these data. They show a variation from approximately 70 to 90 percent depending upon the type and size of system. Laboratory tests on a gas conversion burner in a heating boiler operated with on and off cycles gave about 72 percent efficiency.[6] Other tests on coal-fired room heaters indicated, for the heating season, efficiencies of 65 to 75 percent, when the heat from the flue pipe was included.[7] A survey of 30 residences in one locality showed a variation of 45 to 75 percent in utilization efficiency, depending upon the condition of the equipment and the fuel used.[8]

Experience at the University of Illinois was used in establishing overall efficiencies for a tabulation of the comparative costs of heating the same building with various fuels to be found in a publication of the Small Homes Council.[9]

The efficiencies of utilization over the heating season shown in Table 1 are *suggested* as a guide. Considerable judgment may have to be exercised in selection of appropriate values for any given case of fuel consumption calculations.

Table 1 .... Efficiency of Utilization Over the Heating Season (Residential Systems)

Type of Fuel-Burning Unit	*Efficiency, Percent*
Gas, designed unit	70–80
Gas, conversion unit	60–80
Oil, designed unit	65–80
Oil, conversion unit	60–80
Bituminous coal, hand-fired with controls	50–65
Bituminous coal, stoker-fired	50–70
Anthracite, hand-fired with controls	60–80
Anthracite, stoker-fired	60–80
Coke, hand-fired with controls	60–80

CALCULATED HEAT LOSS METHOD

The quantity of fuel or energy required for heating may be found by the Calculated Heat Loss Method from the equation

$$F = \frac{XN}{EC} \tag{1}$$

where

F = quantity of fuel or energy required (in the units in which C is expressed).
X = average heat requirement for the period under consideration, Btu per hour.
N = number of heating hours in estimate period (for an Oct. 1–May 1 heating season, 212 days × 24 hr = 5088).
E = efficiency of utilization of the fuel over the period, expressed as a decimal; not the efficiency at peak or rated load condition.
C = heating value of one unit of fuel or energy.

The value of X is usually found from the equation

$$X = \frac{H(t - t_a)}{t_i - t_o} \tag{2}$$

where

H = calculated heat loss including infiltration loss, Btu per hour, based on t_i and t_o.
t = average inside temperature maintained during heating period, Fahrenheit.
t_a = average outside temperature through estimate period, Fahrenheit (for U. S. cities with an Oct. 1–May 1 heating season—see Table 2).
t_i = indoor design temperature, Fahrenheit (usually 70 F).
t_o = outdoor design temperature, Fahrenheit (see Table 1, Chapter 25 of the 1961 GUIDE AND DATA BOOK).

so that the value of F becomes

$$F = \frac{H(t - t_a)N}{E(t_i - t_o)C} \tag{3}$$

The calculation of X, the average heat requirement, Btu per hour, over the period under consideration is given only approximately by Equation 2, when the value of H used is the calculated maximum load, or design heating load for the building, as computed by the methods outlined in Chapters 23, 24, and 25 of the 1961 GUIDE AND DATA BOOK. This value is commonly used since it is usually available from the heating system design calculations. This procedure will usually lead to values of X which are too high. In the first place, the design wind speed on which such calculations are based is usually higher than the average wind speed for the period so that infiltration losses may be overestimated. In addition there will usually be many sources of heat not taken into account in the estimation of maximum heat demand which may actually contribute to the heating and thus may decrease the fuel or energy required for heating without necessarily affecting the maximum heat demand. The more important sources are solar radiation, people, lights, and equipment.

Improved estimates of fuel requirements will result if H can be recalculated so as to be more representative of *average* conditions over the heating period rather than the *maximum* conditions used in maximum heating load estimation. Further improvement may be obtained at the expense of more involved calculations by making estimates of the average heat gains, and deducting these from the calculated heat losses. There is a practical limit to the refinement in calculations which should be attempted since there will always be some factors which are only approximately known. The weather, for example, very largely determines the heat losses, but will normally be described only approximately in terms of average values of a limited number of weather elements. Wind speed, and sunshine will not necessarily be distributed uniformly over periods of different outdoor temperatures. In addition there is a limit to the accuracy of prediction of the weather elements over the period of interest which is always in the future. For these and other reasons, including such unpredictable factors as the way in which windows and doors will be opened and closed, the determination of H or of X must always be in the nature of an estimate only.

