http://waterheatertimer.org/9-ways-to-save-with-water-heater.html

http://waterheatertimer.org/Figure-Volts-Amps-Watts-for-water-heater.html

http://waterheatertimer.org/pdf/Water-heater-Formulas-and-terminology.pdf

A.O.Smith
Water Heaters

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http://waterheatertimer.org/Figure-Volts-Amps-Watts-for-water-heater.html

FORMULAS & FACTS

BTU (British Thermal Unit) is the heat required to raise 1 pound of water 1°F

1 BTU = 252 cal = 0.252 kcal
1 cal = 4.187 Joules
BTU X 1.055 = Kilo Joules
BTU divided by 3,413 = Kilowatt (1 KW)

To convert from Fahrenheit to Celsius:
(°F – 32) x 5/9 or .556 = °C.

FAHRENHEIT	CENTIGRADE
32	0
41	5
60.8	16
120.2	49
140	60
180	82
212	100

One gallon of 120°F (49°C) water weighs approximately 8.25 pounds.

Pounds x .45359 = Kilogram
Gallons x 3.7854 = Liters

% of hot water =
(Mixed Water Temp. – Cold Water Temp.) divided by (Hot Water Temp. – Cold Water Temp.)

% thermal efficiency =
(GPH recovery X 8.25 X temp. rise X 1.0) divided by BTU/H Input

BTU output (Gas) =
GPH recovery x 8.25 x temp. rise x 1.0

BTU output (Electric) =
BTU Input (Not exactly true due to minimal flange heat loss.)

Capacity of a cylindrical tank
– 1/2 diameter (in inches) x 3.146 x length. (in inches) Divide by 231 for gallons.

Doubling the diameter
of a pipe will increase its flow capacity (approximately) 5.3 times.

Linear expansion of pipe – in inches per 100 Ft.

TEMP °F RISE	STEEL	COPPER
50°	0.38″	0.57″
100°	.076″	1.14″
125°	.092″	1.40″
150°	1.15″	1.75″

Grain – 1 grain per gallon = 17.1 Parts Per million (measurement of water hardness)

TC-092

FORMULAS & FACTS

A.O.Smith Water Heaters

FORMULAS & FACTS

GPH (Gas) =
(BTU/H Input X % Eff.) divided by (temp. rise x 8.25)

GPH (Electric) =
(KW x 3413) divided by (temp. rise x 8.25) or (KW x 414) divided by (temp rise.)

KW required =
(GPH X 8.25 X temp. rise) divided by 3413 or
(GPH x Temp. rise) divided by 414

1 KW =
3413 BTH = 4.1 GPH @ 100° temp. rise or 4.6 GPH @ 80° temp. rise

Meters = Inches x .0254
Centimeters = Inches X 2.54
mm (millimeters) = Inches x 25.4

One boiler horsepower (BHP) =
33,475 BTU

One cubic foot of Natural Gas contains about 1000 BTU of heat.

One "therm" is equal to 100,000 BTU (100 CU. FT.)

One cubic foot of Propane Gas contains about 2500 BTU of heat.

One gallon of Propane gas contains about 91,250 BTU of heat.

One pound of Propane gas contains about 21,600 BTU of heat.

One pound of **gas pressure** is equal to 27.7 inches water column pressure

Inches of Water Column x .036091 = PSI

Inches of Water Column x .073483 = Inches of Mercury (Hg.)

One pound per sq. in. = 16 oz per sq. in.

Water expands
approximately 2% in volume for a 100°F temperature rise (from 40°F to 140°F)

Water confined
to a storage tank or piping system, when subjected to a temperature rise of 10°F (increasing from 75° to 85°), **increases pressure** from 50 psi to 250 psi.

Water capacity of copper tubing per foot

TUBING SIZE	1/2	3/4	1	1 1/2	2	3
g/ft type L	.012	.025	.044	0.92	.161	.354

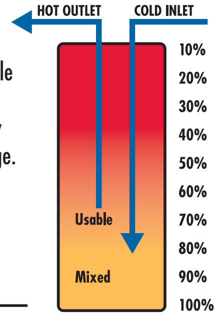
TC-092

FORMULAS & FACTS

A.O.Smith Water Heaters

COMMON TERMS

Draw efficiency is the quantity of hot water available to the consumer before the outlet water temperature decreases 25°F. A 40-gallon water heater will typically provide 70% (28 gallons) within this temperature range. The burner or elements are allowed to operate during this test. Incoming, cold water mixes the remaining stored water below this 25° limitation.



