APPENDICES

HOUSE DIMENSION TAKEOFF FORM 1

LOCATION OF HOUSE _____ LATITUDE _____

SITE - FLAT OR SLOPING? _____ IF SLOPING GIVE PERCENTAGE GRADE AND

DIRECTION OF SLOPE _____ (10% = 1' rise in 10' & 5% = 0.5' in 10')

DEGREE DAYS HEATING PER YEAR _____ INDOOR DESIGN TEMPERATURE _____

FLOOR AREA _____ PERIMETER _____ AVERAGE CEILING HEIGHT _____

WALL AREAS		INSULATION TYPE AND THICKNESS	R VALUE OF THE WALL
EAST	_____	_____	_____
WEST	_____	_____	_____
NORTH	_____	_____	_____
SOUTH	_____	_____	_____
DOORS: #1	_____	_____	_____
#2	_____	_____	_____

WINDOW AREA		SINGLE, DOUBLE, TRIPLE GLAZING	NIGHT INSULATION TYPE AND R VALUE	HOURS IN PLACE AT NIGHT
EAST	____	_____	_____	_____
WEST	____	_____	_____	_____
NORTH	____	_____	_____	_____
SOUTH	____	_____	_____	_____

ROOF AREA _____ ROOF INSULATION TYPE & THICKNESS _____

ROOF R VALUE _____ IF EARTH SHELTERED GIVE DEPTH OF DIRT _____

BELOW GRADE

Is there a basement? _____ If YES what is the height? _____

Specify insulation type and thickness _____ R Value below grade _____

If slab on grade give exterior insulation specs _____

Exposed Perimeter _____ R Value _____

HOUSE DIMENSION TAKEOFF FORM 2

PASSIVE SOLAR SPECIFICATIONS

	PASSIVE SOLAR TYPE	WINDOW AREA	LOCATION
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____

IF HOME IS A DOUBLE SHELL PROVIDE THE FOLLOWING INFORMATION:

Interior wall area: North ____ South ____ Roof ____ R Value _____

Exterior glazing area greenhouse _____ Interior wall glazing area ___

Specify fans if used ____ Specify type of night shutter _____

R Value of night shutters _____ Location of shutters _____

IF A TROMBE WALL IS EMPLOYED IS THERE A SELECTIVE SURFACE? _____

IF A SUNSPACE IS USED WHAT WILL BE THE MINIMUM TEMPERATURE ALLOWED? ___

Describe location and type of glazing _____ Glazing area _____

Specify night shutter type _____ R value ____ Hours in place _____

Sunspace floor area _____ Describe mass (brick, water, etc.)_____

Glazing area between sunspace and house _____

Wall area and R value betwen sunspace and house _____

IS SOLAR DOMESTIC HOT WATER HEATING DESIRED? _____ YES _____ NO

ARE SOLAR COVENANTS IN FORCE? _____ YES _____ NO _____ NOT APPLICABLE

ARE THERE LEGAL GUARANTEES TO SOLAR ACCESS? _____ YES _____ NO

BACKUP

BACKUP SYSTEM DESIRED (gas, electricity, oil, etc.) _____

COST OF FUEL (consult fuel dealer or utility) _____

WOOD STOVES TO BE USED? ___YES ___NO HOW MANY? ____ LOCATION _____

_____ HEATING CAPACITY (btuh)

FIREPLACES TO BE USED? ____YES ___NO HOW MANY? ____ LOCATION _____

_____ HEATING CAPACITY)btuh)

SKIN FORM

construction

(circle one) wall window roof door

describe location

components	thickness	R value
outside air film		
inside air film		

R_t = total R value =

U = $1/R_{total}$ =

A = skin area =

UA (U x A) btu/° F =

diagram (optional)

DESIGN HEAT LOSS FORM (DHL) 1

ΔT = $t_{indoor\ desired}$ - $t_{outdoor\ design\ temperature}$ = _____

1.1 SKIN LOSSES: UA PRODUCT (from skin form)

1. Walls

UA_{North} _____

UA_{South} _____

UA_{East} _____

UA_{West} _____

2. Windows

UA_{North} _____

UA_{South} _____

UA_{East} _____

UA_{West} _____

3. Roof UA _____

4. Doors UA _____

5. UA Total Sum of All Above _____

ΔT (from above) x _____

Total Skin Loss (btuh) = _____ 1.1

1.2 AIR INFILTRATION LOSSES

Volume (Average ceiling height X floor area) _____

ΔT x _____

ACH (from table 5.3) x _____

CONSTANT (.018) x .018

AIR INFILTRATION (btuh) = _____ 1.2

DESIGN HEAT LOSS FORM (DHL) 2

1.3 BELOW GRADE & BASEMENT LOSSES

(Choose one of below) (A or B)

A) BASEMENT:

WALLS: Perimeter

Sum of values from Table 5.4	x	
54 (constant)	x	54
Total basement wall loss	=	

walls

FLOOR: Floor Area

Table 5.5 value	x	
54 (constant)	x	54
Total basement floor losses	=	

floor

Total Basement Losses (add walls and floors)	=	

1.3

B) SLAB ON GRADE:

Perimeter (in feet) Table 5.6 or 5.7 value	x	
SLAB ON GRADE LOSS	=	

1.3

1.4 DHL

Total Design Heat Loss = Total Skin Loss + Air Infiltration + Below Grade or Basement

DHL = (Sum of 1.1 + 1.2 + 1.3)	=	

DHL

SOLAR SAVINGS FRACTION FORM (SSF)

PRELIMINARY DATA ENTRY

UA south (from DHL form) _____

△T (from DHL form) x _____

SOUTH WINDOW LOSSES = _____

DHL, Design Heat Loss (from DHL form) _____

South Window Losses (from above) –

dhl (little DHL without south losses) = [ ] dhl

Constant 24 x 24

△T (from DHL form) ÷ _____

BLC (building load coefficient) = [ ] BLC

South Window Area (from House Dimensions Take Off Form) _____

LCR (load collector ratio) = [ ] LCR

Use LCR Value to find SSF Value from SSF Graph of your Locale in the Appendix **2** - Read SSF of your passive solar type and enter here

SOLAR SAVINGS FRACTION = [ ] SSF

THERMAL INTEGRITY FACTOR FORM (TIF)

PRELIMINARY DATA

TOTAL FLOOR AREA _____ DHL _____ SSF _____
DDy (degree days per year) _____ ΔT _____

$Q_{GROSS} = \frac{DHL \times DDY \times 24}{\Delta T}$

DHL (from data above)		
DDy (from data above)	x	
24 (constant)	x	24
ΔT (from data above)	÷	
GROSS ANNUAL HEAT LOSS	=	Q_{GROSS}

$Q_{INTERNAL}$ = NUMBER OF INHABITANTS x 3 MILLION BTU

NUMBER OF INHABITANTS		
3 MILLION (constant)	x	3,000,000
INTERNAL HEAT GAIN	=	$Q_{INTERNAL}$

$Q_{NET} = Q_{GROSS} - Q_{INTERNAL}$

Q_{GROSS} (from above)		
$Q_{INTERNAL}$ (from above)	-	
NET ANNUAL HEATING REQUIREMENTS	=	Q_{NET}

$Q_{SOLAR} = Q_{NET} \times SSF$

Q_{NET} (from above)		
SSF (from data above)	x	
ANNUAL SOLAR CONTRIBUTION	=	Q_{SOLAR}

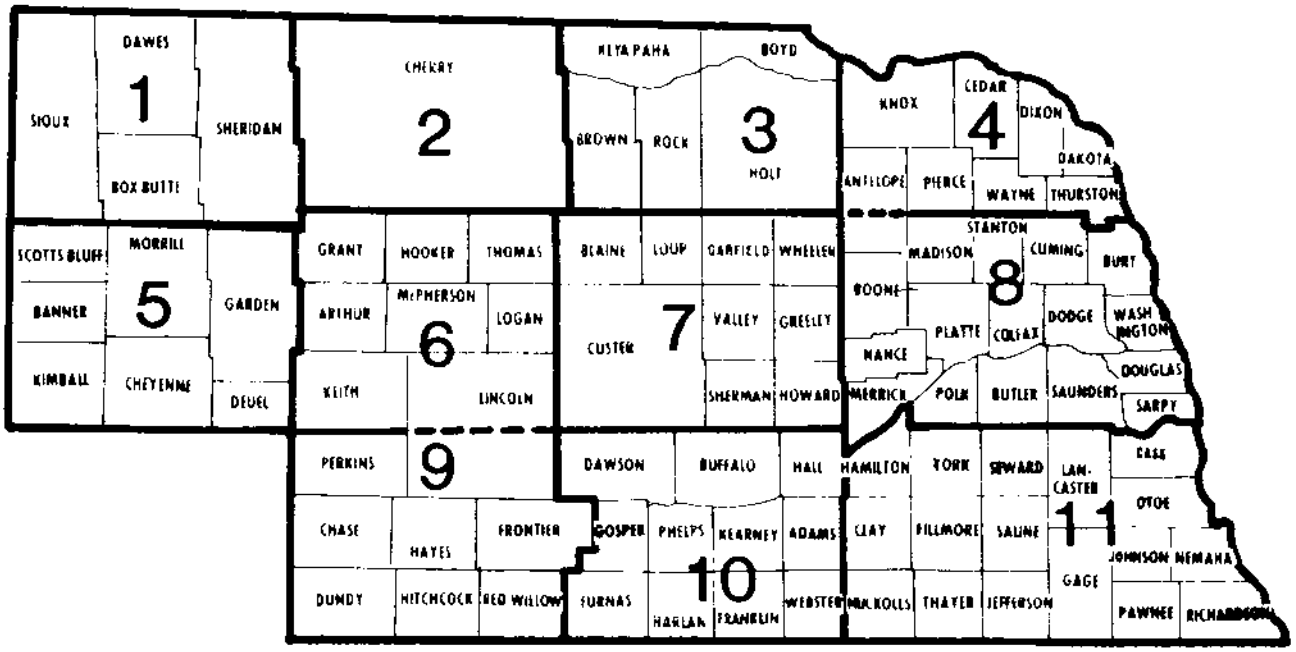
$Q_{AUXILIARY} = Q_{NET} - Q_{SOLAR}$

Q_{NET} (from above)		
Q_{SOLAR} (from above)	-	
TOTAL AUXILIARY HEAT REQUIRED	=	$Q_{AUXILIARY}$

$TIF = (Q_{AUXILIARY}) / (DDY \times FLOOR\ AREA)$

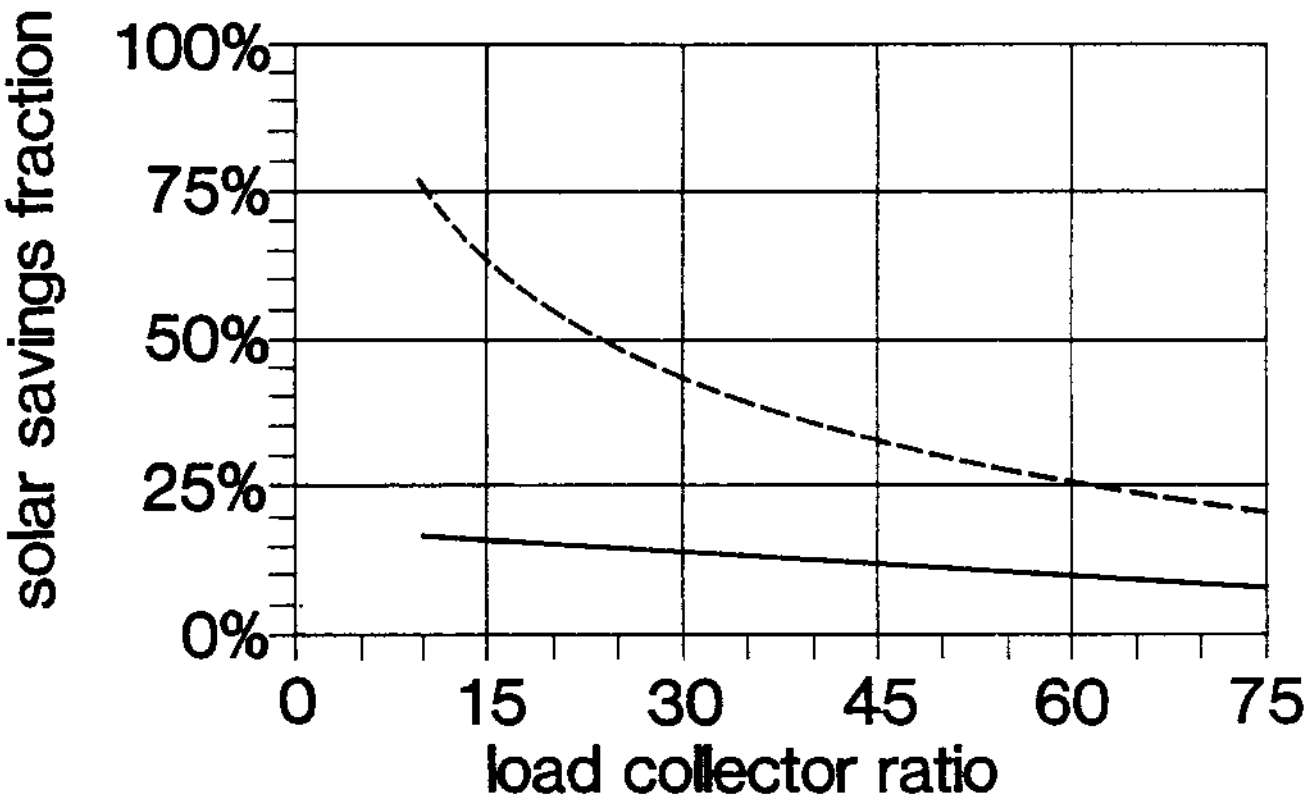
$Q_{AUXILIARY}$ (from above)		
DDY (from data above)	÷	
FLOOR AREA (from data above)	÷	
THERMAL INTEGRITY FACTOR	=	TIF

APPENDIX 2



NEBRASKA AREAS

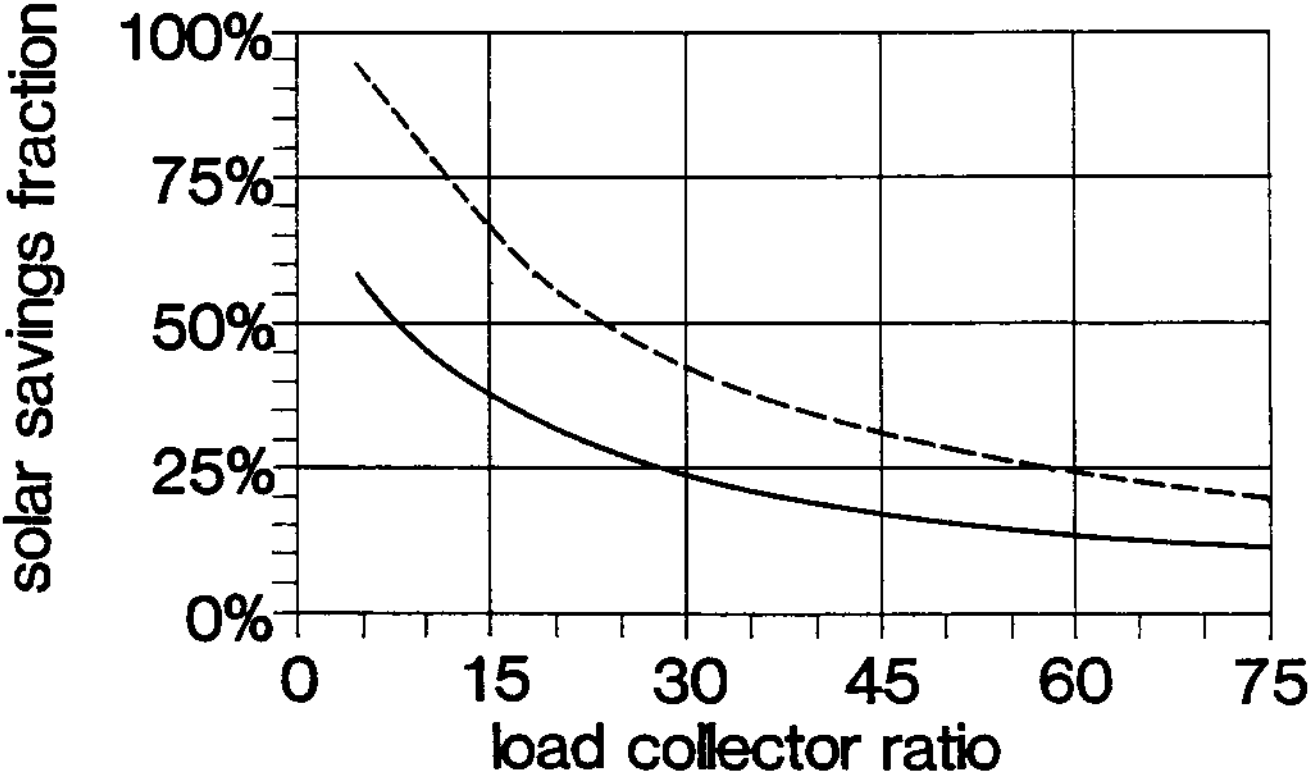
APPENDIX 2



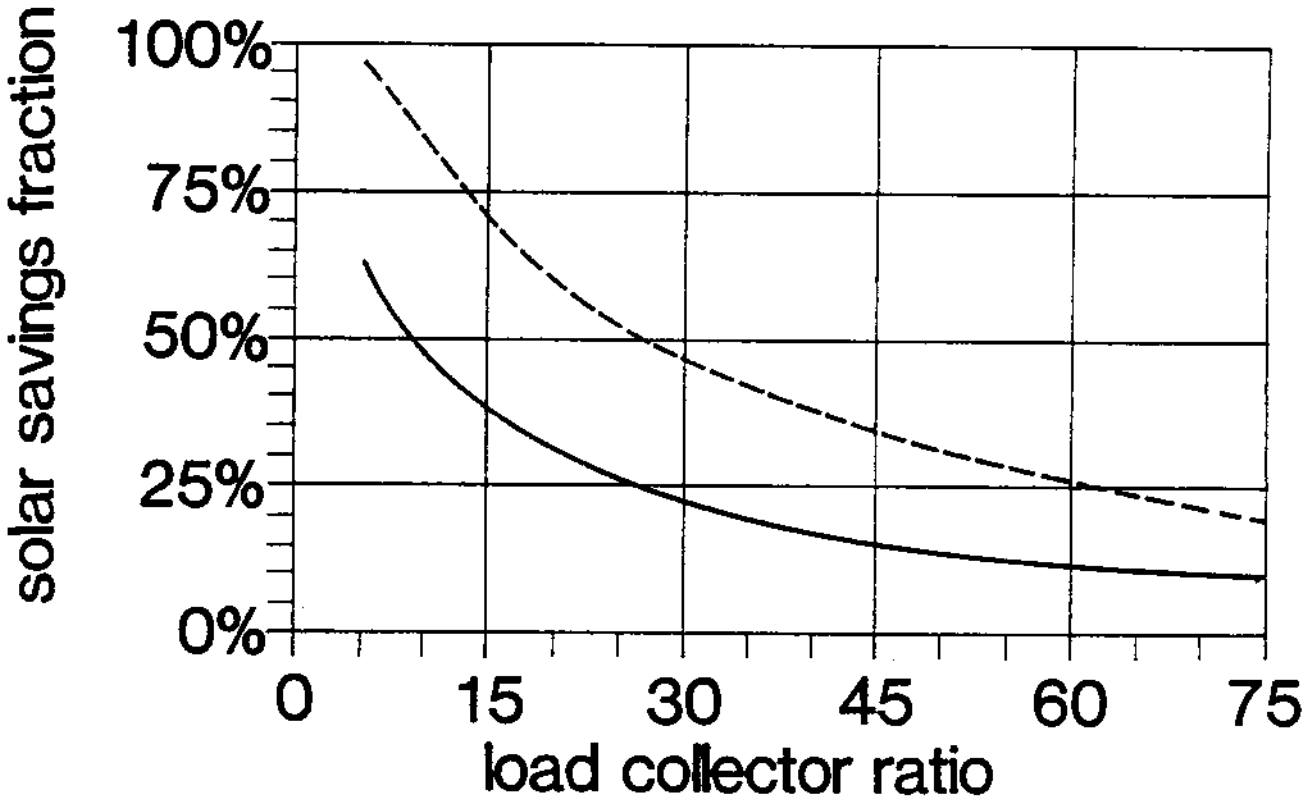
DIRECT GAIN AREA 1

night insulation

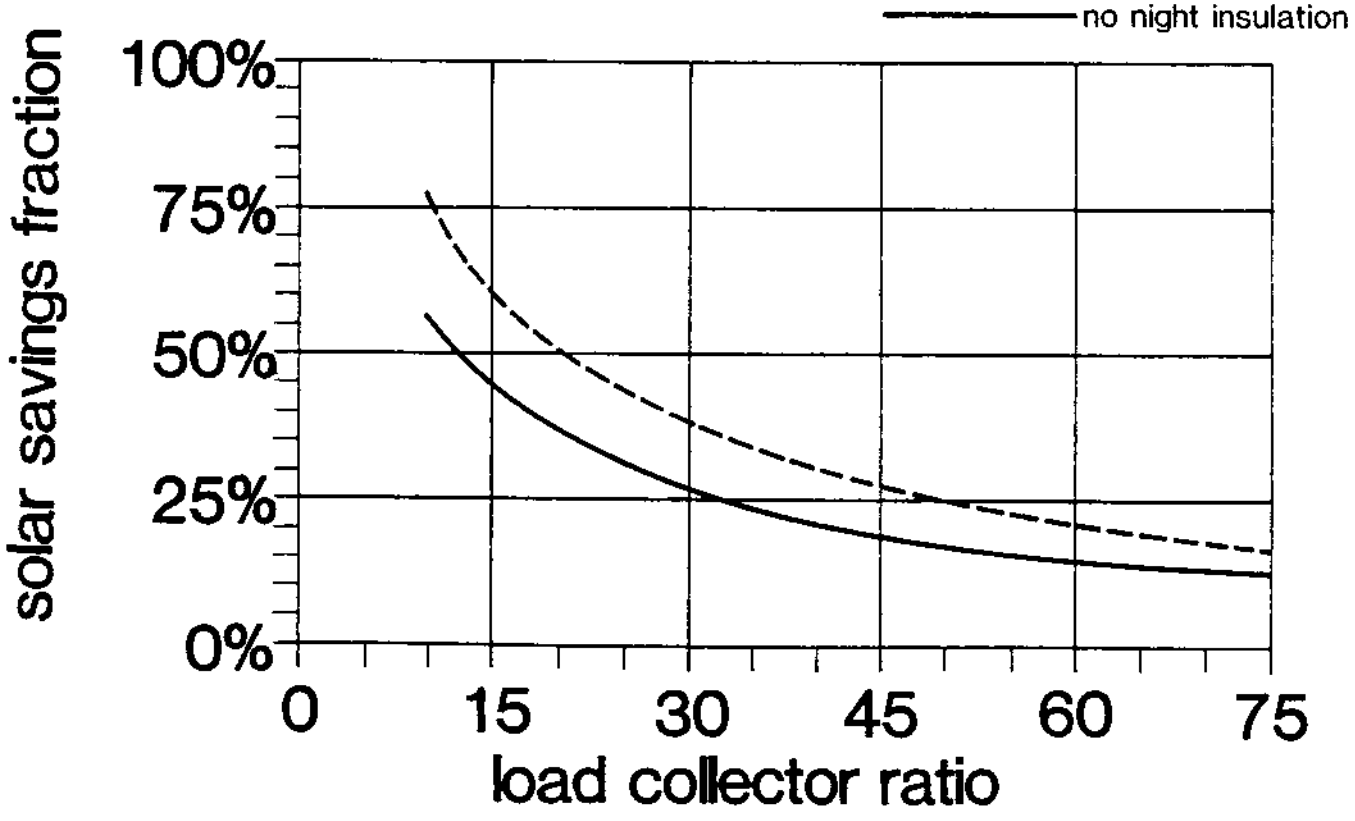
no night insulation



TROMBE WALL AREA 1

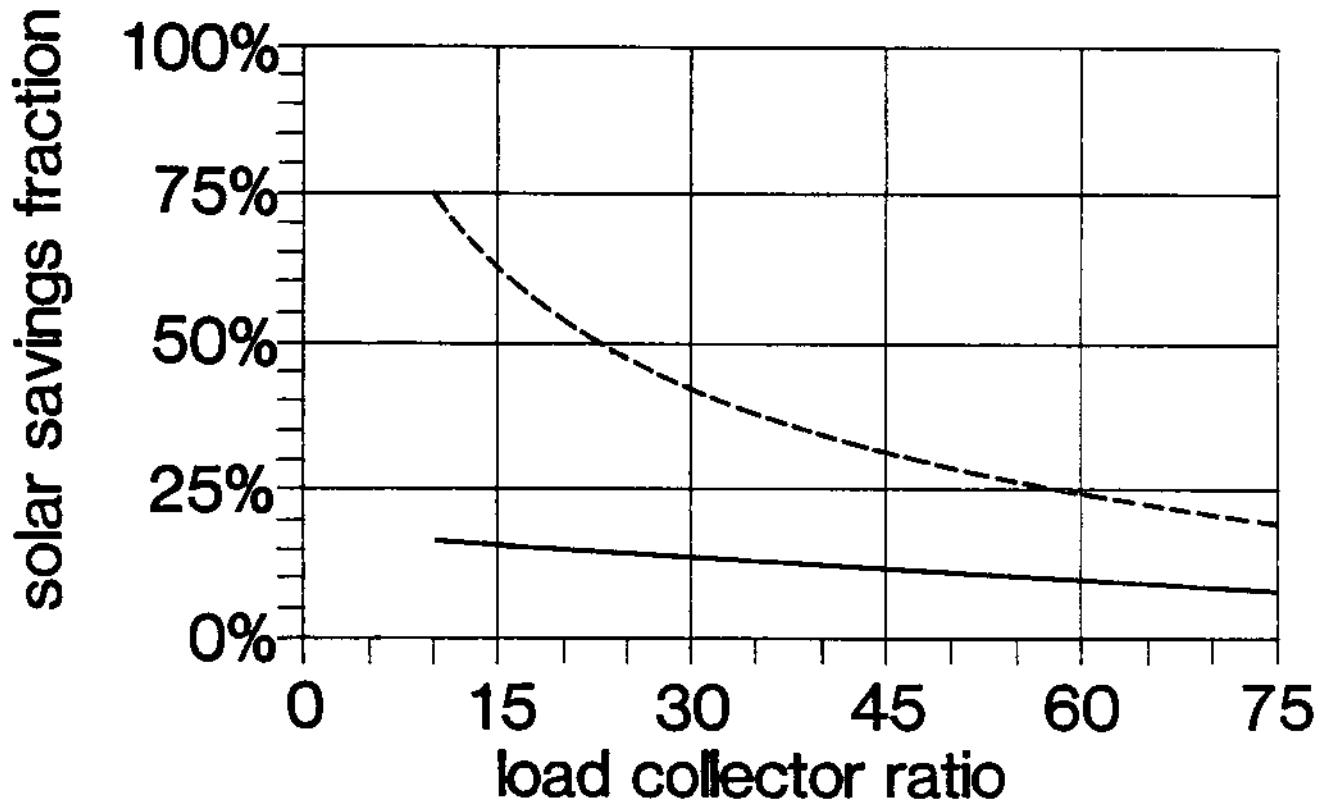


WATER WALL AREA 1



GREENHOUSE AREA 1

APPENDIX 2



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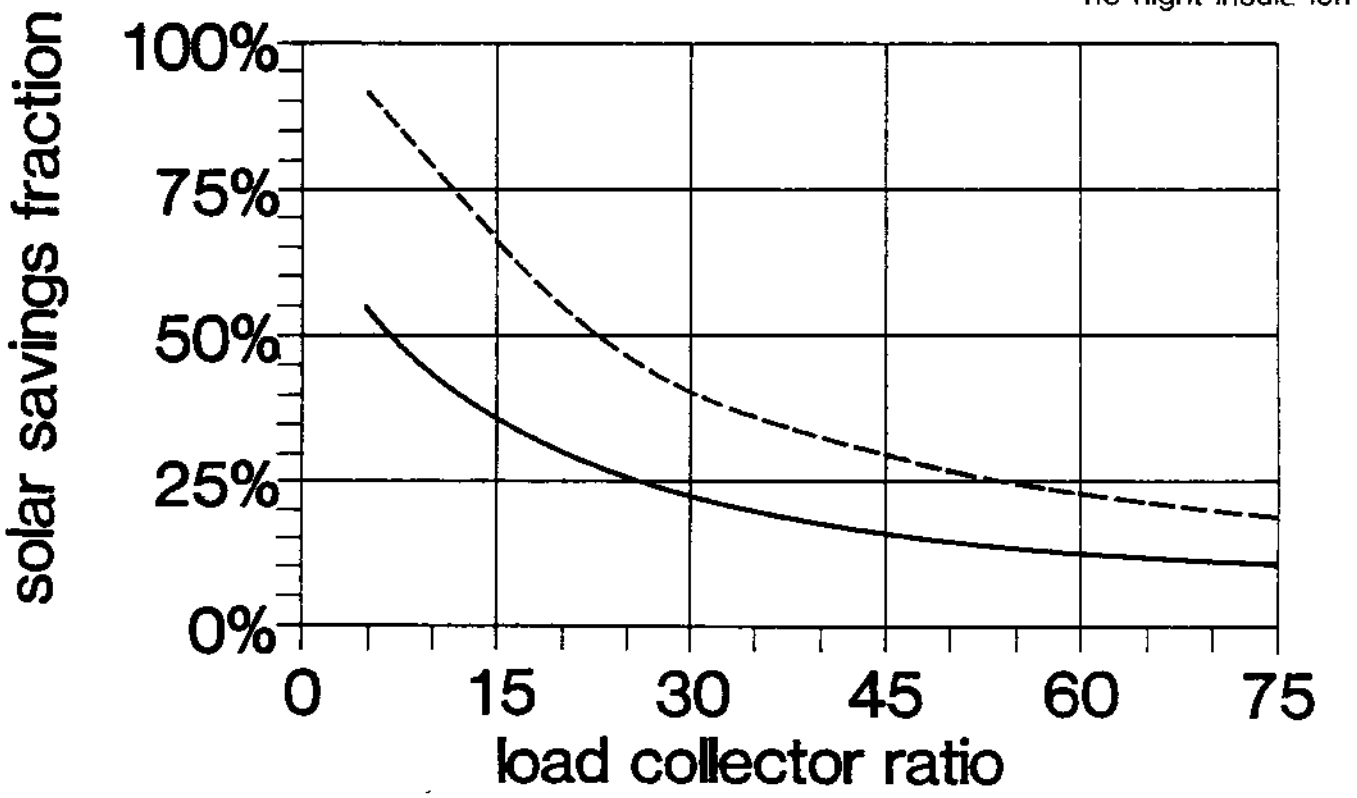

