

# *Useful Information and Calculations*

*Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information about it.*

— Samuel Johnson 1709 - 1784

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## Introduction

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For over ten years I have collected useful tables, general rules, and calculations from technicians at natural gas companies. These precious bits of information are usually part of collection of handwritten and photocopied pages that are stapled together, tattered, and often barely legible. Although the authors are almost always unknown, the users cherish these collections and refer to them often.

The information included in this chapter has been selected for relevance and scrutinized for accuracy. I hope you find it as useful as I have.

First are tables of useful information, including Btuh input values of common residential gas appliances, Btu values of various fuels, equipment service life estimates, a method for sizing water heaters, and much more. Some tables are included with the kind permission of the referenced professional organizations.

Useful calculations are next, including estimating annual fuel costs, determining the cost per therm of various fuels, converting from CCF and MCF to therms, and more.

Worst-case draft testing is becoming a more important procedure as homes become tighter and exhaust fans become more powerful. This combustion safety test should always be performed when appropriate.

Finally, relevant unit conversion factors are included.

If it will serve you well, photocopy this chapter and add it to your own tattered collection of useful information you have collected over the years.

## Tables of Useful Information

**Table 6-1. Typical Natural Gas Distribution Pressures**

Please note that gas distribution pressures vary from one gas company to another and sometimes within one gas distribution territory. This table represents typical gas distribution pressures.

Typical Natural Gas Distribution Pressures	
Low	5 to 14 inches of water
Medium	3 to 10 pounds/in <sup>2</sup> gauge
Intermediate	11 to 65 pounds/in <sup>2</sup> gauge
High	66 to 175 pounds/in <sup>2</sup> gauge
Note: 1 pound/in <sup>2</sup> = 27.68 inches of water column	

Table 6-1

**Table 6-2. Approximate Input Values for Common Gas Appliances**

For precise Btu/hr input values, check with the manufacturer of the gas appliance.

Approximate Input Values for Common Gas Appliances	
Appliance	Btu/hr Input, Approximate
Range, free standing, residential	54,000
Built-in oven/boiler, residential	25,000
Built-in range-top unit	36,000
Water heater, 30 to 40 gallon	45,000
Water heater, 50 gallon	55,000
Fireplace/Gas log	21,000 - 55,000
Outdoor grill	30,000 - 40,000
Clothes dryer, residential	20,000 - 35,000
Gas light	2,500
Incinerator, residential	35,000

Table 6-2

**Table 6-3. Energy Budgets for Commercial Buildings**

An energy budget is a range of projected energy use for a particular building facility type. Energy budgets vary according to climate, envelope characteristics, usage, etc., therefore, the values should be used with caution.

If a building is located in a more moderate climate and is built using relatively energy-efficient standards, it will be nearer the lower end of the energy budget range.

Energy Budgets for Commercial and Public Facilities	
Facility Type	Energy Budget, 10 <sup>3</sup> Btu/ft <sup>2</sup> , yr
Dining and entertainment	
Cafeterias	50 to 400
Restaurants	50 to 500
Bars	50 to 400
Night clubs	20 to 250
Commercial kitchens	100 to 400
Office buildings	25 to 300
Libraries, museums	
Average	150 to 250
Archival	25 to 100
Communications	
Telephone terminals	150 to 500
Teletype centers	50 to 150
Radio & TV studios	100 to 200
Transportation centers	
Airport terminals	100 to 150
Ship docks	25 to 100
Bus terminals	150 to 250
Garages	20 to 200
Warehouses	20 to 350

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Table 6-3

**Table 6-4. Btu Equivalent Fuel Input Values**

The "Btu Equivalent" values in the following table are input values, not output values—combustion efficiencies are not included. Many of the values vary according to the source of the fuel or the refining methods. For example, the Btu value of natural gas may be as low as 950 or as high as 1100 Btu per cubic foot. The value for No. 2 oil may be as low as 138,000 or as high as 140,000 Btu per gallon.

