INTRODUCTION

Residential water heaters are produced in a large variety of tank sizes and heat inputs to permit the selection of the one best suited to do the job. Ideally this heater would have a combination of storage and heat input equal to the usage. In addition to the design factors and the sizing examples which follow, a glossary section provides detailed explanations of selected terminology. This is done to avoid expanding the content of the sizing procedure.

DESIGN FACTORS

Theses design factors are the result of combining engineering test data and practical experience to form a usable guide for the selection of minimum water heater tank sizes and heat inputs. As stated previously, the factors may be adjusted to suit individual needs.

1. Two hour peak usage period.
   Residential peak usage, based on accepted practice, is the two hour period during the day when the heaviest draw of hot water will occur.
   For example, from 7:00 to 9:00 A.M.

2. Gallons of 140° F hot water required:
   - 20 gallons per person for the first two persons.
   - 5 gallons per person for each person over the first two.
   - 10 gallons for each full bath over the first bath.
   - 10 gallons for an automatic dishwasher
   - 20 gallons for an automatic clothes washer.

3. Storage tank size selection:
   NOTE: The draw efficiency of a gas or electric water heater storage tank is considered to be 70%.
   - 30 gallon size (21 gallon draw) for one bath residence.
   - 40 gallon size (28 gallon draw) for two bath residence -or- one bath with an automatic clothes washer.
   - 50 gallon size (35 gallon draw) for three bath residence -or- two baths with an automatic clothes washer.
   - When a whirlpool tub is part of the home equipment, it is suggested that the heater storage tank capacity, or the sum total of an additional auxiliary storage tank and heater, be sized in accordance with the following table. This method of tank sizing, will in most cases, cancel all previous statements as noted above concerning tank sizing.

4. Heat input VS recovery capacity.

Gas water heater recovery table (calculated at 75% recovery efficiency) GALLONS								
Tub Capacity To Overflow Outlet	80	90	100	110	120	130	140	150
(@ 140ºF Water) Min. Stored Water Capacity	65	71	80	89	98	108	117	125
(@ 160ºF Water*) Min. Stored Water Capacity	54	59	66	74	82	90	97	104
*A mixing valve is recommended to be installed in heater or auxiliary tank hot water outlet piping.								
Based on tub water temperature of 105º								

5.

Gas Water Heater Recovery Table (Calculated at 75% Recovery Efficiency)					
Input Rating Btuh	GPH Recovery At Indicated Temperture Rise				
	60º	70º	80º	90º	100º
30,000	45.5	39.0	34.1	30.3	27.3
33,000	50.0	42.9	37.5	33.3	30.0
35,000	53.0	45.5	39.8	35.4	31.8
40,000	60.6	51.9	45.5	40.4	36.4
43,000	65.2	55.8	48.9	43.4	39.1
50,000	75.8	64.9	56.8	50.5	45.5
60,000	90.9	77.9	68.2	60.6	54.5
70,000	106.1	90.9	79.5	70.7	63.6
80,000	121.2	103.9	90.9	80.8	72.7
90,000	136.4	116.9	102.3	90.9	81.8
100,000	151.51	129.9	113.6	101.0	90.9

6.

Electric Water Heater Recovery Table (Calculated at 100% Recovery Efficiency)					
Heating Element Wattage	GPH Recovery At Indicated Temperture Rise				
	60º	70º	80º	90º	100º

750	5.1	4.4	3.8	3.4	3.1
1000	6.8	5.8	5.1	4.6	4.1
1250	8.5	7.3	6.4	5.7	5.1
1500	10.2	8.8	7.7	6.8	6.1
2000	13.7	11.7	10.2	9.1	8.2
2250	15.4	13.2	11.5	10.2	9.2
2500	17.1	14.6	12.8	11.4	10.2
3000	20.5	17.5	15.4	13.6	12.3
3500	23.9	20.5	17.9	15.9	14.3
4000	27.3	23.4	20.5	18.2	16.4
4500	30.7	26.3	23.0	20.5	18.4
5000	34.1	29.2	25.6	22.7	20.5
5500	37.6	32.2	28.2	25.0	22.5
6000	41.0	35.1	30.7	27.3	24.6

7.

