:2.1 **Calculation of The Angle of Incidence of Direct Beam Solar Radiation on the External Surface of the Membrane.**

cell	code	purpose	units
X30	H50	day number	#
X33	B34	site longitude	° w
X36	L52	GMT	h:m:s
V30	360*(X30-1)/365.242	angle function x	°
V33	(-0.128*SIN(((X30*360/365.25)-2.8)*PI()/180))-(0.165*SIN(((2*(X30*360/365.25))+19.7)*PI()/180))	equation of time	h:m:s
V36	(X36-(X33/(15*24)))+(V33/24)	solar time	h:m:s
T30	23.45*(SIN((280.1+(0.9863*X30))*PI()/180))	solar declination	°
T33	D34	site latitude	° n
T36	15*ABS(12-24*V36)	hour angle	°
R33	ASIN((COS(T33*PI()/180)*COS(T30*PI()/180)*COS(T36*PI()/180))+(SIN(T33*PI()/180)*SIN(T30*PI()/180)))	solar altitude	radians
P33	R33*180/PI()	solar altitude	degrees
T39	ASIN(COS(T30*PI()/180)*SIN(T36*PI()/180)/COS(R33))	solar azimuth	radians
R39	T39*180/PI()	convert solar azimuth	°
P39	IF((V36<0.5),-R39,R39)	correct solar azimuth	°
X40	D37	surface inclination from horizontal	°
X43	B37	surface azimuth	° w of s
V43	ACOS((COS(R33)*COS((P39-X43)*PI()/180))*SIN(X40*PI()/180)+SIN(R33)*COS(X40*PI()/180))	angle of incidence on membrane surface	radians
T43	V43*180/PI()	convert incidence on surface	°
R43	90-T43	surface solar altitude	°

A2:2.2 **Calculation of the Composition of Solar Radiation Incident on the External Surface of the Membrane.**

cell	code	purpose	units
O57	(-24.4465*SIN(R33))+(154.017*((SIN(R33))^2))+(-742.181*((SIN(R33))^3))+(2263.36*((SIN(R33))^4))+(-3804.89*((SIN(R33))^5))+(2261.05*((SIN(R33))^6))	e constant sum	#

Q57	EXP(O60*((-0.0017*O60)-0.1172))*EXP(3.67985+O57)	air mass (altitude<10)	#
O60	F34/1000	site elevation	km
Q60	EXP(O60*((-0.0017*O60)-0.1174))/SIN(S57*PI()/180)	air mass (altitude>10)	#
S60	IF(P33<10,Q57,Q60)	air mass	#
S57	P33	solar altitude	°
U57	(2*PI()*L51)/366	w	#
U58	1	i 1	#
U59	2	i 2	#
U60	3	i 3	#
V58	COS($U$57*U58*PI()/180)	coswi	radians
V59	COS($U$57*U59*PI()/180)	coswi	radians
V60	COS($U$57*U60*PI()/180)	coswi	radians
X60	10.44+(-6.468*V58)+(-3.492*V58)+(1.056*V59)+(2.049*V59)+(-0.128*V60)+(0.579*V60)	atmospheric precipitable water content	mm
V63	0	i	#
W63	1	i	#
X63	2	i	#
Y63	3	i	#
U64	0	b	#
U65	1	b	#
U66	2	b	#
V64	-0.129641	w	#
V65	0.00412828	w	#
V66	-0.0112096	w	#
W64	-0.0642111	w	#
W65	-0.00801046	w	#
W66	0.0153069	w	#
X64	-0.0046883	w	#
X65	-0.00220414	w	#
X66	-0.00429818	w	#
Y64	0.000844097	w	#
Y65	-0.000191442	w	#
Y66	0.000374176	w	#
V67	((V64*($X$60^$U$64))+(V65*($X$60^$U$65))+(V66*($X$60^$U$66)))*($S$60^V63)	bw	#
W67	((W64*($X$60^$U$64))+(W65*($X$60^$U$65))+(W66*($X$60^$U$66)))*($S$60^W63)	bw	#