Btu Equivalent Fuel Input Values		
<i>Fuel</i>	<i>Btu Equivalent</i>	<i>Unit</i>
Natural gas	1,030	Cubic foot
No. 1 oil	135,000	Gallon
No. 2 oil	139,000	Gallon
No. 4 oil	145,600	Gallon
No. 5L oil	148,400	Gallon
No. 5H oil	150,700	Gallon
No. 6 oil	153,600	Gallon
Propane	91,600	Gallon
Electricity	3,412	Kilowatt hour
District heat	1,000	Pound
Note: Btu values may vary.		

Table 6-4

**Table 6-5. Equipment Service Life Values**

Equipment service life values are often needed for a feasibility or energy-economics study of the installation of new equipment or the replacement of existing equipment.

If, while talking with a potential customer, you become aware that a piece of equipment is near or past the end of its median service life (listed in the table below), there is good reason to bring it to the attention of the manager or owner.

For example, if you find that an electrically-driven centrifugal packaged chiller (median service life of 23 years) has been in operation for 24 years, it would be a good time to convert to a gas absorption chiller, certainly a better

than if the electrically-driven chiller had been in operation for only five years.

The numbers listed in the table are *median* values, not average values. Thus, for the equipment surveyed, one-half of the pieces of equipment had longer service lives and one-half had shorter service lives than the years listed.

Equipment Service Life Estimates	
<i>Equipment</i>	<i>Years</i>
Air conditioner, commercial	15
Air conditioner, window unit	10
Air conditioner, water-cooled package	15
Boiler, hot water, fire-tube	25
Boiler, hot water, water-tube	24
Coil, DX, water, or steam	20
Compressor, reciprocating	20
Condenser, air-cooled	20
Condenser, evaporative	20
Cooling tower, ceramic	34
Engine, reciprocating	20
Furnaces, gas- or oil-fired	18
Heat pump, air-to-air, resid. and comm.	15
Heat pumps, water-to-air, commercial	19
Package chiller, absorption	23
Package chiller, reciprocating	20
Package chiller, centrifugal	23
Rooftop AC, multizone	15
Rooftop AC, single zone	15
Unit heater, gas or electric	13
Water heater, storage, gas and electric	13
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Table 6-5

**Table 6-6. Gas Boiler Conversion Factors**

This table is for converting boiler horsepower (bhp) to MCF (1,000 cubic feet) of natural gas per hour. Notice that there is an example at the bottom of the table that shows how the Gas Demand values are calculated.

<b>Gas Boiler Conversion Factors</b> (Boiler Demands @ 80% Efficiency) Natural Gas at 1,030,000 Btu/MCF	
<i>Boiler Horse Power</i>	<i>Gas Demand</i>
10 bhp	0.41 MCF/hr
25 bhp	1.02 MCF/hr
30 bhp	1.22 MCF/hr
40 bhp	1.63 MCF/hr
50 bhp	2.03 MCF/hr
75 bhp	3.05 MCF/hr
100 bhp	4.06 MCF/hr
200 bhp	8.13 MCF/hr
250 bhp	10.16 MCF/hr
300 bhp	12.19 MCF/hr
400 bhp	16.25 MCF/hr
500 bhp	20.31 MCF/hr
33,475 Btu = 1 boiler horsepower  $\frac{33,475}{0.80} = 41,844 \text{ Btu/bhp input at 80\% efficiency}$  $\frac{41,844 \text{ Btu/bhp input}}{1,030,000 \text{ Btu/MCF}} = 0.04062 \text{ MCF/bhp input}$  $250 \text{ bhp} \times 0.04062 \text{ MCF/bhp} = 10.16 \text{ MCF/hr}$	

Table 6-6

**Table 6-7. Efficiency/Output/Input Equations**

Use these simple equations for space heating systems.

$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$
$\text{Output} = \text{Input} \times \text{Efficiency}$
$\text{Input} = \frac{\text{Output}}{\text{Efficiency}}$

Table 6-7

**Table 6-8. Approximate Percentage of Heating Fuel Consumption by Month, United States**

The three coldest months of the heating season in the United States are almost always December, January, and February. These percentages can be useful when estimating a customer's heating bill. For example, the heating bill will be much higher for the months of December and January (38 percent of estimated annual bill) than for the months of March and April (23 percent of estimated annual bill).