Energy factor is an indicator of the combined thermal efficiency and standby efficiency of a water heater. The higher the energy factor, the more efficient the water heater will be.

What Happens When Water Is Heated:

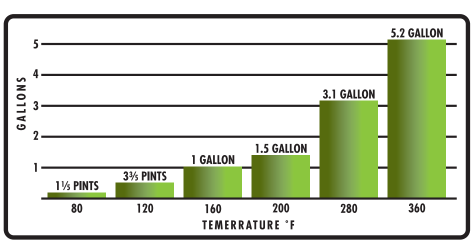
1 **The relationship between water temperature and time to burn normal adult skin.**

WATER TEMP. °F	TIME FOR 1ST DEGREE BURN	TIME FOR PERMANENT BURNS (2nd AND 3rd DEGREE)
105	Normal shower temperature	
122	1 minute	5 minutes
131	5 seconds	25 seconds
140	2 seconds	5 seconds

2 **Water cannot** (for all practical purposes) be compressed.

3 **Water expands** when it is heated. Approximately .00023% per degree F temperature rise.

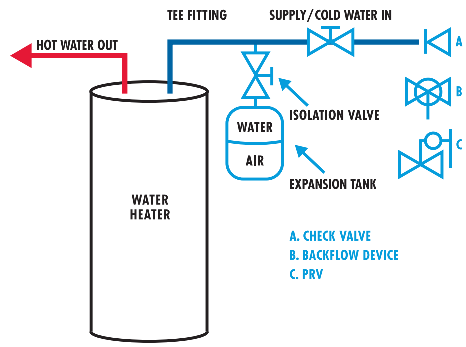
This expansion will result in a pressure increase in a "closed" system. Water confined to a storage tank or piping system will, when subjected to a temperature rise of 10°F (increasing from 75°F to 85°F) increase in pressure from 50 psi to 250 psi.



COMMON TERMS

A.O.Smith
Water Heaters

COMMON TERMS



The closed system illustrated requires the thermal expansion tank because of the preceding #2 and #3 facts.

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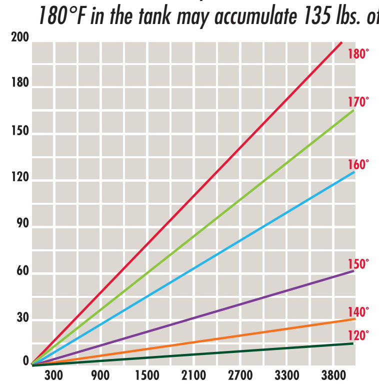
4 **Gases** in the water **will separate** from the water as temperature rises.

5 **Water boils at 212°F** – at sea level – unless it is contained under pressure. At 52 psi gauge pressure, water would not boil until it exceeded 300° F.

6 **Minerals** in the water **will separate** from the water as temperature is added. This may lead to a much faster scaling rate in the tank.

Ex: *10 grains hardness; 2700 gallons of hot water per day.*
Water stored at 140°F in the tank may accumulate 19 lbs. of lime per year.

160°F in the tank may accumulate 85 lbs. of lime per year.
180°F in the tank may accumulate 135 lbs. of lime per year.



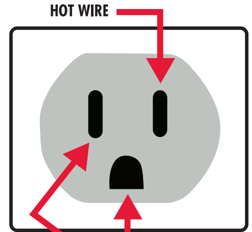
7 Adding heat to water may make it **more corrosive**.

*Water may be **2 times** more corrosive at 160°F than at 140°F.*
*Water may be **2 times** more corrosive at 180°F than at 160°F.*

A.O.Smith
Water Heaters

COMMON TERMS

Polarity – Verify that an electrical socket has correct "polarity." Verify that the "Neutral" (typically white on a 120V circuit) wire has no power to ground and that the "Hot" (typically black wire on a 120V circuit) has 115 – 125V to ground.



Watts divided by Volts = Amps (single phase)

(**Watts** x .557) divided by (Volts) = Amps (3 phase)

Volts x amps = watts.

Volts divided by amps = ohms (resistance)

For insulating purposes "R" value is a measure of the resistance of a substance to heat flow.

Recovery rate is the amount of water that is heated to a specific temperature rise, per hour. An example might be that a water heater has a recovery rate of 30 gallons of water per hour at 80° F temperature rise.

Thermal efficiency is approximately the percentage of generated BTU that enters the stored water. A percentage of the total BTU input passes out through the vent piping.