X67	((X64*($X$60^$U$64))+(X65*($X$60^$U$65))+(X66*($X$60^$U$66)))*($S $60^X63)	bw	#
Y67	((Y64*($X$60^$U$64))+(Y65*($X$60^$U$65))+(Y66*($X$60^$U$66)))*($S $60^Y63)	bw	#
O64	K81-0.85+2.25*SIN(R33)-1.11*(SIN(R33))^2	corrected turbidity	#
Q64	-0.128	turbidity coefficient	#
O67	1353	solar constant	W/m²
Q67	O67*(1+(0.033*COS(((360-L51)/365)*PI()/180)))	corrected solar constant	W/m²
S64	IF(H31>0,EXP(V67+W67+X67+Y67)*EXP(-Q64*S60),0)	insolation / external irradiance	ratio
S67	IF(P33>0,S64*Q67,0)	theoretical direct normal solar radiation	W/m²
O69	0	i	#
P69	1	i	#
Q69	2	i	#
R69	3	i	#
S69	4	i	#
T69	5	i	#
U69	6	i	#
V69	7	i	#
P70	47.382	f	#
Q70	29.671	f	#
R70	-15.8621	f	#
S70	4.3463	f	#
T70	-0.57764	f	#
U70	0.03472	f	#
V70	-0.0007362	f	#
P71	B195*(($P$33/10)^A195)	f sum	#
Q71	B196*(($P$33/10)^A196)	f sum	#
R71	B197*(($P$33/10)^A197)	f sum	#
S71	B198*(($P$33/10)^A198)	f sum	#
T71	B199*(($P$33/10)^A199)	f sum	#
U71	B200*(($P$33/10)^A200)	f sum	#
V71	B201*(($P$33/10)^A201)	f sum	#
O72	297	g	#
P71	1.8313	g	#
Q71	-3.7082	g	#
R71	4.1233	g	#

S71	-0.6409	g	#
T71	0.02855	g	#
O73	O72*(($P$33/10)^O69)	gsum	#
P73	P72*(($P$33/10)^P69)	gsum	#
Q73	Q72*(($P$33/10)^Q69)	gsum	#
R73	R72*(($P$33/10)^R69)	gsum	#
S73	S72*(($P$33/10)^S69)	gsum	#
T73	T72*(($P$33/10)^T69)	gsum	#
O76	(P71+Q71+R71+S71+T71+U71+V71)*(1+(0.033*COS(((360-L51)/370)*PI()/180)))	f coefficient	#
Q76	(10^-3)*(O73+P73+Q73+R73+S73+T73)*S67*SIN(R33)	g coefficient	#
O79	IF((2+O76-Q76)>0,(2+O76-Q76),0)	clear sky diffuse solar radiation	W/m^2
O82	S67*SIN(S57*PI()/180)	theoretical direct horizontal solar radiation	W/m^2
Q82	O79+O82	theoretical clear sky horizontal global solar radiation	W/m^2
Q79	IF(H31>0,H31,0)	measured horizontal global solar radiation	W/m^2
S79	IF(AND(H31>0,P33>0),Q79/Q82,0)	measured solar radiation / calculated solar radiation	ratio
S81	IF(S79<0.4,0.94,(1.29-(1.19*S79))/(1-(0.334*S79)))	cloud cover correction	ratio
S82	IF(S79>1,0.15,S81)	cloud cover correction	ratio
U82	IF(P33<4,0,S82*Q79*0.5*(1+COS(0))*(1+(1-((S82*Q79)^2/Q79^2))*((SIN(0))^3))*(1+(1-((S82*Q79)^2/Q79^2))*((SIN((90-P33)*PI()/180))^3)))	horizontal diffuse solar radiation	W/m^2
U79	IF(P33<4,0,Q79-U82)	horizontal direct beam solar radiation	W/m^2
S76	X40	angle of inclination	°
U76	IF(U79*SIN((180-R43)*PI()/180)/SIN(R33)<0,0,U79*SIN((180-R43)*PI()/180)/SIN(R33))	direct beam solar intensity on membrane surface	W/m^2
W82	IF(P33>0,S82*Q79*0.5*(1+COS(S76*PI()/180))*(1+(1-((S82*Q79)^2/Q79^2))*((SIN(0.5*S76*PI()/180))^3))*(1+(1-((S82*Q79)^2/Q79^2))*((SIN((90-P33)*PI()/180))^3)),0)	incident sky diffuse solar radiation	W/m^2
Y70	(E41*0.32)+(E42*0.23)+(E43*0.25)+(E44*0.2)+(E45*0.14)+(E46*0.1)	surrounding diffuse reflect	W/m^2
Y73	U89*U103*Y70	obstructions diffuse solar reflection	W/m^2
Y76	U79*T103*Y70	ground diffuse solar reflection	W/m^2
Y82	U79*T103*L47	ground reflectance of direct beam solar radiation	W/m^2
Y79	Y82+Y76+Y73	total solar reflection of surroundings	W/m^2
W79	IF((W82+Y79)>0,W82+Y79,0)	total incident diffuse solar radiation	W/m^2
W76	IF(U76>0,U76+W79,W79)	total incident solar radiation	W/m^2