<b>Approximate Percentage of Heating Fuel Consumption by Month</b>	
<i>Month</i>	<i>Percentage of Annual</i>
September	1
October	6
November	11
December	18
January	20
February	18
March	15
April	8
May	3
<b>Total</b>	<b>100</b>

Table 6-8

Table 6-9. Cooling Load Quick-Check Figures

These are quick-check figures only, used to check if a load calculation is within range. Do not use these values for sizing cooling equipment.

Btu/hr, Ft <sup>2</sup> of Floor Area & Ft <sup>2</sup> per Ton of Air Conditioning		
Facility Type	Btu/hr, ft <sup>2</sup>	Ft <sup>2</sup> /Ton
Apartments, high rise	30	400
Apartments, corridors	22	550
Auditoriums and theaters		18*
Banks	50	240
Barber shops	48	250
Bars and taverns	133	90
Beauty parlors	66	180
Bowling alleys	68	175
Churches		20*
Cocktail lounges	68	175
Computer rooms	141	85
Dental offices	52	230
Department stores, basement	34	350
Main floor	40	300
Upper floor	30	400
Dormitories, rooms	40	300
Corridors	30	400
Dress shops	43	280
Drug stores	80	150
Educational facilities, classrooms		150
Factories, assembly areas		150
Light manufacturing		150
Heavy manufacturing		80
<i>(continued on next page)</i>		

Table 6-9

Table 6-9 continued.

Btu/hr, Ft <sup>2</sup> of Floor Area & Ft <sup>2</sup> per Ton of Air Conditioning (continued)		
Facility Type	Btu/hr, ft <sup>2</sup>	Ft <sup>2</sup> /Ton
High rise offices, external rooms	46	263
Internal rooms	37	325
Hospitals, patient rooms		220
Public areas		140
Hotels, dormitories, guest rooms	44	275
Public spaces	55	220
Corridors	30	400
Libraries and museums		280
Medical centers	28	425
Motels	28	425
Office buildings, general	43	280
Residences	20	600
Restaurants	60	200
Retail stores	55	220
Shoe stores	55	220
Shopping centers	34	350
Specialty shops	60	200
*Persons per ton. One ton = 12,000 Btu/hr. Values will vary with age of building, structure, and amount of thermal insulation and glass.		

Table 6-9 (continued)

Table 6-10. Electric Compressor Energy Use

Electric Compressor Energy Consumption	
Compressor Type	Electrical Consumption
Centravac	~0.51 to 0.65 kW/ton
Reciprocating water cooled	~0.95 kW/ton
Reciprocating air cooled	~1.20 kW/ton
Incremental unit	~1.50 kW/ton
Scroll, water cooled	~0.84 kW/ton
Series R, water cooled	~0.80 kW/ton

Table 6-10

Table 6-11. Condenser Data

Condenser Data	
Condenser Flow Rate	
CTV/reciprocating	~3.0 gpm/ton
ABS	~3.6 to 4.5 gpm/ton
Heat Rejection	
Water cooled	~1.25 x Evaporator Btu
Air cooled	~1.30 x Evaporator Btu

Table 6-11

Table 6-12. Evaporator Data

Evaporator Data	
Evaporator flow rate	~2.4 gpm/ton

Table 6-12

Table 6-13. Absorption Cooling and Vapor-Compression Cooling Cycles Compared

Absorption cooling and vapor-compression cooling cycles perform the same basic operations, but in different ways. This table compares the two cycles.

Absorption and Vapor-Compression Cooling Cycles Compared		
	Absorption Cooling Cycle	Vapor-Compression Cooling Cycle
Energy source	Gas, steam, or electricity	Electricity or natural gas-driven engine
Energy input	Generator (boiler)	Compressor
Heat removed	Absorber and condenser	Compressor and condenser
Refrigerant	Ammonia or water	Halocarbon or ammonia

Table 6-13

Table 6-14. Properties of Selected Gases.

