heated per day, and the maximum amount which will be used in any one hour, as well as the duration of the peak load.

In cases where the requirements for hot water are reasonably uniform, as in residences, apartment buildings, hotels, and the like, smaller storage capacity is required than in the case of factories, schools, and office buildings, where practically the entire day's usage of hot water occurs during a very short period. Correspondingly, *the heating capacity must be proportionately greater with uniform usage of hot water than with intermittent usage where adequate storage can be provided to carry over the momentary peak load.* With intermittent usage there may be several hours between peak demands during which the water in the storage tank can be brought up to temperature. As a general rule, it is desirable to have a large storage capacity in order that the heating capacity, and consequently the size of the heater, or the load on the heating boiler, may be as small as possible.

In estimating the hot water which can be drawn from a storage tank, it should be borne in mind that only about 70 percent of the volume of the tank is available, since, by the time this quantity has been drawn off, the incoming cold water has cooled the remainder down to a point where it can no longer be considered hot water.

Where steam from the heating boiler is used to heat domestic hot water, the computed load on the boiler should be increased by 4 sq ft EDR (equivalent direct radiation) for every gallon of water per hour heated through a 100 deg rise. The actual requirement is $(100 \times 8.33)/240 = 3.48$ sq ft per gal heated 100 deg. The value of 4 allows for transmission losses.

There are two methods in common use for estimating the hot water requirements of a building: (1) by the number of people, and (2) by the number of plumbing fixtures installed. Where the number of people to be served can be reasonably estimated, the data in Table 11 may be used.

Example 3: Determine the heater size and storage tank capacity for a residence housing five people.

Solution: From Table 11, a residence housing five people would have a daily requirement of $5 \times 40 = 200$ gal per day, and a maximum hourly demand of $200 \times 1/7 = 28.5$ gal. The heater should have a storage capacity of $200 \times 1/5 = 40$ gal, and a heating capacity of $200 \times 1/7 = 28.5$ gal per hr.

The conditions given in *Example 3* may be cited as average. It is possible to vary the storage and heating capacity by increasing and decreasing one over the other. Such a condition is illustrated in *Example 4*.

Example 4: Determine the required heater capacity for an apartment housing 200 people, if the storage tank has a capacity of 1000 gal. What heater capacity will be required if the storage tank is changed to 2500 gal capacity?

Solution: Assume an apartment house housing 200 people. From the data in Table 11: *Daily requirements* $= 200 \times 40 = 8000$ gal. Maximum hours demand $= 8000 \times 1/7 = 1140$ gal. Duration of peak load = 4 hr. Water required for 4-hr peak $= 4 \times 1140 = 4560$.

If a 1000-gal storage tank is used, hot water available from the tank $= 1000 \times 0.70 = 700$. Water to be heated in 4 hr $= 4560 - 700 = 3860$ gal. Heating capacity per hour $= 3860/4 = 965$ gal.

If instead of a 1000-gal tank, a 2500-gal tank had been installed, the required heating capacity per hour would be $[4560 - (2500 \times 0.70)]/4 = 688$ gal.

Table 12 may be used to determine the size of water heating equipment from the number of fixtures. To obtain the *probable maximum demand*, multiply the total quantity for the fixtures by the *demand factor* in line 19. The heater or coil should have a water heating capacity equal to this *probable maximum demand*. The storage tank should have a capacity equal to the *probable maximum demand* multiplied by the storage capacity factor in line 20. *Example 5* will illustrate the procedure.

Example 5: Determination of heater and storage tank size for an apartment building from number of fixtures.

60 lavatories	× 2 =	120 gal per hr
30 bathtubs	× 20 =	600 gal per hr
30 showers	× 75 =	2250 gal per hr
60 kitchen sinks	× 10 =	600 gal per hr
15 laundry tubs	× 20 =	300 gal per hr
Possible maximum demand	=	3870 gal per hr
Probable maximum demand	=	3870 × 0.30
	=	1161 gal per hr
Heater or coil capacity	=	1161 gal per hr
Storage tank capacity	=	1161 × 1.25
	=	1450 gal

Although, in private dwellings a water temperature of 140 F is reasonable for dishwashing, in public places sanitation regulations make 180 F water mandatory in the rinsing cycle.

Thus the hot water requirements for food service establishments present special problems, due to the need for two water temperatures. The lower temperature water is distributed for general use, but the 180 F water should be confined to the equipment requiring it, and should be obtained by boosting the temperature at that point. It would be dangerous to distribute 180 F water for general use.