Values of the average outdoor temperature, t_a, are required for the calculation of X by means of Equation 2. Such values for the period October 1 to May 1 are given for U. S. cities in Table 2. The assumption of an Oct. 1–May 1 heating season is reasonably accurate in the well-populated New York-Chicago zone but heating may be required over a longer period for points as far north as Minneapolis, and over a shorter period south of Washington, D. C. Consequently values taken from Table 2 may have to be adjusted appropriately. When data on degree days are available these may be used in the calculation of average outdoor temperature for use in Equation 2 or 3. (See definition of degree day, Chapter 63 of the 1961 GUIDE AND DATA BOOK.)

It may be noted that a portion of Equation 3, $(t - t_a)N$ will, when divided by 24, correspond exactly to the degree days for the period, provided that $t = 65$ F, the usual basis for calculating degree days (see discussion of degree days in

Table 2 .... Average Monthly and Yearly Degree Days for Cities in the United States and Canada[a, b, c] (Base 65 F)

State	Station	Years	No. of Seasons	Avg. Winter Temp.[d]	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Yearly Total
Ala.	Anniston .... A			52.3	0	0	17	118	438	614	614	485	381	128	25	0	2820
	Birmingham ..... A			51.8	0	0	13	123	396	598	623	491	378	128	30	0	2780
	Mobile .... A				0	0	0	28	219	376	416	304	222	47	0	0	1612
	Mobile C			58.9	0	0	0	23	198	357	412	290	209	40	0	0	1529
	Montgomery ..... A				0	0	0	69	304	491	517	388	288	80	0	0	2137
	Montgomery C			56.4	0	0	0	55	267	458	483	360	265	66	0	0	1954
Ariz.	Flagstaff .... A			35.9	49	78	243	586	876	1135	1231	1014	949	687	465	212	7525
	Phoenix .... A			59.5	0	0	0	22	223	400	474	309	196	74	0	0	1698
	Phoenix C			57.7	0	0	0	13	182	360	425	275	175	62	0	0	1492
	Yuma .... A			62.5	0	0	0	0	105	259	318	167	88	14	0	0	951
Ark.	Bentonville	06/07–40/41	35		1	1	38	216	516	810	879	716	519	247	86	7	4036
	Fort Smith ...... A				0	0	9	131	435	698	775	571	418	127	24	0	3188
	Little Rock ...... A				0	0	10	110	405	654	719	543	401	122	18	0	2982
Calif.	Eureka C			49.3	267	248	264	335	411	508	552	465	493	432	375	282	4632
	Fresno .... A				0	0	0	86	345	580	629	400	304	145	43	0	2532
	Independence	98/99–40/41	43		0	0	28	216	512	778	799	619	477	267	120	18	3834
	Los Angeles ...... A				31	22	56	87	200	301	378	305	273	185	121	56	2015
	Los Angeles C			59.3	0	0	17	41	140	253	328	244	212	129	68	19	1451
	Needles	17/18–38/39	22		0	0	0	19	217	416	447	243	124	26	3	0	1495
	Point Reyes	98/99–40/41	43		350	336	263	282	317	425	467	406	437	413	415	363	4474
	Red Bluff .... A			52.9	0	0	0	59	319	564	617	423	336	177	51	0	2546
	Sacramento ...... A				0	0	22	98	357	595	642	428	348	222	103	7	2822
	Sacramento C			53.0	0	0	17	75	321	567	614	403	317	196	85	5	2600
	San Diego .... A				11	7	24	52	147	255	317	247	223	151	97	43	1574
	San Francisco .... A				144	136	101	174	318	487	530	398	378	327	264	164	3421
	San Francisco C			54.2	189	177	110	128	237	406	462	336	317	279	248	180	3069
	San Jose C			53.5	7	11	26	97	270	450	487	342	308	229	137	46	2410
Colo.	Denver .... A			37.0	5	11	120	425	771	1032	1125	924	843	525	286	65	6132