The properties of the three most common combustion gases are shown here. Natural gas is made up of a high percentage of methane, often with a small, but variable, percentage of propane. Propane stored in pressurized tanks often contains a small percentage of butane.

The ratio of gas to air must be within the lower and upper flammability limits before the gas/air mixture will burn.

The specific gravity of air is 1.0, so methane rises when released into the atmosphere and propane falls (specific gravity greater than that of air).

Properties of Selected Gases			
	Methane	Propane	Butane
Symbol	CH <sub>4</sub>	C <sub>3</sub> H <sub>8</sub>	C <sub>4</sub> H <sub>10</sub>
Lower explosive limit	5.3%	2.1%	1.8%
Upper explosive limit	14%	9.5%	8.4%
Btu per cubic foot	1000	2500	3200
Specific gravity	0.64	1.52	2.0
Ignition temperature	1310	871	761

Table 6-14

**Table 6-15. Comparison of Gas & Electric Food Service Equipment Operating Costs**

The comparative operating costs of gas and electric food service equipment can be determined by using the information in the table below. The equation for comparison is included at the bottom of the table. Food service equipment energy ratios, needed for the comparison, are listed in the table.

Comparison of Gas and Electric Food Service Equipment Operating Costs	
Equipment	Energy Ratio
Broiler	2
Braising pan	1.7
Fryer, standard	2.2
Fryer, pressure	2.3*
Griddle, flat	2.1
Griddle, grooved	1.4*
Oven, convection	1.8
Oven, deck	2.2*
Range, hot top	2.2
Range, open burner	2.3
Steam kettle	1.7*
Steamer, atmospheric	2
Steamer, pressure	2.1*
<b>Operating Cost Ratio Calculation</b> = Energy Ratio x Gas cost x 0.03412 Electric cost  For example, a hot top range: = 2.2 x \$0.60/therm x 0.03412 = 64% \$0.07/kWh  Therefore, the cost of operating this appliance with natural gas is 64% the cost of operating it with electricity at the given fuel costs.	
Sources: *University of Minnesota, 1982 and <i>Efficient Use of Natural Gas in Hotels and Motels</i> , AGA, 1984, p. 12, PG&E study, 1987.	

Table 6-15

**Table 6-16. Sizing Residential Storage Water Heaters**

Residential storage water heaters are sized by matching the peak first-hour demand with the first-hour rating of the appliance.

Use this table to determine the peak first-hour demand for a household. Multiply the usage in gallons (column 2) by the number of times used (column 3) during the peak- hot-water-use hour. Record the result in column 4. Add the gallons used in one hour (column 4 values) to find the total peak first-hour demand in gallons. A typical peak first-hour demand for a family of three to four is 66 to 74 gallons (250 to 280 liters).

After determining the peak first-hour demand, select a water heater having a first-hour rating within one to two gallons of the calculated peak first-hour demand. First-hour ratings for gas-fired storage water heaters are listed in the *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment*, published by GAMA, available on the Internet at <http://www.gamanet.org/consumer/certification/certdir.htm>.

First-Hour Demand Calculation for Residential Storage Water Heaters			
(1) Hot Water Use	(2) Gallons of Hot Water per Usage	(3) Times Used During Hour	(4) Gallons Used in One Hour
Shower	20	x	=
Bath	20	x	=
Shaving	2	x	=
Hands & face washing	4	x	=
Hair shampoo	4	x	=
Hand dish washing	4	x	=
Automatic dishwasher	14	x	=
Food preparation	5	x	=
Automatic clothes washer	32	x	=
<b>Total peak first-hour demand, gallons</b>			
Source: <i>Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment</i> , by GAMA.			

Table 6-16

As an example of a typical residential sizing calculation, see the sizing chart below. After calculating the required first-hour rating of 70 gallons, consult the *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment* (GAMA Directory is the informal title) to find a natural gas water heater with a first-hour rating close to this value, for example, 68 to 72 gallons per hour.