Notes on element operation:

a. Two element water heaters, simultaneous element operation; figure the upper element recovery at 1/3* the GPH shown for wattage, figure lower element at the GPH shown.

*The bottom element contributes to the heat at the top of the tank. This tends to shut off the top element. Metered tests indicate the upper element operates about 1/3 of the time.

b. Two element water heaters, non-simultaneous (interlocking) element operation; figure the largest wattage element recovery only - at the GPH shown.

c. Single element water heaters; figure the recovery at the GPH shown.

8. Storage VS Input.

Water heater selection is best made on the basis of hot water usage. However, calculations may lead to a combination of tank size and heat input which doesn't exist. In this case, the tank size and/or heat input must be balanced to achieve the desired result.

Therefore, it is necessary to understand that heat input provides hot water, at the

hourly recovery rate, hour after hour. The storage tank represents instant hot water at greater-than-heater recovery.

The supply of hot water in the storage tank cannot be replenished until the peak usage period has ended and heater recovery is available for this purpose.

Having enough storage tank capacity is important when large quantities of hot water are required in a short period of time. If the peak usage period is for an extended period of time (more than two hours), the heater recovery capacity assumes major importance.

DESIGN EXAMPLES

Given: Family of four persons
Two full baths
Automatic dishwasher
Automatic clothes washer

Hot Water Required:

Two persons @ 20 gallons/person	40 Gallons
Two persons @ 5 gallons/person	10 Gallons
Second full bath	10 Gallons
Automatic dishwasher	10 Gallons
Automatic clother washer	20 Gallons
Total two hour peak hot water usage	90 Gallons

This mean 45 gallons of water per hour, for two hours, must be provided by the water heater through storage and heat input.

Storage Tank Size:

According to design factor 3, the storage tank is 50 gallons.

The draw efficiency of the storage tank is considered to be 70%. Therefore, 35 gallons of "usable" hot water is available from the tank.

Storage VS Input:

90 gals. two hour peak hot water usage

-35 gals. of hot water from storage tank
55 gals. of hot water to be produced by heat input during 2 hr. peak.

This means 27.5 gallons of hot water per hour must be provided by heat input at the accepted temperature rise used in the locale.

GAS WATER HEATER SELECTION

From the gas water heater recovery table it is found that, at 90° temperature rise, 27,225 Btuh will produce 27.5 GPH.

A gas water heater with at least a 50 gallon storage tank and at least 27,225 Btuh input is required to meet the peak usage requirements. Consult water heater specification sheets to determine model needed.

ELECTRIC WATER HEATER SELECTION

NOTE: In the following example the fuel used is electricity instead of gas. This does not change the amount of hot water required by the family of four. It may mean a change in the ratio of tank storage versus heat input to reflect the availability or amount of electricity which is obtainable during the peak usage period.

Two element, non-simultaneous operation:
Upper element - 4500 watts
Lower element - 4500 watts

90 gals. two hour peak hot water usage
-35 gals. of hot water from storage tank
55 gals. of hot water to be produced by heat input during 2 hr. peak.

Figure recovery of one element…the one with largest wattage. In this example both elements are of same wattage.

20.5 GPH recovery x 2 hours = 41.0 gallons available from element recovery. This is less than the amount of recovery needed.

55.0 gallons of hot water needed from heat input (using 50 gallon storage tank)
-41.0 from two hour recovery of (1) 4500 watt element
*11.0 gallons of hot water "short" two hour peak

It is necessary to increase the size of the storage tank and/or element wattages to satisfy the calculated peak usage. Check your local utility for maximum

storage tank size requirement. Consult water heater specification sheets to determine model needed.