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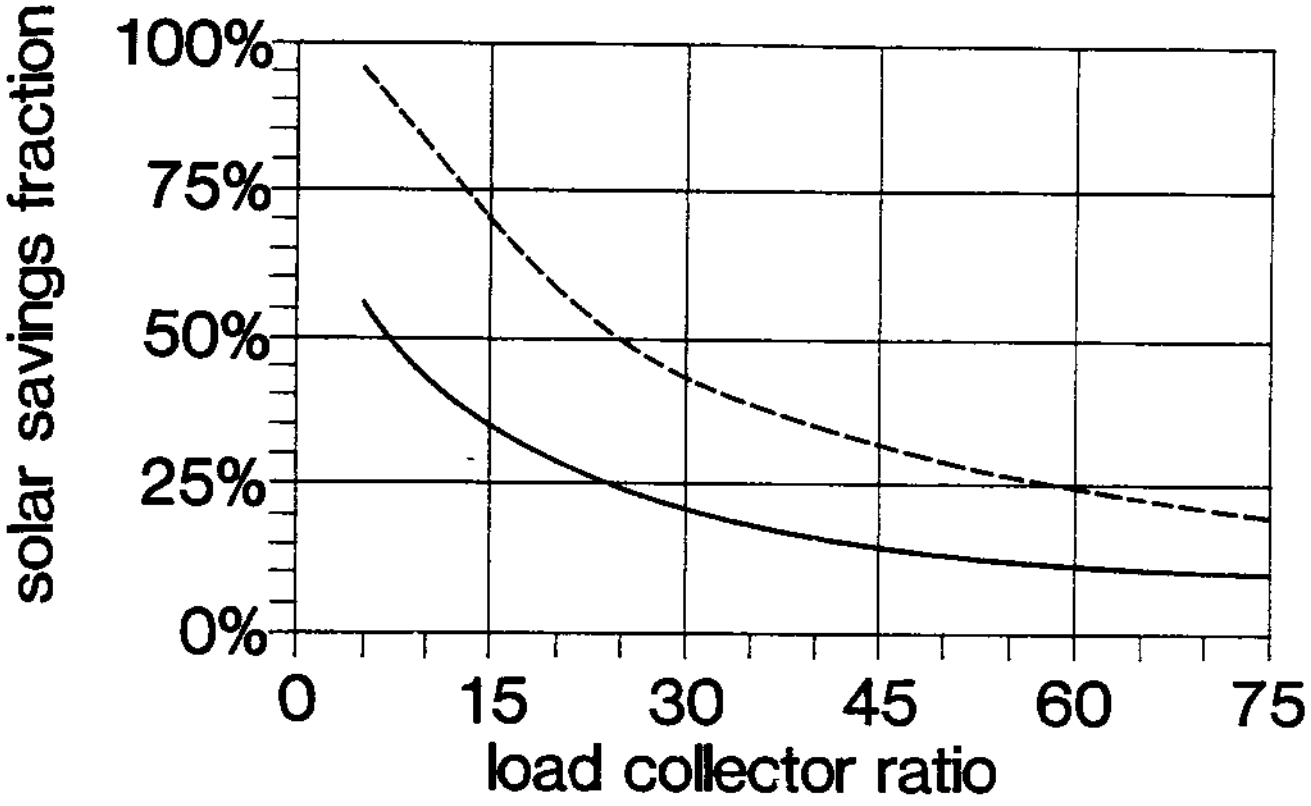
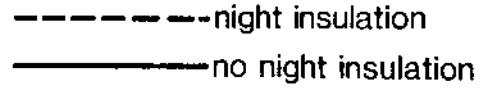
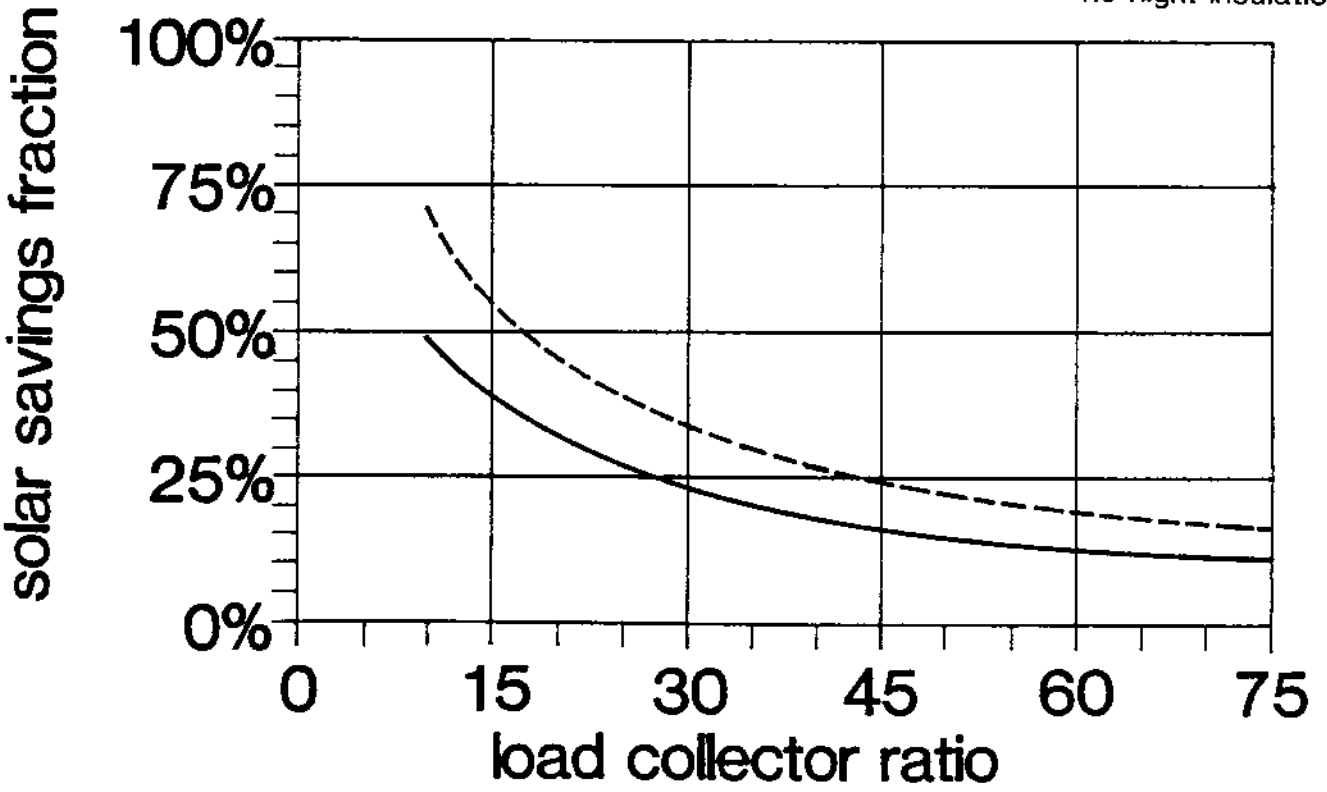