First-Hour Demand Calculation for Residential Storage Water Heaters			
(1) Hot Water Use	(2) Gallons of Hot Water per Usage	(3) Times Used During Hour	(4) Gallons Used in One Hour
Shower	20	x 3	= 60
Bath	20	x	=
Shaving	2	x 1	= 2
Hands & face washing	4	x 1	= 4
Hair shampoo	4	x 1	= 4
Hand dish washing	4	x	=
Automatic dishwasher	14	x	=
Food preparation	5	x	=
Automatic clothes washer	32	x	=
<b>Total peak first-hour demand, gallons</b>			<b>70</b>

Source: *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment*, by GAMA.

Residential water heater sizing should not be determined by the storage capacity of the unit, but by first-hour rating. If you examine gas and electric storage water heaters in the GAMA Directory, you will find that gas water heaters have a greater first-hour rating for a given storage capacity. For example, an average gas water heater with a storage capacity of 40 gallons has a first-hour rating range of 68 to 72 gallons. The average 40 gallon electric unit has a first-hour rating range of 45 to 50 gallons. This difference is a result of the different firing rates: the average gas unit fires at a rate of 38,000 Btu/hr. while the average electric fires at about 15,000 Btu/hr.

Table 6-17. Storage Water Heater Comparisons

These are good values for natural gas and electric cost comparisons. See the GAMA Directory for other values and comparisons.

Operating Cost Comparisons for Storage Water Heaters			
Equipment	EF*	Annual Energy Used	Annual Operating Cost
Nat. gas	0.7	214 therms	\$160
Nat. gas	0.53	283 therms	\$211
Electric	0.95	4662 kWh	\$397
Electric	0.84	5227 kWh	\$450

\*Energy Factor. See GAMA Directory for list of water heater energy factors. Source: U.S. Department of Energy, Feb. 1995, adjusted for 2002 fuel costs. Based on equipment with 65 to 74 gallon first-hour rating (typical for residential). Energy costs per unit: Natural gas, \$0.75 per therm; electricity, \$0.0867 per kWh.

Table 6-17

Table 6-18. Operating Cost Comparisons for Heating Systems

These are good values for natural gas, oil and electric cost comparisons. See *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment* (GAMA Directory) for a method of determining space heating costs.

Operating Cost Comparisons for Residential Heating					
Equipment	Eff.	Annual Energy Used	Annual Operating Costs		
			Fuel	Elec.	Total
Nat. gas	78%	921 therms/695 kWh	\$687	\$60	\$747
Nat. gas	94%	752 therms/142 kWh	\$560	\$12	\$572
No. 2 oil	80%	633 gallons/839 kWh	\$635	\$72	\$707
No. 2 oil	87%	608 gallons/475 kWh	\$610	\$41	\$651
Electric	99%	20,087 kWh	—	\$1,727	\$1,727
Heat pump	8.0*	8,812 kWh	—	\$758	\$758

\*Heating Season Performance Factor (HSPF). Source: U.S. Department of Energy, Feb. 1995, adjusted for 2002 fuel costs. Analysis based on 2100 square foot, well insulated home in St. Louis, MO. Energy costs: Natural gas, \$0.75 per therm; electricity, \$0.0867 per kWh; No. 2 oil, \$1.10 per gallon.

Table 6-18

## Useful Calculations

### Pool Heater Sizing Estimate

To estimate the size of an outdoor swimming pool heater (boiler), use this procedure. The final sizing of the pool heater should be done with a more accurate and dependable method.

1. Determine the desired temperature of the pool water.
2. Determine the average outdoor temperature of the coldest month of pool use.
3. Subtract number 2 from number 1. This is the temperature rise.
4. Calculate the pool surface area.
5. With this formula, estimate the pool heater size:

$$\text{Heater Size} = \text{Pool Area} \times \text{Temp Rise} \times 12$$

For example:

1. The desired temperature of the pool water is 80°F.
2. The average outdoor temperature of the coldest month of pool use is 65°F.
3. The temperature rise is, therefore, 15°F.
4. The pool surface area is 1000 square feet.
5. The pool heater size estimate is:

$$\text{Heater Size} = 1000 \times 15 \times 12$$

$$\text{Heater Size} = 180,000 \text{ Btuh}$$

### Annual Heating Cost, From Fuel X to Natural Gas

Use the following equation to find the cost of space heating with natural gas in a building that has been heated with an alternative fuel. You must know the cost of heating the building with the alternative fuel, the cost of the alternative fuel per unit, the cost of natural gas per unit, the efficiency of the alternative space heating system, and the efficiency of the replacement gas system.

