5.5.5 External Wall Criteria for Heating and Cooling

5.5.5.1 The external wall heating criteria (WC_h) and cooling criteria (WC_c) represent limits on cumulative annual heating and cooling energy flux attributable to transmission and solar gain. These limits accommodate variation in internal load and wall heat capacity. They shall be determined for a building envelope design using Equations 5.5–2 and 5.5–6 in Attachment 5B, "Equations to Determine External Wall Heating and Cooling Criteria (WC_c and WC_h) and to Determine Compliance (C_i and H_i) With the Criteria."

5.5.6 Wall Heating and Cooling Compliance Values

5.5.6.1 The wall heating compliance value H_i and the wall cooling compliance value C_i are estimates of the cumulative annual heating and cooling energy flux attributable to heat transmission and solar gains. These estimates consider the effects of variations in internal load and wall heat capacity. They shall be calculated using Equations 5.5–2 and 5.5–6 in Attachment 5B.

5.5.6.3 Applying the Criteria

5.5.6.3.1 The wall criteria shall be applied as follows:

(a) For all buildings that are heated and mechanically cooled, the sum of the calculated wall heating and cooling compliance values, H_i and C_i, for all orientations of the proposed design, as determined in Section 5.5.6, shall not exceed the sum of the corresponding wall criteria for all orientations for wall heating (WC_h) and wall cooling (WC_c).

(b) For buildings that are only heated, the sum of the calculated wall heating compliance values, H_i, for all orientations of the proposed design, as determined in Section 5.5.6, shall not exceed the sum of the corresponding wall heating criterion WC_h for all orientations.

(c) For buildings that are only mechanically cooled, the sum of the calculated cooling compliance values, C_i, for all orientations of the proposed design, as determined from Section 5.5.6, shall not exceed the sum of the corresponding wall cooling criteria, WC_c for all orientations.

5.5.6.4 Constraints on Thermal Transmittance Values

5.5.6.4.1 The compliance calculation procedure in Section 5.5.6.3 allows great flexibility in selecting values for envelope components as long as the overall criteria are met. In calculating compliance, two constraints are imposed on thermal transmittance values for opaque wall assemblies and fenestration assemblies comprising the U_o term, as follows:

(a) *Opaque Wall Assemblies:* The opaque portion of walls with heat capacity (HC) less than 7 Btu/ft²·°F shall have an overall thermal transmittance (U_{ow}) not greater than the value specified in Figure 5.5–4. Procedures, specified in Section 5.3, shall be used to determine acceptable combinations of materials that meet the required value.

(b) *Fenestration Assemblies:* The overall thermal transmittance (U_{of}) of fenestration assemblies shall not exceed 0.81 Btu/h·ft²·°F for all locations with more than 3000 HDD65 if the fenestration area exceeds 10% of the total wall area exposed to the outside air. Thermal transmittance for the fenestration shall be determined using the calculation procedures in Section 5.3.1 and shall include the effects of sash, frames, edge effects, and spacers for multiple-glazed units.

5.5.6.5 Constraint on Daylighting Credit

5.5.6.5.1 For a given orientation, daylight credit may be used in Equations 5.5–2 and 5.5–6 only for that portion of the fenestration that is less than or equal to 65% of the gross wall area of the orientation.

5.5.6.6 Lighting Power Density

5.5.6.6.1 The Lighting Power Density used in calculating the compliance value shall be:

(a) The building average unit Interior Lighting Power Allowance of the proposed design in W/ft² as specified in Section 3.0;

(b) The average of the Lighting Power Budgets for all activity areas within 15 ft of each exterior wall based on the procedures set forth in Section 5.3; or

(c) The actual lighting power density of the proposed design in W/ft², either building average or average of the lighting power within 15 ft of each exterior wall.

5.5.6.7 Equipment Power Density

5.5.6.7.1 The equipment power density used in determining compliance shall be either:

(a) The "Average Receptacle Power Densities" from Table 5.4–32, or

(b) The actual average Equipment Unit Power Density, considering diversity, either building average or average in the activity areas within 15 ft of each exterior wall, not to exceed 1 W/ft².

5.5.6.8 Occupancy Loads

5.5.6.8.1 An occupancy load of 0.6 W/ft² is assumed. If the occupancy loads in the building design are different from this value, use the larger value.

BILLING CODE 6450–01–M

Attachment 5A
List of Cities and Climate Data

NO	CITY	STATE	HDD50	HDD65	WSN	VSEW	VSS	CDD50	CDD65	CDH80	DR	NO HRS T<55	8AM-4PM 55≤T≤69	ACP TABLE
Alabama														
23	Birmingham	AL	765	2882	464	789	908	5182	1825	6272	17.5	720	760	5.4- 7
143	Mobile	AL	164	1580	486	816	919	6478	2419	7479	16.6	408	774	5.4- 9
145	Montgomery	AL	491	2261	462	823	981	5821	2116	8473	19.5	609	734	5.4- 9
Alaska														
2	Adak	AK	3562	8913	280	434	652	124	0	0	9.9	2754	156	5.4-30
9	Anchorage	AK	5301	10540	272	538	926	236	0	0	13.8	2398	521	5.4-30
10	Annette Island	AK	2545	7277	285	482	739	756	12	0	10.1	2169	719	5.4-30
24	Bethel	AK	8285	13449	252	453	789	312	0	0	14.3	2555	347	5.4-31
25	Big Delta	AK	9355	14069	249	527	989	777	16	25	19.0	2141	606	5.4-31
76	Fairbanks	AK	9841	14414	241	492	919	922	19	8	18.2	2083	682	5.4-31
93	Gulkana	AK	8265	13846	257	522	943	498	4	6	18.5	2225	615	5.4-31
105	Juneau	AK	4223	9350	254	410	642	348	0	0	12.7	2367	540	5.4-30
106	King Salmon	AK	6843	11992	270	499	860	330	4	6	15.4	2395	502	5.4-31
109	Kodiak	AK	3775	8896	276	509	852	360	6	0	10.6	2519	384	5.4-30
132	McGrath	AK	9967	14868	246	467	841	578	3	0	15.9	2265	596	5.4-31
152	Nome	AK	9061	14418	242	478	871	119	0	0	9.0	2710	210	5.4-31
208	Summit	AK	9210	14530	247	488	893	155	0	0	13.6	2616	298	5.4-31
231	Yakutat	AK	4486	9714	247	402	650	248	0	0	9.3	2471	439	5.4-30
Arizona														
163	Phoenix	AZ	90	1332	488	1116	1310	7830	3647	34521	21.2	373	746	5.4-13
171	Prescott	AZ	1477	4462	473	1090	1334	3385	895	3973	24.0	1021	725	5.4-16
218	Tucson	AZ	178	1601	500	1112	1280	6822	2769	19657	21.9	399	716	5.4-11
229	Winslow	AZ	1695	4603	471	1092	1338	3708	1141	7347	27.7	1130	634	5.4-16
234	Yuma	AZ	43	782	493	1151	1330	8921	4186	37892	23.5	247	697	5.4-13
Arkansas														
79	Fort Smith	AR	1149	3394	462	842	1005	5307	2077	10413	22.4	925	547	5.4-19
121	Little Rock	AR	912	3091	465	831	981	5351	2055	8450	17.5	865	626	5.4- 9
California														
12	Arcata	CA	582	5020	407	724	926	1038	1	0	8.9	1396	1509	5.4- 4
19	Bakersfield	CA	305	2194	474	1053	1211	5879	2294	15447	28.9	645	848	5.4-10
48	China Lake	CA	409	2444	468	1091	1312	6222	2782	26739	27.4	582	772	5.4-11
58	Daggett	CA	237	1916	475	1102	1309	6516	2720	22302	27.0	472	841	5.4-11
71	El Toro	CA	32	1577	486	977	1163	4764	834	2391	22.3	215	1474	5.4- 6
82	Fresno	CA	492	2700	459	1029	1199	5070	1803	13085	31.8	780	785	5.4- 8
122	Long Beach	CA	54	1483	482	956	1144	4947	900	1616	16.1	263	1502	5.4- 6
123	Los Angeles	CA	3	1494	482	962	1146	4456	472	136	14.1	145	1849	5.4- 6
146	Mount Shasta	CA	1947	5583	419	909	1153	2395	556	2073	16.2	1544	756	5.4-22
156	Oakland	CA	157	2922	453	909	1102	2792	82	23	16.4	770	1905	5.4- 5
167	Point Mugu	CA	8	2193	477	936	1131	3435	145	70	12.3	209	2146	5.4- 5
176	Red Bluff	CA	589	2884	428	951	1177	5110	1930	14404	29.5	860	810	5.4- 8
185	Sacramento	CA	381	2753	444	987	1185	4274	1171	7315	34.6	834	990	5.4- 8
191	San Diego	CA	2	1275	490	950	1121	4865	662	383	11.5	102	1911	5.4- 6
192	San Francisco	CA	186	3238	454	941	1146	2496	73	204	20.2	782	1796	5.4- 5
194	Santa Maria	CA	138	3041	476	950	1128	2663	92	513	20.9	414	2016	5.4- 5
209	Sunnyville	CA	142	2708	456	947	1145	3112	204	421	16.9	610	1794	5.4- 5
Colorado														
50	Colorado Springs	CO	2587	5996	435	976	1321	2557	491	2075	24.0	1357	725	5.4-22
62	Denver	CO	2652	6083	428	971	1321	2611	567	2934	25.5	1329	739	5.4-22
68	Eagle	CO	4232	8317	432	976	1296	1480	90	1008	35.4	1650	660	5.4-28
86	Grand Junction	CO	2616	5701	438	1003	1303	3611	1221	6147	27.4	1383	518	5.4-24
173	Pueblo	CO	2223	5285	442	992	1309	3384	971	5899	27.5	1077	720	5.4-22
Connecticut														
95	Hartford	CT	2953	6277	384	646	834	2857	706	2197	23.7	1459	598	5.4-21
Delaware														
227	Wilmington	DE	2133	5084	414	726	921	3602	1078	2188	17.2	1289	617	5.4-20