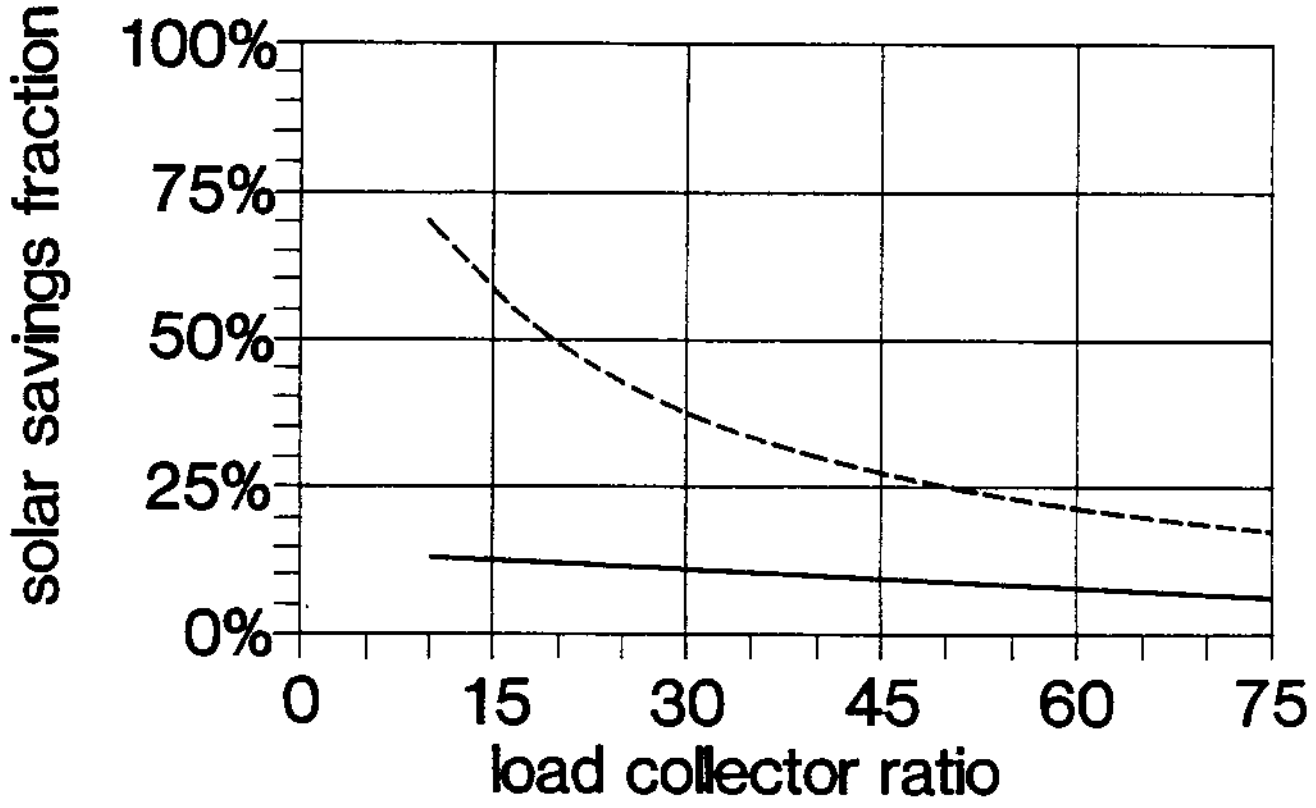
WATER WALL AREA 2



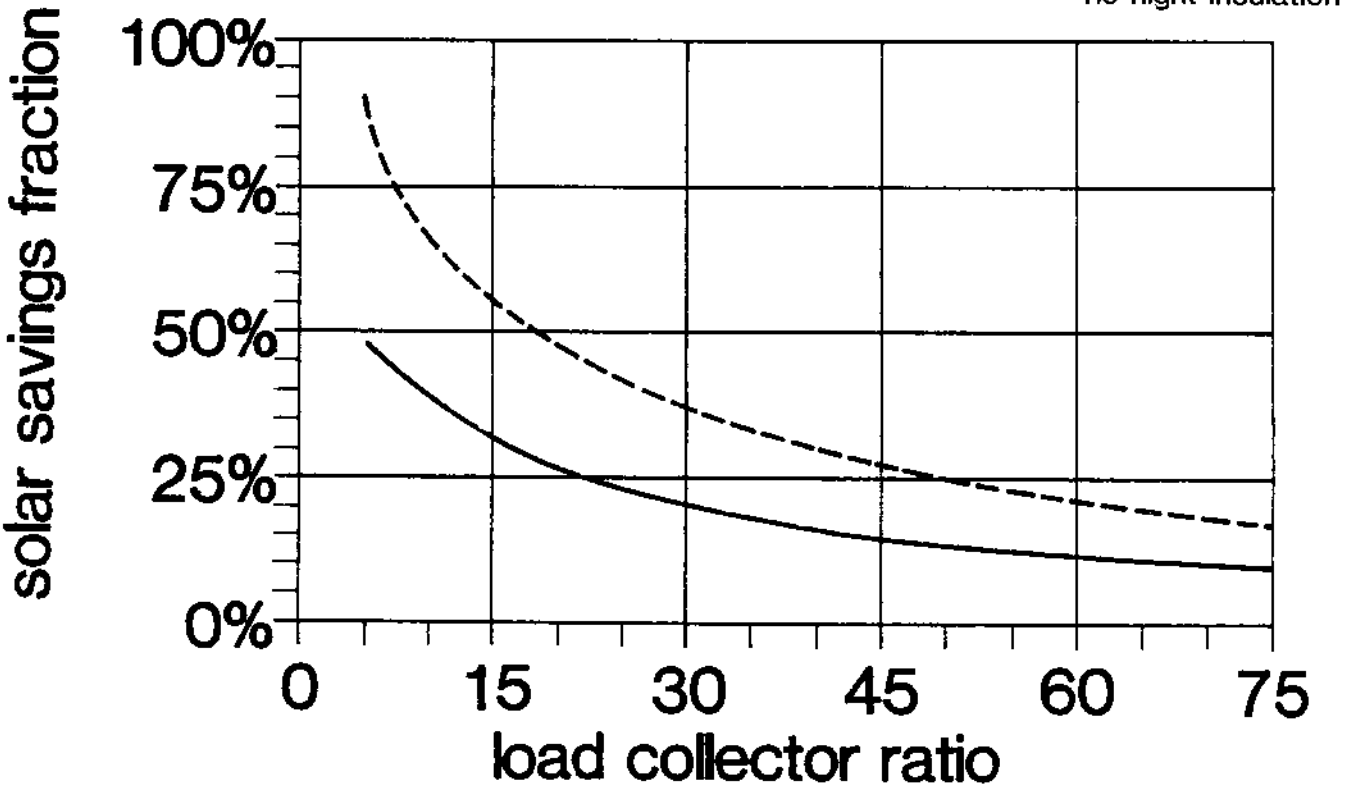


GREENHOUSE AREA 2

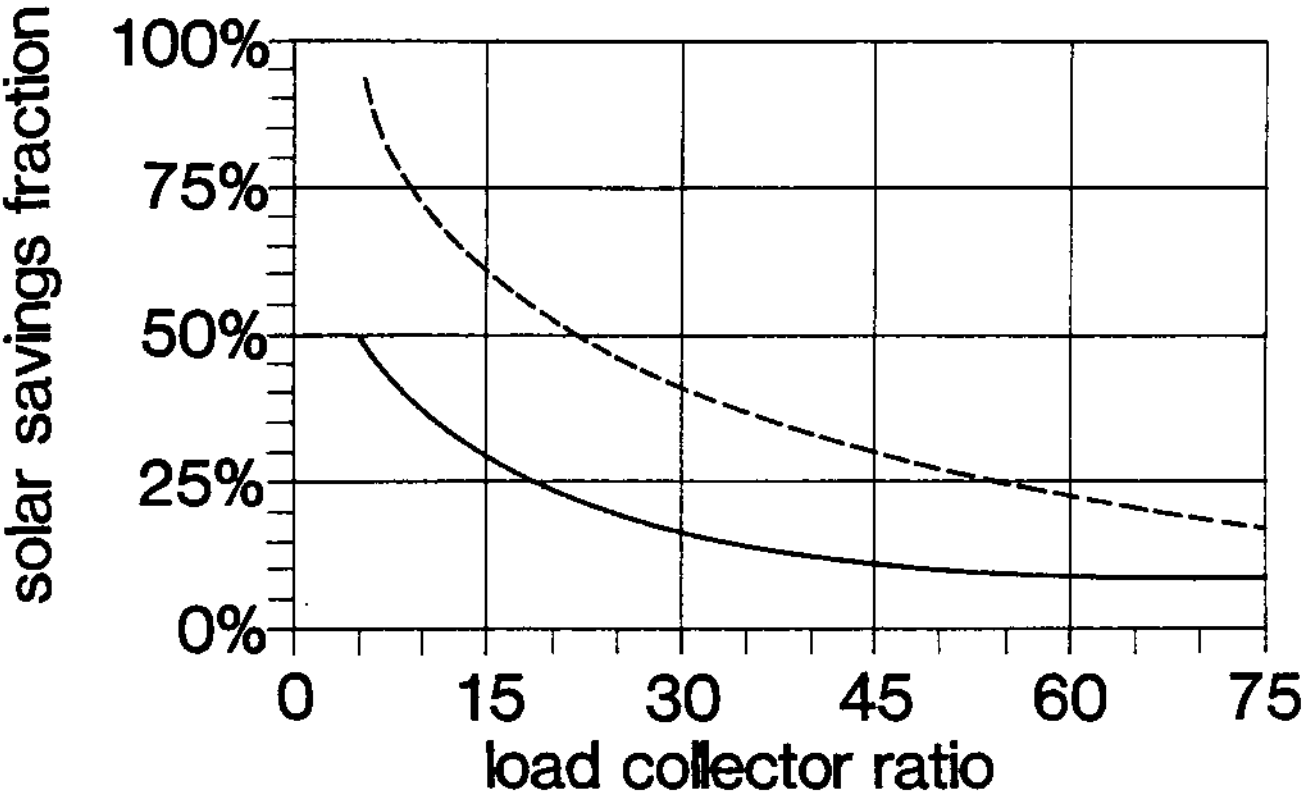
APPENDIX 2



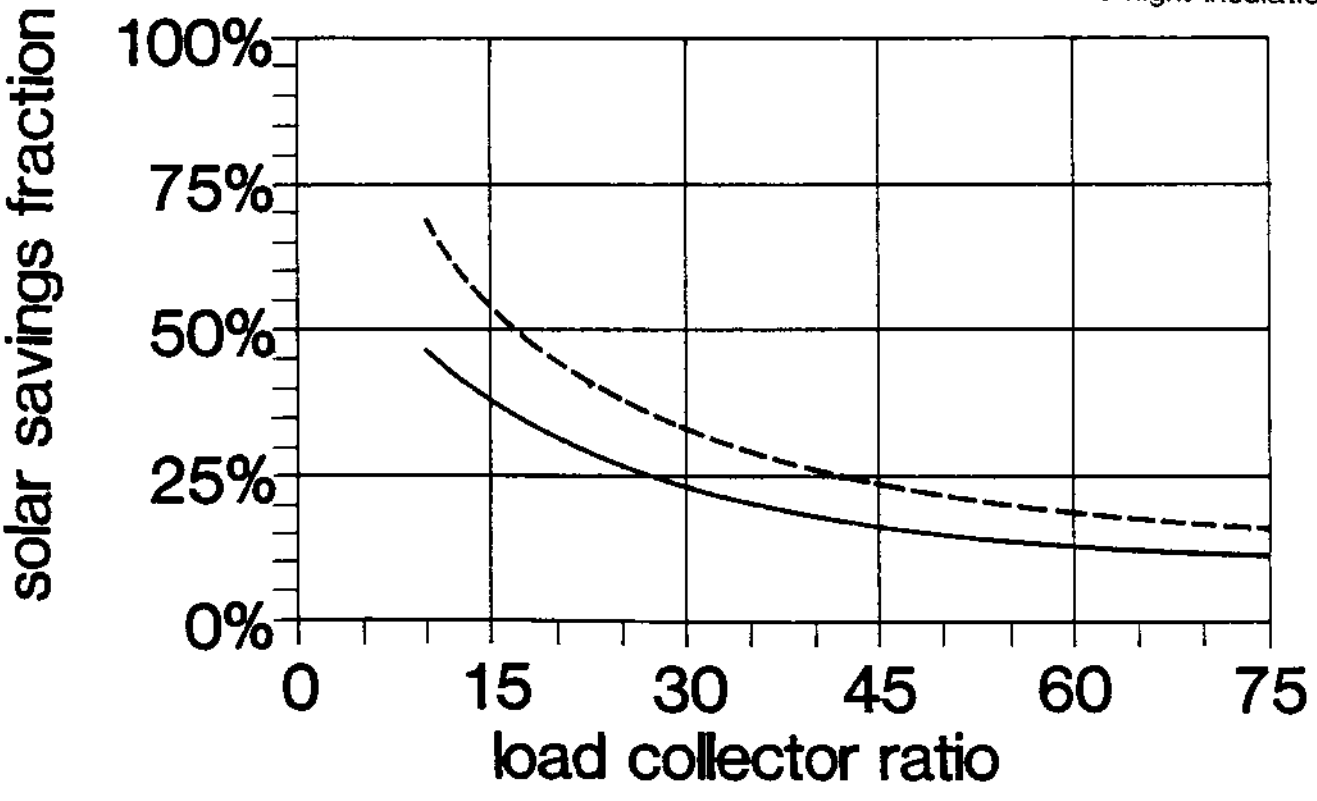
DIRECT GAIN AREA 3



TROMBE WALL AREA 3

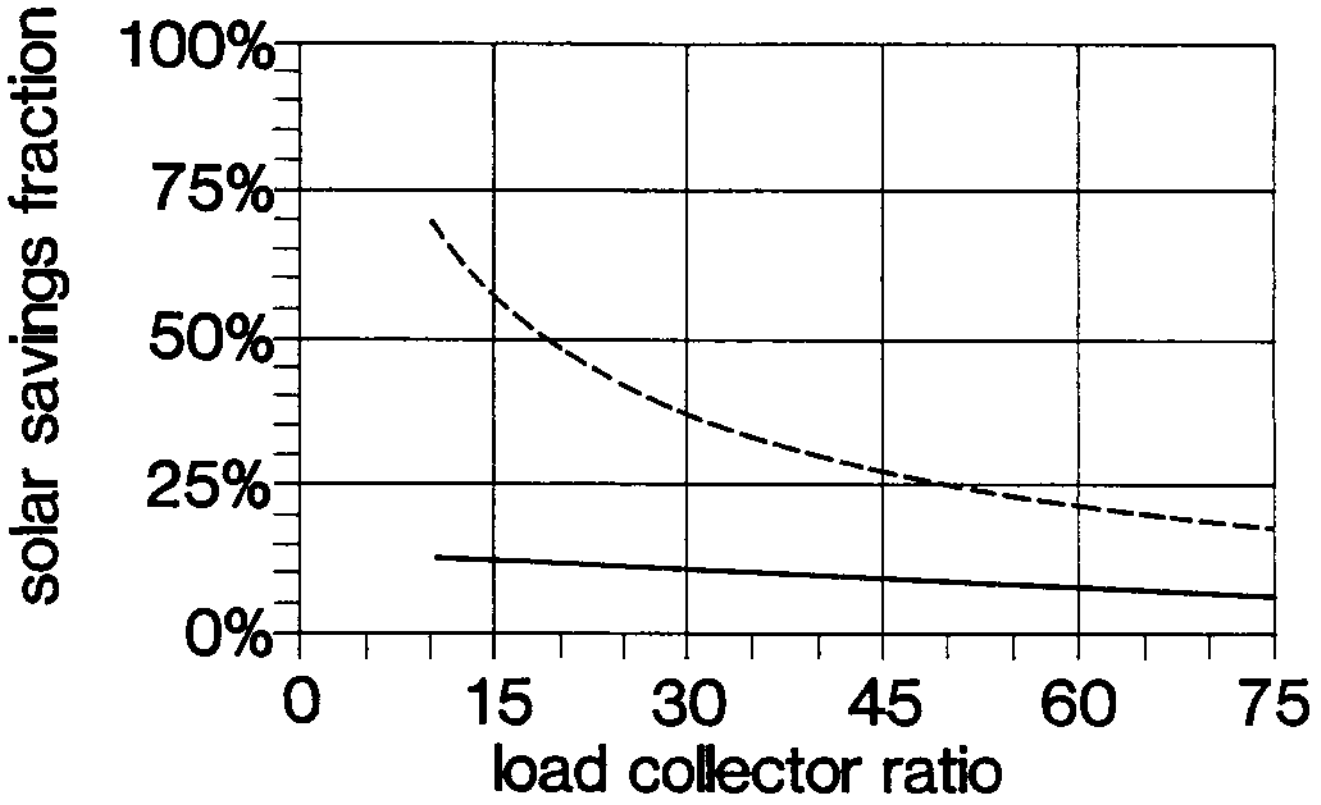


WATER WALL AREA 3

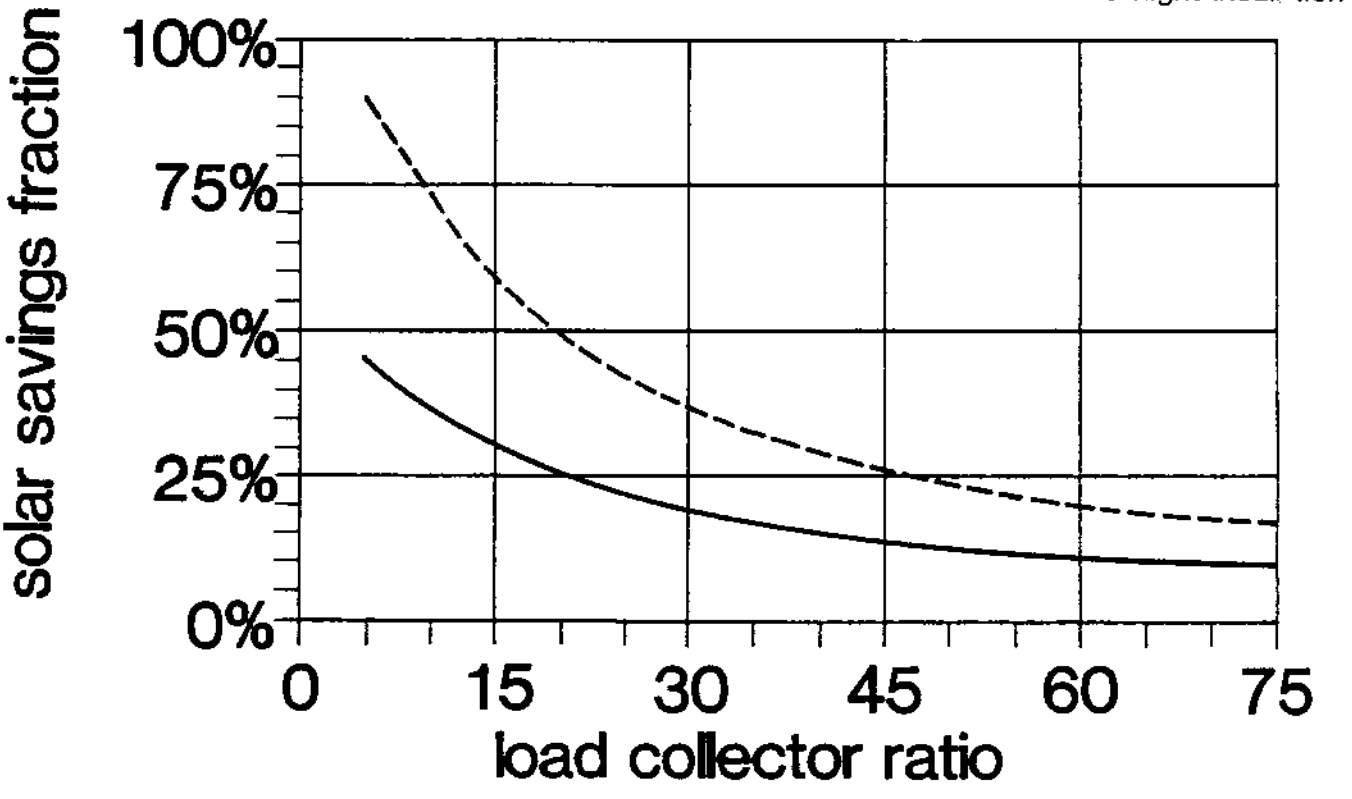


GREENHOUSE AREA 3

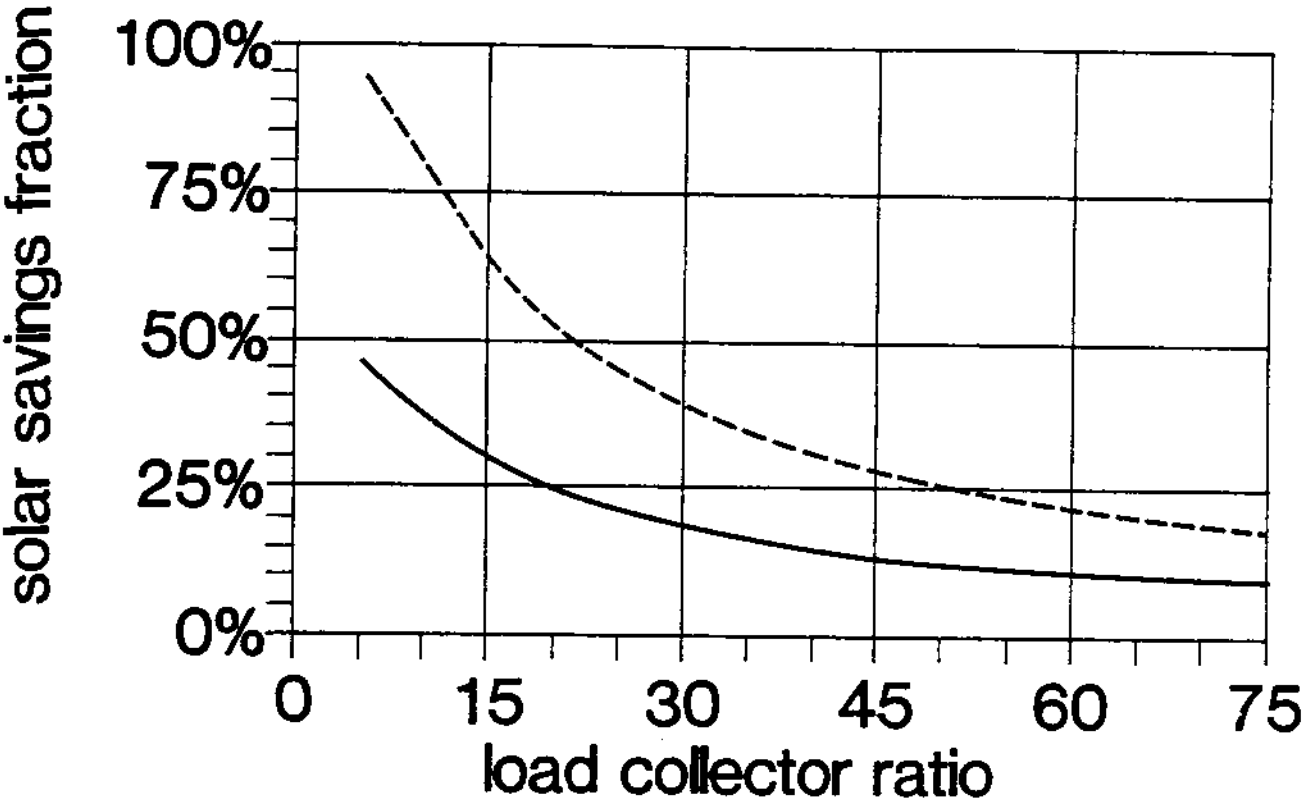
APPENDIX 2



DIRECT GAIN AREA 4



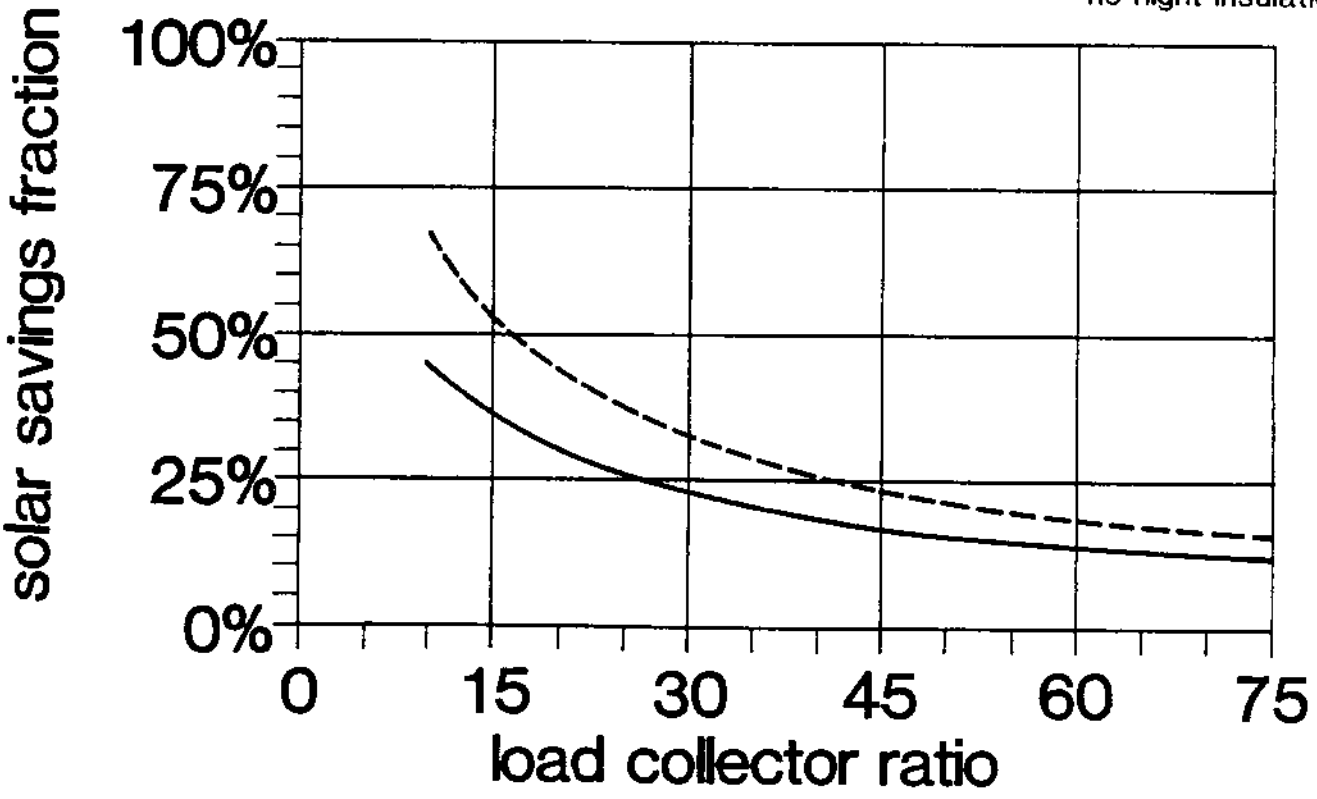
TROMBE WALL AREA 4



WATER WALL AREA 4

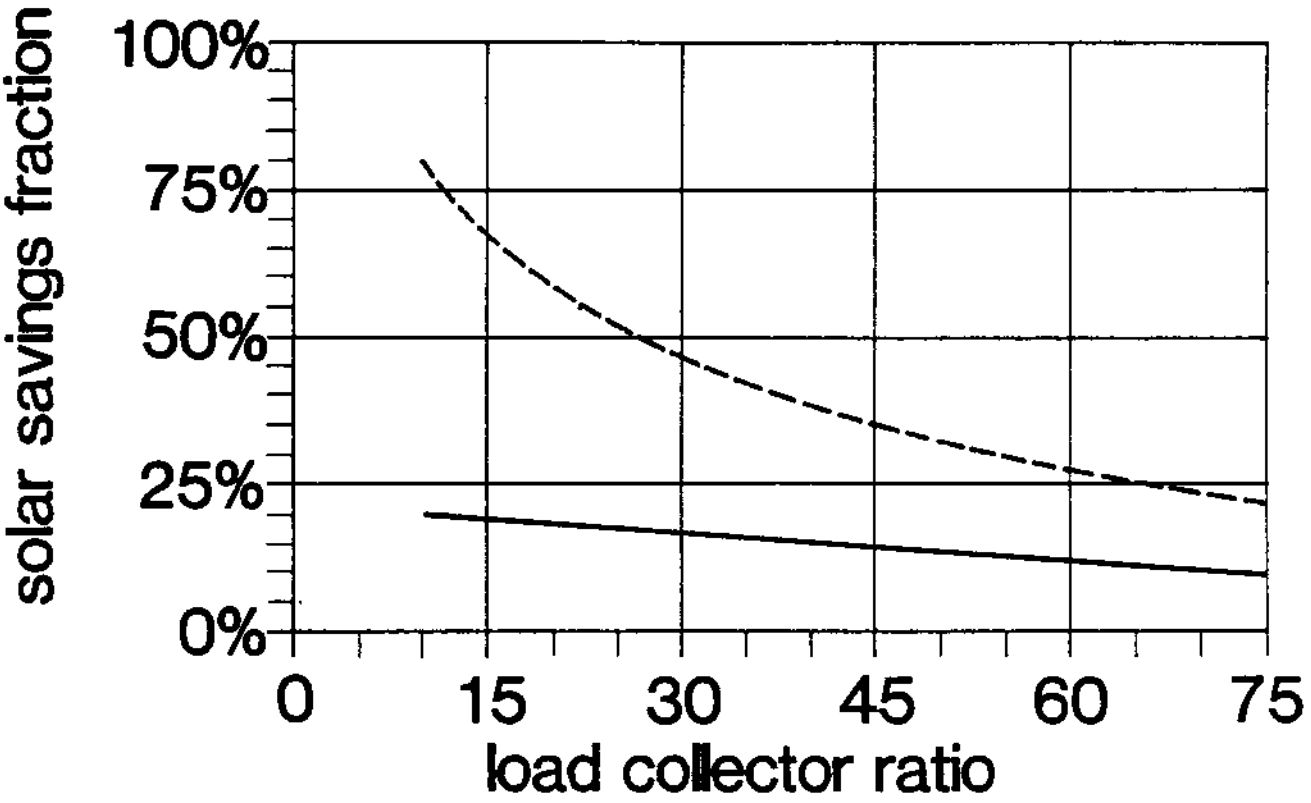
night insulation

no night insulation

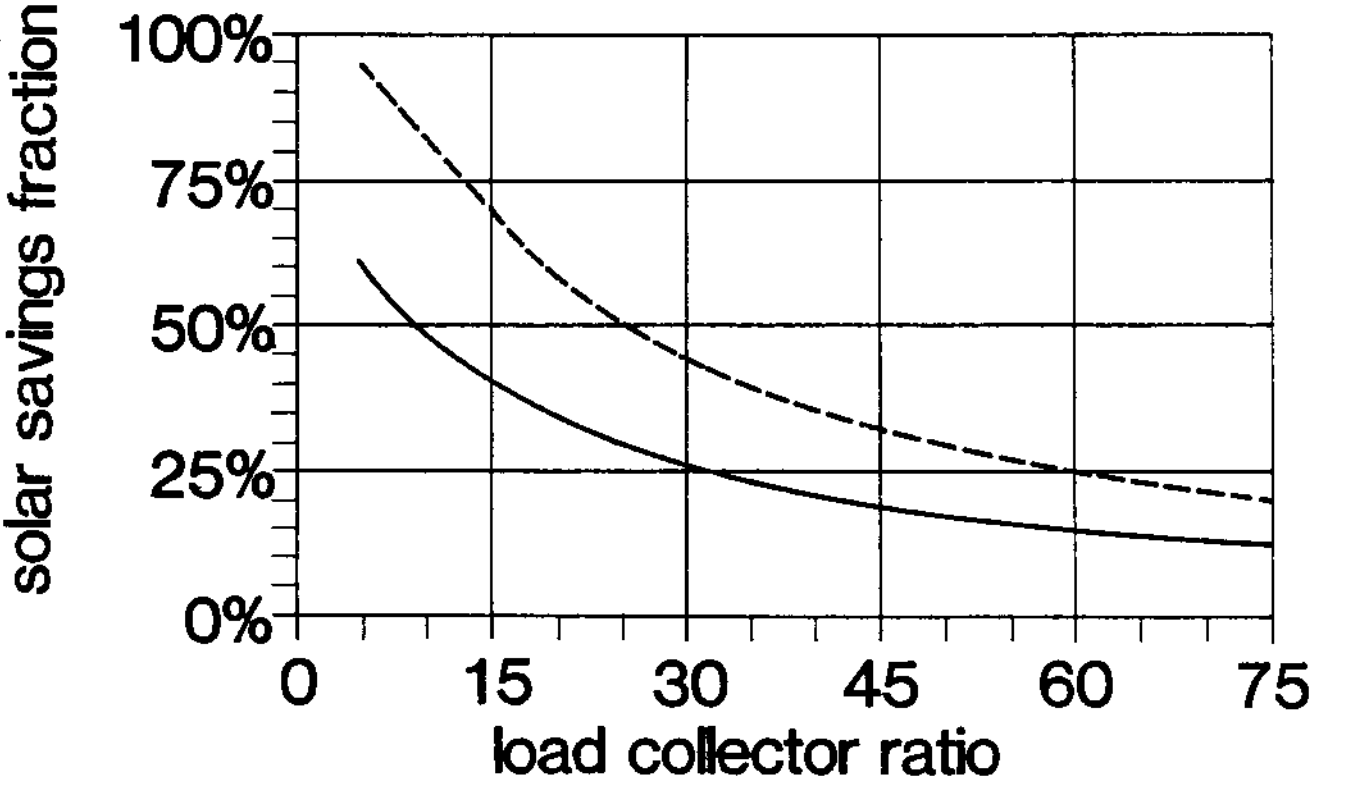


GREENHOUSE AREA 4

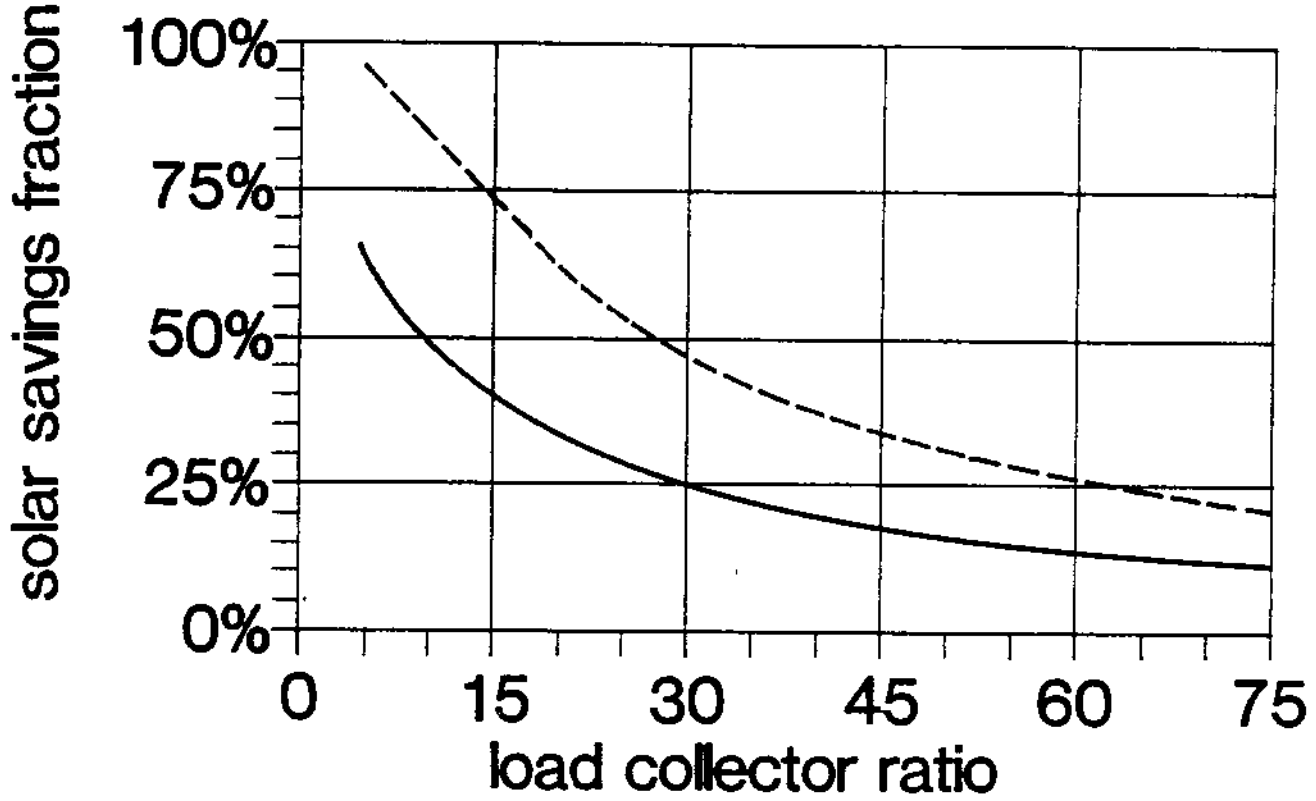
APPENDIX 2



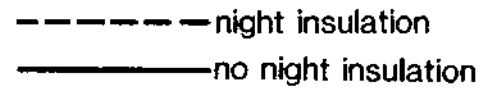
DIRECT GAIN AREA 5

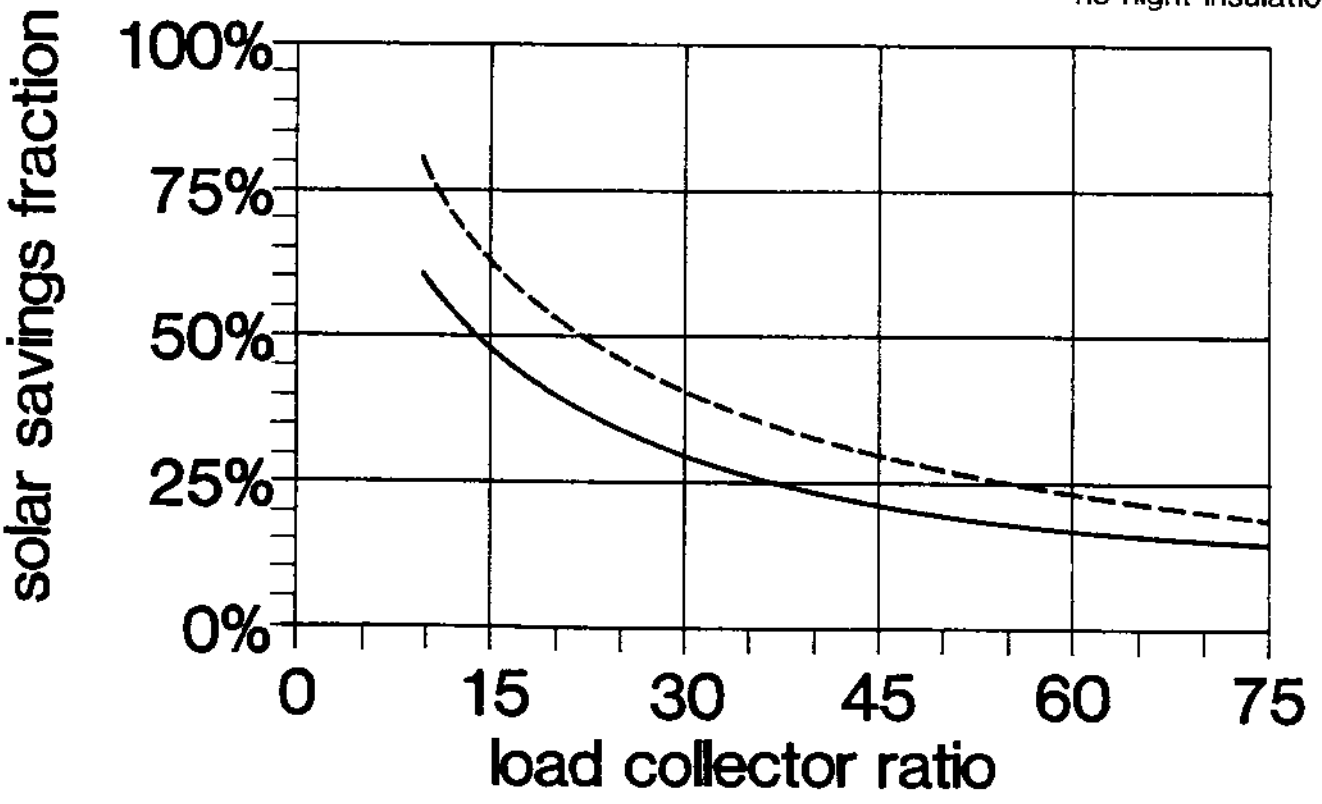


TROMBE WALL AREA 5



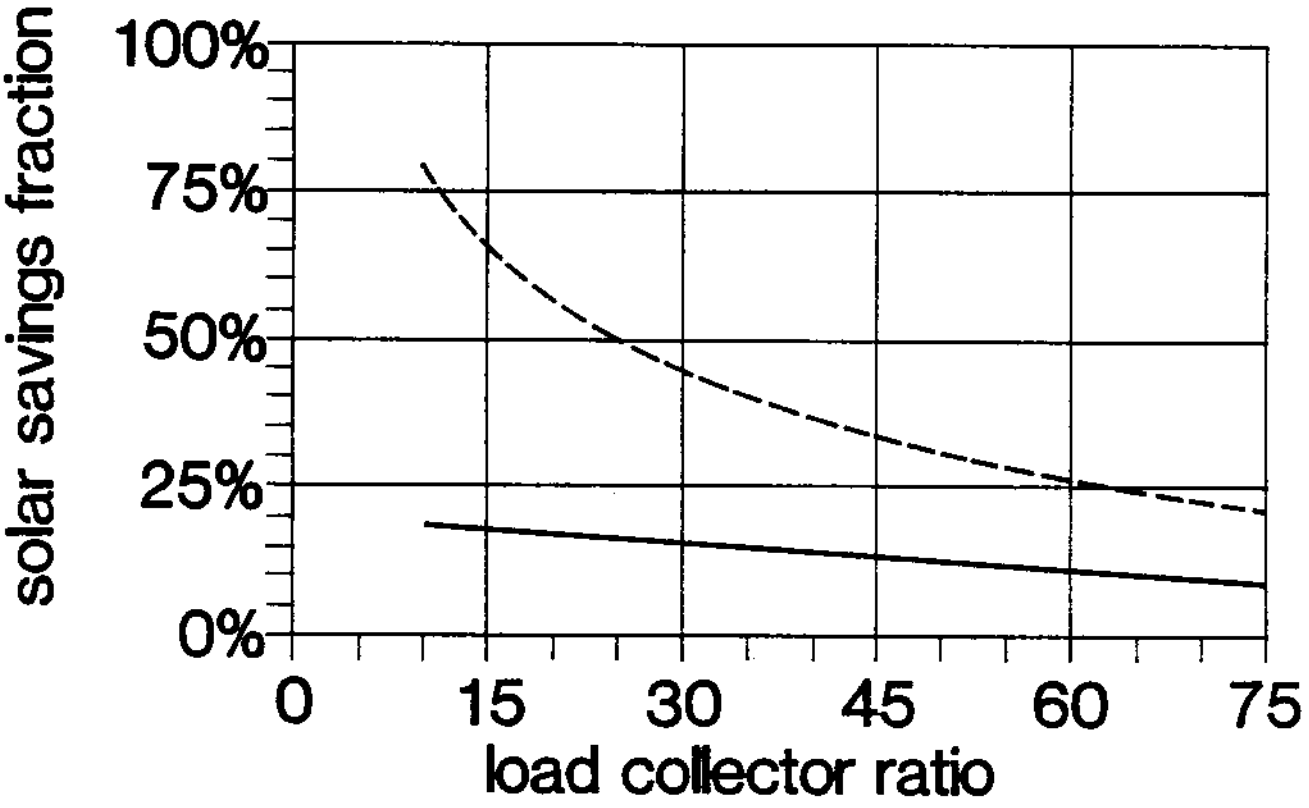
WATER WALL AREA 5



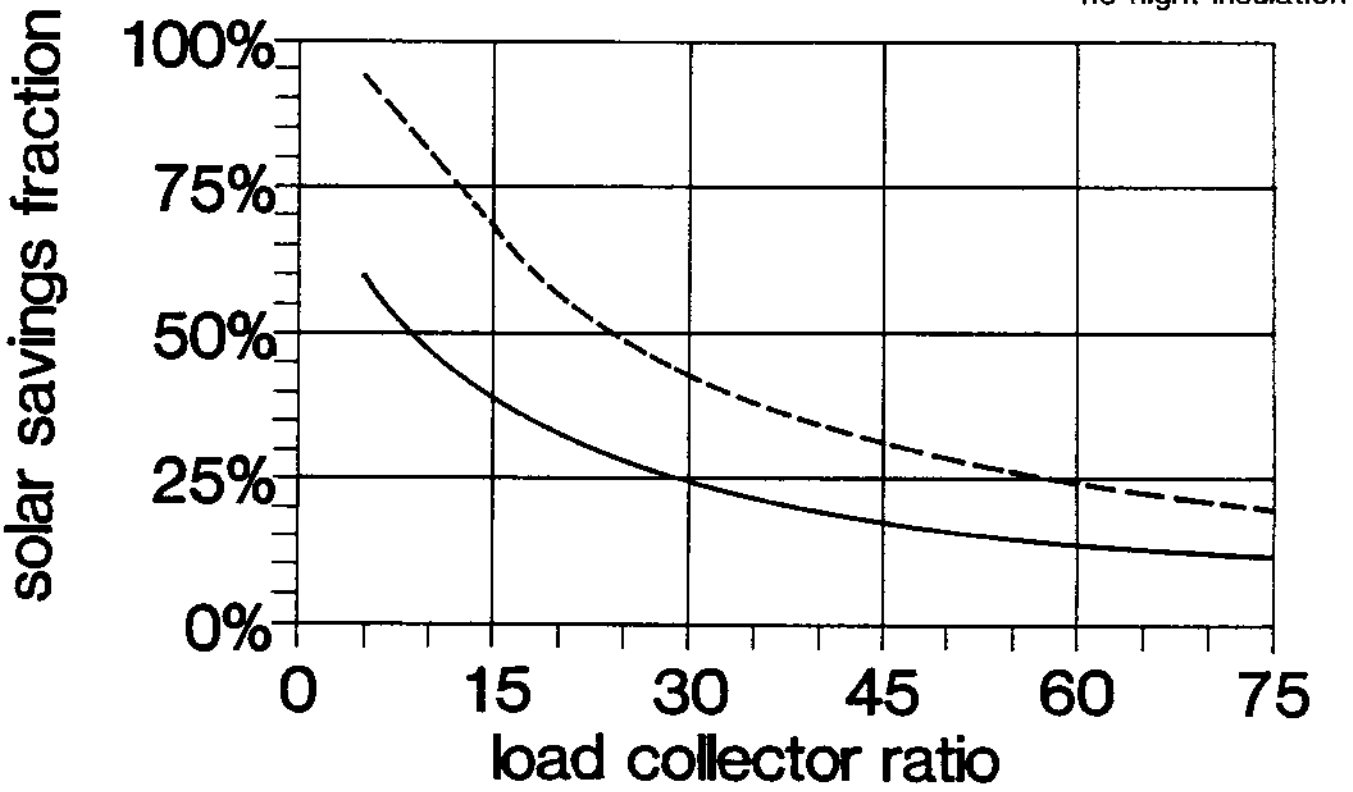


GREENHOUSE AREA 5

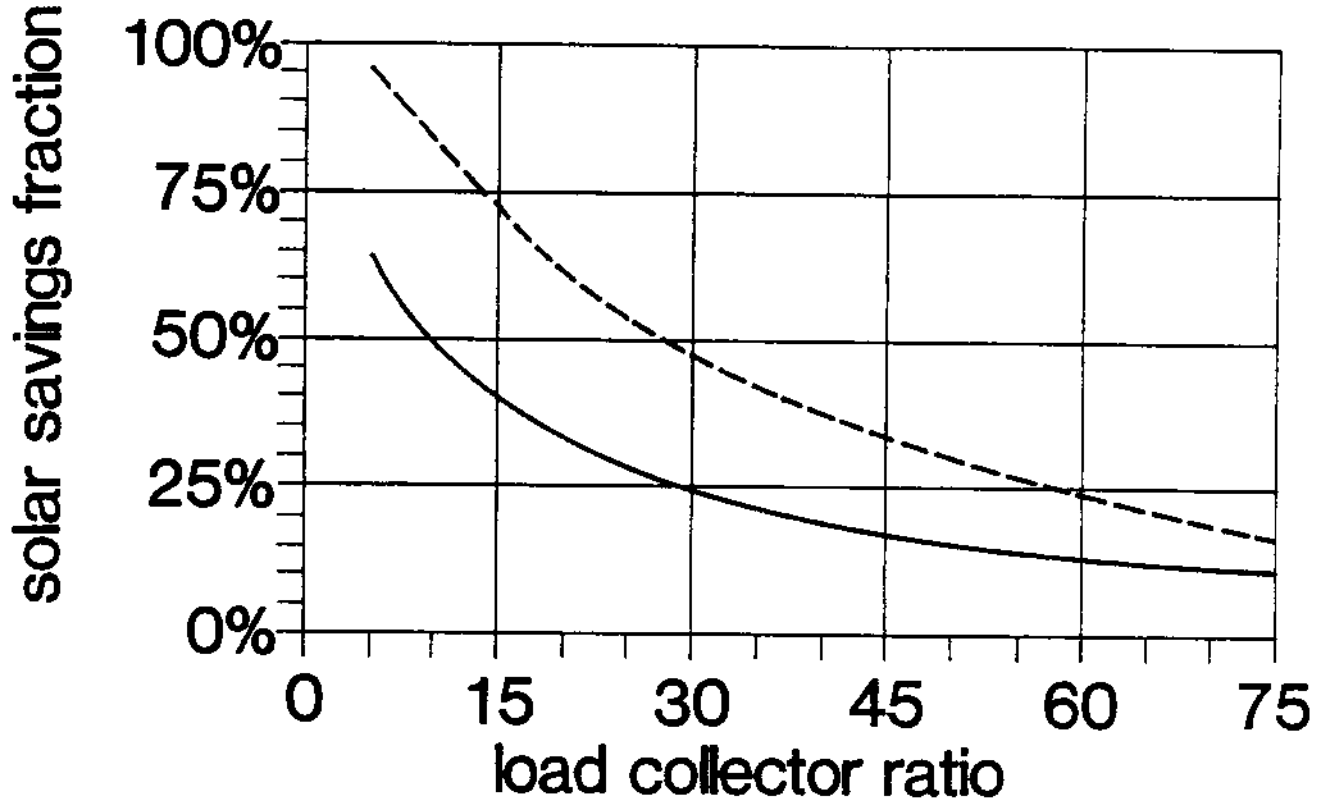
APPENDIX 2



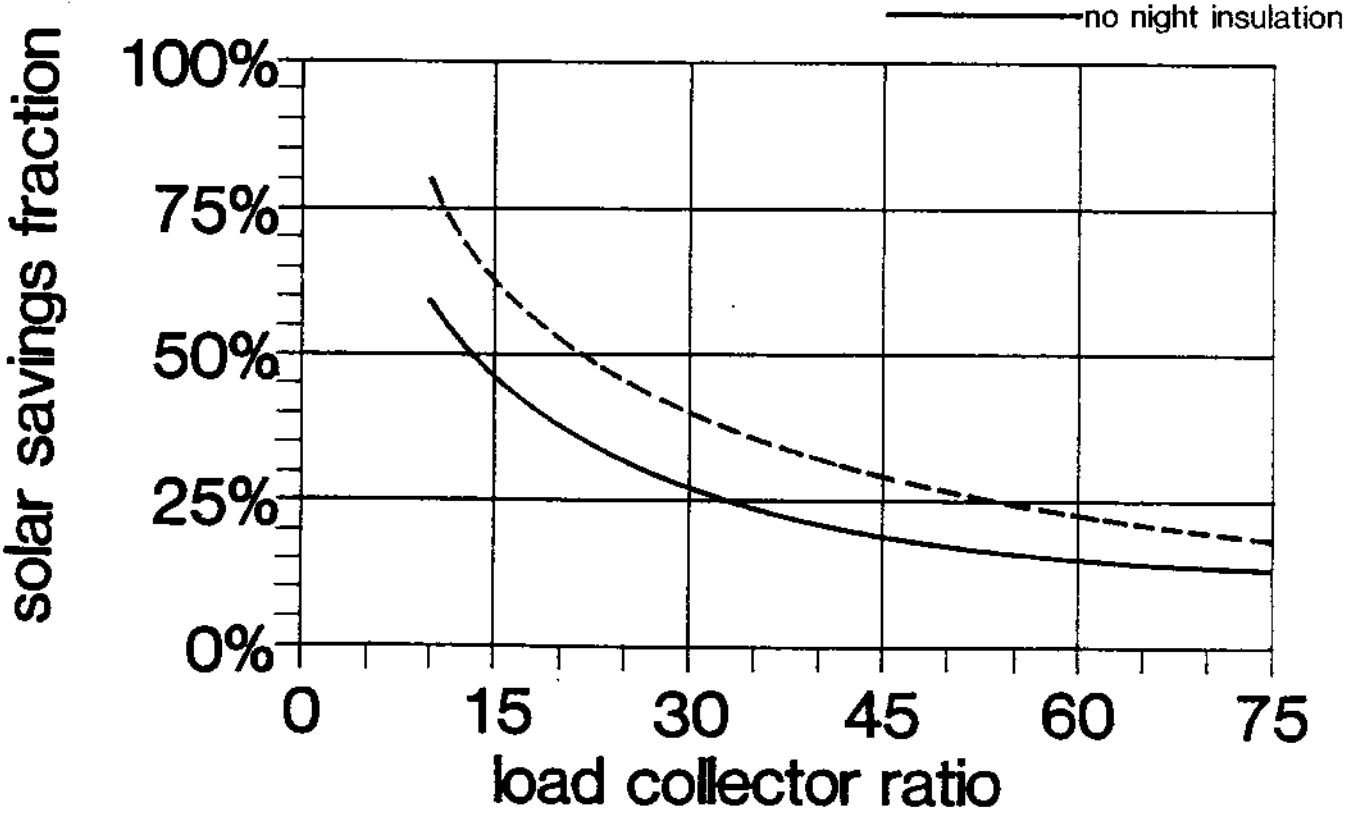
DIRECT GAIN AREA 6



TROMBE WALL AREA 6

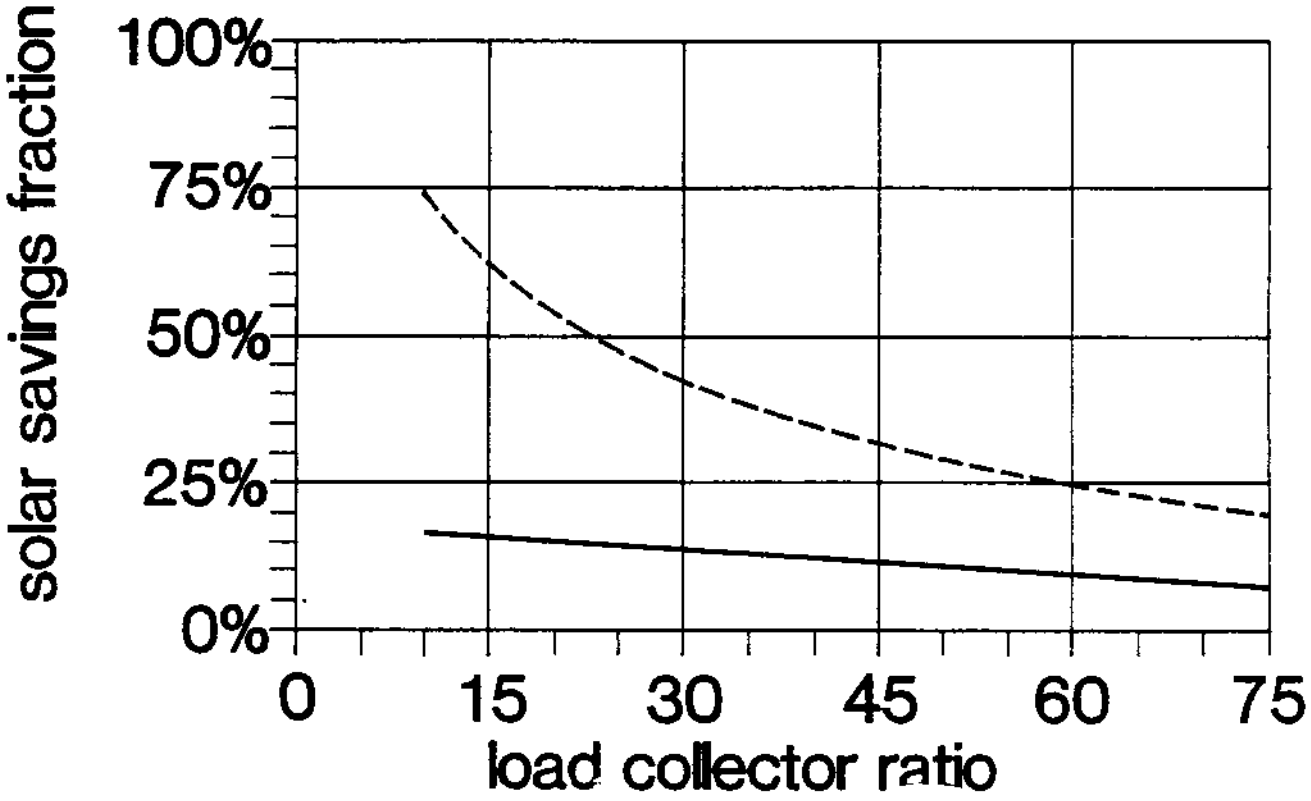


WATER WALL AREA 6

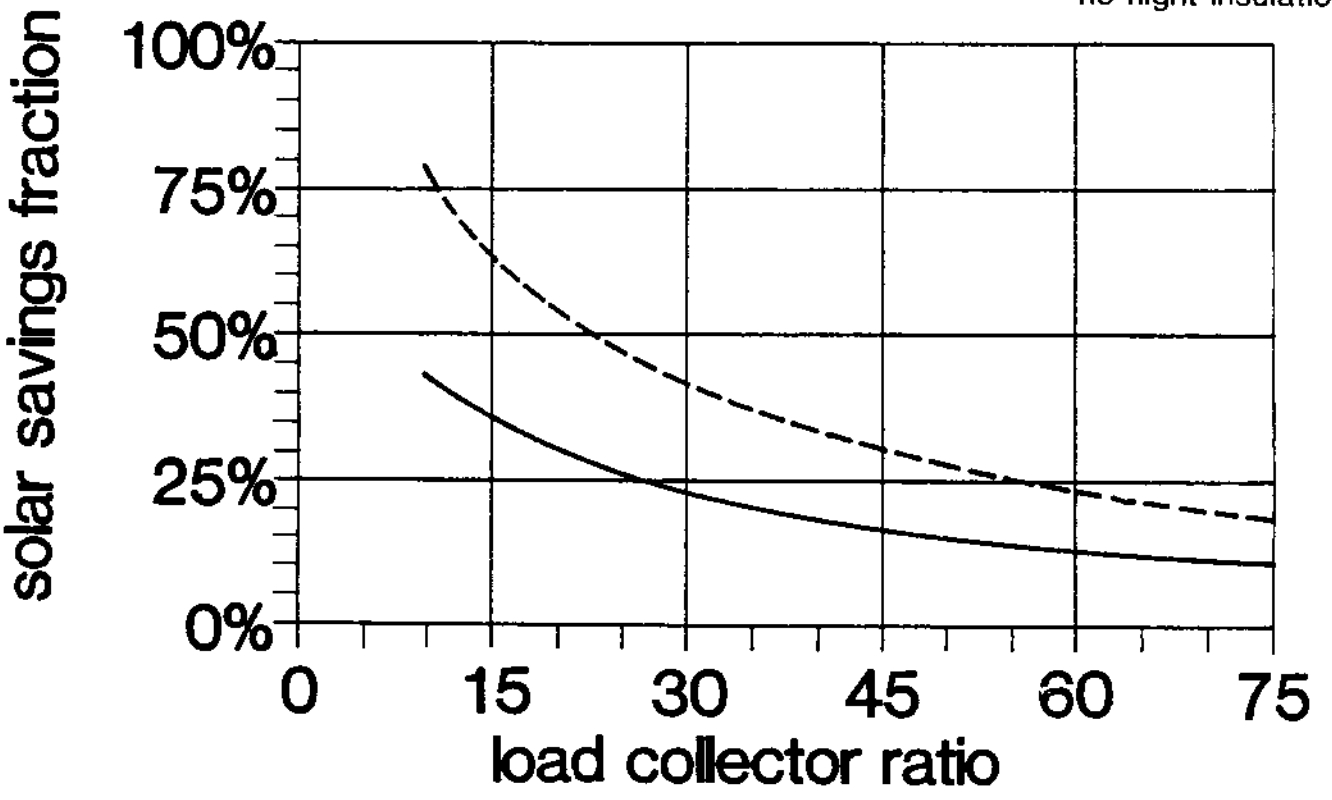


GREENHOUSE AREA 6

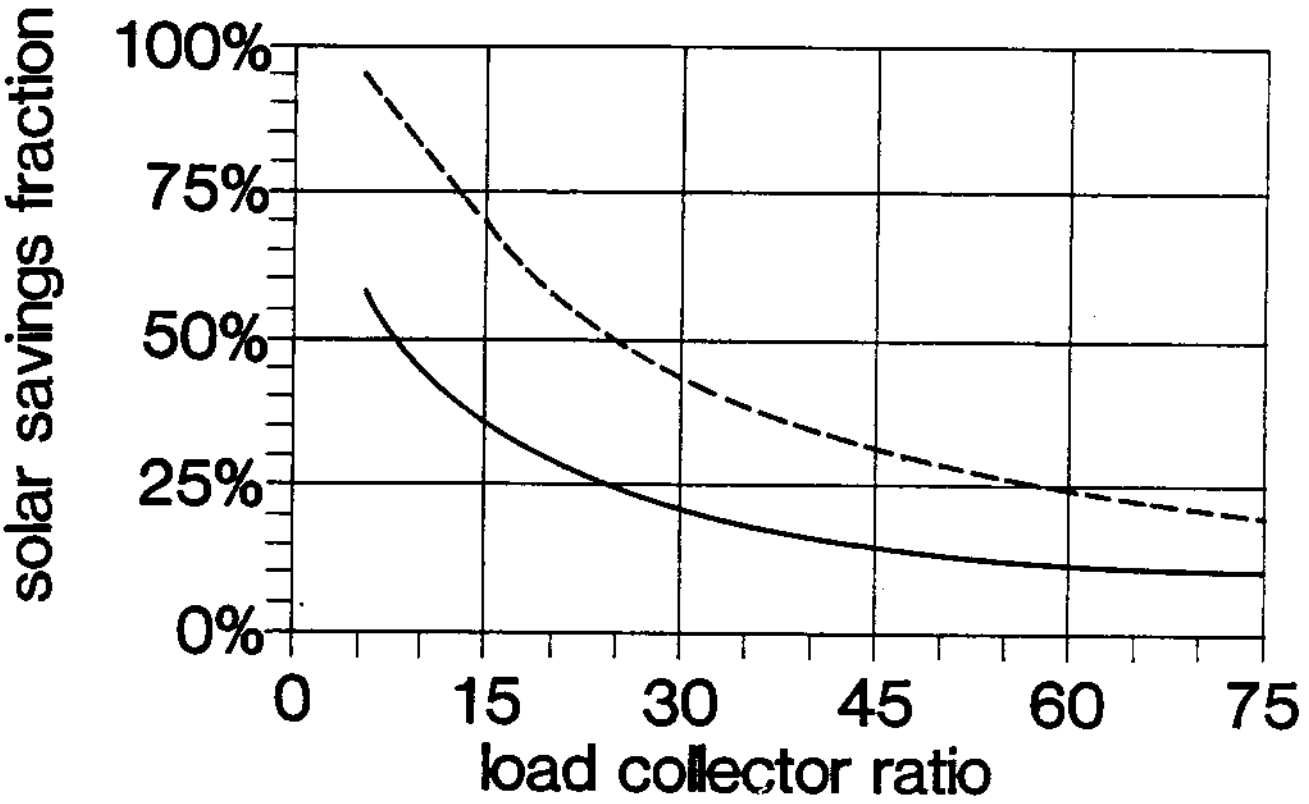