This procedure uses the cost of gas per therm, rather than per CCF or MCF. If you need to convert from either of these units to therms, please see “Converting from CCF and MCF to Therms” in this chapter.

$$\text{Total Gas Cost} = \left[ \frac{\sum \text{Cost Alt}}{\$/\text{Unit Alt}} \right] \left[ \frac{\text{Eff Alt}}{\text{Eff Gas}} \right] \times P \times \$/\text{therm}$$

Where:

*Total Gas Cost* = Equivalent annual cost of space heating with natural gas.

$\sum \text{Cost Alt}$  = Total cost of space heating building with the alternative fuel.

$\$/\text{Unit Alt}$  = Cost of alternative space-heating fuel in kWh or gallons (oil or propane).

*Eff Alt* = Original seasonal efficiency of alternative system.

*Eff Gas* = Seasonal efficiency of replacement natural gas heating system.

*P* = Therms per unit of alternative fuel, from table below.

$\$/\text{Therm}$  = Cost of natural gas per therm.

Note:  $\$/\text{Therm} = \$/\text{CCF} \times [100,000 / (\text{Btu per CCF})]$ .

Values for P	
Alternative Fuel	Value for P
Electricity	0.034
No. 2 oil	1.39
No. 4 oil	1.5
No. 5 oil	1.52
No. 6 oil	1.53
Propane, LPG	0.916

**Example:** If it has cost \$12,000 per year to heat a building with electric resistance heat, what will be the approximate cost to heat the same building with natural gas? The cost of gas is \$.75 per therm, the electric cost has been \$0.11 per kWh, electric heat efficiency is 100%, and gas heating system efficiency is 80%. Using the equation above,

$$\text{Total Gas Cost} = \left[ \frac{\$12,000}{\$0.11} \right] \left[ \frac{1.00}{0.8} \right] \times 0.034 \times \$0.75$$

$$\text{Total Gas Cost} = \$3,477$$

This method is fast, but it is for approximation only. You can see that the savings from converting to natural gas from electricity is substantial (\$12,000 - \$3477 = \$8523 savings). This equation can be used to find the estimated saving of natural gas over any major competing fuel.

### Cost Per Therm of Fuel

If you wish to calculate the per therm cost of fuels for a comparison, the equation below will help. The answer, cost per therm of output, incorporates the seasonal efficiency of the appliances being considered. For example, heating system seasonal efficiencies might average 100% for electricity, 72% - 85% for oil-fired, and 72% - 95% for natural gas and propane.

Use a realistic per unit fuel cost for the fuel and facility under consideration. A few examples are worked out below. Refer to Table 6-4 xxx Btu Conversion Factors, on page xxx for Btu values per unit of fuel.

$$\text{Cost per Therm of Output} = \frac{\$/\text{Unit} \times 100,000 \text{ Btu/Therm}}{\text{Btu/Unit} \times \text{Seasonal Efficiency}}$$

If No. 2 oil costs \$1.10 per gallon and the seasonal efficiency (similar to AFUE) of an the oil-fired furnace is 82%, the cost per therm of output is figured like this:

$$\text{Cost per Therm of Output} = \frac{\$1.10/\text{gal} \times 100,000 \text{ Btu/Therm}}{139,000 \text{ Btu/gal} \times 0.82}$$

$$\text{Cost per Therm of Output} = \$0.95$$

If natural gas costs \$0.75 per therm and the seasonal efficiency (similar to AFUE) of an the natural gas furnace is 94%, the cost per therm of output is figured like this:

$$\text{Cost per Therm of Output} = \frac{\$0.75/\text{Therm} \times 100,000 \text{ Btu/Therm}}{100,000 \text{ Btu/Therm} \times 0.94}$$