NO	CITY	STATE	WDD50	WDD65	WSN	WSEW	WSS	CDD50	CDD65	CDH80	DR	NO HRS 8AM-4PM T<55	NO HRS 8AM-4PM 55≤T≤69	ACP TABLE
District of Columbia														
223	Washington	DC	2004	4328	419	724	905	3734	1083	3592	18.6	1205	657	5.4-20
Florida														
11	Apalachicola	FL	163	1366	508	887	971	6967	2695	8289	14.3	322	778	5.4-10
60	Daytona	FL	81	787	503	860	953	7404	2635	5252	14.8	177	641	5.4-10
104	Jacksonville	FL	206	1357	495	849	943	7045	2721	7488	16.4	354	674	5.4-10
136	Miami	FL	3	185	527	874	936	9338	4045	9166	12.4	55	259	5.4-12
160	Orlando	FL	33	532	511	881	974	8288	3312	9757	17.1	131	571	5.4-12
211	Tallahassee	FL	307	1721	495	845	944	6462	2401	7323	16.1	421	747	5.4-10
212	Tampa	FL	37	575	513	890	974	7985	3047	8905	14.9	147	592	5.4-10
224	West Palm Beach	FL	0	177	519	846	906	9203	3904	10324	13.1	22	303	5.4-12
Georgia														
15	Atlanta	GA	866	3070	467	807	930	4837	1566	3799	17.6	915	739	5.4- 7
16	Augusta	GA	664	2584	468	803	933	5458	1904	6904	21.3	690	774	5.4- 7
128	Macon	GA	514	2330	476	822	939	5769	2111	8097	18.7	667	737	5.4- 9
196	Savannah	GA	410	1967	474	805	926	6112	2194	6308	16.6	529	725	5.4- 9
Hawaii														
22	Barbers Point	HI	0	3	592	978	965	9314	3342	3617	11.2	1	97	5.4- 2
97	Hilo	HI	0	0	557	817	805	8494	3019	1112	11.0	0	153	5.4- 2
98	Honolulu	HI	0	0	588	953	932	9625	4150	4537	9.8	0	69	5.4- 2
120	Lihue	HI	0	2	567	895	893	9219	3746	1912	9.6	0	140	5.4- 2
Idaho														
30	Boise	ID	2276	5667	399	916	1228	2828	744	4512	28.9	1542	647	5.4-22
117	Lewiston	ID	2015	5426	370	729	988	2709	645	4121	29.7	1467	748	5.4-20
166	Pocatello	ID	3404	7075	405	935	1262	2330	526	3293	32.8	1681	546	5.4-27
Illinois														
47	Chicago	IL	3000	6151	402	729	936	3339	1015	3190	16.6	1426	613	5.4-21
144	Moline	IL	3085	6250	405	736	959	3204	894	2808	19.5	1357	640	5.4-21
207	Springfield	IL	2490	5448	422	768	962	3675	1158	4038	20.2	1260	600	5.4-23
Indiana														
75	Evansville	IN	1948	4625	426	736	890	4063	1265	4288	18.4	1141	611	5.4-23
80	Fort Wayne	IN	3023	6145	395	664	826	3096	743	1629	17.7	1400	601	5.4-21
101	Indianapolis	IN	2624	5620	407	692	851	3430	951	2263	18.0	1375	602	5.4-21
204	South Bend	IN	3038	6280	396	690	857	2917	684	1840	21.1	1415	635	5.4-21
Iowa														
35	Burlington	IA	3009	6094	419	802	1030	3393	1002	2598	17.1	1354	649	5.4-21
63	Des Moines	IA	3275	6447	413	788	1027	3116	812	2383	17.5	1423	667	5.4-25
130	Mason City	IA	4311	7735	400	783	1053	2708	658	1882	20.8	1548	610	5.4-26
202	Sioux City	IA	3608	6750	406	794	1064	3326	993	3488	18.6	1433	602	5.4-25
Kansas														
66	Dodge City	KS	2280	5131	450	942	1196	4008	1384	7186	26.0	1252	637	5.4-24
84	Goodland	KS	2757	6090	434	935	1228	3047	905	5147	26.3	1358	625	5.4-22
215	Topeka	KS	2458	5201	434	837	1068	4120	1388	5212	22.3	1192	608	5.4-23
Kentucky														
56	Covington	KY	2154	5030	408	687	843	3656	1057	2638	18.3	1316	661	5.4-20
119	Lexington	KY	1921	4649	425	729	872	3904	1157	2853	15.6	1211	618	5.4-23
124	Louisville	KY	1851	4539	424	727	883	4144	1357	4716	17.6	1192	636	5.4-23
Louisiana														
23	Baton Rouge	LA	237	1573	488	806	889	6682	2543	8814	17.2	440	677	5.4- 9
113	Lake Charles	LA	214	1455	489	795	864	6849	2615	7833	14.8	396	668	5.4- 9
148	New Orleans	LA	179	1392	497	838	923	6840	2578	7380	15.1	324	789	5.4- 9
201	Shreveport	LA	447	2265	434	843	954	6022	2365	10039	18.1	687	697	5.4- 9
Maine														
21	Bangor	ME	4132	7998	378	693	950	1853	243	454	21.5	1721	669	5.4-26
38	Caribou	ME	5297	9483	357	649	922	1410	121	203	18.1	1862	692	5.4-29
169	Portland	ME	3531	7305	376	643	856	1946	245	399	19.6	1604	665	5.4-25

NO	CITY	STATE	HDD50	HDD65	VSN	VSEW	VSS	CDD50	CDD65	CDH80	DR	NO HRS 8AM-4PM T<55	NO HRS 8AM-4PM 55<T<69	ACP TABLE
aryland														
30	Baltimore	MD	2020	4946	419	739	932	3683	1134	3825	18.6	1268	593	5.4-20
101	Patuxent	MD	1418	4002	429	758	943	4180	1289	2966	12.9	1118	729	5.4-17
assachusetts														
31	Boston	MA	2416	5775	387	659	849	2810	695	1601	16.5	1495	713	5.4-20
ichigan														
7	Alpena	MI	4282	8164	371	661	862	1928	335	894	17.3	1707	695	5.4-26
64	Detroit	MI	2799	5997	390	676	858	3199	922	2238	18.8	1404	632	5.4-21
73	Flint	MI	3471	6917	379	641	811	2502	473	921	18.1	1563	634	5.4-25
87	Grand Rapids	MI	3392	6777	390	688	872	2680	590	1461	22.2	1562	622	5.4-25
195	Sault Sainte Marie	MI	5087	9282	359	640	858	1399	119	246	21.0	1838	733	5.4-29
216	Traverse City	MI	3934	7654	369	642	818	2193	438	1124	21.0	1651	679	5.4-25
innesota														
67	Duluth	MN	5797	9918	355	633	886	1511	157	258	20.0	1882	650	5.4-29
102	International Falls	MN	6414	10535	351	669	962	1473	119	167	22.0	1870	656	5.4-29
140	Minneapolis	MN	4563	8060	380	709	972	2751	773	2509	20.7	1620	566	5.4-26
181	Rochester	MN	4544	8100	383	691	927	2360	442	590	18.8	1584	652	5.4-26
ississippi														
103	Jackson	MS	546	2424	481	833	942	5927	2330	8789	17.2	646	640	5.4- 9
135	Meridian	MS	546	2446	480	811	905	5723	2148	9508	20.2	613	719	5.4- 9
issouri														
51	Columbia	MO	2225	4994	431	790	972	3940	1234	4242	21.5	1189	633	5.4-23
186	Saint Louis	MO	2111	4860	432	797	983	4193	1467	5379	18.7	1124	614	5.4-23
206	Springfield	MO	1839	4509	446	812	982	4115	1311	4170	20.4	1215	544	5.4-23
ontana														
26	Billings	MT	3627	7156	380	814	1160	2544	598	2695	25.6	1650	617	5.4-25
57	Cutbank	MT	4718	8941	357	768	1150	1368	117	702	27.6	1834	672	5.4-26
65	Dillon	MT	4140	8210	386	838	1187	1564	159	784	28.6	1814	639	5.4-26
83	Glasgow	MT	5082	8828	361	752	1115	2272	543	2642	26.0	1688	570	5.4-29
88	Great Falls	MT	3728	7454	366	776	1133	2199	450	1886	26.7	1684	641	5.4-25
96	Helena	MT	3926	7817	372	771	1098	1911	328	1771	28.3	1784	651	5.4-25
118	Lewistown	MT	4027	8089	368	753	1084	1629	216	1270	29.8	1740	673	5.4-26
138	Miles City	MT	4435	7989	374	800	1156	2694	773	4364	26.9	1588	565	5.4-26
142	Missoula	MT	3492	7560	363	704	957	1629	221	1513	30.8	1843	658	5.4-25
ebraska														
85	Grand Island	NE	3315	6477	420	843	1115	3309	996	4580	24.5	1431	611	5.4-25
155	North Platte	NE	3447	6905	419	880	1183	2731	715	3468	26.2	1514	592	5.4-27
159	Omaha	NE	2981	5968	414	806	1066	3618	1130	3883	19.6	1355	586	5.4-21
197	Scottsbluff	NE	3335	6900	413	861	1168	2603	693	3745	28.3	1457	620	5.4-27
evada														
72	Elko	NV	3345	7178	420	1000	1332	1997	355	4065	37.8	1540	569	5.4-27
73	Ely	NV	3683	7666	432	1014	1350	1650	157	1317	30.1	1529	683	5.4-27
116	Las Vegas	NV	449	2399	456	1136	1417	6567	3043	26408	25.5	604	719	5.4-11
125	Lovelock	NV	2438	5845	418	1094	1452	2813	745	6659	34.7	1358	606	5.4-22
178	Reno	NV	2181	5841	428	1068	1401	2180	365	4059	39.3	1306	752	5.4-22
214	Tonopah	NV	2308	5652	427	1130	1502	2742	611	3777	28.4	1257	660	5.4-22
228	Winnemucca	NV	2774	6471	418	1014	1350	2264	486	6366	41.0	1383	608	5.4-22
233	Yucca Flats	NV	1664	4802	450	1112	1399	3378	1041	11568	35.9	1004	670	5.4-16
ew Hampshire														
54	Concord	NH	3742	7425	375	630	824	2254	463	1865	22.6	1533	683	5.4-25
ew Jersey														
114	Lakehurst	NJ	2174	5265	407	712	917	3299	915	3019	20.5	1312	645	5.4-20
151	Newark	NJ	2027	4956	406	710	912	3556	1009	2487	17.7	1325	644	5.4-20