Temperature rise is the increase in the temperature from its coldest "inlet" water temperature to the desired hot (outlet) setting. Typically this is assumed to be 40° entering water; 120° desired stored water or 80° "temperature rise."

Standby efficiency is the water heater's ability to contain heat in the tank. A minimum of tank water heat loss per hour is desired.

Sample: $\frac{\text{temperature change per hour}}{\text{"R" value}}$ *= BTU/H loss/square foot of tank surface*

Water hammer is a concussion of moving water against the sides of a containing pipe or vessel on a sudden stoppage of flow.

Ex: *1/2″ copper pipe, 5GPM flow (7.2ft/sec.) – stop. Pressure rise of approximately 412 psi*

3/4″ copper pipe, 5GPM flow (3.3ft/sec) – stop. Pressure rise of approximately 188 psi

ELECTRIC WATER HEATER

HANDBOOK

Amperage (Amps) (1 phase) **= Watts** divided by Volts

Amperage (3 phase) = (Watts X .577) divided by Volts

KW Required = (GPH X 8.25 X Temp. Rise X 1.0) divided by (3413)

Ohms = Volts divided by Amperes

One kilowatt is equal to 1000 watts

One kilowatt is equal to 3,413 BTU

Recovery Rate = (KW X 3413) divided by (Temp. Rise X 8.25)

Rise (F) = (KW X 3413) divided by (GPH X 8.25)

Supply electrical fusing or breakers should be sized at least 125% of expected heater amperage.

Water weighs 8.25 pounds per gallon at 120 F (49 C).

% of Hot water = (Mixed temp. – Cold) divided by (Hot temp. – Cold)

Heating element(s)

1 KW	Temperature Rise					
	80	90	100	110	120	130
Gallons Per Hour	5.2	4.6	4.1	3.8	3.5	3.2

This style water heater will have one or two electric, heating elements immersed in the tank. One element will always be located low in the tank; a second element is commonly located down about 1/3 of the tank height from the top of the tank. These elements will seldom be wired to operate at the same time. (If they operate at the same time, amperage draw doubles, wire gauge size increases, fuse size increases and little is gained in heat recovery.)

Formulas and Facts

1 gallon of water weighs 8.33 lbs

1 gallon of water has a volume of 231 cubic inches

1 cubic foot of water weighs 62.38 lbs and contains 7.48 gallons of water

100 feet of 3/4" copper pipe contains 2.5 gallons of water; 1" pipe contains 4.3 gallons

8.33 BTU will raise 1 gal of water 1 degree F at 100% efficiency (electricity

11 BTUs are required to raise 1 gallon of water 1°F at 75% efficiency (gas)

3,412 BTU equals 1 kilowatt hour (Kwhr)

1 Kwhr will raise 410 gallons of water 1 degree F at 100% efficiency

1 BTU X 0.293 = watts

1 KW = 1000 watts

2.42 watts are required to raise 1 gallon of water 1 ° F

1 Kwhr will raise 10.25 gal of water 40 degrees F at 100% efficiency
1 Kwhr will raise 6.8 gal of water 60 degrees F at 100% efficiency
1 Kwhr will raise 5.1 gal of water 80 degrees F at 100% efficiency
1 Kwhr will raise 4.1 gal of water 100 degrees F at 100% efficiency

Formulas:

ELECTRIC

Energy Costs:

Kwhr x fuel costs = energy costs

If I use 100 kilowatt hours of electricity, how much will it cost if each kilowatt hour costs $.05?

100 x .05 = $5.00

To obtain gallons per hour (GPH) recovery

$$\frac{\text{WATTS}}{2.42 \times (\text{temp rise } ° \text{ F})}$$

I have a 30 gallon electric heater, non-simultaneous operation, 4500 watt elements. What is the recover GPH if my cold water is 40° F and my thermostat is set to 120° F?

$$\frac{4500}{2.42 \times 80} = 23 \text{ gallons per hour}$$

GAS

Energy Costs:

Cubic feet x fuel costs = energy costs

If I use 100 cubic feet of gas, how much will it cost if each cubic foot costs $.075?