X47	ACOS(-TAN(T30*PI()/180)*TAN(T33*PI()/180))	sunset hour angle	radians
V47	T33*PI()/180	latitude	radians
T47	T30*PI()/180	declination	radians
R47	25	shadowband ring radius	cm
P47	5	shadowband ring width	cm
P50	2*P47*COS(T47)*(SIN(V47)*SIN(T47*X47)+COS(V47)*COS(T47)*SIN(X47))/(R47*PI())	area obstructed by shadowband	ratio
R50	[MEMMOD3.XLW]DATA.XLS!$K$3	monitored horizontal diffuse solar radiation	W/m²
T50	R50*(1/(1-P50))	corrected horizontal diffuse solar radiation	W/m²
V50	U82	predicted horizontal diffuse solar radiation	W/m²
X50	V50-T50	prediction error	W/m²

A2:2.3 **Calculation of the Composition of Solar Radiation Incident on the Internal Surface of the Membrane.**

cell	code	purpose	units
T124	H56	curved envelope	#
O139	IF(H31>0,H31*F62/100,0)	curved surface representative solar transmission	ratio
Q139	IF(H31>0,O6+P6,0)	test cell solar transmission	ratio
O135	IF([MEMMOD3.XLW]SITE.XLS!$B$12=1,O146,O149)	solar radiation transmitted to interior	W/m²
O131	1	overall view factor	ratio
Q127	J34	approximate reflectivity of interior	ratio
Q131	F65	membrane diffuse reflectivity	ratio
O127	H62	membrane diffuse solar absorptivity	ratio
Q135	F62	membrane diffuse solar transmission	ratio
T128	1	reflection number	#
T129	2	reflection number	#
T130	3	reflection number	#
T131	4	reflection number	#
T132	5	reflection number	#
T133	6	reflection number	#
T134	7	reflection number	#
T135	8	reflection number	#
T136	9	reflection number	#
T137	10	reflection number	#
U128	O135	remaining internal solar radiation	W/m²
U129	U128-V128-W128-X128	remaining internal solar radiation	W/m²