APPENDIX 2



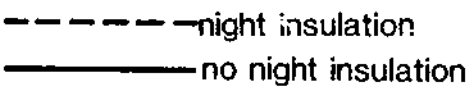
DIRECT GAIN AREA 7

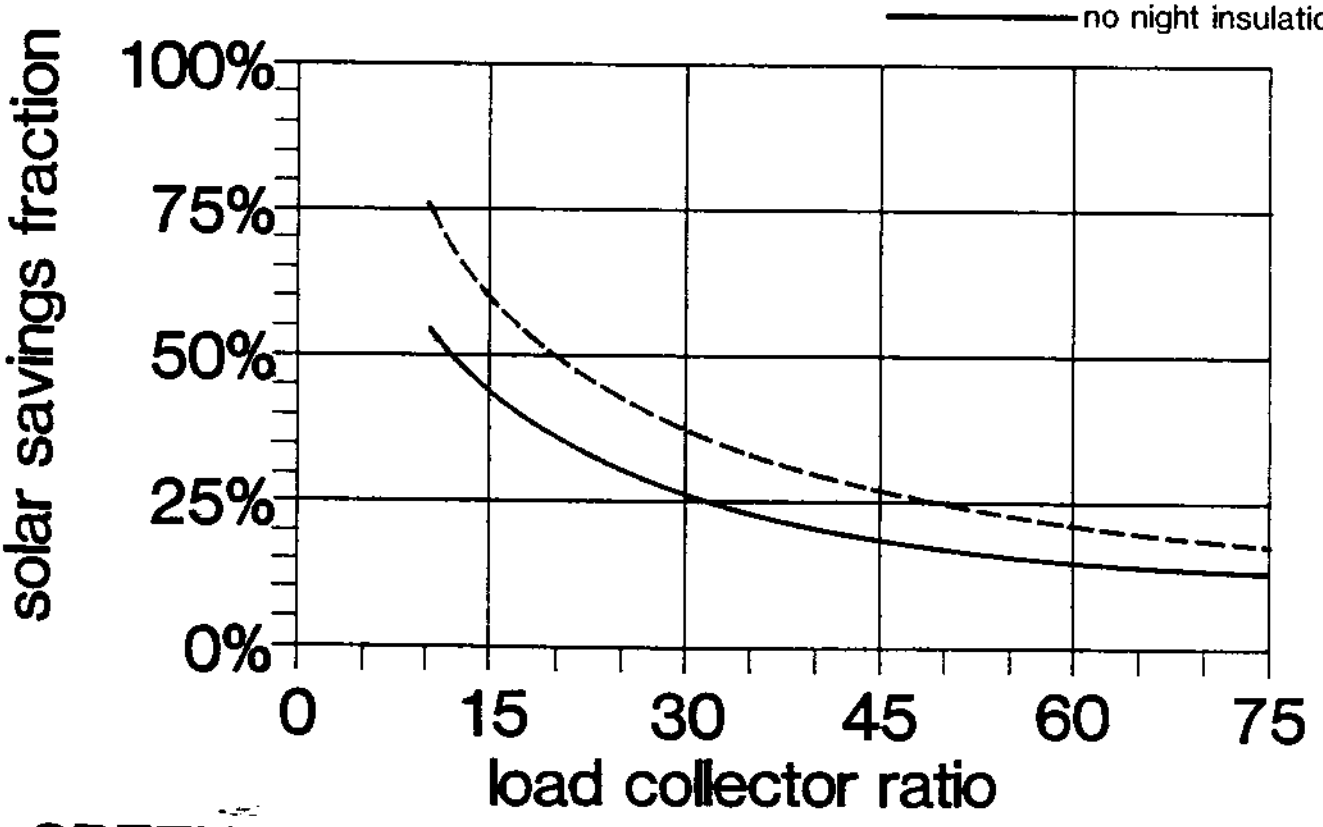


TROMBE WALL AREA 7



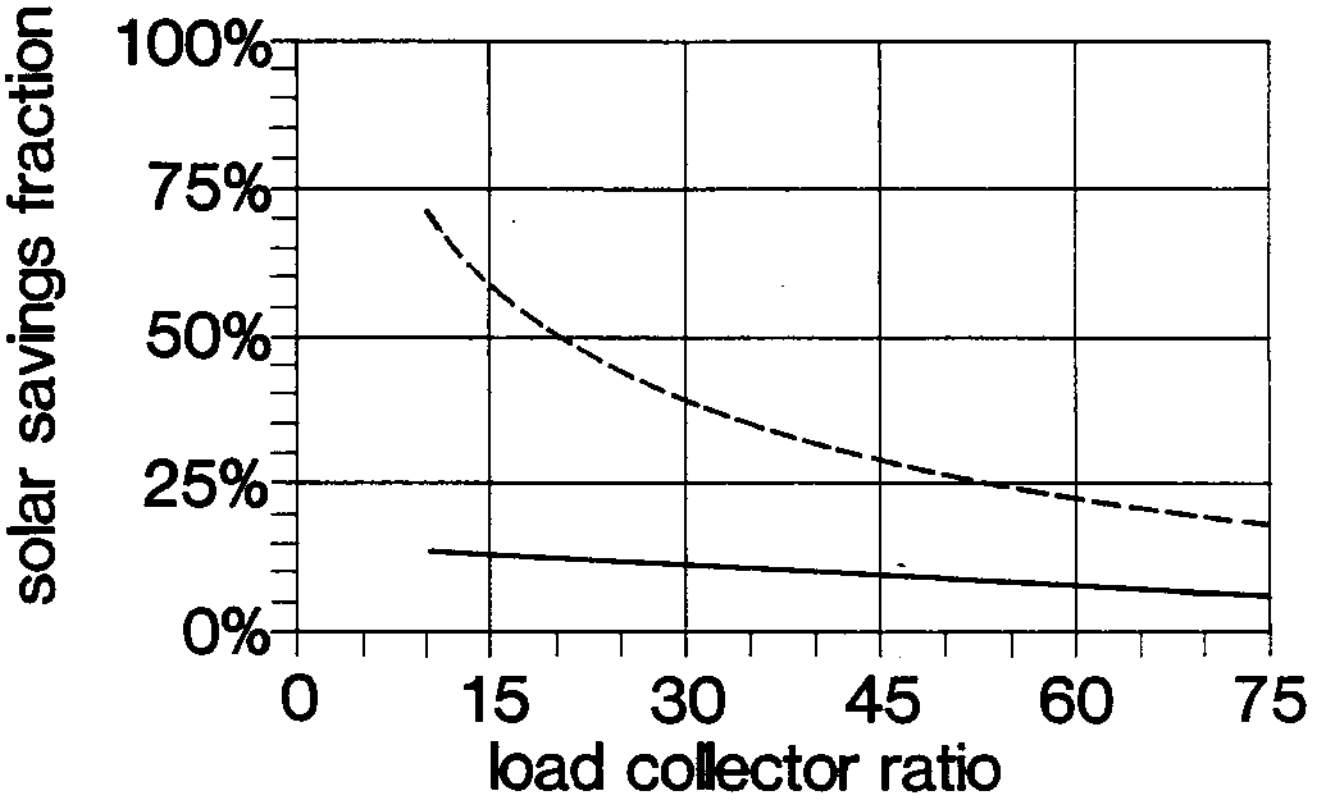
WATER WALL AREA 7



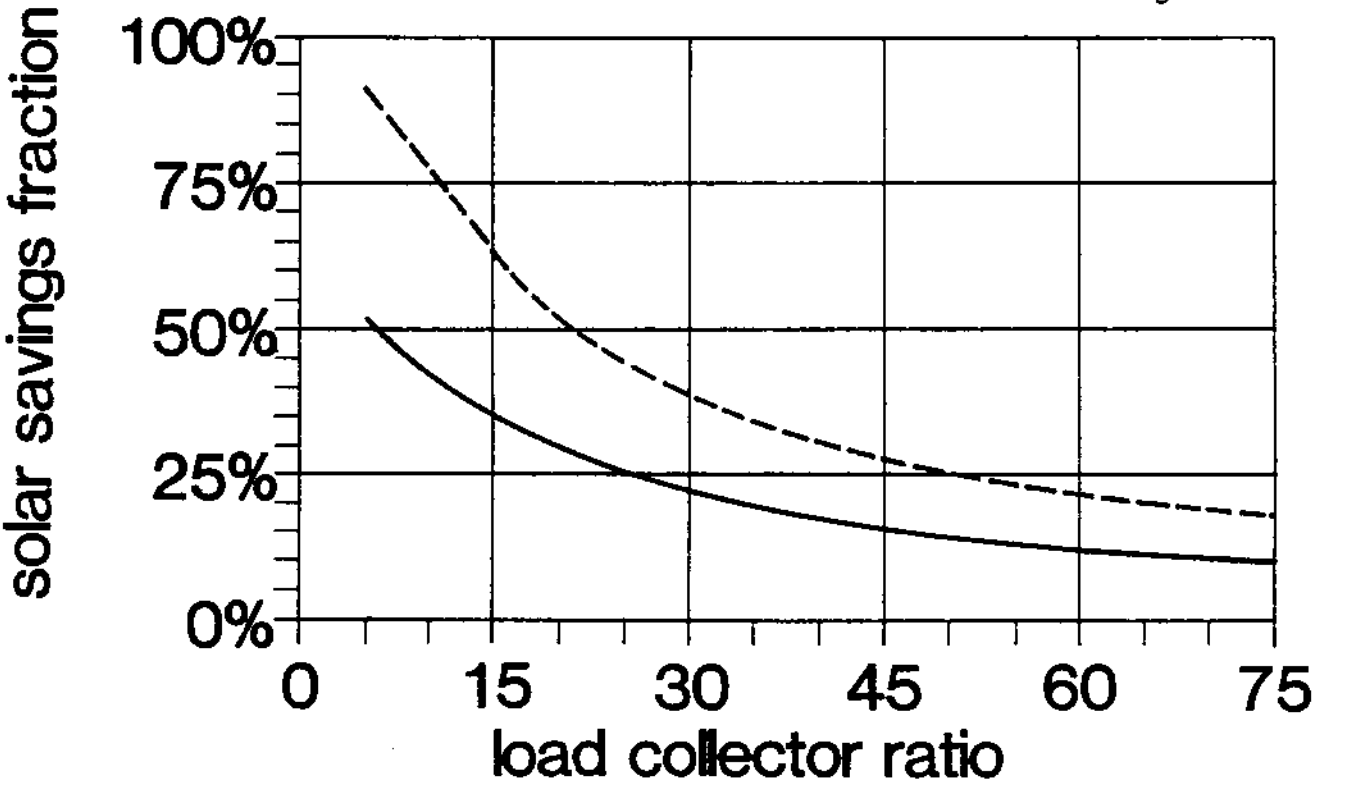


GREENHOUSE AREA 7

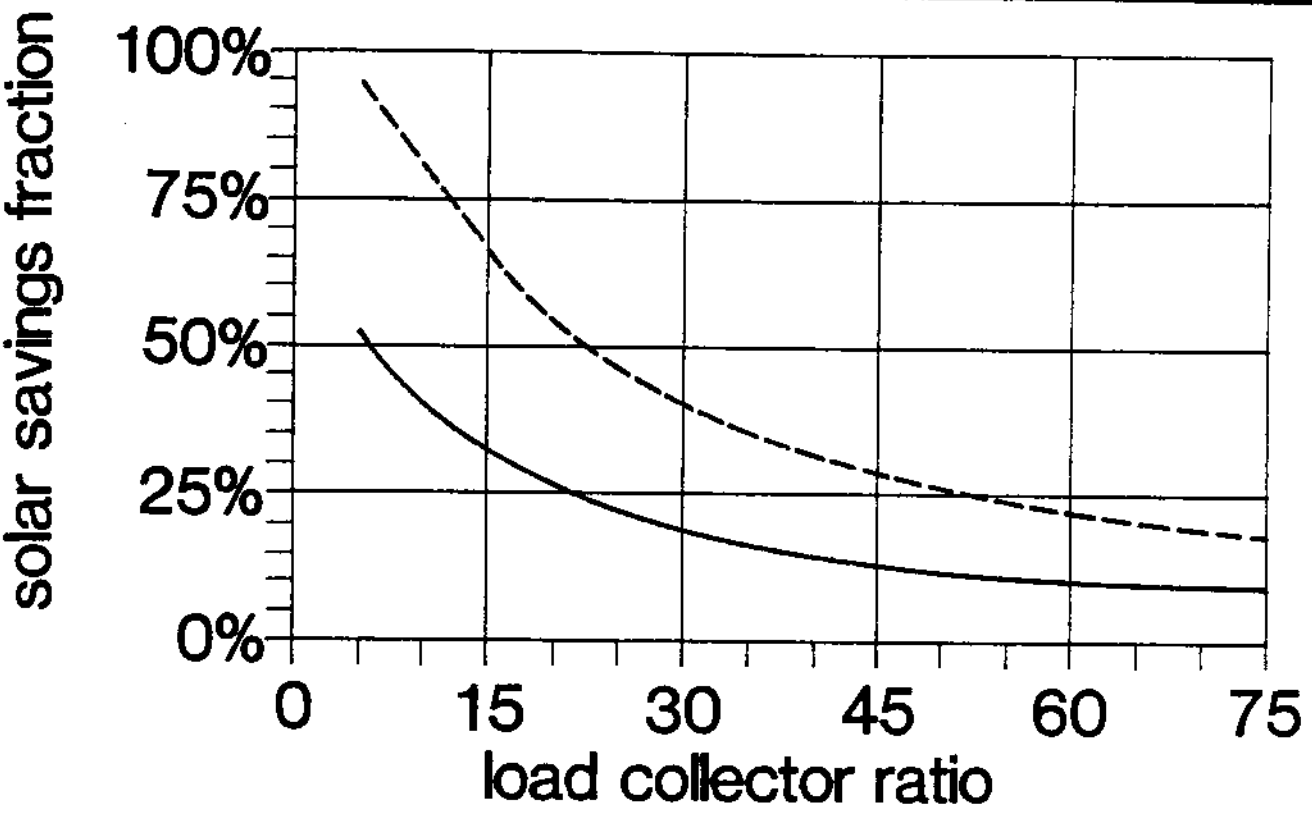
APPENDIX 2



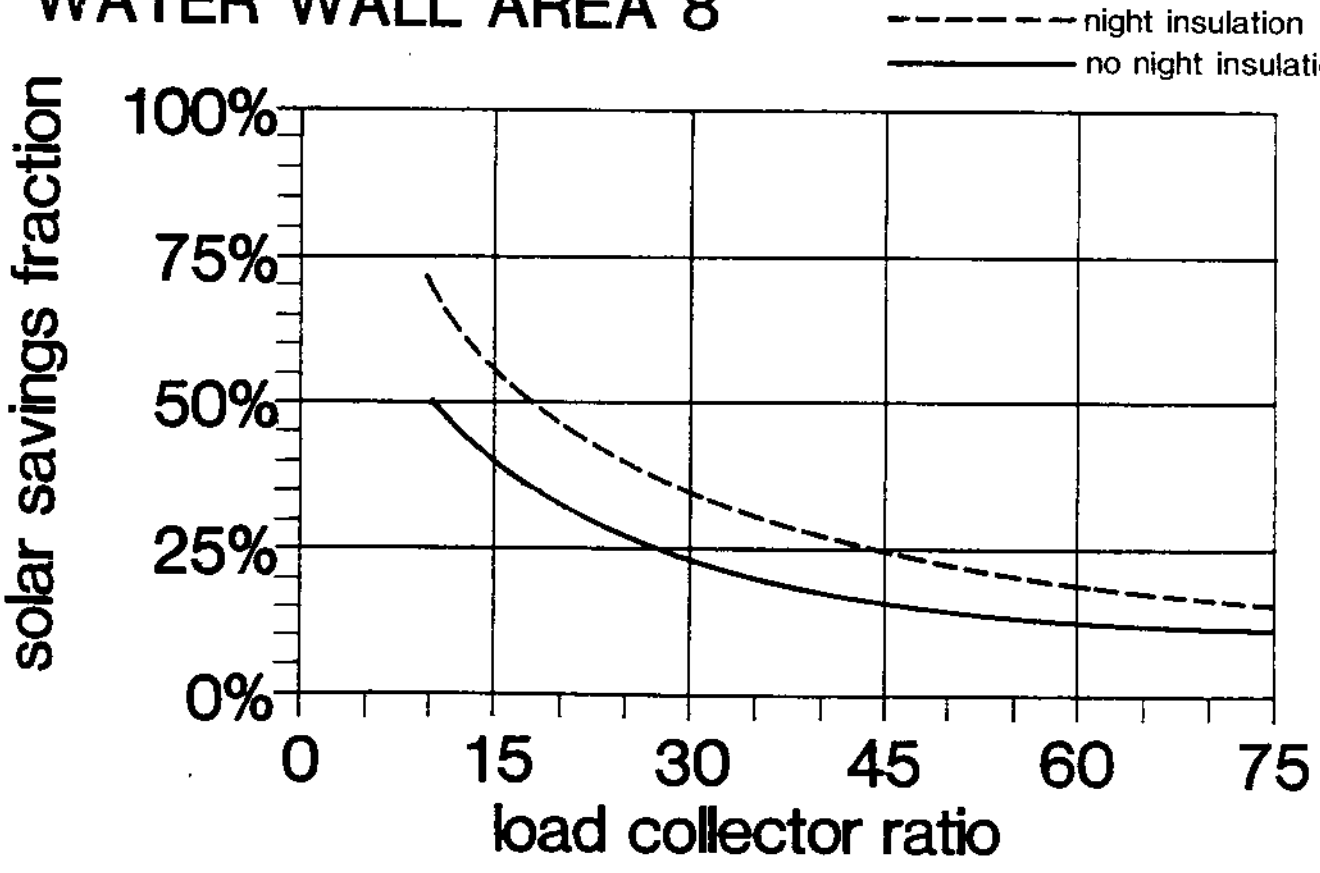
DIRECT GAIN AREA 8



TROMBE WALL AREA 8

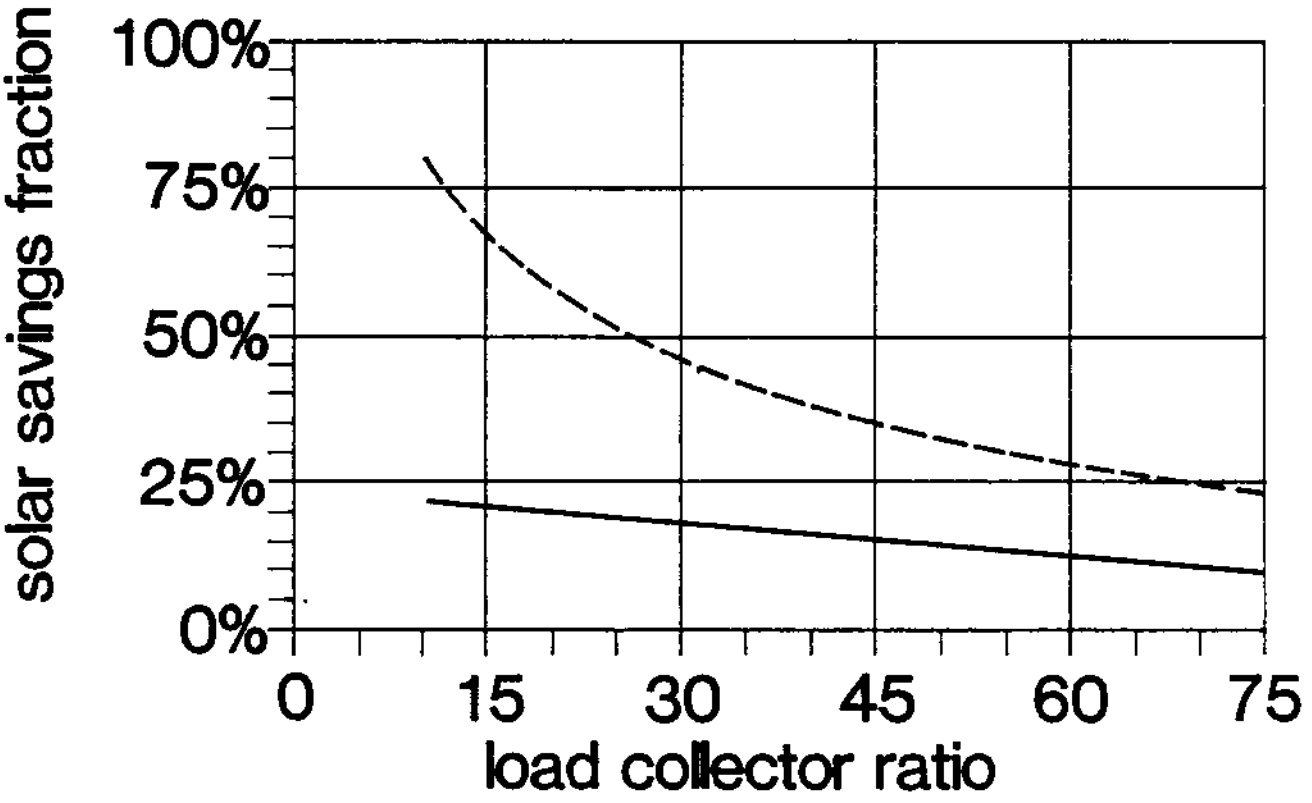


WATER WALL AREA 8

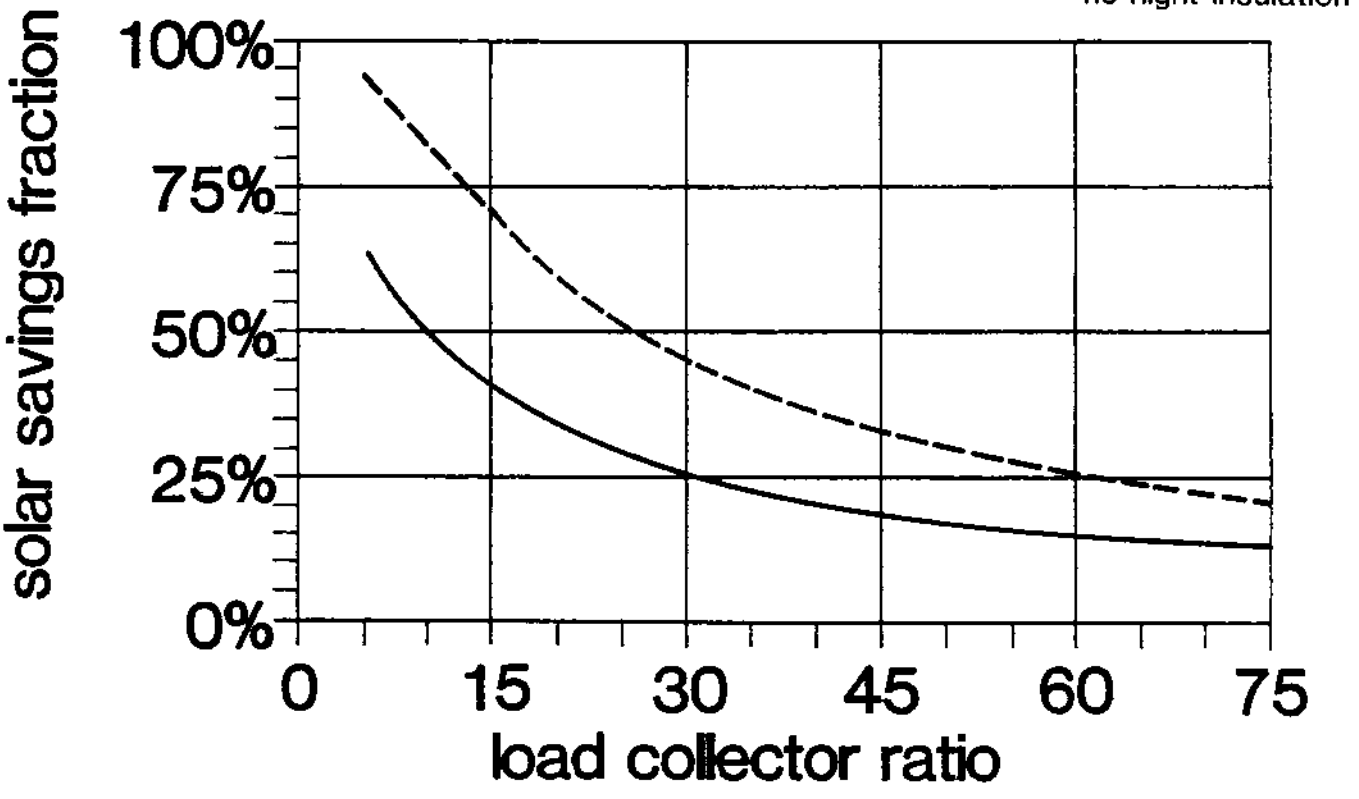


GREENHOUSE AREA 8

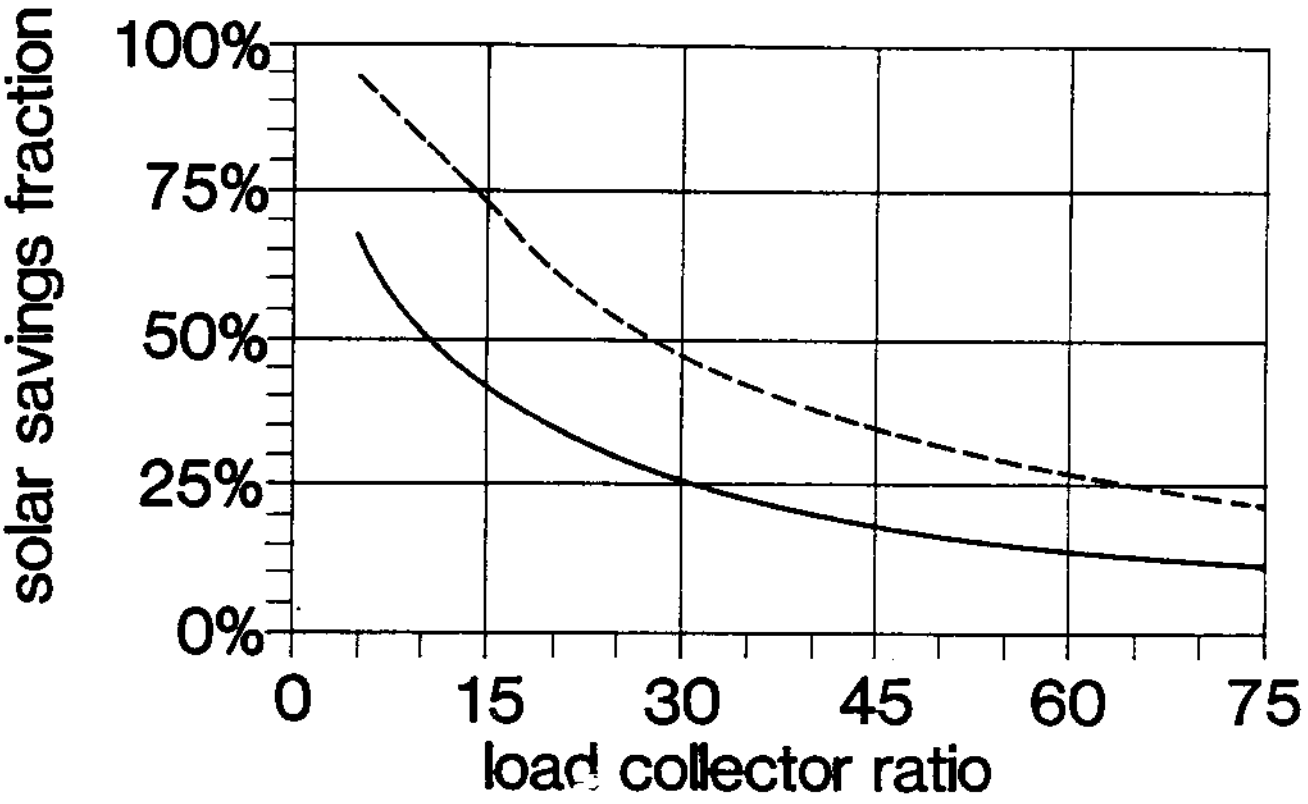
APPENDIX 2



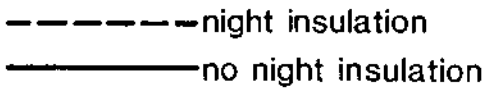
DIRECT GAIN AREA 9

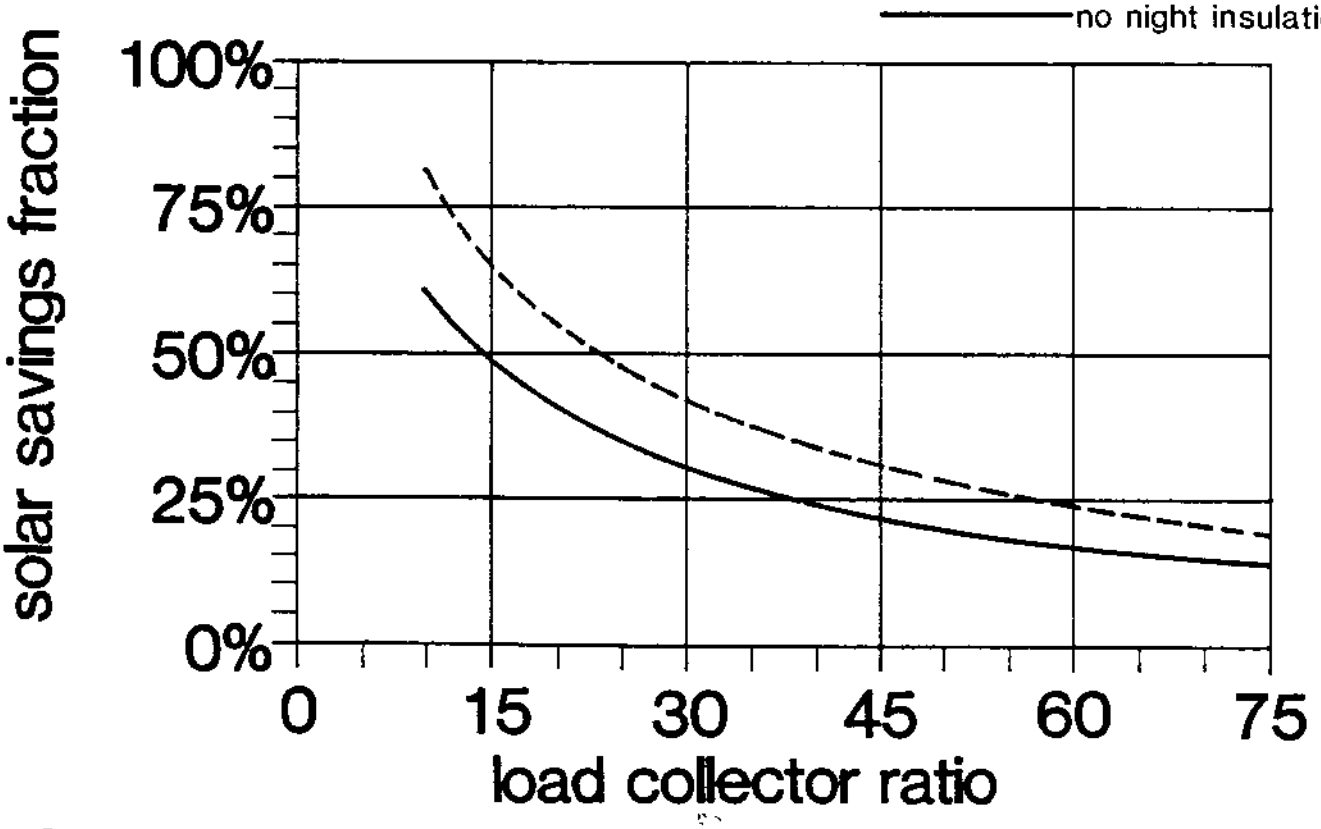


TROMBE WALL AREA 9



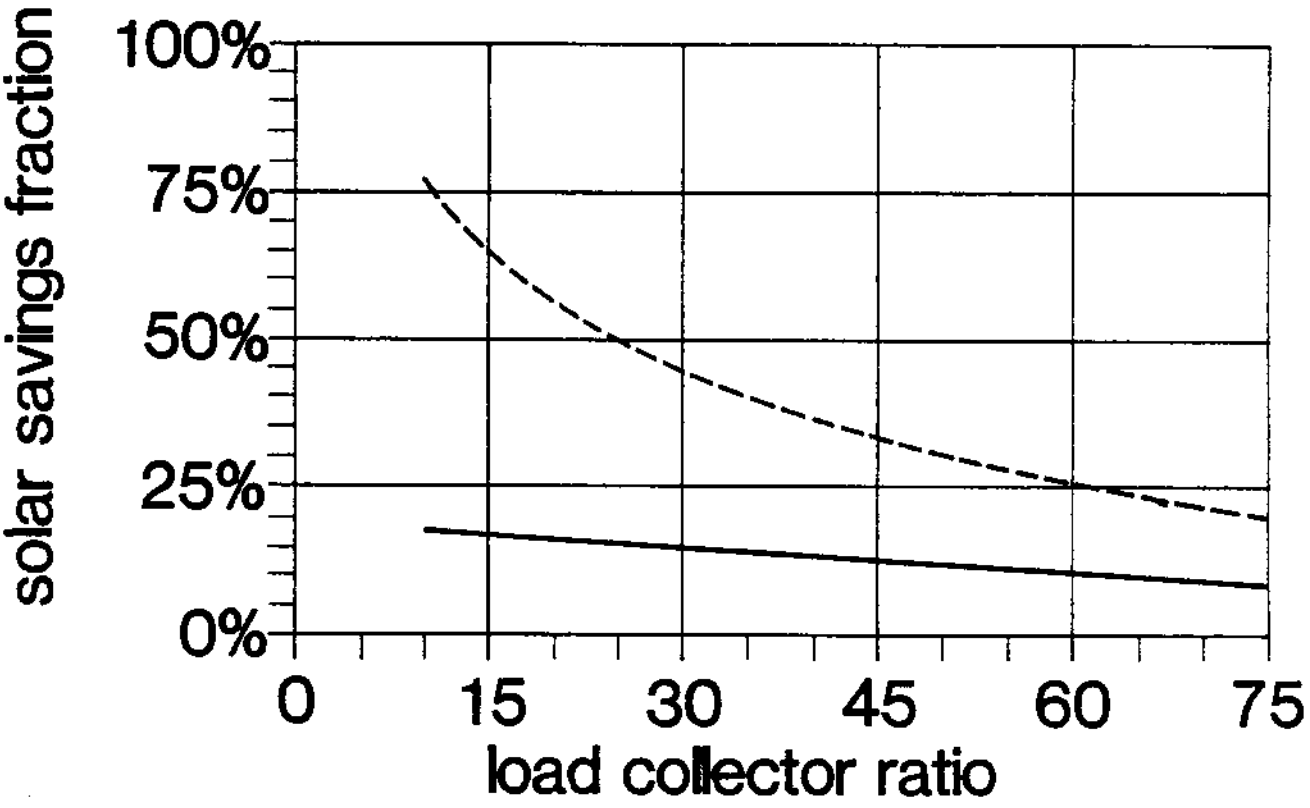
WATER WALL AREA 9



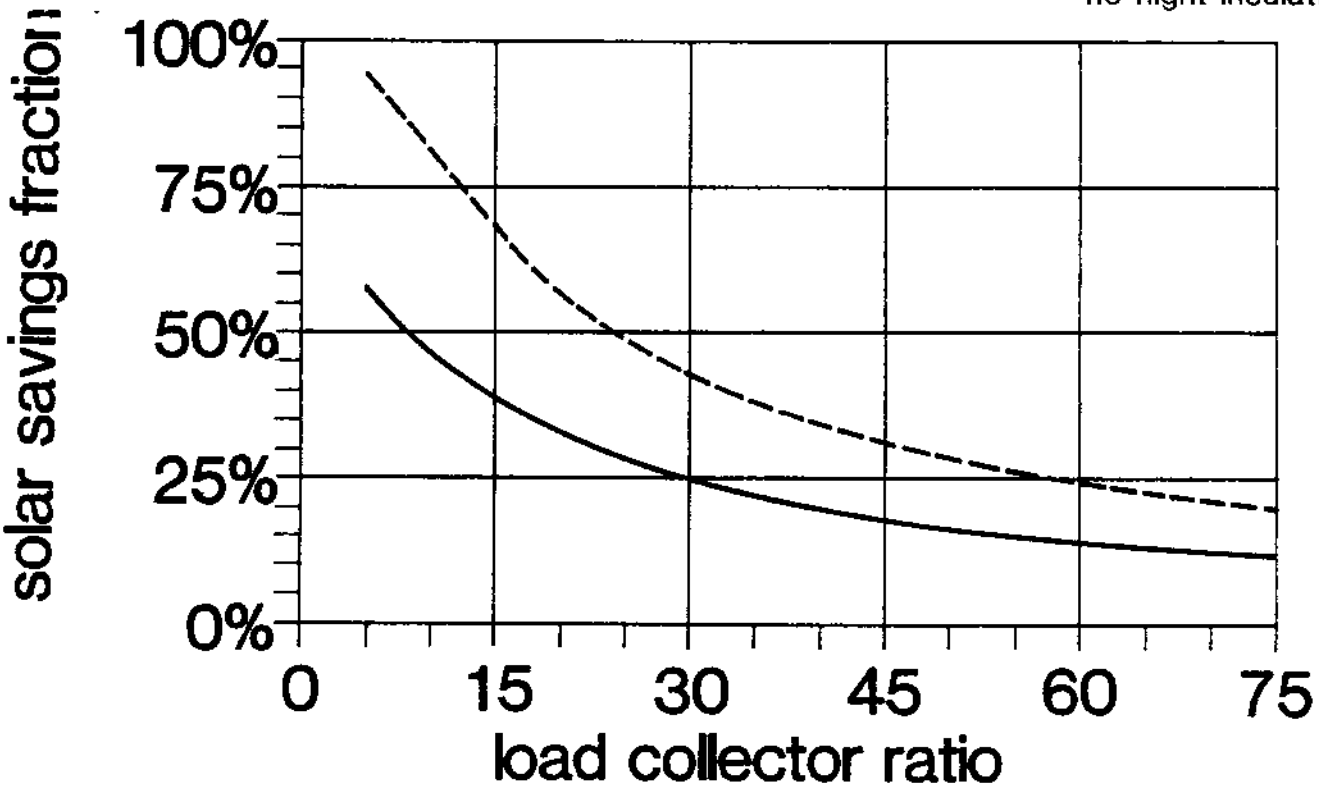


GREENHOUSE AREA 9

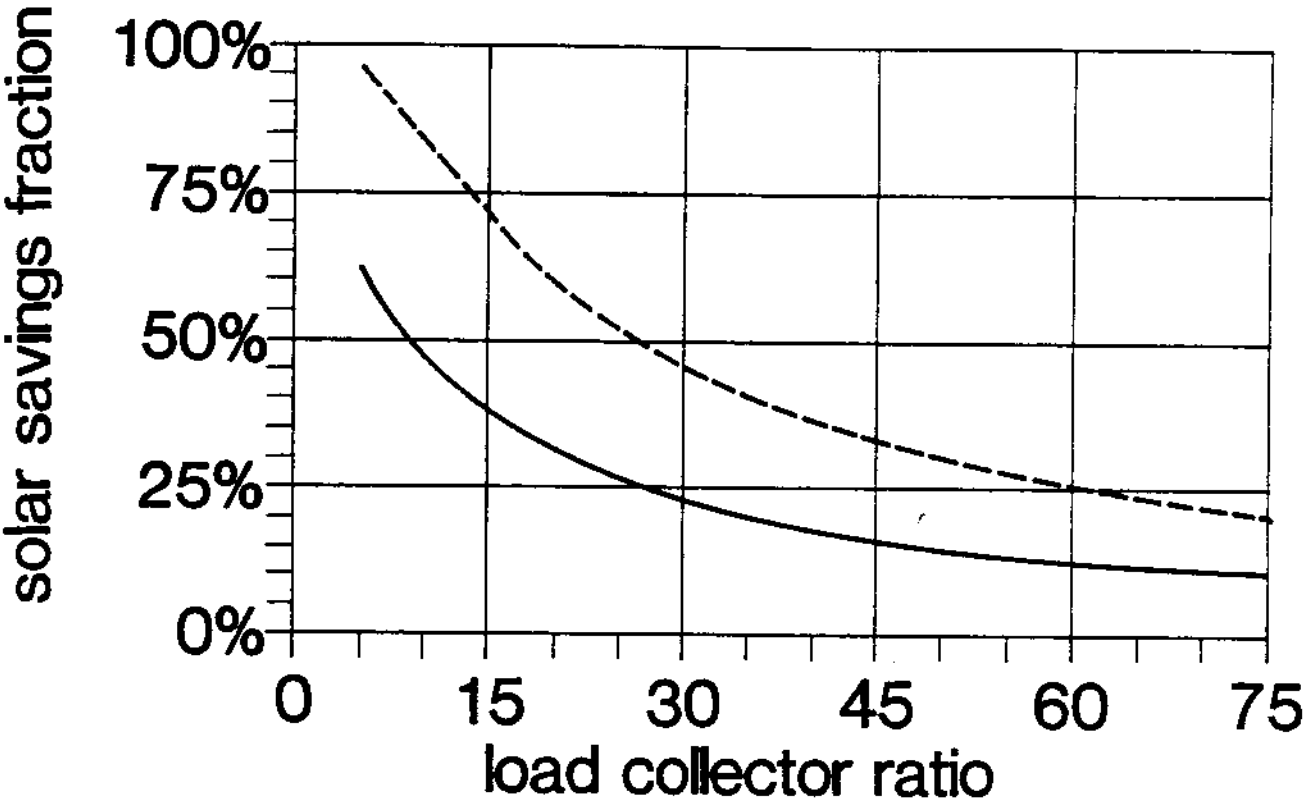
APPENDIX 2



DIRECT GAIN AREA 10



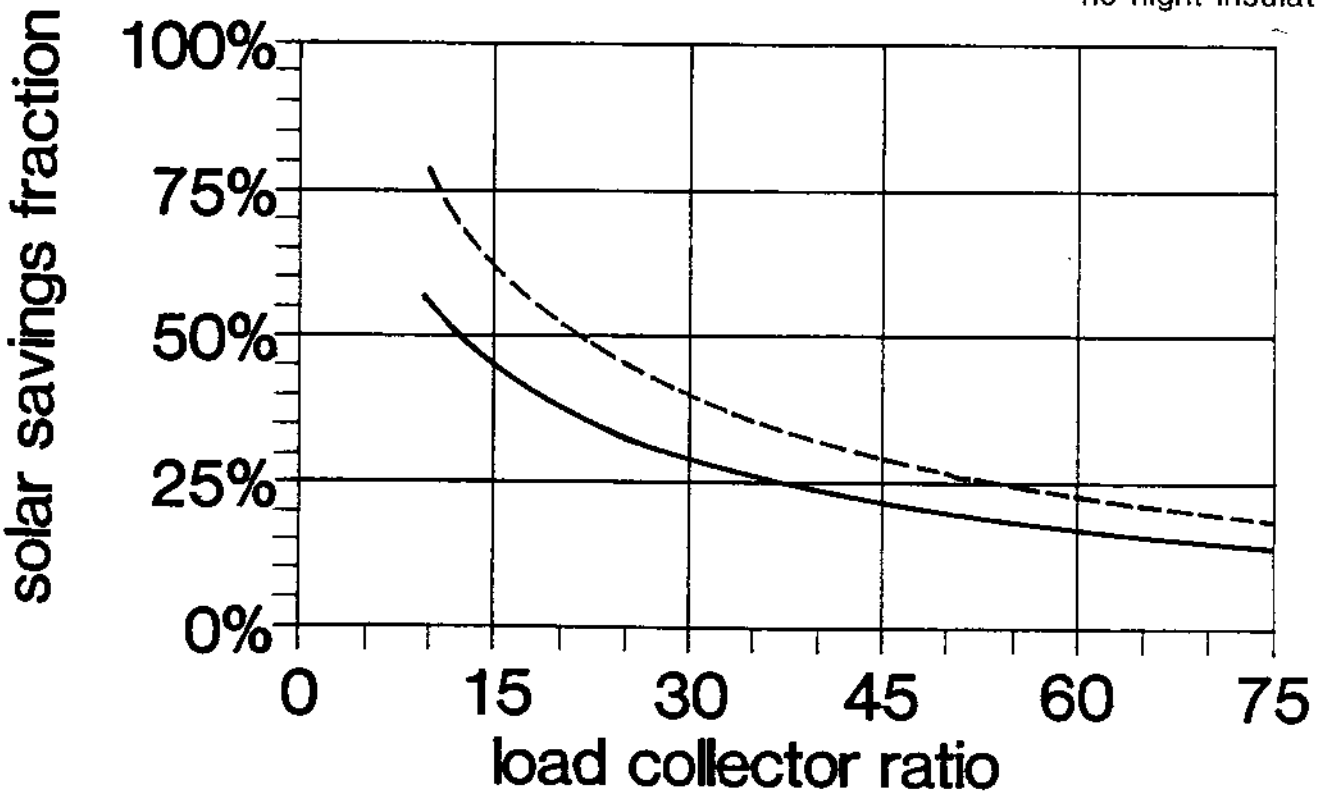
TROMBE WALL AREA 10



WATER WALL AREA 10

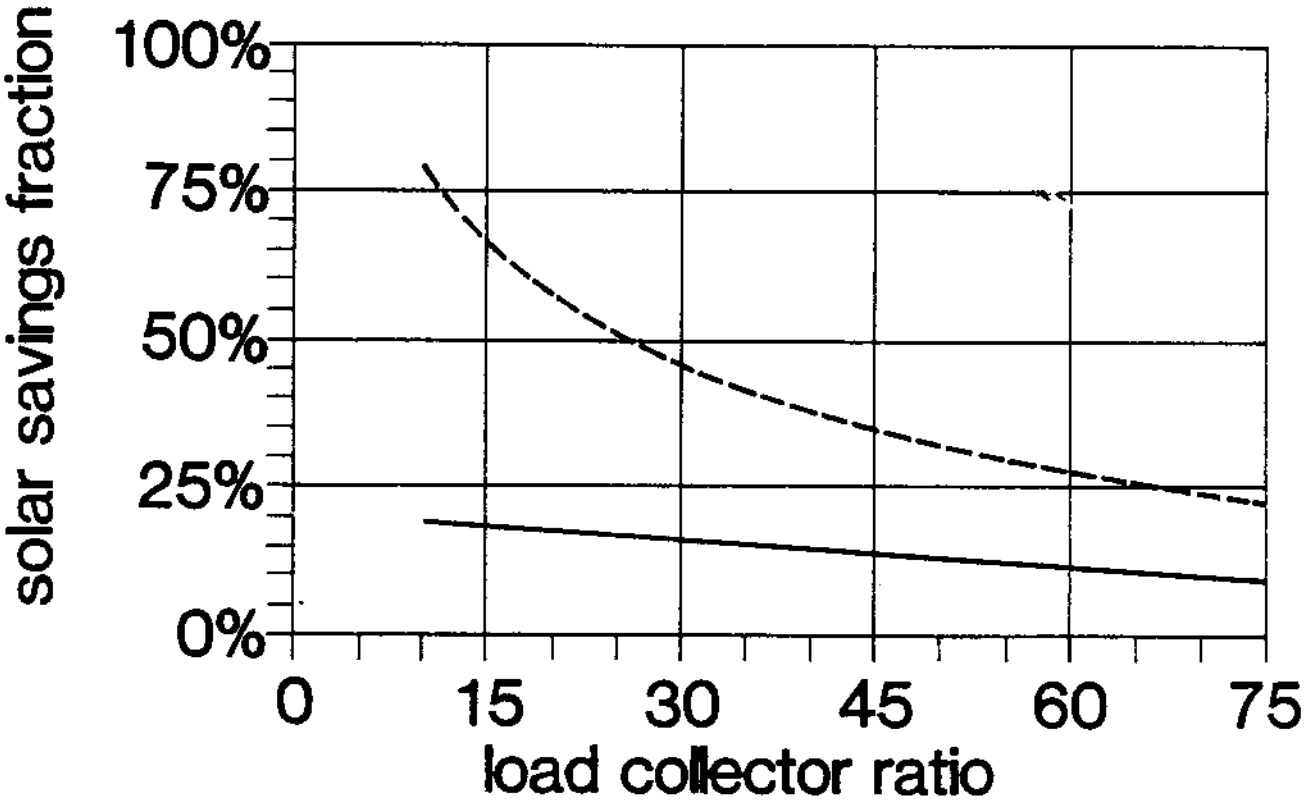
---------night insulation

———————no night insulation

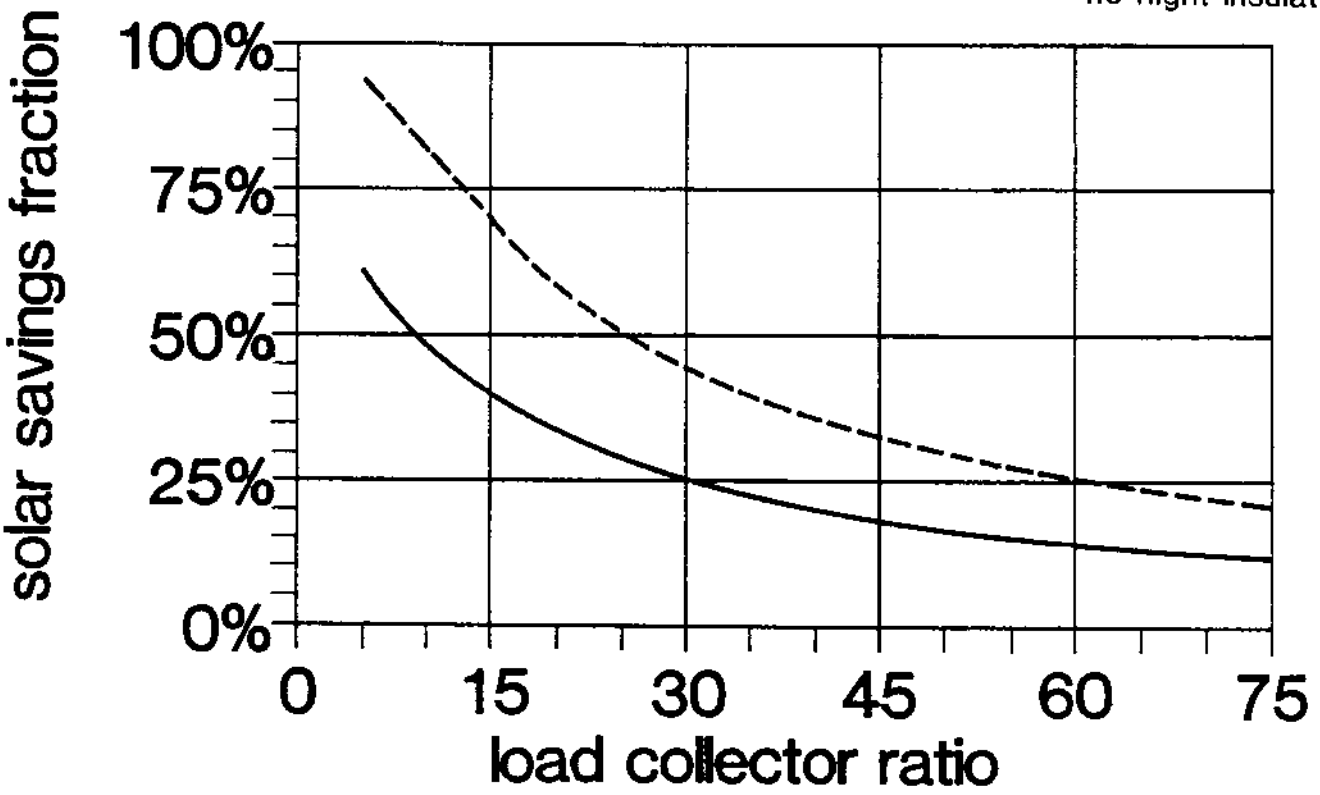


GREENHOUSE AREA 10

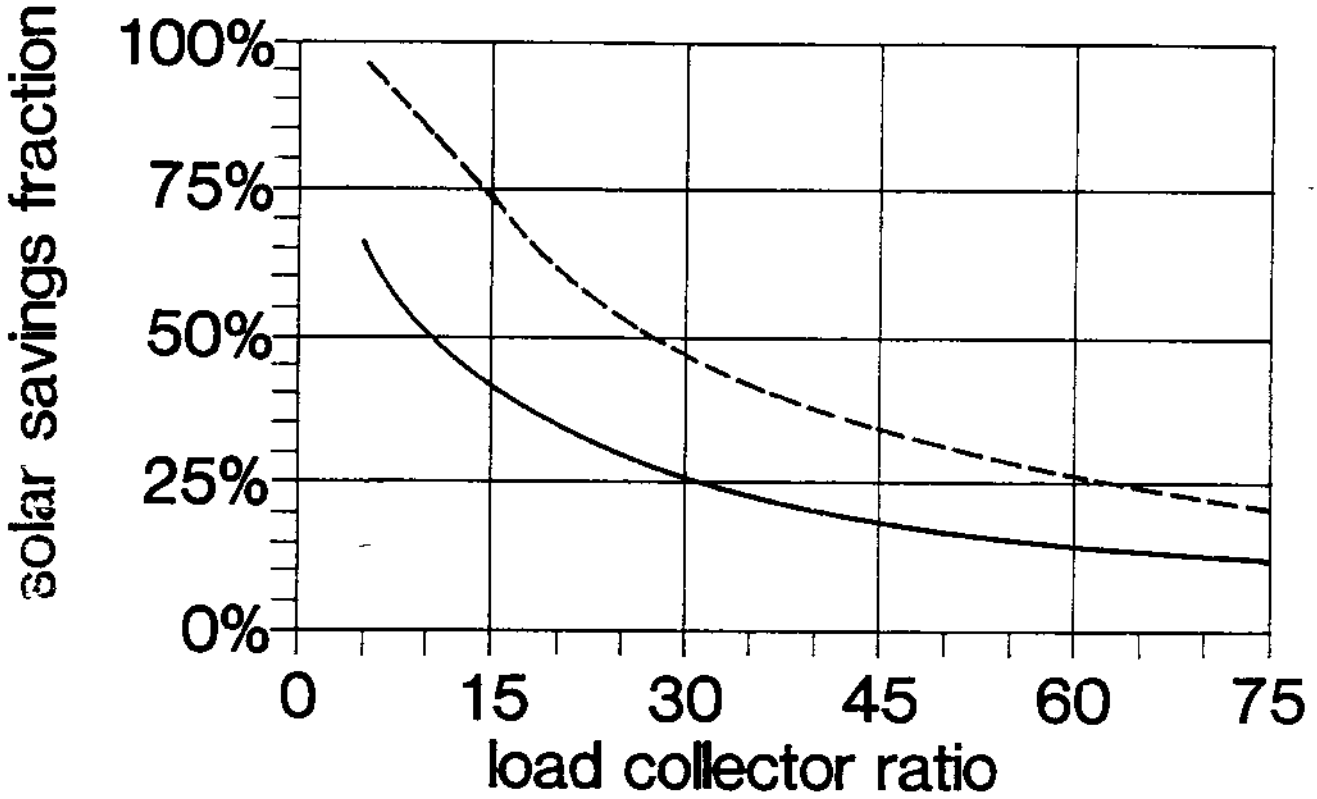
APPENDIX 2



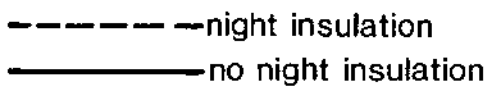
DIRECT GAIN AREA 11

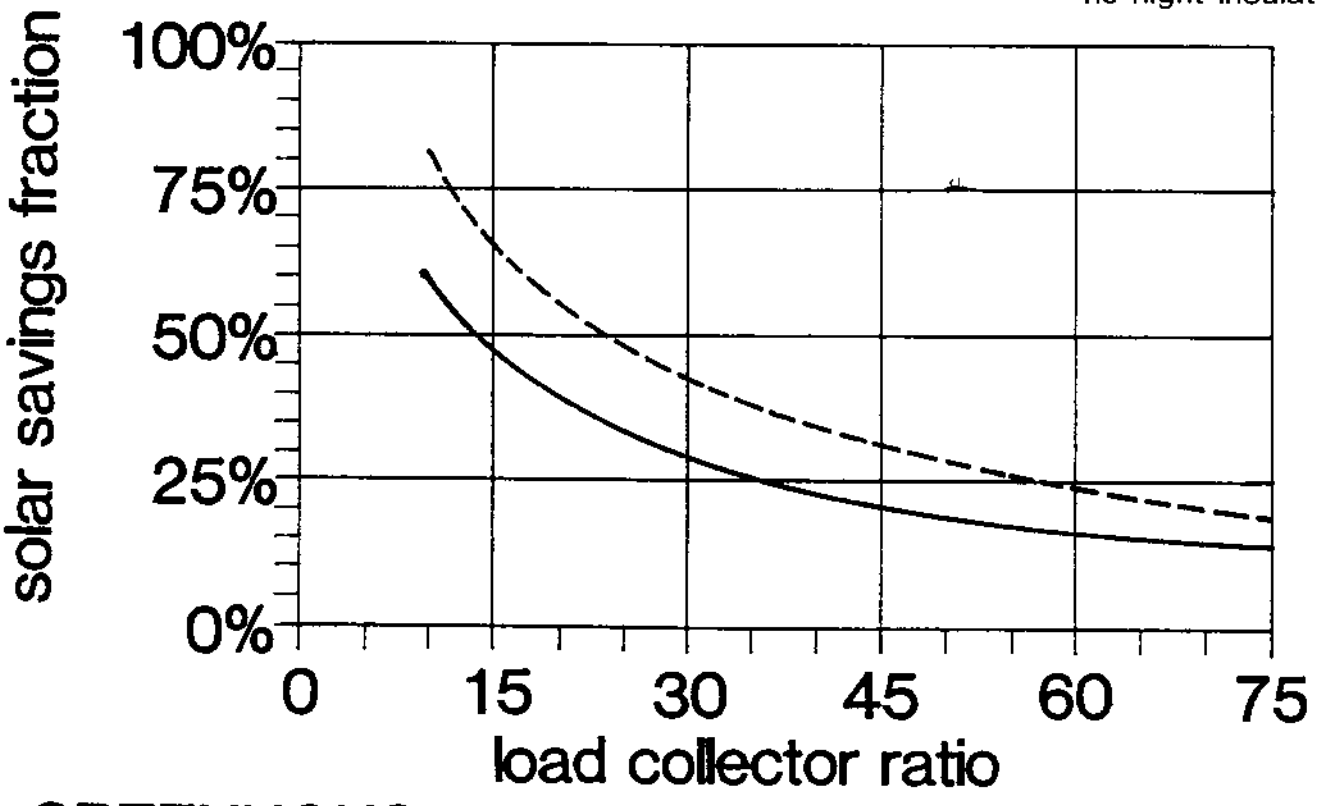