NO	CITY	STATE	HDD50	HDD65	VSW	VSEW	VSS	CDD50	CDD65	CDH80	DP	NO HRS 8AM-4PM T<55	NO HRS 8AM-4PM 55≤T≤69	ACP TABLE
New Mexico														
5	Albuquerque	NM	1633	4423	469	1105	1361	3942	1257	5705	25.3	1148	703	5.4-18
49	Clayton	NM	2138	5176	457	1019	1310	3122	685	2093	20.0	1150	770	5.4-22
134	Roswell	NM	1008	3486	490	1081	1220	4536	1539	11135	26.1	825	677	5.4-18
217	Truth or Consequences	NM	1074	3592	488	1113	1326	4457	1500	6882	23.4	889	744	5.4-18
219	Tucumcari	NM	1344	3922	470	1046	1300	4451	1554	8424	26.9	914	710	5.4-18
New York														
4	Albany	NY	3488	6770	395	719	942	2812	619	1308	19.7	1487	605	5.4-25
27	Binghamton	NY	3885	7397	370	592	733	2373	410	672	18.5	1657	662	5.4-25
34	Buffalo	NY	3213	6721	371	609	746	2476	509	779	19.2	1571	697	5.4-25
131	Massena	NY	4583	8397	380	708	942	2026	365	913	20.9	1674	627	5.4-26
149	New York (Central Pk)	NY	1986	5022	392	650	817	3273	834	911	12.5	1335	790	5.4-20
150	New York (LAG)	NY	1986	5022	392	650	817	3273	834	911	12.5	1335	790	5.4-20
182	Rochester	NY	3482	6995	374	622	771	2557	595	1642	20.1	1612	608	5.4-25
210	Syracuse	NY	3448	6856	371	611	764	2579	513	926	20.2	1521	730	5.4-25
North Carolina														
13	Asheville	NC	1407	4203	449	782	946	3442	763	1298	21.1	1083	915	5.4-15
37	Cape Hatteras	NC	635	2745	460	819	972	4978	1613	2039	10.0	765	820	5.4- 7
43	Charlotte	NC	1086	3412	456	809	968	4698	1549	4299	19.6	892	777	5.4-17
45	Cherry Point	NC	569	2556	461	826	996	5277	1708	3614	15.2	690	757	5.4- 7
90	Greensboro	NC	1261	3760	449	810	994	4274	1298	3642	17.4	1018	718	5.4-17
174	Raleigh	NC	1131	3509	445	774	935	4485	1389	3697	16.5	918	740	5.4-17
North Dakota														
29	Bismarck	ND	5196	8992	371	766	1114	2175	496	2067	27.8	1724	556	5.4-29
77	Fargo	ND	5582	9242	371	751	1077	2388	573	2288	22.2	1730	546	5.4-29
141	Minot	ND	5336	9178	358	724	1059	2064	431	1570	24.5	1800	581	5.4-29
Ohio														
3	Akron	OH	2821	6172	396	664	812	2845	661	1100	17.3	1460	680	5.4-21
53	Columbus	OH	2424	5493	401	671	819	3195	789	2268	22.6	1375	708	5.4-20
59	Dayton	OH	2573	5549	408	696	855	3367	868	1346	17.1	1388	611	5.4-20
213	Toledo	OH	3132	6514	393	676	853	2791	698	1794	17.8	1500	652	5.4-21
232	Youngstown	OH	3129	6557	383	624	760	2593	546	1128	21.4	1523	679	5.4-21
Oklahoma														
157	Oklahoma City	OK	1417	3825	465	875	1053	4901	1834	8878	20.8	980	733	5.4-18
220	Tulsa	OK	1429	3732	453	820	991	5244	2072	10065	19.7	983	591	5.4-19
Oregon														
14	Astoria	OR	1080	5226	350	588	782	1357	29	145	12.3	1571	1236	5.4-14
133	Medford	OR	1531	4893	405	814	1005	2681	568	4081	32.9	1442	749	5.4-15
154	North Bend	OR	629	4678	392	740	977	1429	2	0	11.8	1351	1553	5.4- 4
170	Portland	OR	1151	4577	364	647	841	2321	272	1086	22.8	1421	1060	5.4-14
177	Redmond	OR	2535	6665	395	835	1127	1573	228	2390	34.4	1631	695	5.4-20
187	Salem	OR	1128	4926	373	680	874	1849	172	1224	29.3	1499	916	5.4-14
Pennsylvania														
6	Allentown	PA	2692	5760	401	682	864	3105	698	1146	17.0	1335	710	5.4-21
18	Avoca	PA	2931	6236	389	646	811	2823	652	1547	19.7	1505	705	5.4-21
74	Erie	PA	3006	6426	384	646	792	2527	472	378	14.8	1532	716	5.4-21
94	Harrisburg	PA	2302	5251	404	687	864	3518	992	2860	20.1	1342	648	5.4-20
162	Philadelphia	PA	2044	4923	408	701	889	3661	1065	3172	17.1	1286	646	5.4-20
165	Pittsburgh	PA	2773	5907	392	642	780	2989	648	1040	19.0	1426	700	5.4-21
Rhode Island														
172	Providence	RI	2610	6022	393	677	874	2756	693	1284	16.8	1429	684	5.4-21
South Carolina														
41	Charleston	SC	435	2194	467	796	925	5722	2005	5249	16.4	570	767	5.4- 9
52	Columbia	SC	694	2666	467	816	953	5613	2110	8541	19.5	741	705	5.4- 9
91	Greenville	SC	907	3220	459	814	971	4563	1400	3494	17.7	866	851	5.4- 7

NO	CITY	STATE	HDD50	HDD65	VSN	VSEW	VSS	CDD50	CDD65	CDH80	DR	NO HRS T<55	8AM-4PM 55≤T≤69	ACP TABLE
South Dakota														
100	Huron	SD	4820	8351	390	769	1044	2718	774	3739	24.5	1630	545	5.4-26
164	Pierre	SD	4028	7358	392	822	1147	3079	934	5262	24.2	1564	557	5.4-26
175	Rapid City	SD	3672	7229	394	819	1142	2581	663	3477	28.2	1530	572	5.4-25
203	Sioux Falls	SD	4240	7683	394	778	1078	2811	779	3029	20.2	1553	599	5.4-26
Tennessee														
44	Chattanooga	TN	1232	3595	444	738	869	4652	1541	5079	17.6	1050	684	5.4-17
108	Knoxville	TN	1283	3818	446	762	898	4455	1514	3840	17.8	1076	703	5.4-17
134	Memphis	TN	1034	3259	460	806	935	5319	2069	7807	19.2	865	851	5.4-19
147	Nashville	TN	1165	3609	443	749	863	4583	1552	5078	18.2	897	749	5.4-17
Texas														
1	Abilene	TX	792	2714	494	924	1066	5968	2416	13206	21.5	760	648	5.4-10
8	Amarillo	TX	1592	4331	471	1013	1253	4113	1377	6763	23.9	1109	680	5.4-18
17	Austin	TX	271	1735	503	877	972	6873	2862	14093	19.3	564	664	5.4-10
32	Brownsville	TX	35	642	547	908	908	8531	3664	12218	14.8	191	422	5.4-12
55	Corpus Christi	TX	106	889	529	906	946	8200	3508	13109	17.2	249	543	5.4-12
61	Del Rio	TX	186	1397	511	903	1008	7376	3112	14870	19.8	474	732	5.4-10
70	El Paso	TX	522	2605	503	1133	1306	5617	2225	13224	21.3	660	735	5.4-10
81	Fort Worth	TX	605	2354	485	875	994	6174	2448	13682	20.5	673	772	5.4-10
99	Houston	TX	195	1346	490	805	883	7215	2891	10569	18.2	352	703	5.4- 9
107	Kingsville	TX	49	874	527	881	922	8302	3652	15512	19.2	260	523	5.4-12
115	Laredo	TX	65	842	532	900	936	8827	4130	25225	21.4	286	598	5.4-13
126	Lubbock	TX	1173	3643	488	1070	1267	4754	1749	9827	25.1	917	743	5.4-18
127	Lufkin	TX	370	1846	492	848	942	6667	2668	11737	21.5	478	681	5.4-10
137	Midland	TX	634	2573	504	1079	1247	5695	2159	11177	25.9	698	729	5.4-10
168	Port Arthur	TX	167	1416	497	824	900	6888	2662	8837	17.4	384	697	5.4- 9
189	San Angelo	TX	538	2110	503	944	1076	6522	2619	14621	20.6	641	619	5.4-10
190	San Antonio	TX	261	1579	510	878	955	7170	3013	13841	20.1	462	690	5.4-10
200	Sherman	TX	699	2708	476	862	996	5844	2378	12065	20.2	785	721	5.4-10
221	Waco	TX	488	2166	495	874	972	6676	2879	15658	21.1	651	622	5.4-10
226	Wichita Falls	TX	984	3049	480	911	1077	5708	2299	14487	18.8	802	723	5.4-10
Utah														
33	Bryce Canyon	UT	4709	9288	445	1063	1386	899	4	69	30.0	1660	841	5.4-28
40	Cedar City	UT	2592	5888	447	1054	1342	2802	624	3119	27.1	1392	629	5.4-22
188	Salt Lake City	UT	2570	5975	422	975	1266	3011	941	7030	29.1	1426	586	5.4-22
Vermont														
36	Burlington	VT	4211	7932	382	698	925	2118	365	490	18.3	1697	637	5.4-26
Virginia														
153	Norfolk	VA	1185	3609	443	792	964	4636	1586	4554	15.0	1014	685	5.4-17
179	Richmond	VA	1322	3895	430	745	923	4225	1323	4021	17.6	996	716	5.4-17
180	Roanoke	VA	1520	4192	433	763	946	3986	1183	3306	19.0	1148	713	5.4-17
Washington														
158	Olympia	WA	1546	5550	351	619	819	1550	79	466	26.4	1577	985	5.4-14
198	Seattle/Tacoma	WA	1382	5281	350	621	828	1683	106	256	16.5	1700	982	5.4-14
205	Spokane	WA	2983	6727	363	758	1064	2094	363	1595	25.3	1669	640	5.4-21
225	Whidbey Island	WA	1179	5274	344	630	878	1403	22	7	14.8	1671	1169	5.4-14
230	Yakima	WA	2323	5877	373	790	1091	2370	449	3285	31.2	1413	703	5.4-20
West Virginia														
42	Charleston	WV	1816	4587	409	667	798	3712	1008	3054	20.8	1215	704	5.4-20
Wisconsin														
69	Eau Claire	WI	4751	8285	376	683	923	2545	603	1898	18.2	1565	661	5.4-26
89	Greenbay	WI	4310	8039	380	696	947	2172	426	957	22.1	1604	651	5.4-26
112	La Crosse	WI	3838	7243	386	701	937	2786	716	2121	18.9	1568	644	5.4-25
129	Madison	WI	4009	7466	391	717	955	2559	542	1329	19.1	1511	658	5.4-26
139	Milwaukee	WI	3586	7121	396	724	941	2427	487	1013	17.1	1587	618	5.4-25

NO	CITY	STATE	HDD50	HDD65	VSN	VSEW	VSS	CDD50	CDD65	CDH50	DP	NO HRS T<55	8AM-4PM 55≤T≤69	ACP TABLE
Wyoming														
39	Casper	WY	3824	7617	403	961	1343	2177	495	2699	29.8	1670	535	5.4-27
46	Cheyenne	WY	3435	7218	416	906	1267	1963	271	1040	26.4	1618	603	5.4-27
183	Rock Springs	WY	4407	8391	411	1012	1395	1698	207	702	29.1	1828	552	5.4-28
199	Sheridan	WY	3605	7366	387	806	1133	2074	360	2105	30.8	1650	574	5.4-25
Other Locations Outside U.S.A.														
92	Guantanamo Bay	CU	0	0	612	1045	1018	11071	5596	18452	15.5	0	17	5.4- 3
110	Koror Island	PN	0	0	662	890	827	11435	5960	14548	9.5	0	0	5.4- 3
111	Kwajalein Island	PN	0	0	678	961	888	11635	6160	16217	8.2	0	0	5.4- 3
193	San Juan	PR	0	0	608	963	931	10648	5173	11563	12.7	0	14	5.4- 3
222	Wake Island	PN	0	0	609	1002	977	10369	5394	10167	9.7	0	0	5.4- 3

ATTACHMENT 5B TO SECTION 435.105
EQUATIONS TO DETERMINE EXTERNAL WALL HEATING AND COOLING CRITERIA
AND
TO DETERMINE COMPLIANCE WITH THE CRITERIA

5B.1 Equations and Coefficients

This attachment contains the external wall equations for use in determining external wall heating and cooling criteria (WC_h and WC_c) and for determining compliance (H_i and C_i) with the criteria for north, east, south and west orientations. For NE, NW, SW and SE orientations, WC_h, WC_c, H_i and C_i shall be determined by treating half of each wall area as though it faces each of the adjacent cardinal directions, e.g., treat NE as half north and half east.