U130	U129-V129-W129-($Q$135*U129/100)	remaining internal solar radiation	W/m²
U131	U130-V130-W130-($Q$135*U130/100)	remaining internal solar radiation	W/m²
U132	U131-V131-W131-($Q$135*U131/100)	remaining internal solar radiation	W/m²
U133	U132-V132-W132-($Q$135*U132/100)	remaining internal solar radiation	W/m²
U134	U133-V133-W133-($Q$135*U133/100)	remaining internal solar radiation	W/m²
U135	U134-V134-W134-($Q$135*U134/100)	remaining internal solar radiation	W/m²
U136	U135-V135-W135-($Q$135*U135/100)	remaining internal solar radiation	W/m²
U137	U136-V136-W136-($Q$135*U136/100)	remaining internal solar radiation	W/m²
V128	U128*(1-$Q$127)	enclosed space solar absorptance	W/m²
V129	U129*(1-$Q$127)	enclosed space solar absorptance	W/m²
V130	U130*(1-$Q$127)	enclosed space solar absorptance	W/m²
V131	U131*(1-$Q$127)	enclosed space solar absorptance	W/m²
V132	U132*(1-$Q$127)	enclosed space solar absorptance	W/m²
V133	U133*(1-$Q$127)	enclosed space solar absorptance	W/m²
V134	U134*(1-$Q$127)	enclosed space solar absorptance	W/m²
V135	U135*(1-$Q$127)	enclosed space solar absorptance	W/m²
V136	U136*(1-$Q$127)	enclosed space solar absorptance	W/m²
V137	U137*(1-$Q$127)	enclosed space solar absorptance	W/m²
W128	(U128-V128)*($O$127/100)	membrane internal solar absorptance	W/m²
W129	(U129-V129)*($O$127/100)	membrane internal solar absorptance	W/m²
W130	(U130-V130)*($O$127/100)	membrane internal solar absorptance	W/m²
W131	(U131-V131)*($O$127/100)	membrane internal solar absorptance	W/m²
W132	(U132-V132)*($O$127/100)	membrane internal solar absorptance	W/m²
W133	(U133-V133)*($O$127/100)	membrane internal solar absorptance	W/m²
W134	(U134-V134)*($O$127/100)	membrane internal solar absorptance	W/m²
W135	(U135-V135)*($O$127/100)	membrane internal solar absorptance	W/m²
W136	(U136-V136)*($O$127/100)	membrane internal solar absorptance	W/m²
W137	(U137-V137)*($O$127/100)	membrane internal solar absorptance	W/m²
X128	(U128-V128)*($Q$135/100)	re transmitted solar radiation	W/m²
X129	(U129-V129)*($Q$135/100)	re transmitted solar radiation	W/m²
X130	(U130-V130)*($Q$135/100)	re transmitted solar radiation	W/m²
X131	(U131-V131)*($Q$135/100)	re transmitted solar radiation	W/m²
X132	(U132-V132)*($Q$135/100)	re transmitted solar radiation	W/m²
X133	(U133-V133)*($Q$135/100)	re transmitted solar radiation	W/m²
X134	(U134-V134)*($Q$135/100)	re transmitted solar radiation	W/m²
X135	(U135-V135)*($Q$135/100)	re transmitted solar radiation	W/m²

X136	(U136-V136)*($Q$135/100)	re transmitted solar radiation	W/m²
X137	(U137-V137)*($Q$135/100)	re transmitted solar radiation	W/m²
V139	SUM(V128:V137)	total space absorptance	W/m²
W139	SUM(W128:W137)	total membrane absorptance	W/m²
X139	SUM(X128:X137)	total re transmitted solar radiation	W/m²
T139	U128-V139-W139-X139	zero residual check	W/m²

A2:3 HEAT TRANSFER MODEL.

A2:3.1 **Calculation of the External Surface Long Wave Infra Red Radiation Heat Transfer.**