TROMBE WALL AREA 11



WATER WALL AREA 11





GREENHOUSE AREA 11

APPENDIX 3

NEBRASKA

MONTHLY AND ANNUAL HEATING DEGREE DAY NORMALS

STATION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Ainsworth	7	7	129	395	834	1187	1311	1067	983	520	228	58	6726
Albion	6	15	129	392	837	1215	1376	1103	970	495	210	48	6796
Alliance	11	15	183	487	882	1150	1243	1005	977	585	304	104	6946
Alma	0	0	69	315	750	1104	1206	935	815	383	147	29	5753
Arthur	11	13	154	462	876	1178	1287	1039	980	548	266	88	6902
Ashland	5	8	86	318	765	1163	1336	1047	884	401	159	25	6197
Atkinson	6	8	131	387	840	1221	1361	1103	989	510	217	52	6825
Auburn	0	6	64	278	705	1085	1234	960	797	351	139	17	5636
Beatrice	0	5	69	299	732	1110	1256	977	825	372	154	20	5819
Beaver City	0	0	60	309	744	1082	1187	916	803	375	143	28	5647
Benkelman	0	0	104	352	756	1084	1138	896	828	424	174	46	5766
Big Springs	0	5	126	421	816	1116	1209	974	902	495	234	70	6368
Blair	0	11	98	333	798	1190	1370	1092	924	432	171	27	6437
Box Butte	7	13	190	499	909	1194	1296	1053	1026	618	342	122	7269
Bridgeport	0	6	134	431	837	1125	1203	952	902	510	249	85	6434
Broken Bow	10	9	142	420	852	1184	1305	1050	961	513	235	59	6740
Burwell	10	12	150	436	885	1240	1380	1109	998	528	235	59	7042
Butte	5	8	118	395	855	1240	1386	1117	995	505	212	50	6886