Equations 5.5-2 and 5.5-6 are statistical regression equations that correlate envelope cooling and heating loads, respectively, from thermal transmission and solar gains, as modified by internal gain and mass, to the physical components of the envelope. Seven individual terms are identified for both cooling and heating that correlate variables with physical meaning such as U-values, internal gains, and weather related variables. They are as follows:

1. CLU, CLUO, CLXUO: Terms that correlate cumulative annual cooling loads with thermal transmittance of the wall.

2. CLM: Term that correlates cumulative annual cooling loads with heat capacity of the wall.

3. CLG: Term that correlates cumulative annual cooling loads with internal gains from occupant light and equipment.

4. CLS: Term that correlates cumulative annual cooling loads with incident solar gains.

5. CLC: Term that correlates cumulative annual cooling loads with climate variables for a specific location.

6. HLU, HLUO, HLXUO: Terms that correlate cumulative annual heating loads with thermal transmittance of the wall.

7. HLM: Term that correlates cumulative annual heating loads with heat capacity of the wall.

8. HLG: Term that correlates cumulative annual heating loads with internal gains from occupants, lights, and equipment.

9. HLS: Term that correlates cumulative annual heating loads with incident solar gains.

10. HLC: Term that correlates cumulative annual heating loads with climate variables for a specific location.

The cooling and heating equations with their coefficients follow.

Cooling Equation

$$UC_c \text{ or } C_1 = CLU_i + CLUO_i + CLXUO_i + CLM_i + CLG_i + CLS_i + CLC_i$$

Equation 5.5-2

Where:

i = for each orientation

j = for each wall mass construction type for the orientation

$$\begin{aligned}
CLU = FO \times U_{ow} \times\ & [\ CU1 \times CDH80 \\
& + CU2 \times CDH80^2 \\
& + CU3 \times (VS \times CDH80)^2 \\
& + CU4 \times DR\ ]
\end{aligned}$$

$$\begin{aligned}
CLUO = FC \times UOC \times\ & [\ CUO1 \times EA \times VS \times CDD50 \\
& + CUO2 \times G \\
& + CUO3 \times G^2 \times EA^2 \times VS \times CDD50 \\
& + CUO4 \times G^2 \times EA^2 \times VS \times CDD65\ ]
\end{aligned}$$

$$\begin{aligned}
CLXUO = FC \times 1/UOC \times\ & [\ CXUO1 \times EA \times VS \times CDD50 \\
& + CXUO2 \times EA \times (VS \times CDD50)^2 \\
& + CXUO3 \times G \times CDD50 \\
& + CXUO4 \times G^2 \times EA^2 \times VS \times CDD50 \\
& + CXUO5 \times G^2 \times CDD65\ ]
\end{aligned}$$

$$\begin{aligned}
CLM = FO_j \times CMC_i \times\ & [\ CM1 + CM2 \times EA \times VS \times CDD50 \\
& + CM3 \times EA \times VS \times CDD65 \\
& + CM4 \times EA^2 \times VS \times CDD50 \\
& + CM5 \times G^2 \times CDD65 \\
& + CM6 \times G \times CDD50 \\
& + CM7 \times G \times CDD65 \\
& + CM8 \times G \times EA \times VS \times CDD50\ ]
\end{aligned}$$

$$\begin{aligned}
CLG = FC \times (\ G \times\ & [\ CG1 + CG2 \times CDD50 \\
& + CG3 \times EA \times (VS \times CDD50)^2 \\
& + CG4 \times EA^2 \times VS \times CDD50 \\
& + CG5 \times CDD65 \\
& + CG6 \times CDD50^3 \\
& + CG7 \times CDD65^3\ ] \\
& + G^2 \times\ [\ CG8 \times EA \times VS \times CDD50 \\
& + CG9 \times EA^2 \times VS \times CDD50\ ]\ )
\end{aligned}$$

$$
\begin{aligned}
CLS = FC \times (EA \times [\ & CS1 + CS2 \times VS \times CDD50 \\
& + CS3 \times (VS \times CDD50)^2 \\
& + CS4 \times VS \times CDD65 \\
& + CS5 \times (VS \times CDD65)^2\ ] \\
& + EA^2 \times [\ CS6 + CS7 \times (VS \times CDD65)^2\ ]\ )
\end{aligned}
$$

$$
\begin{aligned}
CLC = FC \times [\ & CC1 \times CDD50 \\
& + CC2 \times CDD50^2 \\
& + CC3 \times CDH80 \\
& + CC4 \times CDH80^2 \\
& + CC5 \times CDD65 \\
& + CC6 \times (VS \times CDD65)^2 \\
& + CC7 \times VS \times CDD50 \\
& + CC8 \times (VS \times CDD50)^2 \\
& + CC9 \times (VS \times CDH80)^2 \\
& + CC10 \times VS \\
& + CC11 \times DR \\
& + CC12 \times DR^2 \\
& + CC13\ ]
\end{aligned}
$$

NOTE: The coefficients for various orientations in the equations listed above are found in Table 58-2. If WC_c or C_1 is less than 0.0, WC_c or C_1 is set equal to 0.0.

Where:

Climate Data

CDD50 = Cooling degree-days base 50 °F

CDD65 = Cooling degree-days base 65 °F

CDH80 = Cooling degree-hours base 80 °F

DR = Average daily temperature range for warmest month.

VS = Annual average daily incident solar energy on facade under consideration, Btu/ft^2/day.

Building Data

FC = Wall area (opaque and glazed) of zone under consideration divided by total wall area (opaque and glazed) of all zones.

FO = Opaque wall area of zone under consideration divided by total wall area (opaque and glazed) of all zones. If multiple mass constructions are present, the FO_j is calculated for each construction j and used to form the area weighted mass correction.

U_{OW} = Area average U-value of opaque walls (including those of mass construction) in zone under consideration.

UOC = Area average U-value of wall (opaque and glazed, evaluated under cooling conditions) in zone under consideration. UOC is equal to UOH.

WWR = Window wall ratio for zone under consideration; defined as fenestration area divided by total wall area (opaque and glazed).

EA = Effective aperature fraction for zone under consideration, where:

$$EA = WWR \times SC_x \times S_{ec}$$

Equation 5.5-3

Where:

S_{ec} = The cooling adjustment factor for horizontal external shading projections:

For $0.0 \leq PF \leq 0.5$ from Equation 5.4-1

For the north orientation:

$$S_{ec} = 1 - 0.4 \times PF$$

Equation 5.5-3a

For the east, south and west orientations:

$$S_{ec} = 1.0 - 1.4877 \times PF + 1.0489 \times PF^2$$

Equation 5.5-3b

G = Effective internal gain (W/ft^2) for zone under consideration, where:

$$G = E_p + L_p \times (1 - R_c \times K_d) + O_l$$

Equation 5.5-4

Where:

L_p = Lighting power, from Section 5.5.7.4

E_p = Equipment power, from Section 5.5.7.5

R_c = The ratio of the electric lights in the same space served by the orientation that have automatic controls for daylighting.

O_l = Occupant load adjustment, from Section 5.5.7.6

$$K_d = 5.871 \, (WWR \times VLT \times S_{ec}) - 13.311 \, (WWR \times VLT \times S_{ec})^2$$

Equation 5.5-4a

If $(WWR \times VLT \times S_{ec}) > 0.22$, then $K_d = 0.647$

Where:

WWR = As defined above, but not to exceed a maximum value of 0.65 in Equation 5.5-4a, per Section 5.5.7.3.

VLT = Visible light transmittance of the glazing material, as defined in Section 5.5.2.1, including any shading devices present that modify the visible transmittance of the glazing material.

CMC = Mass correction (Cooling Delta Load Factor) from Equation 5.5-5. If multiple mass constructions are present, each CMC_j is evaluated separately and combined by area weighting. If the U-value of the mass wall is less than 0.05, then $U_{ow} = 0.05$ shall be used to calculate the CMC. If the value of HC is greater than 20, then HC = 20 shall be used to calculate the CMC.

COOLING DELTA LOAD FACTOR EQUATIONS

Equation 5.5-5 is used to predict the Cooling Delta Load Factor values.

CMC = Cooling Delta Load Factor =

$$\left(1 - e^{-CP_1(HC-1)}\right)\left(CP_2 + CP_3 U - \frac{CP_4}{1 + (CP_5 + CP_6 U)e^{-(CP_7 + CP_8 U^2)(HC-1)}}\right)\left(\frac{1.0}{0.7}\right)$$

Equation 5.5-5

Where:

HC = Wall Heat Capacity (Btu/ft$^{2\cdot}$°F).

U = Wall U-Value (Btu/h/ft$^{2\cdot}$°F).

A = (Cooling degree-hours base 80 °F)/10000 + 2 (°F·h).

B = (Daily Range)/10 + (°F).

Where:

$CP_1 = C_5$

$CP_2 = C_{15}/B^3 + C_{16}/(A^2B^2) + C_{17}$

$CP_3 = C_1/A^3 + C_2B^3 + C_2B^3 + C^3/(A^2\sqrt{B}) + C_4$

$CP_4 = C_{12}/(A^2B^2) + C_{13}/B^3 + C_{14}$

$CP_5 = C_{18}$

$CP_6 = C_6 LN(A)\sqrt{B} + C_7$

LN = Natural Logarithm

$CP_7 = C_{19}/(A^2B^2) + C_{20}/(AB) + C_{21}A^2/\sqrt{B} + C_{22}$

$CP_8 = C_8/(A^2B^2) + C_9/(AB) + C_{10}A^2/\sqrt{B} + C_{11}$

The coefficients C1 through C22 are taken from the following table, Table 58-1.

HEATING EQUATION

$$WC_h \text{ or } H_1 = \Sigma\,(HLU_i + HLUO_i + HLXUO_i + HLM_i + HLG_i + HLS_i + HLC_i)$$

Equation 5.5-6

Where:

i = for each orientation

j = for each wall mass construction type for the orientation

$HLU = FO \times U_{OW} \times [\,HU1 \times HDD50 + HU2 \times (VS \times HDD65)^2\,]$

$HLUO = FC \times UOH \times [\,HUO1 \times HDD50 + HUO2 \times HDD65 + HUO3 \times EA \times VS \times HDD65\,]$

$HLXUO = FC \times (\,(1/UOH) \times [\,HXUO1 \times EA \times (VS \times HDD50)^2 + HXUO2 \times EA \times (VS \times HDD65)^2\,] + (1/UOH^2) \times [\,HXUO3 \times EA^2 \times VS \times HDD65\,]\,)$

$HLM = FO_j \times HMC_j \times [\,HM1 + HM2 \times G \times UOH \times HDD65 + HM3 \times G^2 \times EA^2 \times VS \times HDD50 + HM4 \times UOH \times EA \times VS \times HDD65 + HM5 \times UOH \times HDD50 + HM6 \times EA \times (VS \times HDD65)^2 + HM7 \times EA^2 \times VS \times HDD65/UOH\,]$

$$HLG = FC \times (G \times [HG1 \times HDD65 + HG2 \times UOH \times HDD65 + HG3 \times EA \times VS \times HDD65 + HG4 \times EA^2 \times VS \times HDD50] \times G^2 \times [HG5 \times HDD65 + HG6 \times EA^2 \times VS \times HDD65])$$

$$HLS = FC \times (EA \times [HS1 \times VS \times HDD65 + HS2 \times (VS \times HDD50)^2] + EA^2 \times [HS3 \times VS \times HDD50 + HS4 \times VS \times HDD65])$$

$$HLC = FC \times [HC1 + HC2 \times HDD65 + HC3 \times HDD65^2 + HC4 \times VS^2 + HC5 \times VS \times HDD50 + HC6 \times VS \times HDD65 + HC7 \times (VS \times HDD50)^2]$$

NOTE: The coefficients for various orientations in the equations listed above are found in Table 5B-4. If WC_h or H_1 is less than 0.0, WC_h or H_1 is set equal to 0.0.