cell	code	purpose	units
W95	180-X43	obstruction surface azimuth	°
W92	90-(ACOS((COS(R33)*COS((P39-W95)*PI()/180))*SIN(90*PI()/180)+SIN(R33)*COS(90*PI()/180)))*180/PI()	obstruction surface solar altitude	°
W89	IF(U79*SIN((180-W92)*PI()/180)/SIN(R33)<0,0,U79*SIN((180-W92)*PI()/180)/SIN(R33))	obstruction surface incident direct beam solar radiation	W/m²
Y95	0.5*(Q79*L47)	obstruction surface incident ground reflected solar	W/m²
Y92	IF(Q79=0,0,(U82*(0.5*(1+COS(90*PI()/180)))*(1+(1-(U82^2/Q79^2))*(SIN(0.5*90*PI()/180))^3)*(1+(1-(U82^2/Q79^2))*(SIN((90-P33)*PI()/180))^3)))	obstruction surface incident sky diffuse solar radiation	W/m²
Y89	IF((Y92+Y95)>0,(Y92+Y95),0)	obstruction surface incident diffuse solar radiation	W/m²
U89	Y89+W89	obstruction surface incident solar radiation	W/m²
T89	H31	Horizontal global soar radiation	W/m²
S90	E41	new concrete view factor	ratio
S91	E42	old concrete view factor	ratio
S92	E43	grass view factor	ratio
S93	E44	crushed rock view factor	ratio
S94	E45	bitumen and gravel roof view factor	ratio
S95	E46	bitumen road surface view factor	ratio
T90	(-1+(6*T$89/1200))*$S90	new concrete ground temperature	°c
T91	(-1+(8*T$89/1200))*$S91	old concrete ground temperature	°c
T92	(-2+(7*T$89/1200))*$S92	grass ground temperature	°c
T93	(0+(17*T$89/1200))*$S93	crushed rock ground temperature	°c

T94	(0+(18*T$89/1200))*$S94	bitumen and gravel roof ground temperature	°c
T95	(0+(20*T$89/1200))*$S95	bitumen road surface ground temperature	°c
U90	(-2+(6*U$89/1200))*$S90	new concrete obstruction temperature	°c
U91	(-1+(8*U$89/1200))*$S91	old concrete obstruction temperature	°c
U92	(-2+(7*U$89/1200))*$S92	grass obstruction temperature	°c
U93	(0+(17*U$89/1200))*$S93	crushed rock obstruction temperature	°c
U94	(0+(18*U$89/1200))*$S94	bitumen and gravel roof obstruction temperature	°c
U95	(0+(20*U$89/1200))*$S95	bitumen road surface obstruction temperature	°c
T97	SUM(T90:T95)	ground temp increase above air temp	°c
U97	SUM(U90:U95)	obstruction temperature increase above air temperature	°c
P98	F31+273	screen air temperature	°K
Q98	IF(P33>4,(S82-0.15)/0.79,F56)	cloud cover correction	ratio
O101	1.06*(5.6697*10^-8)*(P98^4)-119	clear sky long wave infra red radiation	W/m²
P101	O101/(5.6697*10^-8*(P98^4))	clear sky emissivity	ratio
Q101	(1-0.84*Q98)*P101+(0.84*Q98)	cloud base emissivity	ratio
R101	Q101*(5.6697*10^-8)*(P98^4)	cloudy sky long wave infra red radiation	W/m²
S101	(R101/(5.6697*(10^-8)))^0.25	equivalent black body sky temperature	°K
T101	P98+T97	ground temperature	°K
U101	P98+U97	obstruction temperature	°K
Y103	D37	membrane inclination	°
W103	H34	average view angle of obstructions above horizon	°
S103	1-U103-T103	sky view factor	ratio
T103	Y103/180	ground view factor	ratio
U103	W103/90	obstruction view factor	ratio
S106	((S103*S101^4)+(T103*T101^4)+(U103*U101^4))^0.25	equivalent temperature	ratio
U106	I56	membrane emmissivity	ratio
W106	D31+273	external surface temperature	°K
Y106	U106*(5.6697*10^-8)*(S106^4-W106^4)	net long wave exchange	W/m²

A2:3.2 **Calculation of the Internal Surface Long Wave Infra Red Radiation Heat Transfer.**

cell	**code**	**purpose**	**units**
Y111	L34	space internal surfaces long wave infra red absorptivity	ratio
U111	L62	membrane internal surface emissivity	ratio
U114	H37	self facing ?	ratio
U111	(U111*U114)+((1-U114)*Y111)	equivalent internal surfaces emissivity	ratio