Cambridge	0	0	94	343	777	1110	1206	935	831	402	159	36	5893
Centr City	0	0	90	334	777	1150	1299	1022	887	426	181	31	6197
Chadron	9	10	165	477	882	1194	1302	1042	983	570	297	100	7031
Clarkson	0	9	107	360	816	1206	1370	1098	939	459	184	34	6582
Clay Center	0	0	77	311	759	1135	1271	977	853	417	169	29	5998
Columbus	0	7	90	335	780	1172	1327	1053	899	429	175	30	6297
Crescent L	10	15	161	468	870	1159	1243	1005	964	543	283	90	6811
Crete	0	0	73	297	747	1128	1280	994	843	389	150	21	5922
Culbertson	0	0	102	376	807	1116	1215	949	862	445	188	48	6102
Curtis	0	0	91	381	813	1132	1225	960	859	439	175	40	6115
David City	0	0	85	326	783	1169	1330	1050	899	425	166	28	6261
Ewing	7	10	128	405	867	1252	1392	1117	983	496	215	47	6919
Fairbury	0	11	90	308	753	1122	1271	991	853	403	155	29	5986
Fairmont	0	5	82	310	756	1135	1293	1005	874	421	176	29	6086
Falls City	0	7	60	263	678	1057	1203	935	780	341	135	16	5475
F Robinson	11	12	183	474	879	1153	1265	1030	922	591	319	116	7025
Franklin	0	0	68	315	741	1085	1209	935	812	386	146	35	5732
Fremont	0	6	76	312	762	1159	1321	1042	871	398	150	20	6117
Geneva	0	6	81	319	768	1138	1283	1002	871	416	173	27	6084
Genoa	0	7	102	346	789	1175	1321	1047	896	432	175	30	6320
Gordon	13	17	184	499	918	1231	1336	1075	1017	591	311	114	7306
Gothenburg	0	0	98	374	801	1128	1234	974	871	441	174	44	6139