Where:

Climate Data

HDD50 = Heating degree-days base 50 °F.

HDD65 = Heating degree-days base 65 °F.

VS = Annual average daily incident solar energy on facade under consideration, Btu/ft^2-day.

Building Data

FC = Wall area (opaque and glazed) of zone under consideration divided by total wall area (opaque and glazed) of all zones.

FO = Opaque wall area of zone under consideration divided by total wall area (opaque and glazed) of all zones. If multiple mass constructions are present, the FO_j is calculated for each and used to form the area weighted mass correction.

U_{ow} = Area average U-value of opaque walls (including those of mass construction) in zone under consideration.

UOH = Area average U-value of wall (opaque and glazed, evaluated under heating conditions) in zone under consideration. UOH is equal to UOC.

WWR = Window wall ratio for zone under consideration; defined as fenestration area divided by total wall area (opaque and glazed).

EA = Effective aperature fraction for zone unce consideration.

$$EA = WWR \times SC_x \times S_{eh}$$

Equation 5.5-7

Where:

For $0.0 \leq PF \leq 0.5$, from Equation 5.4-1:

For the north orientation:

$$S_{eh} = 1 - 0.3 \times PF$$

Equation 5.5-7a

For the east, south and west orientation:

$$S_{eh} = 1 - 0.986 \times PF + 0.4513 \times PF^2$$

Equation 5.5-8

G = Effective internal gain (W/ft^2) for zone under consideration.

$$G = E_p + L_p \times (1 - R_c \times K_d) + O_l$$

Equation 5.5-8

Where:

L_p = Lighting power, from Section 5.5.7.4.

E_p = Equipment power, from Section 5.5.7.5.

O_l = Occupant load adjustment, from Section 5.5.7.6

R_c = The ratio of the electric lights in the space served by the orientation that have automatic controls for daylighting.

K_d = $5.871 \, (WWR \times VLT \times S_{eh}) - 13.311 \, (WWR \times VLT \times S_{eh})^2$

Equation 5.5-8a

If WWR x VLT x S_{eh} > 0.22, then K_d = 0.647

Where:

WWR = As defined above, but not to exceed a maximum value of 0.65 in Equation 5.5-8a per Section 5.5.7.3.

VLT = Visible light transmittance of the glazing material, as defined in Section 5.5.2.1 including any shading devices present that modify the visible transmittance of the glazing material.

HMC = Mass correction from Equation 5.5-9. If multiple mass constructions are present, each HMC_j is evaluated separately and combined by area weighting. If the U-value of the mass wall is greater than 0.40, then U_{ow} = 0.4 shall be used to calculate the HMC. If the U-value of the mass wall is less than 0.05, then U_{ow} = 0.05 shall be used to calculate the HMC. If the value of HC is greater than 20, then HC = 20 shall be used to calculate the HMC.

HEATING DELTA LOAD FACTOR EQUATIONS

Equation 5.5-9 is used to predict the heating Delta Load Factor values.

HMC = Heating Delta Load Factor =

$$\left(1 - e^{-HP_1(HC-1)}\right)\left(HP_2 + HP_3U - \frac{HP_4}{1 + (HP_5 + HP_6U)e^{-(HP_7+HP_8U^2)(HC-1)}}\right)\frac{1.0}{0.7}$$

Equation 5.5-9

Where:

HC = Wall Heat Capacity (Btu/ft^2·°F)

U = Wall U-Value (Btu/h·ft^2·°F)

A = (Heating degree-days base 65 °F/100 + 2 (°F·days)

Where:

$HP_1 = H_6$

$HP_2 = H_{14} LN(A) + H_{15}$

LN = Natural Logarithm

$HP_3 = H_1 A^3 + H_2 A^2 + H_3 / \sqrt{A} + H_4 \sqrt{A} + H_5$

$HP_4 = H_{11} A^2 + H_{12} / A^2 + H_{13}$

$HP_5 = H_{16}$

$HP_6 = H_7 A + H_8$

$HP_7 = H_{17} / A^3 + H_{18}$

$HP_8 = H_9 / A^3 + H_{10}$

The coefficients H1 through H18 are taken from the following table, Table 58-3.

58.2. Determining Heating and Cooling Criteria Using Equations in Section 58.1

To determine the wall thermal criteria for a building design, the following inputs to the equations in Section 58.1 shall be used.

(1) Aspect Ratio. An aspect ratio of 2:1 with longer dimensions facing east and west.

(2) Shading. No use of external shading projections or screens.

(3) Daylight Controls. No use of automatic daylight controls for the lighting system.

(4) Internal Gain (G). The sum of the lighting power density (L_p), the equipment power density (E_p) and the occupant load adjustment (O_l), or 3.0 W/ft^2, whichever is smaller, shall be used. In determining L_p, the value of R_c and VLT shall be set equal to 0.0 in Equations 5.5-4 and 5.5-8.

(5) Wall Area Factor, Opaque and Glazed (FC). The combined opaque and glazed area for the orientation for the building design, divided by the total wall area (opaque and glazed) of all orientations, shall be used. Note that if one changes the wall area or floor area in a zone, this changes the geometry of the building. The criteria and compliance values will change for all zones because both values for each zone are weighted by the relative size of that zone.

(6) Window Wall Ratio (WWR). The smaller of the values of WWR_c and WWR_h determined from (a) and (b) below shall be used.

(a) Using the value for internal gain (G) determined in (4) above, the WWR_c for cooling by interpolation of

the results of (a) and (b) below, shall be determined using Equation 5.5-10:

Where: WWR_{g0} is the window to wall ratio at 0.0 W/ft^2 internal load (G = 0.0 W/ft^2).

WWR_{g30} is the window to wall ratio at 3.0 W/ft^2 internal load (G = 3.0 W/ft^2).

$$WWR_c = WWR_{g0} - (G / 3.0) \times (WWR_{g0} - WWR_{g30})$$

Equation 5.5-10

For G = 0.0:

If CDOSO x VSEW < 8,000,000, then Equation 5.5-11 shall be used.

$$WWR_{g0} = 0.48 - (CDOSO \times VSEW \times 1.625 \times 10^{-8})$$

Equation 5.5-11

If CDOSO x VSEW $\geq$ 8,000,000, then Equation 5.5-12 be used:

$$WWR_{g0} = 0.34$$

Equation 5.5-12

F. G = 3.0:

If CDOSO x VSEW < 8,000,000, then Equation 5.5-13 shall be used:

$$WWR_{g30} = 0.28 - (CDOSO \times VSEW \times 5.0 \times 10^{-9})$$

Equation 5.5-13

If CDD50 x VSEW ≥ 8,000,000, then Equation 5.5-14 shall be used:

$$WWR_{g30} = 0.24$$

Equation 5.5-14

(b) The WWR_h for heating shall be determined using Equation 5.5-15 or Equation 5.5-16.

If HDD65 < 4000, then Equation 5.5-15 shall be used:

$$WRR_h = 0.4 - (HDD65 \times 2.5 \times 10^{-5})$$

Equation 5.5-15

If HDD65 ≥ 4000, then Equation 5.5-16 shall be used:

$$WRR_h = 0.3$$

Equation 5.5-16

(7) Opaque Wall Area Factor (FO). The value of FO shall be determined from Equation 5.5-17.

$$FO = FC \times (1 - WWR)$$

Equation 5.5-17

(8) Shading Coefficient (SC_x). The value of SC_x shall be determined from (a) or (b) below, or as shown in Figure 58-3.

(a) If the heating degree-days base 65 °F for the building location is ≤ to 3000, either Equation 5.5-18 or Equation 5.5-19 shall be used:

If CDD50 x VSEW < 4,000,000, then Equation 5.5-18 shall be used:

$$SC_x = 0.85 - (CDD50 \times VSEW \times 8.75 \times 10^{-8})$$

Equation 5.5-18

If CDD50 x VSEW $\geq$ 4,000,000, then Equation 5.5-19 shall be used:

$$SC_x = 0.5$$

Equation 5.5-19

(b) If the heating degree days base 65 °F for the building location is > 3000, either Equation 5.5-20 or Equation 5.5-21 shall be used:

If CDD50 x VSEW < 4,000,000, then Equation 5.5-20 shall be used:

$$SC_x = 0.85 - (CDD50 \times VSEW \times 1.25 \times 10^{-7})$$

Equation 5.5-20

If CDD50 x VSEW $\geq$ 4,000,000, then Equation 5.5-21 shall be used:

$$SC_x = 0.35$$

Equation 5.5-21

(9) External Shading Projection (S_{eh}). The value of S_{eh} shall be set equal to 0.0.

(10) Opaque Wall U-Value (U_{ow}). The value of U_{ow} shall be determined from either Equation 5.5-22 or Equation 5.5-23, as shown in Figure 5B-4.

If HDD65 < 196, then Equation 5.5-22 shall be used:

$$U_{ow} = 1.0$$

Equation 5.5-22

If HDD65 ≥ 196, then Equation 5.5-23 shall be used:

$$U_{ow} = 42.787 \times HDD65^{(-0.712)}$$

Equation 5.5-23

(11) Heat Capacity of Opaque Wall (HC). The value of HC shall be set equal to 1.0.

(12) Fenestration Assembly U-Value (U_{of}). The value of U_{of} shall be determined from either Equation 5.5-24, 5.5-25, or 5.5-26; or as shown in Figure 58-5.

If HDD65 < 3000, then Equation 5.5-24 shall be used:

$$U_{of} = 1.15$$

Equation 5.5-24

If HDD ≥ 3000 and HDD65 < 7500, then Equation 5.5-25 shall be used:

$$U_{of} = 0.81 - [(HDD65 - 3000) \times 8.0 \times 10^{-5}]$$

If HDD ≥ 7500, then Equation 5.5-26 shall be used:

$$U_{of} = 0.45$$

Equation 5.5-26

(13) For all other inputs to the equations in Section 58.1, the values for the building envelope design under consideration shall be used.