	Denver C			37.9	0	5	103	385	711	958	1042	854	797	492	266	60	5673
	Durango	04/05–40/41	37		25	37	201	535	861	1204	1271	1002	859	615	394	139	7143
	Grand Junction .. A			39.9	0	0	36	333	792	1132	1271	924	738	402	145	23	5796
	Leadville	07/08–40/41	34		280	332	509	841	1139	1413	1470	1285	1245	990	740	434	10678
	Pueblo .... A				0	0	74	383	771	1051	1104	865	775	456	203	27	5709
Conn.	Hartford .... A				0	14	101	384	699	1082	1178	1050	871	528	201	31	6139
	New Haven ...... A				0	18	93	363	663	1026	1113	1005	865	567	261	52	6026
D. C.	Washington ...... A				0	0	37	237	519	837	893	781	619	323	87	0	4333
	Washington C			43.4	0	0	32	231	510	831	884	770	606	314	80	0	4258
Fla.	Apalachicola C			60.9	0	0	0	17	154	304	352	263	184	33	0	0	1307
	Jacksonville ..... A			60.6	0	0	0	16	148	309	331	247	169	23	0	0	1243
	Jacksonville C			62.0	0	0	0	11	129	276	303	226	154	14	0	0	1113
	Key West .... A			72.5	0	0	0	0	0	22	34	25	8	0	0	0	89
	Key West C			73.1	0	0	0	0	0	18	28	24	7	0	0	0	77
	Miami .... A				0	0	0	0	8	52	58	48	12	0	0	0	178
	Miami C			71.4	0	0	0	0	5	48	57	48	15	0	0	0	173
	Pensacola C			59.7	0	0	0	18	177	334	383	275	203	45	0	0	1435
	Tampa .... A				0	0	0	0	60	163	201	148	102	0	0	0	674
Ga.	Atlanta .... A				0	0	8	110	393	614	632	512	404	133	20	0	2826
	Atlanta C				0	0	8	107	387	611	632	515	392	135	24	0	2811
	Augusta .... A				0	0	0	59	282	494	521	412	308	62	0	0	2138
	Macon .... A				0	0	0	63	280	481	497	391	275	62	0	0	2049
	Savannah .... A			56.7	0	0	0	38	225	412	424	330	238	43	0	0	1710
	Thomasville	05/06–40/41	36		0	0	2	48	208	361	359	299	178	52	5	1	1513
Idaho	Boise .... A			39.8	0	0	135	389	762	1054	1169	868	719	453	249	92	5890
	Lewiston .... A				0	0	133	406	747	961	1060	815	663	408	222	68	5483
	Pocatello .... A			35.0	0	0	183	487	873	1184	1333	1022	880	561	317	136	6976
Ill.	Cairo C			46.4	0	0	28	161	492	784	856	683	523	182	47	0	3756
	Chicago .... A			35.1	0	0	90	350	765	1147	1243	1053	868	507	229	58	6310
	Peoria .... A			37.3	0	11	86	339	759	1128	1240	1028	828	435	192	41	6087
	Springfield .... A			37.7	0	6	83	315	723	1066	1166	958	769	404	171	32	5693
	Springfield C			39.8	0	0	56	259	666	1017	1116	907	713	350	127	14	5225

[a] Data for United States cities from a publication of the United States Weather Bureau, *Monthly Normal Temperatures, Precipitation and Degree Days*, 1954, are for the period 1921 to 1950 inclusive. Those United States cities for which years are given in *Column 3 are not listed in the above publication* and the data are those which were computed by the United States Weather Bureau in 1946 and 1947 in accordance with the requirements of the National Joint Committee on Weather Statistics.

[b] *Data for airport stations, A, and city stations, C, are both given where available.*

[c] Data for Canadian cities were computed by the Meteorological Division, Department of Transport from normal monthly mean temperatures, adjusted for the summer months *by a method* described by H. C. S. Thom, The Rational Relationship between Heating Degree Days and Temperature, *Monthly Weather Review*, Vol. 82, No. 1, January 1954.

[d] For period October to April, inclusive.