W114	1/((1/W111)+(1/W111)-1)	emissivity factor	ratio
Y117	B31	membrane internal surface temperature	°c
W120	J37	space internal surface equivalent temperature	°c
Y114	W114*(((273+W120)^4)-((Y117+273)^4))*5.67*10^-8	long wave infra red radiation surface exchange	W/m^2
Q115	R101	external sky long wave radiation	W/m^2
R115	0.945*(5.6697*10^-8)*(T101^4)	external ground long wave radiation	W/m^2
S115	0.945*(5.6697*10^-8)*(T101^4)	external obstruction long wave radiation	W/m^2
Q116	Q115*S103	incident sky long wave radiation	W/m^2
R116	R115*T103	incident ground long wave radiation	W/m^2
S116	S115*U103	incident obstruction long wave radiation	W/m^2
O116	S116+R116+Q116	total incident external long wave radiation	W/m^2
O119	L65	membrane long wave infra red radiation hemispherical transmittance	ratio
Q119	O116*O119	transmitted long wave radiation	W/m^2
R119	Q119*(1-W111)	internal reflection number 1	W/m^2
S119	R119*Y111	membrane absorption	W/m^2
Q120	R119*(1-Y111-O119)	remaining long wave radiation	W/m^2
R120	Q120*(1-W111)	reflection number 2	W/m^2
S120	R120*(1-Y111-O119)	membrane absorption	W/m^2
U120	R120*(1-W111)	remaining long wave radiation	W/m^2
U117	S119+S120	internal incident long wave absorption	W/m^2
W117	Y114+U117	total membrane long wave infra red radiation absorption	W/m^2

A2:3.3 **Calculation of the External Surface Convection Heat Transfer.**

cell	**code**	**purpose**	**units**
AC7	J31	free stream wind velocity	m/s
AC10	L31	free stream direction	° w of s
AC13	X43	surface azimuth	° w of s
AE10	AC10-AC13	corrected wind direction	° w of s
AG10	IF(ABS(AE10)<180,AE10,-(360-ABS(AE10)))	relative wind direction	°
AC16	IF(ABS(AG10)>90,0,AC7)	windward surface wind velocity	m/s
AC19	IF(OR(ABS(AG10)<90,ABS(AG10)=90),0,(0.3+0.05*AC7))	leeward surface wind velocity	m/s
AF12	0.573970443	correction multiplier	#
AF13	1.082933307	correction power	#
AF16	IF(AC7=0,0,10^(((LOG(AC16))-AF12)/AF13))	wind speed correction	m/s

AF19	IF(AC16=0,AC19,AF16)	surface wind velocity	m/s
AI7	IF(AF19>4.88,0,1)	is v<4.88 ?	#
AK7	IF(AF19<4.88,0,1)	is v>4.88(<30.48) ?	#
AI10	0	nature of surface (smooth0, rough1)	ratio
AI13	AI7*((AI10*1.09)+((1-AI10)*0.99))	a if v<4.88	#
AJ13	AI7*((AI10*0.23)+((1-AI10)*0.21))	b if v<4.88	#
AK13	AI7*1	n if v<4.88	#
AI16	0	a if v>4.88(<30.48)	#
AJ16	AK7*((AI10*0.53)+((1-AI10)*0.5))	b if v>4.88(<30.48)	#
AK16	AK7*0.78	n if v>4.88(<30.48)	#
AI19	AI16+AI13	a	#
AJ19	AJ16+AJ13	b	#
AK19	AK16+AK13	n	#
AI23	5.678*(AI19+(AJ19*((AF19/0.3048)^AK19)))	external surface convective heat transfer coefficient	W/m^2°c
AG23	D31	membrane external surface temperature	°c
AE23	F31	external air temperature	°c
AC23	(AI23*(F31-D31))	external surface convective heat transfer	W/m^2

A2:3.4 **Calculation of the Internal Surface Convection Heat Transfer.**

cell	**code**	**purpose**	**units**
AC35	[MEMMOD3.XLW]SITE.XLS!$B$10	vertical surface characteristic length	m
AE35	4*[MEMMOD3.XLW]SITE.XLS!$B$8/[MEMMOD3.XLW]SITE.XLS!$B$9	horizontal surface characteristic length	m
AG35	B31	membrane internal surface temperature	°c
AI35	(F37+AG35)/2	internal air film temperature	°c
AK35	ABS(AG35-AI35)	temperature difference	°c
AI43	D37	membrane panel inclination	°
AD38	1.5	a vertical	#
AE38	1.23	b vertical	#
AF38	0.25	p vertical	#
AG38	0.333333333	q vertical	#
AH38	6	m vertical	#
AD39	1.4	a horizontal	#
AE39	1.63	b horizontal	#