Table 53-1

COOLING DELTA LOAD COEFFICIENTS

COEFFICIENT LABEL	INSULATION POSITION		
	EXTERIOR	INTEGRAL	INTERIOR
C1	220.724503	139.105667	181.616776
C2	-.056589	-.033991	-.055196
C3	-118.835328	-10.326704	-34.158966
C4	-13.674420	-20.867386	-25.591934
C5	.236381	.283282	.081029
C6	.959588	.305851	1.418998
C7	-.255004	.022622	.432421
C8	-905.677979	-307.943848	-1882.926758
C9	425.191895	80.209610	443.195801
C10	-2.510600	.049955	.430200
C11	-43.387955	-5.989545	-28.285065
C12	-259.723389	-11.396114	-63.562256
C13	-33.975525	.366851	20.844650
C14	20.488235	30.253494	9.817521
C15	-26.209152	8.833706	24.459824
C16	-241.173386	-22.254623	-70.337494
C17	18.897781	29.329697	9.284280
C18	-.353790	-.023878	-.114646
C19	156.305634	63.322754	326.344727
C20	-74.098999	-16.334656	-77.635498
C21	.445363	-.011114	-.074788
C22	7.496696	1.295576	5.204088

TABLE 53-2
COOLING COEFFICIENTS

	NORTH	EAST	SOUTH	WEST
CU1	0.001539	0.003315	0.003153	0.00321
CU2	-0.308548E-07	-0.896618E-07	-0.712993E-07	-0.810530E-07
CU3	0.799493E-13	0.379280E-13	0.183083E-13	0.339810E-13
CU4	-0.079647	0.163114	0.286458	0.11178
CM1	0.32314	0.515262	0.71477	0.752643
CM2	0.153060E-05	0.138197E-05	0.161630E-05	0.142228E-05
CM3	-0.204322E-05	-0.160240E-05	-0.211063E-05	-0.197938E-05
CM4	-0.753665E-06	-0.767849E-06	-0.664430E-06	-0.740067E-06
CM5	-0.100472E-05	0	0.801057E-05	0.315193E-05
CM6	0.366708E-04	0.356503E-04	0.448106E-04	0.296012E-04
CM7	-0.673045E-04	-0.640938E-04	-0.000119	-0.766719E-04
CM8	-0.238335E-07	-0.472534E-07	-0.497469E-07	0
CU01	-0.651094E-05	-0.838669E-05	-0.888996E-05	-0.756465E-05
CU02	-1.040207	-1.507235	-1.512625	-1.238545
CU03	-0.433254E-05	-0.278328E-05	-0.231352E-05	-0.412567E-05
CU04	0.126580E-04	0.809874E-05	0.736219E-05	0.106712E-04
CXU01	0.103744E-05	0.119330E-05	0.118588E-05	0.123251E-05
CXU02	-0.132180E-12	-0.134656E-12	-0.116252E-12	-0.130002E-12
CXU03	0.275554E-04	0.202621E-04	0.202365E-04	0.236964E-04
CXU04	0.974090E-07	0.117514E-06	0.939207E-07	0.136276E-06
CXU05	-0.118247E-04	-0.909694E-05	-0.909192E-05	-0.111077E-04
CG1	0.891286	0.533388	0.393756	0.948654
CG2	0.001479	0.001931	0.002081	0.001662
CG3	-0.552042E-12	-0.282139E-12	-0.284766E-12	-0.455720E-12
CG4	0.252311E-05	0.370821E-05	0.430536E-05	0.591511E-05
CG5	-0.001151	-0.001745	-0.001864	-0.00153
CG6	0.195243E-11	0	-0.296055E-11	0.316358E-11
CG7	-0.835805E-11	0.101089E-10	0.330027E-10	0
CG8	0.141022E-05	0.753875E-06	0.713300E-06	0.970752E-06
CG9	-0.238887E-05	-0.164961E-05	-0.163927E-05	-0.197363E-05
CS1	46.9871	33.9683	18.32016	29.3089
CS2	0.348091E-04	0.374118E-04	0.340490E-04	0.502498E-04
CS3	0	0	0.271313E-11	0
CS4	-0.166409E-04	0.694779E-05	-0.282181E-04	-0.277158E-04
CS5	0.842765E-11	0	-0.304677E-11	0.291137E-11
CS6	-56.5446	0	26.9954	14.9771
CS7	-0.134764E-10	-0.588097E-11	-0.650089E-11	-0.789218E-11

TABLE 58-2 (Continued)
COOLING COEFFICIENTS

	NORTH	EAST	SOUTH	WEST
CC1	0.002747	0	0.010349	0.001865
CC2	0	0.318928E-06	-0.304413E-06	0
CC3	-0.000348	0.000319	0.00024	0.000565
CC4	0.122123E-07	-0.775318E-07	-0.271443E-07	-0.544380E-07
CC5	0.012112	0.011894	0.013248	0.009236
CC6	0.104027E-11	-0.622661E-12	-0.205173E-11	0
CC7	-0.124013E-04	-0.706280E-05	-0.165377E-04	-0.602685E-05
CC8	0	0	0.820869E-12	0
CC9	-0.375797E-13	0.606235E-13	0.197598E-13	0.389425E-13
CC10	0.030056	0.023121	0.0265	0.01704
CC11	0	0	-0.271026	-0.244274
CC12	0.002138	0.001103	0.006368	0.007323
CC13	-12.8674	-13.16522	-18.271	-10.1285

Table 58-3
HEATING DELTA LOAD COEFFICIENTS

COEFFICIENT LABEL	INSULATION POSITION		
	EXTERIOR	INTEGRAL	INTERIOR
H1	.000006	.000007	.000006
H2	-.001537	-.001799	-.001492
H3	13.388575	15.116148	19.831360
H4	1.933217	2.105596	1.457923
H5	-11.896660	-13.305299	-15.562034
H6	.464317	.183966	.071887
H7	.009447	.025504	.026392
H8	-.099954	.045871	.775432
H9	-1223.396240	-622.080078	.200792
H10	-.945353	-.519158	-.637875
H11	-.000067	-.000069	-.000007
H12	3.858493	4.137914	2.424339
H13	7.582887	6.238024	7.980392
H14	-.777369	-.771123	-.169907
H15	9.014718	7.722863	8.585447
H16	.200680	.208271	-.038589
H17	206.638214	105.984894	3.139744
H18	.257293	.198297	.186262

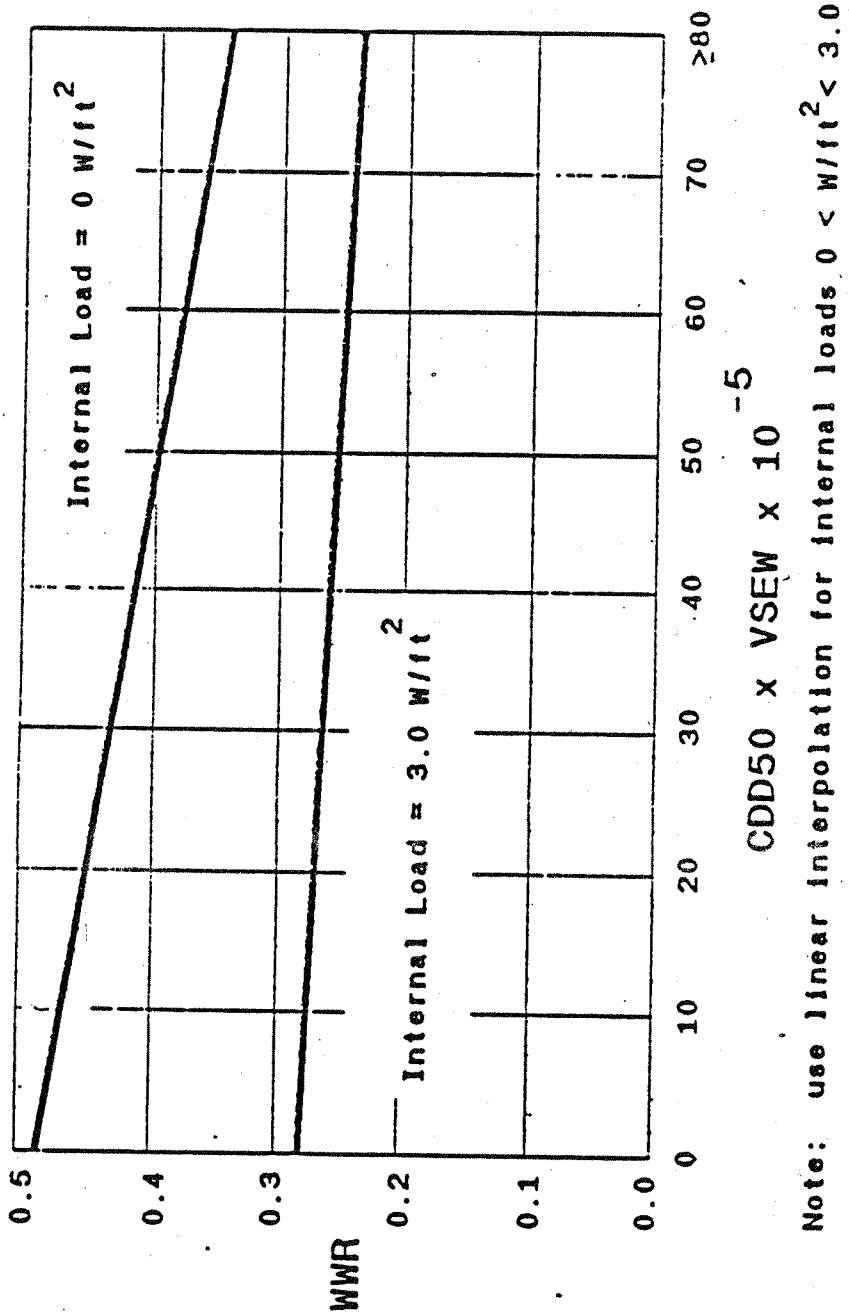
Table 58-4
HEATING COEFFICIENTS

	NORTH	EAST	SOUTH	WEST
HU1	0.006203	0.007691	0.006044	0.006672
HU2	-0.135868E-11	-0.571616E-12	-0.268998E-12	-0.435663E-12
HM1	0.531005	0.545732	0.837901	0.616936
HM2	0.000152	0.000107	0.000208	0.00015
HM3	-0.531826E-06	-0.106191E-06	-0.682531E-06	-0.264566E-06
HM4	-0.773813E-06	-0.147870E-05	0.211938E-05	-0.457827E-06
HM5	-0.000712	-0.000484	-0.001042	-0.000625
HM6	0.334859E-12	0.495762E-13	0.770190E-13	0.737105E-13
HM7	0.239071E-06	0.275045E-06	-0.389837E-06	0
HUO1	0.004943	0.008683	0.009028	0.008566
HUO2	0.013686	0.011055	0.010156	0.01146
HUO3	-0.110178E-04	-0.868956E-05	-0.732317E-05	-0.898665E-05
HXUO1	0.126940E-11	0.785644E-13	-0.282023E-12	0.304904E-13
HXUO2	-0.730582E-12	-0.810900E-13	0.745599E-13	-0.747184E-13
HXUO3	0.197090E-06	0.194026E-06	0.987587E-07	0.195776E-06
HG1	-0.001051	-0.000983	-0.000981	-0.000948
HG2	-0.001063	-0.00093	-0.000815	-0.000975
HG3	0.299013E-05	0.262269E-05	0.241880E-05	0.249976E-05
HG4	0.749049E-06	-0.111056E-05	-0.216687E-05	-0.856049E-06
HG5	0.000109	0.934310E-04	0.975523E-04	0.862389E-04
HG6	-0.555914E-06	-0.315801E-06	-0.260999E-06	-0.291334E-06
HS1	-0.218248E-04	-0.209216E-04	-0.210885E-04	-0.202049E-04
HS2	0.339179E-11	0.190500E-11	0.148388E-11	0.218215E-11
HS3	-0.653253E-05	-0.223413E-04	-0.184726E-04	-0.240488E-04
HS4	0.223087E-04	0.241331E-04	0.245412E-04	0.230538E-04
HC1	-0.106468	-5.19297	-3.66743	-5.29681
HC2	0.00729	0.007684	0.007175	0.007672
HC3	-0.297600E-06	-0.307837E-06	-0.264192E-06	-0.307127E-06
HC4	0.201569E-05	0.630350E-05	0.332112E-05	0.643491E-05
HC5	0.129061E-04	0.477552E-05	0.325089E-05	0.483233E-05
HC6	-0.128594E-04	-0.618539E-05	-0.463086E-05	-0.625101E-05
HC7	0.275861E-11	0.820051E-12	0.438148E-12	0.809106E-12