The U. S. Public Health Service, the National Sanitation Foundation, and other health and sanitation organizations have formulated rules and standards of cleanliness for commercial food service establishments. Certain of these rules assume that the dishes in public eating places are sufficiently free of bacteria. The National Sanitation Foundation has published standards for the design of dishwashing machines and water heaters used by restaurants.

In a restaurant, bacteria kill is usually achieved by exposing the washed dish to a rinse of 180 F water for several seconds. In addition, an ample supply of general purpose hot water, usually 140–150 F, is required for the wash cycle of dishwashers, as well as for personal use, pot washing, general cleaning and other restaurant uses.

In order to correctly size a water heating system it is necessary to determine:

1. Types and sizes of dishwashers used.
2. Required quantity of general purpose hot water (manufacturers' data should be consulted to determine the initial fill requirements of the wash tanks).
3. Duration of peak hot water demand period.
4. *Inlet water temperature.*
5. Type and capacity of existing water heating system.
6. Type of water heating system desired.

The American Gas Association has published a recommended procedure[3] for sizing gas-fired water heaters for restaurants. This procedure is discussed in the following paragraphs.

Table 13 is used to size the required heater or heaters after allowance has been made for the quantity of hot water that may be withdrawn from the storage tank each hour. The general purpose and 180 F water requirements are determined from Tables 14 and 15.

To determine the quantity, in gallons per hour, of usable hot water from storage, the duration, in hours, of consecu-

Table 13 .... Gas Input Requirements for Heating Water[a]

Water Requirements, gph	Temperature Rise, Deg F										
	40	50	60	70	80	90	100	110	120	130	140
	Gas Input Required, in Thousands of Btu per Hour										
25	12	15	18	21	24	27	30	33	36	39	42
50	24	30	36	42	48	54	60	66	72	78	84
75	36	45	54	63	72	81	90	99	108	117	126
100	48	60	72	84	96	108	120	132	144	156	168
125	60	75	90	105	120	135	150	165	180	195	210
150	72	90	108	126	144	162	180	198	216	234	252
175	84	105	126	147	168	189	210	231	252	273	294
200	96	120	144	168	192	216	240	264	288	312	336
225	108	135	162	189	216	243	270	297	324	351	378
250	120	150	180	210	240	270	300	330	360	390	420
275	132	165	198	231	264	297	330	363	396	429	462
300	144	180	216	252	288	324	360	396	432	468	504
325	156	195	234	273	312	351	390	429	468	507	546
350	168	210	252	294	336	378	420	462	504	546	588
375	180	225	270	315	360	405	450	495	540	585	630
400	192	240	288	336	384	432	480	528	576	624	672
425	204	255	306	357	408	459	510	561	612	663	714
450	216	270	324	378	432	486	540	594	648	702	756
475	228	285	342	399	456	513	570	627	684	741	798
500	240	300	360	420	480	540	600	660	720	780	840
525	252	315	378	441	504	567	630	693	756	819	882
550	264	330	396	462	528	594	660	726	792	858	924
575	276	345	414	483	552	621	690	759	828	897	966
600	288	360	432	504	576	648	720	792	864	936	1008
650	312	390	468	546	624	702	780	858	936	1014	1092
700	336	420	504	588	672	756	840	924	1008	1092	1176
750	360	450	540	630	720	810	900	990	1080	1170	1260
800	384	480	576	672	768	864	960	1056	1152	1248	1344
850	408	510	612	714	816	918	1020	1122	1224	1326	1428
900	432	540	648	756	864	972	1080	1188	1296	1404	1512
950	456	570	684	798	912	1026	1140	1254	1368	1482	1596
1000	480	600	720	840	960	1080	1200	1320	1440	1560	1680

Values extracted from Reference 3.
[a] Supply water pressure assumed to be 20 psig.

Table 14 .... Rinse Water (180 F) Requirements for Dishwashing Machines[a]

Type and Size of Dishwasher	Flow Rate, gpm	Hot Water Requirements, gallons per hour at 180 F	
		Heaters With no Internal Storage[b]	Heaters With Internal Storage to Meet gpm Flow Demand[c]
Door type, 16 x 16 in. rack	6.94	416	69
18 x 18 in. rack	8.67	520	87
20 x 20 in. rack	10.4	624	104
undercounter type	5	300	70
Conveyor type single tank	6.94	416	416
multiple tank (dishes flat)	5.78	347	347
multiple tank (dishes inclined)	4.62	277	277
Silver washers	7	420	45
Utensil washers	8	480	75
Make-up water requirements	2.31	139	139

Values extracted from Reference 3.
[a] Flow pressure at dishwashers is assumed to be 20 psig.
[b] Based on the gpm flow rate.
[c] Based on dishwasher operation at 100 percent of mechanical capacity.