AF39	0.25	p horizontal	#
AG39	0.333333333	q horizontal	#
AH39	6	m horizontal	#
AI38	IF(AC35>0,(((AD38*(AK35/AC35)^AF38)^AH38)+((AE38*(AK35^AG38))^AH38))^(1/AH38),0)	vertical surface heat transfer coefficient	W/m^{2}oc
AI39	(((AD39*(AK35/AE35)^AF39)^AH39)+((AE39*(AK35^AG39))^AH39))^(1/AH39)	horizontal surface heat transfer coefficient	W/m^{2}oc
AI40	0.6*((AK35/AE35^2)^0.2)	stratified air heat transfer coefficient	W/m^{2}oc
AJ38	AI43/90	vertical weighting	ratio
AJ39	IF(AG35>AI35,0,(90-AI43)/90)	horizontal weighting	ratio
AJ40	IF(AG35>AI35,(90-AI43)/90,0)	stratified weighting	ratio
AK38	AI38*AJ38	vertical weighted value	W/m^2°c
AK39	AI39*AJ39	horizontal weighted value	W/m^2°c
AK40	AI40*AJ40	stratified weighted value	W/m^2°c
AK43	SUM(AK38:AK40)	natural inclined heat transfer coefficient	W/m^2°c
AC46	[MEMMOD3.XLW]DATA.XLS!$C$1	forced convection internal air speed	m/s
AE46	248.26*AC46/(273.16+((AG35+AI35)/2))	v temperature correction	m/s
AG46	5.678*(0.99+0.21*(AE46/0.3048))	forced convection heat transfer coefficient	W/m^2°c
AI46	IF(AC46>0,AG46,AK43)	selected heat transfer coefficient	W/m^2°c
AK46	AI46*(AI35-AG35)	internal surface convective heat transfer	W/m^2

A2:3.5 **Calculation of the Membrane Core Behaviour.**

cell	**code**	**purpose**	**units**
O10	U76	external incident direct beam solar radiation	W/m^2
P10	B62	external incident direct beam solar transmittance	W/m^2
Q10	O10*(P10/100)	external incident transmitted direct beam solar radiation	W/m^2
R10	O10*(D62/100)	external incident absorbed direct beam solar radiation	W/m^2
O7	W79	external incident diffuse solar radiation	W/m^2
P7	F62	external incident diffuse solar transmittance	ratio
Q7	O7*(P7/100)	external incident transmitted diffuse solar radiation	W/m^2
R7	O7*(H62/100)	external incident absorbed diffuse solar radiation	W/m^2
O4	O135	internal incident solar radiation	W/m^2
P4	F62	internal incident solar transmittance	ratio
Q4	X139	effective external solar transmittance	W/m^2
R4	W139	effective external solar absorptance	W/m^2