Figure 5B-1

Maximum Window to Wall Ratio

Cooling



Note: use linear interpolation for internal loads 0 < W/ft2 < 3.0

Figure 5B-2

Maximum Window to Wall Ratio

Heating

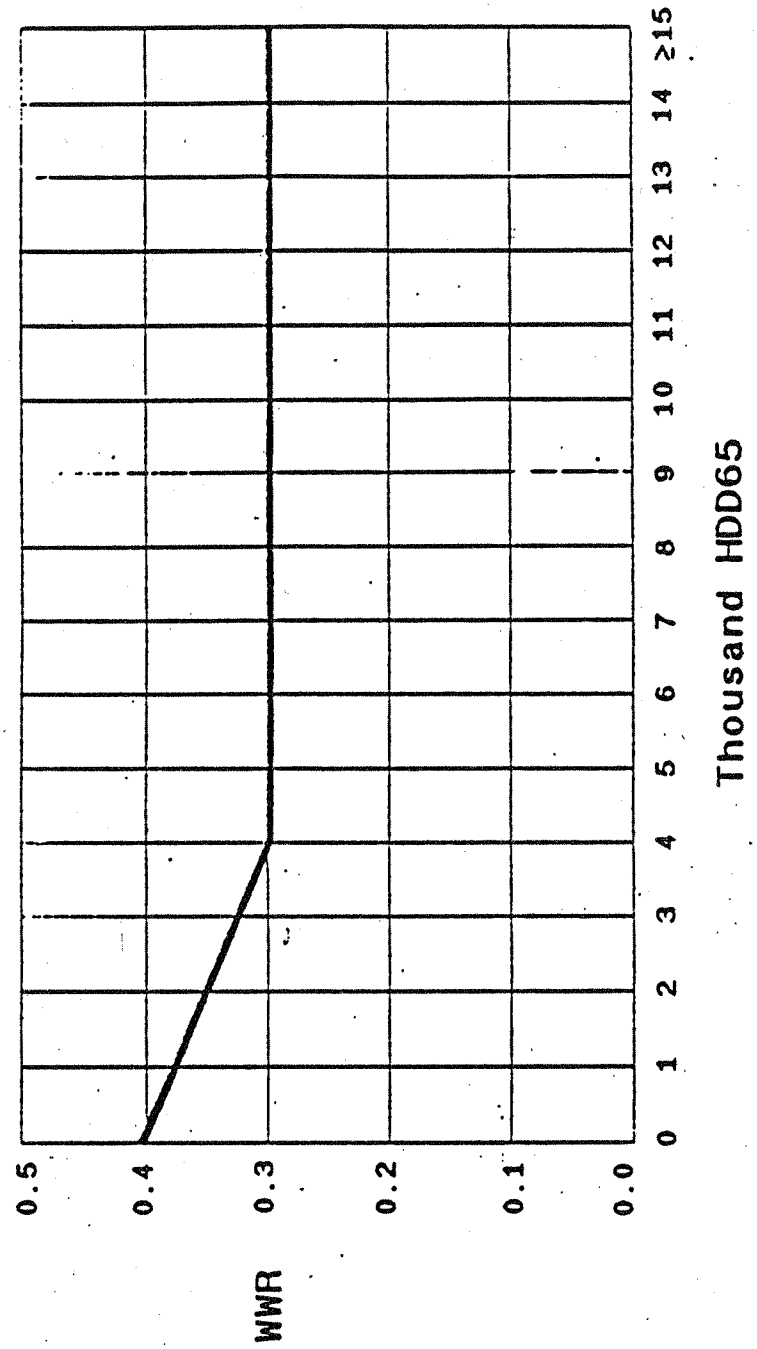


Figure 5B-3

Maximum Shading Coefficient

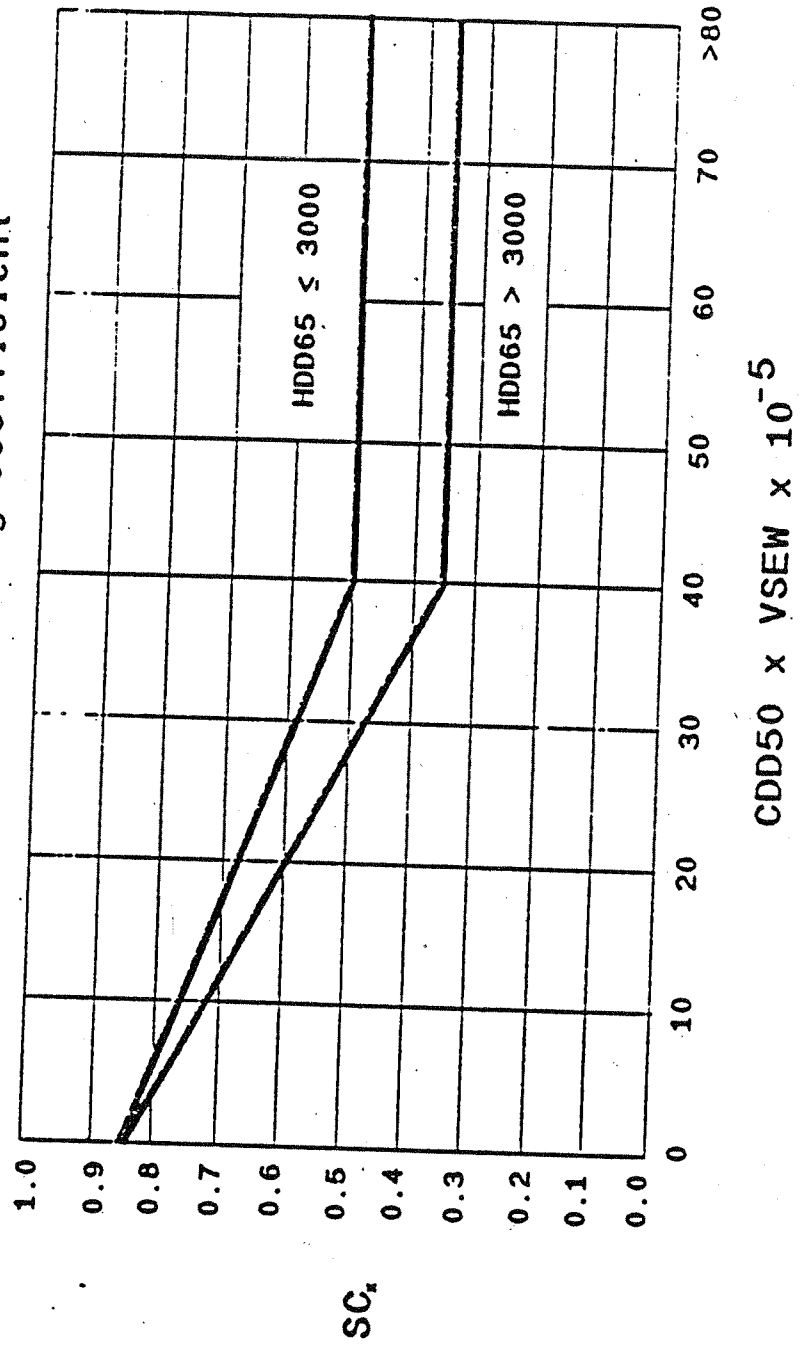
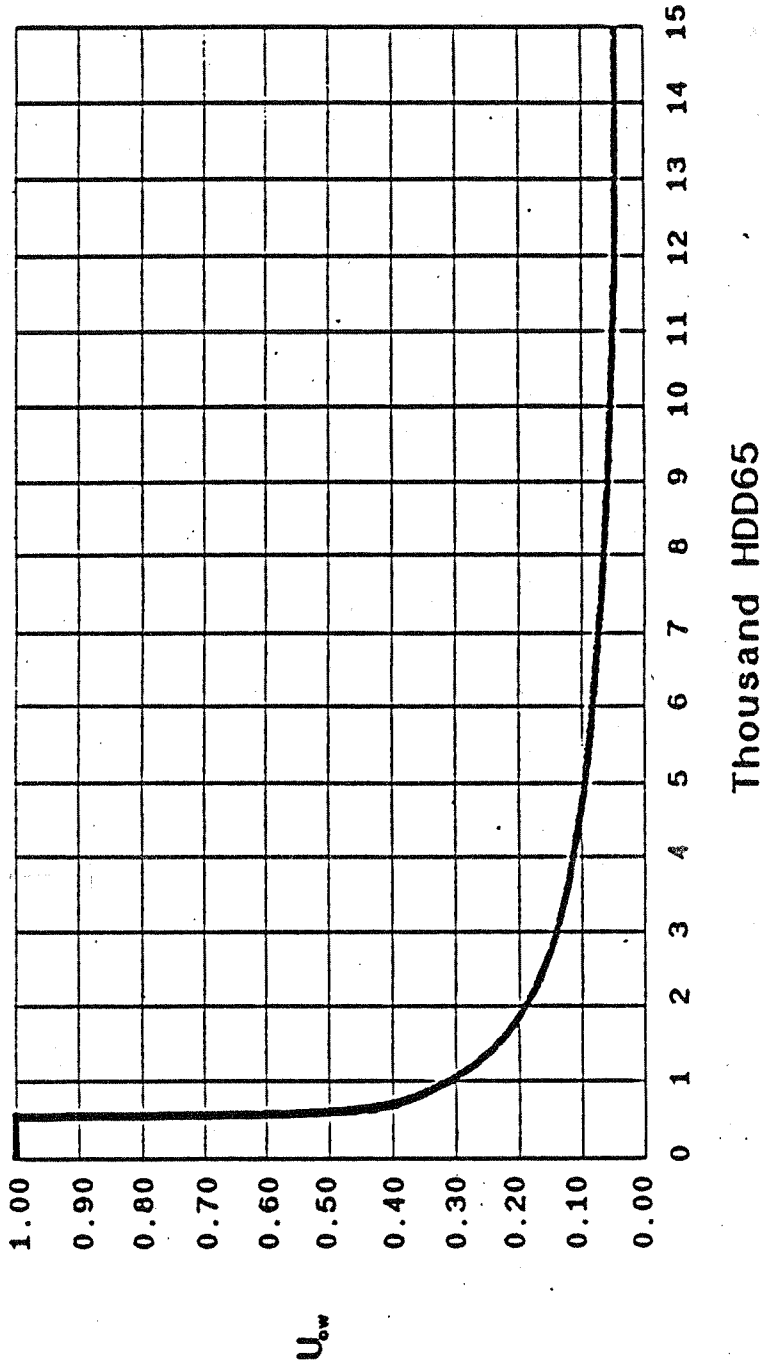