100 x .075 = $7.50

To obtain gallons per hour (GPH) recovery

$$\frac{\text{HOURLY INPUT (BTUs)}}{11.0 \times (\text{temp rise } ° \text{ F})}$$

I have a 30 gallon gas heater rated at 40,000 BTUs. What is the recover GPH if my cold water is 40° F and my thermostat is set to 120° F?

$$\frac{40{,}000}{11.0 \times 80} = 45 \text{ gallons per hour}$$

Formulas and Facts

Temperature Rise (°F)

$$\frac{\text{WATTS}}{2.42 \times \text{GPH}}$$

I have a 30 gallon electric heater, non-simultaneous operation, 4500 watt elements. What is the maximum temperature rise if the heater can recover 23 gallons per hour?

$$\frac{4500}{2.42 \times 23} = 80 \text{ degrees temp rise}$$

Temperature Rise (°F)

$$\frac{\text{HOURLY INPUT (BTUs)}}{11.0 \times (\text{GPH})}$$

I have a 30 gallon gas heater rated at 40,000 BTUs. What is the maximum temperature rise if the heater can recover 45 gallons per hour?

$$\frac{40{,}000}{11.0 \times 45} = 80 \text{ degrees temp rise}$$

Formula for mixing hot water

$$\frac{M-C}{H-C} = \text{PERCENT OF HOT WATER REQUIRED TO PRODUCE DESIRED MIXED TEMPERATURE}$$

Where M = mixed water temperature; C = cold water temperature; H = hot water temperature

For example: How much of a shower is hot water and how much is cold water? My shower temperature is 105° F, my water heater thermostat is set on 120° F and the cold water inlet temperature is 50° F.

$$\frac{105 - 50 = 55}{120 - 50 = 70} = \text{79\% of the shower is 120° hot water}$$

This formula for mixing hot water is important when explaining a NOT ENOUGH HOT WATER trouble call and the water heater is functioning properly.

Electric Working Formulas that apply to Water Heaters

To verify circuit breaker OR amp draw on the heater:

$$\text{amp draw} = \frac{\text{watts}}{\text{voltage}}$$

$$\text{amp draw} = \frac{\text{4500 watts (heating elements shown on rating plate total)}}{\text{240 volts (shown on the rating plate}}$$

amp draw = 18.8 amps (circuit breaker should be 20% higher or 25 amp breaker

Now that you have solved for amps, what is the OHMS resistance of the heating element? (If a heating element has no resistance, then it is *open*, or broken.)

$$\text{ohms resistance} = \frac{\text{voltage}}{\text{amps}}$$

$$\text{ohms resistance} = \frac{\text{240 volts (shown on the rating plate)}}{\text{18.8 (answer from previous problem)}}$$

ohms resistance = 12.8 ohms

Estimated Annual Cost of Operation

You can calculate the estimated yearly cost of operation for a water heater by using one of the following formulas:

For natural gas or propane (LP) gas:

$$\frac{41045 \text{ Btu}}{EF} \times \text{Unit Cost of Fuel\$ per Btu} \times 365 = \text{Estimated Annual Cost of Operation}$$

For Example: Assuming a natural gas unit with an EF of .57 and fuel costs of $.904 per therm -

$$\frac{41045 \text{ Btu}}{.57} \times \$.00000904 \times 365 = \$237 \text{ estimated annual cost of operation}$$

Unit cost of fuel = $.904 per therm or $.904 per 100,000 Btu or $.00000904 per Btu

For electricity:

$$\frac{12.03\text{kWh}}{EF} \times \text{Unit Cost of Fuel\$ per kWh} \times 365 = \text{Estimated Annual Cost of Operation}$$

For Example: Assuming an electric water heater with an EF of .88 and electric costs of $.0817 per kWh -

$$\frac{12.03\text{kWh}}{.88} \times \$.0817 \times 365 = \$407 \text{ estimated annual cost of operation}$$

Definitions:

Energy Factor
Energy factor is a measure of the overall efficiency rating of a water heater. The higher the EF number, the more efficient the water heater.

First Hour Rating (1st Hour Rating)
First hour rating is the amount of hot water that the water heater can supply in the first 60 minutes of operation. It is a combination of how much water is stored in the water heater and how quickly the water heater can reheat cold water to the desired temperature.

Fuel Conversions:

1 therm of natural gas = 100,000 Btu
1 gallon of LP gas = 91,333 Btu
1 kWh (kilowatt hour) = 3,412 Btu

National average unit fuel costs as determined by the Department of Energy, Winter 2001 have been used in these calculations.