V10	IF(AND(H31>0,P33>0),-LN(T10/(T8+T10))/O18,0)	external extinction coefficient	W/gauge
T4	H62	effective internal solar absorptance	ratio
T6	F62	effective internal solar transmittance	ratio
V10	IF(H31>0,-LN(T6/(T6+T4))/O18,0)	internal extinction coefficient	W/gauge
V6	SUM(W13:W23)-R4-R7-R10	extinction error	W/m²
X4	X139+W139	external unreflected solar radiation	W/m²
X10	R10+R7+Q7+Q10	internal unreflected solar radiation	W/m²
O18	1	gauge	mm
P13	0	depth from outside	mm
P14	P13+$O$18/10	depth from outside	mm
P15	P14+$O$18/10	depth from outside	mm
P16	P15+$O$18/10	depth from outside	mm
P17	16+$O$18/10	depth from outside	mm
P18	P17+$O$18/10	depth from outside	mm
P19	P18+$O$18/10	depth from outside	mm
P20	P19+$O$18/10	depth from outside	mm
P21	P20+$O$18/10	depth from outside	mm
P22	P21+$O$18/10	depth from outside	mm
P23	P22+$O$18/10	depth from outside	mm
Q13	D31	external surface temperature	°
Q18	(Q13+Q23)/2	average temperature	°
Q23	B31	internal surface temperature	°
R13	(Q23-Q13)*R18*2	external surface conduction	W/m²
R18	D59	core conductivity	W/m²°c
R23	(Q13-Q23)*R18*2	internal surface conduction	W/m²
S13	Y106	external surface long wave radiation exchange	W/m²
S18	S23+S13	net long wave radiation exchange	W/m²
S23	W117	internal surface long wave radiation exchange	W/m²
T13	AC23	external surface convective exchange	W/m²
T18	T23+T13	net convective exchange	W/m²
T23	AK46	internal surface convective exchange	W/m²
U13	1-EXP(-$V$4*P13)	external extinction	W
U14	1-EXP(-$V$4*P14)	external extinction	W
U15	1-EXP(-$V$4*P15)	external extinction	W
U16	1-EXP(-$V$4*P16)	external extinction	W
U17	1-EXP(-$V$4*P17)	external extinction	W

U18	1-EXP(-$V$4*P18)	external extinction	W
U19	1-EXP(-$V$4*P19)	external extinction	W
U20	1-EXP(-$V$4*P20)	external extinction	W
U21	1-EXP(-$V$4*P21)	external extinction	W
U22	1-EXP(-$V$4*P22)	external extinction	W
U23	1-EXP(-$V$4*P23)	external extinction	W
V13	1-EXP(-$V$10*($O$18-P13))	internal extinction	W
V14	1-EXP(-$V$10*($O$18-P14))	internal extinction	W
V15	1-EXP(-$V$10*($O$18-P15))	internal extinction	W
V16	1-EXP(-$V$10*($O$18-P16))	internal extinction	W
V17	1-EXP(-$V$10*($O$18-P17))	internal extinction	W
V18	1-EXP(-$V$10*($O$18-P18))	internal extinction	W
V19	1-EXP(-$V$10*($O$18-P19))	internal extinction	W
V20	1-EXP(-$V$10*($O$18-P20))	internal extinction	W
V21	1-EXP(-$V$10*($O$18-P21))	internal extinction	W
V22	1-EXP(-$V$10*($O$18-P22))	internal extinction	W
V23	1-EXP(-$V$10*($O$18-P23))	internal extinction	W
W13	(V13-V14)*X4	solar absorption	W
W14	((U14-U13)*$X$10)+((V14-V15)*$X$4)	solar absorption	W
W15	((U15-U14)*$X$10)+((V15-V16)*$X$4)	solar absorption	W
W16	((U16-U15)*$X$10)+((V16-V17)*$X$4)	solar absorption	W
W17	((U17-U16)*$X$10)+((V17-V18)*$X$4)	solar absorption	W
W18	((U18-U17)*$X$10)+((V18-V19)*$X$4)	solar absorption	W
W19	((U19-U18)*$X$10)+((V19-V20)*$X$4)	solar absorption	W
W20	((U20-U19)*$X$10)+((V20-V21)*$X$4)	solar absorption	W
W21	((U21-U20)*$X$10)+((V21-V22)*$X$4)	solar absorption	W
W22	((U22-U21)*$X$10)+((V22-V23)*$X$4)	solar absorption	W
W23	((U23-U22)*$X$10)	solar absorption	W
X13	R13+S13+W13+T13+W14+W15+W16+W17+(W18/2)	external surface net heat transfer	W/m²
X18	SUM(W13:W23)+T13+S13+S23+T23	net heat transfer	W/m²
X23	R23+S23+T23+W23+W22+W21+W20+W19+(W18/2)	internal surface heat transfer	W/m²

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