*To allow for draw efficiency, divide the "shortage" by .7 when increasing tank size.

GLOSSARY

The following provides detailed explanations of selected terminology used in the sizing procedure. This is to promote a greater understanding of water heating terms, formula and theory.

- **BTU**…abbreviation for the British thermal unit, which is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

  Stated another way, 8.25 Btu will raise the temperature of one gallon of water one degree.

  A Btu may be sensed and visualized as about the amount of heat produced by burning one wooden match. One watt-hour of electricity produces 3.413 Btu.

  This is the formula for determining the Btu required to heat a given quantity of water a certain number of degrees:

  Gallons x 8.25 x 1.0 x temp. rise = Btu

  Where…gallons = Total gallons of hot water required
  8.25 = Weight of one gallon of water
  1.0 = Specific heat of water (See Specific heat)

  Temp. Rise = Difference in degrees between lowest incoming water temperature and desired hot water temperature.

  Btu = Gas water heaters; divide answer by .75 (recovery efficiency) to obtain equivalent gas input in Btu. Electric water heaters; multiply by 0.293 to obtain element wattage equivalent. In actual practice a combination of storage and input is used to assure the availability of hot water.

- **Draw efficiency** is considered to be 70% in this report. When using storage type heaters it is common practice to assume 70% of the storage

cold water lowers the hot water temperature below an acceptable level under normal draw conditions. For example, a 40 gallon storage tank would deliver about 28 gallons of usable hot water.

- **Input rating**…The amount of fuel in British thermal units (Btu) consumed by a gas or oil water heater in an hour. In an electric water heater, input is usually expressed in watts or kilowatts. Consuming one watt-hour of electricity produces 3.413 Btu.

- **Interlocking**…(See Non-Simultaneous)

- **Non-Simultaneous (Interlocking)** element operation is where both of the heating elements in an electric water heater are not permitted to operate at the same time. The electrical circuit is interlocked through the upper thermostat to prevent simultaneous operation.

- **Recovery** (capacity)...the amount of water in gallons per hour, raised at a given recovery efficiency and Btuh input. Refer to Recovery table.

  This is the formula for determining recovery capacity:

  $$\frac{\text{Input} \times \text{efficiency}}{8.25 \times \text{temp. rise}} = \text{Recovery in GPH}$$ (See Btu)

  Efficiency = .75 for gas-fired water heaters
  1.0 for electric water heaters
  (also see Recovery efficiency)

- **Recovery efficiency**…The ratio of the heat in the water delivered at the heater outlet to the heat input of the heating unit. Also see Btu.

  Gas-fired residential water heaters are generally considered to have a 75% recovery efficiency. This means 75% of the total heat produced by the burner is absorbed into the water in the tank. The remaining 25% of the heat is used to move the products of combustion through the flue to the outdoors.

  Electric residential water heaters are generally considered to have a 100% recovery efficiency. This is because immersion style elements place all the heat into the water and there is no flue.

- **Simultaneous** element operation is where both of the heating elements in an electric water heater are permitted to operate at the same time if necessary. The actual operation of each element is individually controlled by its own thermostat.

- **Specific heat**...the amount of heat required to raise the temperature of a given weight of a substance one degree as compared with the amount of heat required to raise the temperature of the same weight of water 1° at some specified temperature.

- **Storage tank**, used for storing hot water in advance of needs. Properly sized, the tank permits large volumes of hot water to be drawn from the system at flow rates exceeding the recovery capacity of the heater. Also see Draw efficiency.

- **Temperature rise**, the amount of temperature difference (between incoming and outgoing water) in degrees Fahrenheit.

- **Draw efficiency**, the amount of water that can be drawn from a storage tank, at a 3 gpm flow rate, before the temperature drops 30°F. Heater outlet water temperatures below 110°F is generally not considered as satisfactory or usable.