See the complete GAMA book and web site at: www.gamanet.org

Check for fuel data and prices at the Dept of Energy website at: www.energy.gov/dataandprices/index.html

TECHNICAL SERVICE DEPARTMENT
Technical Service Bulletin
1-800-432-8373

Recovery Rating on the Residential Gas Water Heaters Labeling

The formula and computations for the amount of hot water a gas water heater can produce are different based on the authority of the label. The American National Standards Institute (ANSI) regulates the rating plate and has their formula; the Department of Energy (DOE) regulates the yellow energy guide and has their formula; and the specification sheet Gallons Per Hour (GPH) recovery is an industry accepted mathematical formula that has been in use for years.

Effective with the ANSI Standard Z21.10.1a-2002; CSA 4.1-2001, all residential gas water heaters must have the recovery rating listed on the manufacturer's rating label. By ANSI definition, this recovery is listed in gallons per hour and is the result of the formula:

$$\frac{\textbf{Manufacturer's input rating in Btu per hour}}{\textbf{1179 BTU/Gallon}}$$

To show how this works, lets use an example of a 42V40-40F. This is a 40,000 BTU input 40-gallon capacity water heater.

- 40-gallon tank
- 40.4 GPH recovery at 90 degree rise per the specification sheet and industry accepted formula
- 33.9 gallons recovery per ANSI formula on the rating plate
- 70 gallons first hour delivery per DOE on the yellow energy guide label

As you can see, there is a wide range of delivery capacities notes on the water heater's labeling.

Below is a table that will show you some normal BTU input results using the ANSI formula:

Manufacturers Input Rating in BTU/hr	ANSI Constant	ANSI Recovery Rating
26000	1179	22.1
28000	1179	23.7
30000	1179	25.4
32000	1179	27.1
34000	1179	28.8
36000	1179	30.5
38000	1179	32.2
40000	1179	33.9
42000	1179	35.6
44000	1179	37.3
46000	1179	39.0
48000	1179	40.7
50000	1179	42.4

Manufacturers Input Rating in BTU/hr	ANSI Constant	ANSI Recovery Rating
52000	1179	44.1
54000	1179	45.8
56000	1179	47.5
58000	1179	49.2
60000	1179	50.9
62000	1179	52.6
64000	1179	54.3
66000	1179	56.0
68000	1179	57.7
70000	1179	59.4
72000	1179	61.1
74000	1179	62.8

This recovery number may be different from the First Hour Deliver computation on the yellow Energy Guide Label attached to your water heater. The First Hour Deliver rating includes recovery, ***PLUS*** storage available and the units ability to reheat water while being consumed. Therefore, the First Hour Deliver number will be higher than on the manufacturer's rating plate.

Recovery Rates in Gallons per Hour - Gas Water Heaters

Temperature Rise - Degrees Fahrenheit

INPUT BTU	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°
20,000	45	36	30	26	23	20	18	17	15	14	13
26,000	59	47	39	34	30	26	24	21	20	18	17
28,000	64	51	42	36	32	28	25	23	21	20	18
30,000	68	55	45	39	34	30	27	25	23	21	19
32,000	73	58	48	42	36	32	29	26	24	22	21
34,500	78	63	52	45	39	35	31	29	26	24	22
36,000	82	65	55	47	41	36	33	30	27	25	23
37,000	84	67	56	48	42	37	34	31	28	26	24
40,000	91	73	61	52	45	40	36	33	30	28	26
50,000	114	91	76	65	57	51	45	41	38	35	32
57,000	130	104	86	74	65	58	52	47	43	40	37
60,000	136	109	91	78	68	61	55	50	45	42	39
69,000	157	125	105	90	78	70	63	57	52	48	45
75,000	170	136	114	97	85	76	68	62	57	52	49
98,000	223	178	148	127	111	99	89	81	74	69	64
100,000	227	182	152	130	114	101	91	83	76	70	65
114,000	259	207	173	148	130	115	104	94	86	80	74
156,000	355	284	236	203	177	158	142	129	118	109	101
160,000	364	291	242	208	182	162	145	132	121	112	104
180,000	409	327	273	234	205	182	164	149	136	126	117
199,900	454	363	303	260	227	202	182	165	151	140	130
250,000	568	455	379	325	284	253	227	207	189	175	162
270,000	614	491	409	351	307	273	245	223	205	189	175
300,000	682	545	455	390	341	303	273	248	227	210	195
360,000	818	655	545	468	409	364	327	298	273	252	234
399,900	909	727	606	519	454	404	364	330	303	280	260
500,000	1136	909	758	649	568	505	455	413	379	350	325

To figure recovery by hand and you know the BTU input:

$$\frac{\text{Hourly input (BTUs)}}{11.0 \times (\text{temperature rise } ^\circ F)}$$