STATION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Grand Is	6	0	107	362	804	1178	1324	1044	915	461	184	35	6420
Halsey	7	5	133	413	849	1184	1305	1047	958	506	233	54	6684
Harrison	23	29	238	546	948	1228	1330	1096	1082	684	402	161	7766
Hartington	0	11	113	364	840	1256	1420	1137	983	475	190	39	6827
Hastings	0	8	107	325	765	1122	1249	991	871	426	172	34	6070
Hayes Cntr	7	11	127	376	801	1101	1215	974	905	486	214	67	6284
Hay Springs	9	12	179	493	906	1200	1302	1050	1011	597	316	114	7189
Hebron	0	5	78	311	762	1128	1283	1000	856	400	161	26	6010
Holdrege	0	0	90	326	765	1107	1225	958	849	414	160	32	5926
Imperial	0	0	105	388	792	1082	1181	946	884	476	213	55	6122
Kearney	0	0	113	366	819	1169	1308	1042	936	475	194	45	6467
Kimball	7	11	176	484	849	1097	1178	966	946	588	317	104	6723
Kingsley D	0	7	104	365	768	1073	1203	974	899	483	225	69	6169
Lexington	0	0	107	384	804	1147	1256	997	899	469	202	44	6309
Lincoln	0	0	83	329	780	1169	1327	1039	884	419	166	22	6218
Lodgepole	0	6	124	407	804	1079	1159	938	893	501	246	76	6233
Loup City	0	6	119	392	831	1194	1324	1053	921	466	192	43	6541
Madison	0	7	104	369	819	1212	1373	1098	939	454	181	30	6586
Madrid	0	0	100	384	807	1110	1203	960	890	476	202	47	6179
McCook	0	0	86	330	744	1057	1163	913	815	392	170	44	5714
Merriman	9	11	145	443	873	1194	1308	1058	1001	560	269	84	6955
Minden	0	0	93	322	768	1116	1237	972	859	426	172	37	6002
Mitchell	5	14	186	477	364	1156	1249	1002	970	579	300	105	6907
Mullen	8	7	135	413	822	1138	1246	1014	952	516	220	75	6546
Norfolk	6	11	123	397	861	1265	1429	1151	998	500	203	37	6981
North Loup	0	8	117	385	819	1190	1327	1053	930	473	200	43	6545
N Platte	7	8	141	439	864	1184	1290	1033	952	522	238	65	6743
Oakdale	8	13	135	411	855	1243	1401	1126	983	489	211	45	6920
Ogallala	0	7	131	425	834	1135	1240	986	911	494	218	65	6446
Omaha Epp	0	6	71	301	750	1147	1314	1036	865	391	148	20	6049
Omaha North	7	10	99	342	813	1218	1389	1106	942	456	186	33	6601
O Neill	6	9	136	407	858	1246	1386	1126	1004	513	220	49	6960
Osceola	0	6	92	336	783	1175	1339	1053	899	436	170	28	6317
Oshkosh	0	11	129	438	846	1138	1234	980	915	506	234	70	6501
Osmond	0	9	118	390	855	1262	1426	1145	989	482	193	37	6903
Pawnee City	0	0	48	252	681	1060	1203	930	769	332	135	16	5426
Purdum	7	6	121	409	840	1178	1290	1047	961	513	225	60	6657
Ravenna	0	0	94	358	807	1183	1283	1014	893	439	174	36	6261
Red Cloud	0	0	75	326	762	1122	1240	955	825	384	143	27	5859
Saint Paul	6	7	105	364	804	1175	1308	1039	902	442	173	34	6359

APPENDIX 3

STATION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
Scottsbluff	0	8	160	459	864	1169	1243	994	952	564	280	91	6774
Seward	0	5	83	322	762	1141	1293	1014	862	398	160	23	6063
Sidney	0	7	153	454	846	1113	1197	963	924	546	275	86	6564
Stanton	6	15	117	376	825	1225	1383	1103	946	456	189	36	6677
Stapleton	10	8	131	416	840	1166	1274	1030	955	522	233	65	6650
Syracuse	0	7	73	302	750	1135	1296	1011	843	380	145	19	5961
Tecumseh	0	7	77	309	738	1119	1271	983	825	386	153	22	5890
Tekamah	0	6	83	320	783	1181	1355	1078	908	417	175	24	6330
Valentine	8	10	154	470	912	1259	1383	1134	1048	576	273	73	7300
Wakefield	5	14	116	395	846	1262	1426	1134	970	472	186	34	6860
Walthill	0	10	120	384	849	1249	1432	1142	964	467	185	41	6843
Wpng Water	5	6	82	307	753	1147	1305	1019	856	393	158	25	6056
West Point	0	13	105	353	816	1218	1395	1112	942	444	172	32	6602
York	0	0	87	320	762	1138	1290	1011	874	416	160	24	6082

APPENDIX 4

INSULATING VALUES OF CONSTRUCTION MATERIALS

1.Conductivities (k), Conductances (C) and Resistance (R) of Building and Insulating Materials

(The constants are expressed in Btu/hr-sq ft-^{o}F. Conductivities are per inch thickness, and Conductances are for thickness or construction stated, but not per inch thickness. All values are for a mean temperature of 75 ^{o}F, except as noted by an (*) which have been reported at 45 ^{o}F.)

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb (^{o}F)
BUILDING BOARD						
Boards, Panels,Subflooring, Sheathing, Woodboard Panel Products						
Asbestos-cement board.....	120	4.0	--	0.25	--	0.24
Asbestos-cement board..0.125".	120	---	33.00	----	0.03	
Asbestos-cement board...0.25"	120	---	16.50	----	0.06	
Gypsum or plaster board.0.375".	50	---	3.10	----	0.32	0.26
Gypsum or plaster board...0.5".	50	---	2.22	----	0.45	
Gypsum or plaster board.0.625".	50	---	1.78	----	0.56	
Plywood (Douglas fir).....	34	0.8	--	1.25	--	0.29
Plywood (Douglas fir)....0.25".	34	---	3.20	----	0.31	
Plywood (Douglas fir)...0.375".	34	---	2.13	----	0.47	
Plywood (Douglas fir).....0.5".	34	---	1.60	----	0.62	
Plywood (Douglas fir)...0.625".	34	---	1.29	----	0.77	
Plywood or wood panels...0.75".	34	---	1.07	----	0.93	0.29
Vegetable fiber board						
Sheathing, regular density.....0.5".	18	---	0.76	----	1.32	0.31
.....0.78125".	18	---	0.49	----	2.06	
Sheathing, intermediate density.....0.5".	22	---	0.82	----	1.22	0.31
Nail-base sheathing....0.5".	25	---	0.88	----	1.14	0.31
Shingle backer.....0.375".	18	---	1.06	----	0.94	0.31
Shingle backer.....0.3125".	18	---	1.28	----	0.78	
Sound deadening board..0.5".	15	---	0.74	----	1.35	0.30
Tile and lay-in panels, plain or acoustic.....	18	0.4	----	2.50	----	0.14
.....0.5".	18	---	0.80	----	1.25	
.....0.75".	18	---	0.53	----	1.89	
Laminated paperboard.....	30	0.5	----	2.00	----	0.33
Homogeneous board from repulped paper.....	30	0.5	----	2.00	----	0.28

APPENDIX 4

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb (°F)
Hardboard						
Medium density	50	0.73	----	1.37	----	0.31
High density, service temp. service underlay	55	0.82	----	1.22	----	0.32
High density, std. tempered.	63	1.00	----	1.00	----	0.32
Particleboard						
Low density	37	0.54	----	1.85	----	0.31
Medium density	50	0.94	----	1.06	----	0.31
High density	62.5	1.18	----	0.85	----	0.31
Underlayment 0.625".	40	---	1.22	----	0.82	0.29
Wood subfloor 0.75".		---	1.06	----	0.94	0.33
BUILDING MEMBRANE						
Vapor--permeable felt	---	---	16.7	----	0.06	
Vapor-- seal, 2 layers of mopped 15-lb felt	---	---	8.35	----	0.12	
Vapor--seal, plastic film	---	---	----	----	Negl.	
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	---	---	0.48	----	2.08	0.34
Carpet and rubber pad	---	---	0.81	----	1.23	0.33
Cork tile 0.125".	---	---	3.60	----	0.28	0.48
Terrazzo 1".	---	---	12.5	----	0.08	0.19
Tile-- asphalt, linoleum, vinyl, rubber	---	---	20.0	----	0.05	0.30
vinyl abestos						0.24
ceramic						0.19
Wood, hardwood finish 0.75".			1.47		0.68	
INSULATING MATERIALS						
BLANKET and BATT						
Mineral fiber, fibrous from processed from rock, slag, or glass						
approx.[2] 2-2.75"	0.3-2.0	---	0.143	----	7	0.17-0.23
approx.[2] 3-3.5"	0.3-2.0	---	0.091	----	11	
approx.[2] 3.5-6.5"	0.3-2.0	---	0.053	----	19	
approx.[2] 6-7"	0.3-2.0		0.045		22	
approx.[3] 8.5"	0.3-2.0		0.033		30	

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb ($^\circ$F)
BOARD and SLABS						
Cellular glass	8.5	0.38	---	2.63	----	0.24
Glass fiber, organic bonded	4-9	0.25	---	4.00	----	0.23
Expanded rubber (rigid)	4.5	0.22	---	4.55	----	0.40
Expanded polystyrene extruded						
Cut cell surface	1.8	0.25	---	4.00	----	0.23
Expanded polystyrene extruded						
Smooth skin surface	2.2	0.20	---	5.00	----	0.29
Expanded polystrene extruded						
Smooth skin surface	3.5	0.19	---	5.26	----	
Expanded polyurethane[4]						
(R-11 exp.)	1.5	0.16	---	6.25	----	0.38
(thickness 1" or greater)	2.5					
Mineral fiber with resin						
binder	15	0.29	---	3.45	----	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	---	2.94	----	
Acoustical tile	18	0.35	---	2.86	----	0.19
Acoustical tile	21	0.37	---	2.70	----	
Mineral fiberboard, wet molded						
Acoustical tile[5]	23	0.42	---	2.38	----	0.14
Wood or cane fiberboard						
Acoustical tile[5]..0.5"	----	---	0.80	----	1.25	0.31
Acoustical tile[5].0.75"	----	---	0.53	----	1.89	
Interior finish(plank, tile)	15	0.35	---	2.86	----	0.32
Wood shredded(cemented in						
performed slabs)	22	0.60	---	1.67	----	0.31
LOOSE FILL						
Cellulosic insulation(milled						
paper or wood pulp)	2.3-3.2	0.27-0.32	---	3.13-3.7	----	0.33
Sawdust or shavings	8-15	0.45	---	2.22	----	0.33
Wood fiber softwoods	2.0-3.5	0.30	---	3.33	----	0.33
Perlite, expanded	5-8	0.37	---	2.70	----	0.26
Mineral fiber(rock,						
slag or glass)						
approx.[2] 3.75-5"	0.6-2	---	---		11	0.17
approx.[2] 6.5-8.75"	0.6-2	---	---		19	
approx.[2] 7.5-10"	0.6-2	---	---		22	
approx.[2] 10.25-13.75	0.6-2	---	---		30	
Vermiculite, exfoliated	7-8.2	0.47	---	2.13	----	3.20
	4-6	0.44		2.27	----	

APPENDIX 4

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb (^{o}F)
ROOF INSULATION[6]						
Performed, for use above deck						
Different roof insulations are available in different thicknesses to provide the design C values listed.[6] Consult individual manufactures for actual thickness of their material			0.72 to 0.12			1.39 to 8.33
MASONRY MATERIALS						
CONCRETES						
Cement mortar	116	5.0	---	0.20	----	
Gypsum-fiber concrete 87.5% gypsum, 12.5% wood chips	51	1.66	---	0.60	----	0.21
Lightweight aggregates	120	5.2	---	0.19	----	
including expanded shale,	100	3.6	---	0.28	----	
clay or slate; cinders;	80	2.5	---	0.40	----	
pumice; vermiculite; also	60	1.7	---	0.59	----	
cellular concretes	40	1.15	---	0.86	----	
	30	0.90	---	1.11	----	
	20	0.70		1.43		
Perlite, expanded	40	0.93		1.08		
	30	0.71		1.41		
	20	0.50		2.00		0.32
Sand and gravel or stone aggregate(oven dried)	140	9.00	---	0.11		0.22
Sand and gravel or stone aggregate(not dried)	140	12.0	---	0.08		
Stucco	116	5.00	---	0.20		

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb ($^\circ$F)
MASONRY UNITS						
Brick, common[7]	120	5.0	---	0.20	----	0.19
Brick, face[7]	130	9.0	---	0.11	----	
Clay tile, hollow:						
1 cell deep.....3".	---	---	1.25	----	0.80	0.21
1 cell deep.....4".	---	---	0.90	----	1.11	
2 cells deep.....6".	---	---	0.66	----	1.52	
2 cells deep.....8".	---	---	0.54	----	1.85	
2 cells deep.....10".	---	---	0.45	----	2.22	
3 cells deep.....12".	---	---	0.40	----	2.50	
Concrete blocks, three oval core:						
Sand and gravel aggregate.....4".	---	---	1.40	----	0.71	0.22
.....8".	---	---	0.90	----	1.11	
.....12".	---	---	0.78	----	1.28	
Cinder aggregate.....3".	---	---	1.16	----	0.86	0.21
.....4".	---	---	0.90	----	1.11	
.....8".	---	---	0.58	----	1.72	
.....12".	---	---	0.53	----	1.89	
Lightweight aggregate.....3".	---	---	0.79	----	1.27	0.21
(expanded shale,.....4".	---	---	0.67	----	1.50	
clay, slate or.....8".	---	---	0.50	----	2.00	
slag; pumice).....12".	---	---	0.44	----	2.27	
Concrete blocks, rectangular core[8]						
Sand and gravel aggregate						
2 core, 8" 36 lb.[9].....	---	---	0.96	----	1.04	0.22
Same with filled cores[8].....	---	---	0.52	----	1.93	0.22
Lightweight aggregate(expanded shale, clay, slate or slag, pumice):						
3 core, 6" 19 lb.[9].....	---	---	0.61	----	1.65	0.21
Same with filled cores[10].....	---	---	0.33	----	2.99	
2 core, 8" 24 lb.[9].....	---	---	0.46	----	2.18	
Same with filled cores[10].....	---	---	0.20	----	5.03	
3 core, 12" 38 lb.[9].....	---	---	0.40	----	2.48	
Same with filled cores[10].....	---	---	0.17	----	5.82	
Stone, lime or sand.....	---	12.5	----	0.08	----	0.19
Gypsum partition tile:						
3 x 12 x 30" solid.....	---	---	0.79	----	1.26	0.19
3 x 12 x 30" 4-cell.....	---	---	0.74	----	1.35	
4 x 12 x 30" 3-cell.....	---	---	0.60	----	1.67	

APPENDIX 4

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb (^{o}F)
PLASTERING MATERIALS						
Cement plaster, sand aggregate.	116	5.0	----	0.20	---	0.20
Sand aggregate.....0.375".	---	---	13.3	----	0.88	0.20
Sand aggregate.....0.75".	---	---	6.66	----	0.15	0.20
Gypsum plaster:						
Lightweight aggregate.....0.5".	45	---	3.12	----	0.32	
.....0.625".	45	---	2.67	----	0.39	
Lightweight agg. on metal lath.....0.75".	---	---	2.13	----	0.47	
Perlite aggregate.....	45	1.5	----	0.67	----	0.32
Sand aggregate.....	105	5.6	----	0.18	----	0.20
Sand aggregate.....0.5".	105	---	11.1	----	0.09	
Sand aggregate.....0.625".	105	---	9.10	----	0.11	
Sand aggregate on metal lath.....0.75".	---	---	7.70	----	0.13	
Vermiculite aggregate.....	45	1.7	----	0.59	----	
ROOFING						
Asbestos-cement shingles.....	120	---	4.76	----	0.21	0.24
Asphalt roll roofing.....	70	---	6.50	----	0.15	0.36
Asphalt shingles.....	70	---	2.27	----	0.44	0.30
Build-up roofing.....0.375".	70	---	3.00	----	0.33	0.35
Slate.....0.5".	---	---	20.0	----	0.05	0.30
Wood shingles, plain and plastic film faced.....	---	---	1.06	----	0.94	0.31
SIDING MATERIALS(ON FLAT SURFACE)						
Shingles						
Asbestos-cement.....	120	---	4.75	----	0.21	
Wood, 16", 7.5 exposure...	---	---	1.15	----	0.87	0.31
Wood, double, 16", 12" exposure.....	---	---	0.84	----	1.19	0.28
Wood, plus insul. backer board,0.1325".....	---	---	0.71	----	1.40	0.31

Description	Density (lb/ft^3)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per Inch thickness (1/k)	Resistance[1] (R) For thickness listed	Specific Heat, Btu/lb (^{o}F)
Siding						
Asbestos-cement, 0.25, lapped	---	---	4.76	----	0.21	0.24
Asphalt roll roofing	---	---	6.50	----	0.15	0.35
Asphalt insulating siding (0.5" bed)	---	---	0.69	----	1.46	0.35
Wood, drop, 1 x 8"	---	---	1.27	----	0.79	0.28
Wood, bevel 0.5 x 8", lapped	---	---	1.23	----	0.81	0.28
Wood, bevel 0.75 x 10", lapped	---	---	0.95	----	1.05	0.28
Wood, plywood, 0.375", lapped	---	---	1.59	----	0.59	0.29
Wood, medium density siding, 0.4375"	40	1.49	----	0.67		0.28
Aluminum or steel[11], over sheathing						
Hollow-backed	---	---	1.61	----	0.61	0.29
Insulating-board backed nominal 0.375"	---	---	0.55	----	1.82	0.32
Insulating-board backed nominal 0.375", foil backed			0.34		2.96	
Architectural glass	---	---	10.0	----	0.10	0.20
WOODS						
Maple, oak, and similar hardwoods	45	1.10	----	0.91	----	0.30
Fir, pine, and similar softwoods	32	0.80	----	1.25	----	0.33
.....0.75"	32	----	1.06	----	0.94	0.33
.....1.5"		----	0.53	----	1.89	
.....2.5"		----	0.32	----	3.12	
.....3.5"		----	0.23	----	4.35	

APPENDIX 4

NOTES:

1. Resistance values are the reciprocals of C before rounding off to two decimal places.
2. Conductivity varies with fiber diameter.Insulation is produced by different densities; therefore, there is a wide variation in thickness for the same R-value among manufacturers. No effort should be made to relate any specific R-value to any specific thickness.
3. Does not include paper backing and facing, if any.
4. Values are for aged board stock.
5. Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.
6. The U.S. Department of Commerce, Simplified Practice Recommendation for Thermal Conductance Factors for Preformed Above-Deck Roof Insulation, No. R257-55, recognizes the specifications of roof insulation on the basis of the C-values shown. Roof insulation is made in thicknesses to meet these values.
7. Face brick and common brick do not always have these specific densities. When density is different from that shown, there will be a change in thermal conductivity.
8. Data on rectangular core concrete blocks differ from the above data on oval core blocks, due to core configuration, different mean temperatures, and possibly differences in unit weights. Weight data on the oval core blocks tested are not available.
9. Weights of units approximately 7.625" high and 15.75" long. These weights are given as a means of describing the blocks tested, but conductance values are for 1 square foot of area.
10. Vermiculite, perlite, or mineral wool insulation. Where insulation is used, vapor barries or other precautions must be considered to keep insulation dry.
11. Values for metal siding applied over flat surfaces vary widely, depending on amount of ventilation of air space beneath the siding; whether air is reflective or nonreflective; and on the thickness, type, and were obtained from several guarded hotbox tests(ASTM C236) or calibrated hotbox(BSS 77) on hollowbacked types and types made using backing-boards of wood fiber,foamed plastic, and glass fiber. Departures of + or -50% or more from the values given may occur.

2. THERMAL CONDUCTIVITY (K) OF INDUSTRIAL INSULATION FOR MEAN TEMPERATURES INDICATED

(Expressed in Btu/hr-sq ft-^{o}F-in.)

Form, Material Composition	Accepted Max Temp for Use, ^{o}F[1]	Typical Density (lb/ft^{3})	Typical Conductivity (k) at Mean Temp ^{o}F							
			-25	0	25	50	75	100	200	300
BLANKETS & FELTS										
Mineral Fiber										
Mineral fiber, glass Blanket, flexible, fine-fiber organic bonded	350	0.65	0.25	0.26	0.28	0.30	0.33	0.36	0.53	
		0.75	0.24	0.25	0.27	0.29	0.32	0.34	0.48	
		1.0	0.23	0.24	0.25	0.27	0.29	0.32	0.43	
		1.5	0.21	0.22	0.23	0.25	0.27	0.28	0.37	
		2.0	0.2	0.21	0.22	0.23	0.25	0.26	0.33	
		3.0	0.19	0.2	0.21	0.22	0.23	0.24	0.31	
Blanket, flexible, textile-fiber organic bonded	350	0.65	0.27	0.28	0.29	0.3	0.31	0.32	0.5	0.68
		0.75	0.26	0.27	0.28	0.29	0.31	0.32	0.48	0.66
		1.0	0.24	0.25	0.26	0.27	0.29	0.31	0.48	0.6
		1.5	0.22	0.23	0.24	0.25	0.27	0.29	0.39	0.51
		3.0	0.2	0.21	0.22	0.23	0.24	0.25	0.32	0.41
Felt, semirigid organic bonded Laminated & felted Without binder	400	3-8			0.24	0.25	0.26	0.27	0.35	0.44
	850	3	0.19	0.2	0.21	0.22	0.23	0.24	0.35	0.55
Note: Other values include: -100F:0.16; -75F:0.17; -50F:0.18										
	1200	7.5								0.35
Note: Other values include: 500F:0.45; 700F:0.6										
Mean Temperatures:					25	50	75	100	200	300	500
(Rock, slag or glass) Blanket metal reinforced	1200	6-12						0.26	0.32	0.39	0.54
	1000	2.5-6						0.24	0.31	0.40	0.61
Vegetable & Animal Fiber										
Hair felt or hair felt plus jute	180	10	0.26	0.28	0.29	0.30				

APPENDIX 4

Form, Material Composition	Accepted Max Temp for Use, °F[1]	Typical Density (lb/ft³)	Typical Conductivity (k) at Mean Temp °F							
BLOCKS, BOARDS, PIPE INSULATION										
Mean Temperatures:			50	75	100	200	300	500	700	900
Asbestos										
Laminated asbestos paper	700	30			0.40	0.45	0.5	0.6		
Corrugated & laminated asbestos paper										
4-ply	300	11-13		0.54	0.57	0.68				
6-ply	300	15-17		0.49	0.51	0.59				
8-ply	300	18-20		0.47	0.49	0.57				
Molded Amosite & Binder	1500	15-18			0.32	0.37	0.42	0.52	0.62	0.72
85% Magnesia	600	11-12			0.35	0.38	0.42			
Calcium Silicate	1200	11-13			0.38	0.41	0.44	0.52	0.62	0.72
	1800	12-15						0.63	0.74	0.95
Diatomaceous Silica	1600	21-22						0.64	0.68	0.72
	1900	23-25						0.70	0.75	0.80
Cellular Glass	800	9	0.38	0.40	0.42	0.48	0.55			
Note: other values include, -50F:0.32; -25F:0.33; 0F:0.35; 25F:0.36										
Mean Temperatures:			0	25	50	75	100	200	300	500
Mineral Fiber Glass, Organic bonded, block and boards	400	3-10	0.20	0.22	0.24	0.25	0.26	0.33	0.4	
Note:other values include,-100F:0.16; -75F:0.17; -50F:0.18; -25F:0.19										
Nonpunking binder	1000	3-10					0.26	0.31	0.38	0.52
Pipe insulation, slag or glass	350	3-4	0.2	0.21	0.22	0.23	0.24	0.29		
	500	3-10	0.2	0.22	0.24	0.25	0.26	0.33	0.4	
Inorganic bonded-block	1000	10-15					0.33	0.38	0.45	0.55
	1800	15-24					0.32	0.37	0.42	0.52
Note: other values include, 700F:0.62; 900F:0.74										
Pipe insulation slag or glass	1000	10-15					0.33	0.38	0.45	0.55
Resin binder		15	0.25	0.26	0.28	0.29				
Note: other values include, -50F:0.23; -25F:0.24										

Form, Material Composition	Accepted Max Temp for Use, °F[1]	Typical Density (lb/ft^3)	Typical Conductivity (k) at Mean Temp °F							
Mean Temperatures			-100	-75	-50	-25	0	25	50	75
Rigid Polystyrene Extruded, Refrigerant 12 exp	170	3.5	0.16	0.16	0.15	0.16	0.16	0.17	0.18	0.19
Note: other value includes, 100F:0.20										
Extruded, Refrigerant 12 exp	170	2.2	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.2
Extruded	170	1.8	0.17	0.18	0.19	0.20	0.21	0.23	0.24	0.25
Note: other value includes, 100F:0.27										
Molded beads Polyurethane[2]	170	1	0.18	0.20	0.21	0.23	0.24	0.25	0.26	0.28
Refrigerant 11 exp	210	1.5-2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16
Note: other value includes, 100F:0.17										
Rubber, Rigid Foamed	150	4.5						0.20	0.21	0.22
Note: other value includes, 100F:0.23										
Vegetable & Animal Fiber Wool felt(pipe insulation)	180							0.28	0.30	0.31
Note: other value includes, 100F:0.33										

APPENDIX 4

Form, Material Composition	Accepted Max Temp for Use, ^{o}F[1]	Typical Density (lb/ft^3)	Typical Conductivity (k) at Mean Temp ^{o}F

INSULATING CEMENTS

Mean Temperatures			100	200	300	500	700	900
Mineral Fiber (Rock, slag, or glass)								
With colloidal clay binder	1800	24-30	0.49	0.55	0.61	0.73	0.85	
With hydraulic setting binder	1200	30-40	0.75	0.80	0.85	0.95		

LOOSE FILL

Mean Temperatures		-75	-50	-25	0	25	50	75	100
Cellulose insulation (milled pulverized paper or wood pulp)	2.5-3						0.26	0.27	0.29
Mineral fiber, slag, rock or glass	2-5		0.19	0.21	0.23	0.25	0.26	0.28	0.31
Perlite(expanded)	5-8	0.27	0.29	0.30	0.32	0.34	0.35	0.37	0.39
Note: other value includes, -100F:0.25									
Vermiculite (expanded)	7-8.2		0.39	0.40	0.42	0.44	0.45	0.47	0.49
	4-6		0.34	0.35	0.38	0.40	0.42	0.44	0.46

Notes:
1. These temperatures are generally accepted as maximum. When operating temperature approaches these limits follow the manufacture's recommendations.
2. Values are for aged board stock. Note: Some polyurethane foams are formed by means which produce a stable product(with respect to k), but most are blown with refrigerant and will change with time.

3. U VALUES OF SOLID WOOD DOORS

	Btu per (hr x sq ft x ^{o}F)			
	Winter			Summer
Thickness[1]	No Storm Door	Storm Door[2] Wood	Metal	No Storm Door
1"	0.64	0.30	0.39	0.61
1.25"	0.55	0.28	0.34	0.53
1.5"	0.49	0.27	0.33	0.47
2"	0.43	0.24	0.24	0.42

Notes:
1. Nominal thickness.
2. Values for wood storm doors are for approximately 50% glass; for metal storm door values apply for any percent of glass.