Figure 5B-4

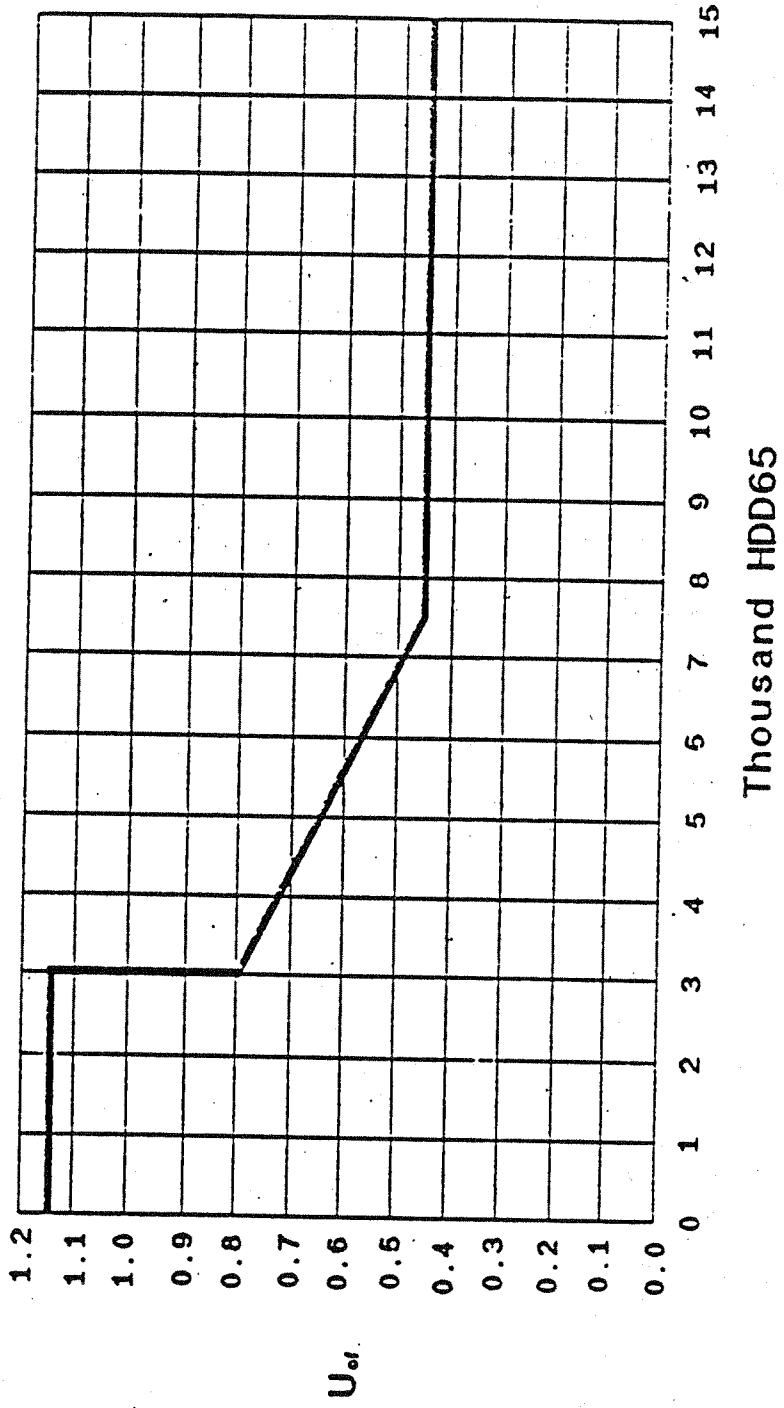
Overall Thermal Transmittance of Opaque Wall Sections



Note: for HDD65 < 196, $U_{ow} = 1.0$
for 196 ≤ HDD65 ≤ 15000, $U_{ow} = 42.787/HDD65^{0.712}$

Figure 5B-5

Maximum Overall Thermal Transmittance of Fenestration Assemblies



BILLING CODE 6450-01-C

Attachment 5C to § 435.105 Bibliography

1. Pacific Northwest Laboratory. October. 1983. *Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings.* For Building System Division. Assistant Secretary. Conservation and Renewable Energy. U.S. Department of Energy. (Contract No. DE-AC06-76RLO 1830). The report is issued in 4 volumes consisting of 40 separate publications (PNL-4870-1 through PNL-4870-40). The publications most pertinent to the envelope analysis are cited below:

Volume 2: Description of the Development Process: Appendix A: Envelope Research Documentation.

Volume 3: Description of the Testing Process: Appendix B: Envelope Compliance Code Documentation.

Volume 4: Documentation of Test Results: (Each in 3 volumes): A: Small Office Building (Branch Bank); B: Medium Office Building; C: Large Office Building; D: Retail Store (Anchor Store); E: Strip Store; F: Apartment House; G: Hotel; H: Warehouse; I: Assembly Building (Church); J: School.

2. Jones, Jerold, W., Special Project 41: "Development of Recommendations to Upgrade ASHRAE Standard 90A-1980. 'Energy Conservation in New Building Design'", *ASHRAE Journal.* October. 1983.

3. Wilcox, B., A. Gumerlock, C. Barnaby, R. Mitchell, and C. Huizenga. Berkeley Solar Group. December 1985. "The Effects of Thermal Mass Exterior Walls on Heating and Cooling Loads in Commercial Buildings: A Procedure for Calculations in ASHRAE Standard 90." *Proceedings. Thermal Performance of the Exterior Envelopes of Buildings III.* ASHRAE/DOE/BTECC. pp 1187-1224. Clearwater Beach. Florida.

4. Hirsch, James J. December 1982. "Simulation of HVAC Equipment in the DOE-2 Program." Energy and Environment Division. Lawrence Berkeley Laboratory. University of California. LBL-14026. DOE Contract DE-AC03-76SF00098.

5. Johnson, R., D. Arasteh, D. Connell and S. Selkowitz. "The Effect of Daylighting Strategies on Building Cooling Loads and Overall Energy Performance." Windows and Daylighting Group. Lawrence Berkeley Laboratory. University of California. LBL-20374.

6. D. Arasteh, R. Johnson, S. Selkowitz and D. Connell. September 1985. "Cooling Energy and Cost Savings with Daylighting in a Hot and Humid Climate." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-19734. DOE Contract DE-AC03-76SF00098.

7. Sullivan, R., Y.J. Huang, J. Buil, I. Turiel, R. Ritschard and S. Selkowitz. April 1985. "Thermal Analysis of Buildings—Configuration Perturbations and Observed Climate Interface." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-19383. DOE Contract DE-AC03-76SF00098. *ASHRAE Transactions.* Vol. 92. Part 1. 1986.

8. Johnson, R., D. Arasteh, and S. Selkowitz. March. 1985. "Energy Reduction Implications of Fenestration." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-19304. DOE Contract DE-AC03-76SF00098.

9. Selkowitz, S. October 1984. "Influence of Windows on Building Energy Use." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-18663. DOE Contract DE-AC03-76SF00098.

10. Johnson, R., R. Sullivan, S. Selkowitz, S. Nozaki, C. Conner and D. Arasteh. 1984. "Glazing Energy Performance and Design Optimization with Daylighting." *Energy and Buildings.* 6 (1984) pp. 305-317.

11. Selkowitz, S., D. Arasteh, and R. Johnson. July 1984. "Peak Demand Savings from Daylighting in Commercial Buildings." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-18128. DOE Contract DE-AC03-76SF00098.

12. Johnson, R., S. Selkowitz, and R. Sullivan. April 1984. "How Fenestration Can Significantly Affect Energy Use in Commercial Buildings." Energy Efficient Buildings Program. Lawrence Berkeley Laboratory. University of California. LBL-17330. DOE Contract DE-AC03-76SF00098.

13. Sullivan, R., S. Nozaki, R. Johnson, and S. Selkowitz. October 1983. "Commercial Building Energy Performance Analysis Using Multiple Regression Procedures." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-16645. DOE Contract DE-AC03-76SF00098.

14. September 1983. "Data Base Definition and Procedural Guidelines for Building Envelope Thermal and Daylighting Analysis in Support of Recommendation to Upgrade ASHRAE/IES Standard 90." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBID-801. DOE Contract DE-AC03-76SF00098.

15. Johnson, R., R. Sullivan, S. Nozaki, S. Selkowitz, C. Conner, and D. Arasteh. September 1983. *Building Envelope Thermal and Daylighting Analysis In Support of Recommendations to Upgrade ASHRAE/IES Standard 90—Final Report.* Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-16770. DOE Contract DE-AC03-76SF00098.

16. Selkowitz, S., S. Choi, R. Johnson and R. Sullivan. 1983. "The Impact of Fenestration on Energy Use and Peak Loads in Daylighted Commercial Buildings." *Progress in Passive Solar Energy Systems.* Copyright 1983. (0731-8826/83).

17. Choi, S., R. Johnson and S. Selkowitz. 1984. "The Impact of Daylighting on Peak Electrical Demand." *Energy and Buildings.* 6 (1984) pp. 387-399.

18. Selkowitz, S. and F. Winkelmann. May 1983. "New Models for Analyzing the Thermal and Daylighting Performance of Fenestration." Energy Efficient Buildings Program. Lawrence Berkeley Laboratory. University of California. LBL-14517. DOE Contract DE-AC03-76SF00098.

19. Selkowitz, S., J. J. Kim, M. Navvab and F. Winkelmann. June 1982. "The DOE-2 and Superlite Daylighting Programs." Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-14569. DOE Contract DE-AC03-76SF00098.

20. Johnson, R., S. Selkowitz, F. Winkelmann and M. Zenter. October 1981. "Glazing Optimization Study for Energy Efficiency in Commercial Office Buildings." Energy Efficient Buildings Program. Lawrence Berkeley Laboratory. University of California. LBL-12764. DOE Contract DE-AC03-76SF00098.

21. Arasteh, D., Johnson, R., Selkowitz, S., and Sullivan R. 1985. "Energy Performance and Savings Potential with Skylights." *ASHRAE Transactions.* Vol. 91. Part 1.

22. Arasteh, D., Johnson, R., and Selkowitz, S. May 1985. *The Effects of Skylight Parameters on Daylighting Energy Savings.* Applied Science Division. Lawrence Berkeley Laboratory. University of California. LBL-17456. DOE Contract DE-AC03-76SF00098.

23. Crawley, D.B., Briggs, R.S., December 1985. *Envelope Design Implications of ASHRAE Standards 90.1P: A Case Study View. Proceedings.* Thermal Performance of the Exterior Envelope of Buildings III. ASHRAE/DOE/BTECC. Clearwater Beach. FL. Pacific Northwest Laboratory. Richland. WA. DOE Contract DE-AC06-76RLO-1830.

§ 435.106 Electric power and distribution.

6.1 General

6.1.1 This section contains minimum requirements for all building electrical systems, except required emergency systems.

6.1.2 A building shall be considered in compliance with this section if the minimum requirements of Section 6.3 are met.

6.2 Principles of Design

6.2.1 Electric Distribution Systems

6.2.1.1 Transformers and generating units shall be sized as close as possible to the actual anticipated load (i.e., oversizing is to be avoided so that fixed thermal losses are minimized).

6.2.1.2 Distribution of electric power at the highest practical voltage and load selection at the maximum power factor consistent with safety shall be considered. The use of distribution system transformers shall be minimized.

6.2.1.3 Tenant submetering can one of the most cost-effective energy conservation measures available. A large portion of the energy use in tenant facilities occurs simply because there is no economic incentive to conserve.

6.3 Minimum Requirements

6.3.1 Electrical Distribution System

6.3.1.1 All commercial or multi-family high rise residential buildings, having designed connected electric service over 250 kVA, shall have electrical energy consumption check metered on the basis of usage category or tenant occupancy, depending on conditions defined below. For buildings that are occupied by multiple tenants, the metering shall be per tenant, if the