4. U VALUES OF WINDOWS, SKYLIGHTS AND LIGHT-TRANSMITTING PARTITIONS

(These values are for heat transfer from air to air in Btu/hr-sq ft-^{o}F)

PART A--Vertical Panels(Exterior Windows, Sliding Patio Doors, and Partitions)-Flat Glass, Glass Block, and Plastic Sheet

	Exterior[1]		
Description	Winter	Summer	Interior
FLAT GLASS[2]			
Single glass	1.10	1.04	0.73
Insulating glass--double[3]			
0.1875" air space[4]	0.62	0.65	0.51
0.25" air space[4]	0.58	0.61	0.49
0.5" air space[5]	0.49	0.56	0.46
0.5" air space, low emittance coating[6]			
e= 0.20	0.32	0.38	0.32
e= 0.40	0.38	0.45	0.38
e= 0.60	0.43	0.51	0.42
Insulating glass--triple[3]			
0.25" air space[4]	0.39	0.44	0.38
0.5" air space[5]	0.31	0.39	0.30
Storm windows			
1" to 4" air space[4]	0.50	0.50	0.44
PLASTIC SHEET			
Single glazed			
0.125" thick	1.06	0.98	----
0.25" thick	0.96	0.89	----
0.5" thick	0.81	0.76	----

APPENDIX 4

Description	Exterior[1] Winter	Exterior[1] Summer	Interior
PLASTIC SHEET (continued)			
Insulating unit--double[3]			
0.25" air space[4]	0.55	0.56	----
0.5" air space[3]	0.43	0.45	----
GLASS BLOCK[8]			
6 x 6 x 4" thick	0.60	0.57	0.46
8 x 8 x 4" thick	0.56	0.54	0.44
-- with cavity divider	0.48	0.46	0.38
12 x 12 x 4" thick	0.52	0.50	0.41
-- with cavity divider	0.44	0.42	0.36
12 x 12 x 2" thick	0.60	0.57	0.46

PART B--Horizontal Panels(Skylights)--Flat Glass, Glass Block, and Plastic Domes

Description	Exterior[1] Winter[9]	Exterior[1] Summer[10]	Interior[6]
FLAT GLASS[5]			
Single glass	1.23	0.83	0.96
Insulating glass--double[3]			
0.1875" air space[4]	0.70	0.57	0.62
0.25" air space[4]	0.65	0.54	0.59
0.5" air space[3]	0.59	0.49	0.56
0.5" air space, low emittance coating[6]			
e= 0.20	0.48	0.36	0.39
e= 0.40	0.52	0.42	0.45
e= 0.60	0.56	0.46	0.50
GLASS BLOCK[8]			
11 x 11 x 3" thick with cavity divider	0.53	0.35	0.44
12 x 12 x 4" thick with cavity divider	0.51	0.34	0.42
PLASTIC DOMES[11]			
Single-walled	1.15	0.80	----
Double-walled	0.70	0.46	----

PART C--Adjustment Factors for Various Window and sliding Patio Door Types
(Multiply U Values in Parts A and B by These Factors)

Description	Single Glass	Double or Triple Glass	Storm Windows
WINDOWS			
All glass[12]	1.00	1.00	1.00
Wood sash--80% glass	0.90	0.95	0.90
Wood sash--60% glass	0.80	0.85	0.80
Metal sash--80% glass	1.00	1.20[13]	1.20[13]
SLIDING PATIO DOORS			
Wood frame	0.95	1.00	----
Metal frame	1.00	1.10[13]	----

Notes:
1. See Part C for adjustment for varies window and sliding patio doors types.
2. Emittance of uncooled glass surface = 0.84.
3. Double and triple refer to the number of lights of glass.
4. 0.125" glass
5. 0.25" glass
6. Coating on either glass surface facing air space; all other glass surfaces uncoated.
7. Window design: 0.25" glass--0.125" glass--0.25" glass.
8. Dimensions are nominal.
9. For heat flow up.
10. For heat flow down.
11. Based on area or opening, not total surface area.
12. Refers to windows with negligible opaque area.
13. Values will be less than thes when metal sash and frame incorporate thermal breaks. In some thermal break designs, U values wll be equal to or less than those for the glass. Windows manufactures should be consulted for specific data.

APPENDIX 4

5. RESISTANCE (R) VALUES OF AIR SURFACES

Position of Surface	Direction of Heat Flow	Type of Surfaces: Nonreflective Materials Resistance(R)	Reflective Aluminum Coated Paper Resistance(R)	Highly Reflective Foil Resistance(R)
STILL AIR				
Horizontal	Upward	0.61	1.10	1.32
45 degree slope	Upward	0.62	1.14	1.37
Vertical	Horizontal	0.68	1.35	1.70
45 degree slope	Down	0.76	1.67	2.22
Horizontal	Down	0.92	2.70	4.55
MOVING AIR				
(any position)				
15 mph wind	Any	0.17(winter)	----	----
7 1/2 mph wind	Any	0.25(summer)	----	----

6. RESISTANCE (R) VALUES OF AIR SPACE

Position of air Space and Thickness(in.)		Direction of Heat Flow	Season	Types of surfaces on Opposite Sides: Both Surfaces Nonreflective Materials Resistance(R)	Aluminum Coated Paper/Non-Reflective Material Resistance(R)	Foil/Non-Reflective Material Resistance(R)
Horizontal	3/4	Up	W	0.87	1.71	2.23
	3/4		S	0.76	1.63	2.26
	4		W	0.94	1.99	2.73
	4		S	0.80	1.87	2.75
45 degree slope	3/4	Up	W	0.94	2.02	2.78
	3/4		S	0.81	1.90	2.81
	4		W	0.96	2.13	3.00
	4		S	0.82	1.98	3.00
Vertical	3/4	Hori-	W	1.01	2.36	3.48
	3/4	zontal	S	0.84	2.10	3.28
	4		W	1.01	2.34	3.45
	4		S	0.91	2.16	3.44
45 degree slope	3/4	Down	W	1.02	2.40	3.57
	3/4		S	0.84	2.09	3.24
	4		W	1.08	2.75	4.41
	4		S	0.90	2.50	4.36
Horizontal	3/4	Down	W	1.02	2.39	3.55
	1 1/2		W	1.14	3.21	5.74
	4		W	1.23	4.02	8.94
	3/4		S	0.84	2.08	3.25
	1 1/2		S	0.93	2.76	5.24
	4		S	0.99	3.38	8.03

APPENDIX 4

EMISSIVITY OF VARIOUS MATERIALS

Material Description	Emissivity Ratio	Surface Condition
Alumimum	0.03	Polished
Aluminum(alloy 1100)	0.09	Commericial sheet heavily oxidized
Aluminum-coated paper	0.20	Polished
Aluminum foil	0.05	Bright
Aluminum sheet	0.12	
Asbestos, board	0.96	
Asbestos, insulation	0.93	"Paper"
Black surface, absolute	1.0	
Brass:		
red(85% Cu, 15% Zn)	0.030	Highly polished
yellow(65% Cu, 35% Zn)	0.033	Highly polished
Brick building	0.93	
Building materials:		
wood, paper, masonry, nonmetallic paints	0.90	
Cadmium	0.02	
Carbon(gas retort)	0.81	
Chalk	0.34	
Concrete	0.88	
Concrete	0.97	Rough
Copper(electrolytic)	0.072	Commercial, shiny
Earth	0.41	Dry, packed
Fireclay brick	0.75	At 1832 degree F
German silver(nickel silver)	0.135	Polished
Glass:		
crown(soda-lime)	0.94	Smooth
regular	0.84	Smooth
Gold	0.02	Highly polished
Graphite "Karbate" (impervious)	0.75	
Gypsum	0.903	On a smooth plate
Ice (32 ^{o}F)	0.95	
Iron:		
cast	0.435	Freshly turned
wrought	0.94	Dull, oxidized
Lead	0.28	Grey, oxidized
Limestone	0.36-0.90	At 145-380^{o}F
Lime wash	0.91	
Magnesium	0.55	Oxidized
Marble	0.931	Light grey,polished
Nickel	0.045	Electroplated, polished

EMISSIVITY OF VARIOUS MATERIALS

Material Description	Emissivity Ratio	Surface Condition
Paints:		
aluminum	0.50	
aluminum lacquer	0.39	On rough plate
black lacquer	0.80	
black shellac	0.91	"Matte" finish
flat black lacquer	0.96	
oils	0.92-0.96	All colors
white enamel	0.91	On rough plate
white lacquer	0.80	
Paper	0.92	Pasted on tinned plate
Plaster	0.91	Rough, white
Platinum	0.054	Polished
Porcelain	0.92	Glazed
Rubber:		
vulcanized(soft)	0.86	Rough
vulcanized(hard)	0.95	Glossy
Silver	0.02	Polished and at 440°F
Steel, galvanized	0.25	Bright
Steel(mild)	0.12	Cleaned
Tin	0.06	Bright and at 122°F
Tungsten	0.032	Filament at 80°F
Wood, white oak	0.90	Planed
Zinc:		
cast	0.05	Polished
galvanizing	0.23	Fairly bright

APPENDIX 5

CONVERSION TABLES
1. Conversion Factors

Multiply	By	To Obtain
acres	43,560	square feet
acres	0.004047	square kilometers
acres	4,047	square meters
acres	0.0015625	square miles
acres	4,840	square yards
acre-feet	43,560	cubic feet
acre-feet	1,233.5	cubic meters
acre-feet	1,613.3	cubic yards
angstroms	$1x10^{-8}$	centimeters
angstroms	$3.937x10^{-9}$	inches
angstroms	0.0001	microns
barrels (petroleum, U.S.) (bbl.)	5.6146	cubic feet
barrels	35	gallons (imperial)
barrels	42	gallons (U.S.)
barrels	158.98	liters
barrels	5,800,000	Btu (energy)
board feet	0.0833	cubic feet
brick number of common	5.4	pounds
British thermal unit (Btu)	251.99	calories, gram
Btu	777.649	foot-pounds
Btu	0.00039275	horsepower-hours
Btu	1,054.35	joules
Btu	0.000292875	kilowatt-hours
Btu	1,054.35	watt-seconds
Btu	0.55556	centigrade heat units
Btu/hr	4.2	cal/min
Btu/hr	777.65	ft-lb/hr
Btu/hr	0.0003927	horsepower
Btu/hr	0.000292875	kilowatts
Btu/hr	0.292875	watts (or joule/sec)
Btu/hr	$7.25x10^{-4}$	cal/gr
Btu/sq ft	0.271246	cal/sq cm (or langleys)
Btu/sq ft	0.292875	watt-hr/sq ft
Btu/sq ft/hr	$3.15x10^{-3}$	kilowatts/sq meter
Btu/sq ft/hr	$4.51x10^{-3}$	cal/sq cm/min (or langleys/min)
Btu/sq ft/hr	$3.15x10^{-4}$	watts/sq cm
Btu/hr/sq ft/deg F	$5.783x10^{4}$	watts/cm^2/deg C
Btu/hr/sq ft (deg F/in)	1	chu/hr/sq ft (deg C/in)
calories (cal)	0.003968	Btu
calories	3.08596	foot-pounds
calories	$1.55857x10^{-6}$	horsepower-hours
calories	4.184	joules (or watt-sec)
calories	1.1622x10-6	kilowatt-hours

Multiply	By	To Obtain
calories, food unit (Cal)	1,000	calories
cal/min	0.003968	Btu/min
cal/min	0.06973	watts
cal/sq cm	3.68669	Btu/sq ft
cal/sq cm	1.0797	watt-hr/sq ft
cal/sq cm/min	796,320	Btu/sq ft/hr
candle power (spherical)	12.566	lumens
cantigrade heat units(chu)	1.8	Btu
centimeters (cm)	0.032808	feet
centimeters	0.03937	inches
centimeters	0.01	meters
centimeters	10.000	microns
cords	8	cord-feet
cords	128 (or 4x4x8)	cubic feet
cubic centimeters	3.5314667	cubic feet
cubic centimeters	0.06102	cubic inches
cubic centimeters	$1x10^{-6}$	cubic meters
cubic centimeters	0.001	liters
cubic centimeters	0.0338	ounces (U.S. fluid)
cubic feet (ft^3)	0.02831685	cubic meters
cubic feet	7.4805	gallons (U.S.,liq)
cubic feet	28.31685	liters
cubic feet	29.922	quarts (U.S.,liq)
cubic feet	0.037037	cubic yards
cubic feet of common brick	120	pounds
cubic feet of water (60 deg F)	62.366	pounds of water
cubic feet/second	448.83	gallons
cubic inches (in^3)	16.387	cubic centimeters
cubic inches	0.0005787	cubic feet
cubic inches	0.004329	gallons (U.S.,liq)
cubic inches	0.5541	ounces (U.S.,fluid)
cubic meters	$1x10^6$	cubic centimeters
cubic meters	35.314667	cubic feet
cubic meters	264.172	gallons (U.S.,liq)
cubic meters	1,000	liters
cubic yard	27	cubic feet
cubic yard	0.76455	cubic meters
cubic yard	201.97	gallons (U.S.,liq)
cubic yards of sand	2,700	pounds
feet (ft)	30.48	centimeters
feet	12	inches
feet	0.00018939	miles (statute)
foot-candles	1	lumens/sq ft
foot-pounds (ft-lb)	0.001285	Btu
foot-pounds	0.324048	calories
foot-pounds	$5.0505x10^{-7}$	horsepower-hours
foot-pounds	$3.76616x10^{-7}$	kilowatt-hours

APPENDIX 5

Multiply	By	To Obtain
furlong	220	yards
gallons (U.S.,dry)	1.163647	gallons (U.S.,liq)
gallons (U.S.,liq)	3,785.4	cubic centimeters
gallons	0.13368	cubic feet
gallons	231	cubic inches
gallons	0.0037854	cubic meters
gallons	3.7854	liters
gallons	8	pints (U.S.,liq)
gallons	4	quarts (U.S.,liq)
gallons of water	8.3453	pounds of water at 60 deg F
grams (gr)	0.035274	ounces (avdp.)
grams	0.002205	pounds (avdp.)
grams-centimeters	9.3011×10^{-8}	Btu
horsepower	42.4356	Btu/min
horsepower	2.546	Btu/hr
horsepower	33,000	ft lb/min
horsepower	1.014	metric horsepower
horsepower-hours	2,546.14	Btu
horsepower-hours	0.7457	kilowatt-hours
horsepower, metric (chevalvapours)	0.9863	horsepower
inches	2.54	centimeters
inches	0.83333	feet
joules	0.0009485	Btu
joules	0.73756	foot-pounds
joules	0.0002778	watt-hours
joules	1	watt-seconds
kilo calories/gram	1,378.54	Btu/lb
kilograms	2.2046	pounds (avdp)
kilometers	1,000	meters
kilometers	0.62137	miles (statute)
kilometer/hour	54.68	ft/min
kilowatts	56.90	Btu/min
kilowatts	3,414.43	Btu/hr
kilowatts	737.56	ft-lb/sec
kilowatts	1.34102	horsepower
kilowatt hours	3,414.43	Btu
kilowatt hours	2.66×10^{6}	foot-pounds
kilowatt hours	1.34102	horsepower-hours
langleys	1	cal/sq cm
langleys	3.69	Btu/sq ft
langleys/minutes	0.00698	watts/sq cm
liters	1,000	cubic centimeters
liters	0.0353	cubic feet
liters	0.2642	gallons (U.S.,liq)
liters	1.0567	quarts (U.S.,liq)
lumens	0.079577	candle power (spherical)

Multiply	By	To Obtain
lumens(at 5,550 angstroms)	0.0014706	watts
meters	3.2808	feet
meters	39.37	inches
meters	1.0936	yards
micron	10,000	angstroms
micron	0.0001	centimeters
miles (statute)	5,280	feet
miles	1.6093	kilometers
miles	1.760	yards
milliliter	1	cubic centimeter
millimeter	0.1	centimeters
months (mean calendar)	730.1	hours
ounces (avdp)	0.0625	pounds (avdp)
ounces (U.S.,liq)	29.57	cubic centimeters
ounces	1.8047	cubic inches
ounces	0.0625 (or 1/16)	pint (U.S.,liq)
pints (U.S.,liq)	473.18	cubic centimeters
pints	28.875	cubic inches
pints	0.5	quarts (U.S.,liq)
pounds (avdp)	0.45359	kilograms
pounds	16	ounces (avdp)
pounds of water	0.01602	cubic feet of water
pounds of water	0.1198	gallons (U.S.,liq)
pounds of water evaporated at 212 deg F	970.3	Btu
quarts (U.S.,liq)	0.25	gallons (U.S.,liq)
quarts	0.9463	liters
quarts	32	ounces (U.S.,liq)
quarts	2	pints (U.S.,liq)
radians	57.30	degrees
square centimeters	0.0010764	square feet
square centimeters	0.1550	square inches
square feet	2.2957×10^{-5}	acres
square feet	0.09290	square meters
square inches	6.4516	square centimeters
square inches	0.006944	square feet
square kilometers	247.1	acres
square kilometers	1.0764×10^{7}	square feet
square kilometers	0.3861	square miles
square meters	10.7639	square feet
square meters	1.196	square yards
square miles	640	acres
square miles	2.788×10^{7}	square feet
square miles	2.590	square kilometers
square yards	9 (or3x3)	square feet
square yards	0.83613	square meters
therms	1×10^{5}	Btu
tons (long)	1,016	kilograms

APPENDIX 5

Multiply	By	To Obtain
tons	2,240	pounds (avdp)
tons (metric)	1,000	kilograms
tons	2,204.6	pounds (avdp)
tons (short)	907.2	kilograms
tons	2,000	pounds (avdp)
tons	0.907185	metric tons
tons of refrigeration	12.000	Btu/hr
watts	3.4144	Btu/hr
watts	0.05691	Btu/min
watts	14.34	cal/min
watts	0.001341	horsepower
watts	1	joule/sec
watts/sq cm	3,172	Btu/sq ft/hr
watt-hours	3.4144	Btu
watt-hours	860.4	calories
watt-hours	0.001341	horsepower-hours
yards	3	feet
yards	0.9144	meters

2. Fahrenheit-Centigrade Conversion Table

The numbers in the center column refer to the temperature in either Fahrenheit or Centigrade degrees. If it is desired to convert from Fahrenheit to Centigrade degrees, consider the center column as a table of Fahrenheit temperatures and read the corresponding Centigrade temperature in the column at the left. If it is desired to convert from Centigrade to Fahrenheit degrees, consider the center column as a table of Centigrade values, and read the corresponding Fahrenheit temperature on the right.

For conversions not covered in the table, the following formulas are used:

$$F = 1.8C + 32 \qquad C = (F-32)/1.8$$

Deg C		Deg F	Deg C		Deg F
-46	-50	-58	-17.2	1	33.8
-40	-40	-40	-16.7	2	35.6
-34	-30	-22	-16.1	3	37.4
-29	-20	-4	-15.6	4	39.2
-23	-10	14	-15.0	5	41.0
-17.8	0	32-	-14.4	6	42.8

Deg C		Deg F	Deg C		Deg F
-13.9	7	44.6	12.2	54	129.2
-13.3	8	46.4	12.8	55	131.0
-12.8	9	48.2	13.3	56	132.8
-12.2	10	50.0	13.9	57	134.6
-11.7	11	51.8	14.4	58	136.4
-11.1	12	53.6	15.0	59	138.2
-10.6	13	55.4	15.6	60	140.0
-10.0	14	57.2	16.1	61	141.8
-9.4	15	59.0	16.7	62	143.6
-8.9	16	60.8	17.2	63	145.4
-8.3	17	62.6	17.8	64	147.2
-7.8	18	64.4	18.3	65	149.0
-7.2	19	66.2	18.9	66	150.8
-6.7	20	68.0	19.4	67	152.6
-6.1	21	69.8	20.0	68	154.4
-5.6	22	71.6	20.6	69	156.2
-5.0	23	73.4	21.1	70	158.0
-4.4	24	75.2	21.7	71	159.8
-3.9	25	77.0	22.2	72	161.6
-3.3	26	78.8	22.8	73	163.4
-2.8	27	80.6	23.3	74	165.2
-2.2	28	82.4	23.9	75	167.0
-1.7	29	84.2	24.4	76	168.8
-1.1	30	86.0	25.0	77	170.6
-0.6	31	87.8	25.6	78	172.4
0-	32	89.6	26.1	79	174.2
0.6	33	91.4	26.7	80	176.0
1.1	34	93.2	27.2	81	177.8
1.7	35	95.0	27.8	82	179.6
2.2	36	96.8	28.3	83	181.4
2.7	37	98.6	28.9	84	183.2
3.3	38	100.4	29.4	85	185.0
3.9	39	102.2	30.0	86	186.8
4.4	40	104.0	30.6	87	188.6
5.0	41	105.8	31.1	88	190.4
5.6	42	107.6	31.7	89	192.2
6.1	43	109.4	32.2	90	194.0
6.7	44	111.2	32.8	91	195.8
7.2	45	113.0	33.3	92	197.6
7.8	46	114.8	33.9	93	199.4
8.3	47	116.6	34.4	94	201.2
8.9	48	118.4	35.0	95	203.0
9.4	49	120.2	35.6	96	204.8
10.0	50	122.0	36.1	97	206.6
10.6	51	123.8	36.7	98	208.4
11.1	52	125.6	37.2	99	210.2
11.7	53	127.4	37.8	100	212.0

APPENDIX 5

HEAT EQUIVALENTS OF FUELS AND OTHER ENERGY SOURCES

Material	Heating Value[1]	Source[2]	Heat Obtainable[3]
Solids	(Btu/lb)		(Btu/lb)
Anthracite coal	12,700-13,600	(1)	6,800-10,150
Bituminous coal	11,000-14,350	(1)	4,400-10,045
Subbituminous coal	9,000	(1)	
"Good Illinois" coal	8,500	(2)	
Lignite coal	6,900	(1)	
Coke	11,000-12,000	(3)	
Newspaper	8,500	(2)	
Brown paper	7,670	(2)	
Corrugated board	7,400	(2)	
Food cartons	7,700	(2)	
Pulp trays	8,300	(2)	
Waxed milk cartons	11,680	(2)	
Plastic film	13,780	(2)	
Polystyrene	15,730	(2)	
Polyethylene	14,890	(2)	
Typical urban refuse	5,000	(5)	
Wood-general	8,000-10,000		
-green		(4)	3,000-4,600
-dry		(4)	5,300-6,000
LIQUIDS	Btu/gal		Btu/gal
Distillate fuel oils			
-Grade 1	132,900-137,000	(1)	94,000
-Grade 2	137,000-141,800	(1)	97,300
-Grade 4	143,100-148,100	(1)	102,200
Residual fuel oils			
-Grade 5L	146,800-150,000	(1)	
-Grade 5H	149,500-152,000	(1)	
-Grade 6	151,300-155,900	(1)	
Kerosene	133,000		
Gasoline	111,000		
GASES	(Btu/ft^3)		(Btu/ft^3)
Natural gas	1,000-1,050	(1)	780
Commercial propane	2,500	(1)	1,870
Commercial butane	3,200	(1)	2,400
Propane-air or butane-air	500-1,800	(1)	350- 1,250
Acetylene	1,500	(3)	

GASES	(Btu/ft^3)	(Btu/ft^3)
Bio-gas	550	
Methane	950-1,050	
Manufactured gas (from coal)	450	

OTHER SOURCES	POTENTIAL MAXIMUM	HEAT OBTAINABLE
Electricity		
-resistance heating	3,412 Btu kwh	3,413 Btu/kwh
Water/gravity		
-per foot of heat	60 kwh/acre/ft	36 kwh/acre/ft
Wind[4] (per sq ft collector)	1.4 kwh/1,000 ft^3	.8 kwh/1,000 ft^3
-5mph avg		.5 kwh/month
-10 mph avg		4.0 kwh/month
-15 mph avg		8.0 kwh/month
Sun[4] (per sq ft collector)	432 Btu/hr (solar constant, outer atmosphere)	150 Btu/hr

NOTES:

1. Heat of combusion or calorific values. The heat produced by complete combustion of the specific fuei. This value also includes the latent heat generated by the condensation of the water vapor content of the fuel.
2. Sources for the values found in column 2 are:
   (1) ASHRAE . Handbook of Fundamentals, 1972.
   (2) MIT . Technology Review, February, 1972.
   (3) Ram Bux Singh. Biogas Plant. Gobar Gas Research Station, India, 1971.
   (4) Peter Allen. Firewood for Heat . Department of Resources and Economic Development, New Hampshire. Bulletin # 17.
   (5) Power Generation Alternatives. City of Seattle, 1972.
3. Heat obtainable, or useful heat, is equal to the heat of combustion minus heat losses due to incomplete combustion, waste flue gases, water vapor in fuels, equipment limitations, etc. These loses vary between 20% of the heat of combustion for a well-engineered gas or oil unit and 50% for a hand-fired, uncontrolled coal-burning unit.
4. Energy received from the sun and wind varies widely with time and place. These figures are illustrative only.

SOURCE:

Bruce Anderson, Solar Energy: Fundamentals in Building Design (Harrisville, N.H.: Total Environmental Action Press, 1977).

APPENDIX 5

35° NORTH LATITUDE

	N			NE			E			SE		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	3.5	1.6	3.5	3.5	1.6	3.5	3.5	1.6	3.5	3.5	1.6	3.5
5%	4.0	1.8	4.0	3.5	1.7	4.2	3.1	1.6	4.0	3.0	1.5	3.5
10%	4.6	2.0	4.6	3.5	1.8	5.3	2.8	1.6	4.6	2.6	1.5	3.5
15%	5.5	2.2	5.5	3.5	2.0	7.2	1.6	5.5	2.3	2.3	1.4	3.5
20%	6.8	2.5	6.8	3.5	2.2	11.4	2.3	1.7	6.8	2.0	1.3	3.5

40° NORTH LATITUDE

	N			NE			E			SE		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	4.8	2.0	4.8	4.8	2.0	4.8	4.8	2.0	4.8	4.8	2.0	4.8
5%	5.7	2.2	5.7	4.8	2.2	6.2	4.1	2.0	5.7	3.8	1.9	4.8
10%	7.2	2.5	7.2	4.8	2.3	9.1	3.6	2.0	7.2	3.2	1.8	4.8
15%	9.6	2.9	9.6	4.8	2.6	16.6	3.2	2.0	9.1	2.8	1.7	4.8
20%	14.5	3.4	14.5	4.8	2.8	97.5	2.8	2.0	14.5	2.4	1.6	4.8

45° NORTH LATITUDE

	N			NE			E			SE		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2
5%	9.6	2.9	9.6	7.2	2.8	11.2	5.7	2.5	9.6	5.3	2.3	7.2
10%	14.6	3.4	14.6	7.2	3.1	25.6	4.8	2.5	14.6	4.2	2.2	7.2
15%	30.3	4.1	30.3	7.2	3.5	---	4.1	2.6	30.3	3.5	2.0	7.2
20%	---	5.2	---	7.2	4.0	---	3.6	2.6	---	2.9	1.9	7.2

	S			SW			W			NW		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	3.5	1.6	3.5	3.5	1.6	3.5	3.5	1.6	3.5	3.5	1.6	3.5
5%	3.1	1.5	3.1	3.5	1.5	3.0	4.0	1.6	3.1	4.2	1.7	3.5
10%	2.8	1.4	2.8	3.5	1.5	2.6	4.6	1.6	2.8	5.3	1.8	3.5
15%	2.5	1.3	2.5	3.5	1.4	2.3	5.5	1.6	2.5	7.2	2.0	3.5
20%	2.3	1.3	2.3	3.5	1.3	2.3	6.8	1.7	2.3	11.4	2.2	3.5

	S			SW			W			NW		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2
5%	4.1	1.8	4.1	4.8	1.9	3.8	5.7	2.0	4.1	6.2	2.2	4.8
10%	3.6	1.7	3.6	4.8	1.8	3.2	7.2	2.0	3.6	9.1	2.3	4.8
15%	3.2	1.6	3.2	4.8	1.7	2.8	9.6	2.0	3.2	16.6	2.6	4.8
20%	2.8	1.5	2.8	4.8	1.6	2.4	14.5	2.0	2.8	97.5	2.8	4.8

	S			SW			W			NW		
SLOPE	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM	AM	NOON	PM
0%	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2	7.2	2.5	7.2
5%	5.7	2.2	5.7	7.2	2.3	5.3	9.6	2.5	5.7	11.2	2.8	7.2
10%	4.8	2.0	4.8	7.2	2.2	4.2	14.3	2.5	4.8	25.6	3.1	7.2
15%	4.1	1.9	4.1	7.2	2.0	3.5	30.3	2.6	4.1	---	3.5	7.2
20%	3.6	1.7	3.6	7.2	1.9	2.9	---	2.6	3.6	---	4.0	7.2

APPENDIX 6

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