$$\text{Cost per Therm of Output} = \$0.798$$

If natural gas costs \$0.77 per CCF and the seasonal efficiency (similar to AFUE) of an the natural gas furnace is 94%, the cost per therm of output is figured like this (assuming the natural gas is 103,000 Btu/CCF):

$$\text{Cost per Therm of Output} = \frac{\$0.77/\text{CCF} \times 100,000 \text{ Btu/Therm}}{103,000 \text{ Btu/CCF} \times 0.94}$$

$$\text{Cost per Therm of Output} = \$0.795$$

If electricity costs \$0.084 per kWh and the seasonal efficiency is 100%, the cost per therm of output is figured like this:

$$\text{Cost per Therm of Output} = \frac{\$0.084/\text{kWh} \times 100,000 \text{ Btu/Therm}}{3412 \text{ Btu/kWh} \times 1.0}$$

$$\text{Cost per Therm of Output} = \$2.46$$

### Break-Even Price of a Fuel

The break-even price of fuels is the cost at which using one fuel at a given efficiency will just equal the cost of using another fuel. If you know the cost per therm of one fuel (the alternative fuel) and wish to find the break-even price of another fuel (the base fuel), use the following equation.

$$\$/\text{Unit}_{B-E} = \frac{\text{Btu/Unit} \times \text{Seasonal Efficiency} \times \$/\text{Therm of Alternative}}{100,000}$$

Where:

$\$/\text{Unit}_{B-E}$  = Break-even price of base fuel, based on a per therm cost of an alternative fuel.

$\text{Btu/Unit}$  = British thermal units per unit of the base fuel.

$\text{Seasonal Efficiency}$  = Seasonal efficiency for the base fuel. Usually the same seasonal efficiency used for calculating the cost per therm of the alternative fuel is used here, but this is not required.

$\$/\text{Therm of Alternative}$  = Calculated cost per therm of alternative fuel.

See "Cost per Therm of Fuel" section above for this calculation procedure.

For example, if the price of No. 2 heating oil is \$1.10 per gallon, what is the break-even price of heating with natural gas, if the seasonal efficiencies of both the gas and the oil heating units is 82%? In the previous section, the cost per therm of No. 2 heating oil at \$1.10 per gallon and 82% seasonal efficiency is calculated to cost \$0.965 per therm of output. Thus,

$$$/Unit_{B-E} = \frac{100,000 \times 0.82 \times \$0.965}{100,000}$$

$$$/Unit_{B-E} = \$0.79$$

This result indicates that natural gas has a price advantage over \$1.10 per gallon No. 2 oil if the price of natural gas is less than \$0.79 per therm (assuming the seasonal efficiencies of the oil and natural gas heating systems are 82%). If the price of natural gas is more than \$0.79 per therm, No. 2 oil at \$1.10 has a price advantage. In other words, the break-even price of natural gas compared to No. 2 oil priced at \$1.10 per gallon (\$0.965 cost per therm of output) is \$0.79 per therm.

### Converting from CCF and MCF to Therms

Natural gas is billed to customers in CCF or therms. At various times it is necessary to convert from one unit to another.

Note: CCF = 100 CF, MCF = 1000 CF, MCF = 10 CCF.

$$\text{Therms} = \text{CCF} \times \frac{\text{Btu/CCF}}{100,000 \text{ Btu/Therm}}$$

$$\text{Therms} = \text{MCF} \times \frac{\text{Btu/CCF}}{100,000 \text{ Btu/Therm} \times 10}$$

$$\text{CCF} = \text{Therms} \times \frac{100,000 \text{ Btu/Therm}}{\text{Btu/CCF}}$$

$$\text{MCF} = \text{Therms} \times \frac{100,000 \text{ Btu/Therm} \times 10}{\text{Btu/CCF}}$$

For example, if a customer is being billed for 897 CCF, how many therms is the customer being billed for if one CCF is equal to 103,000 Btu?

$$\text{Therms} = 897 \text{ CCF} \times \frac{103,000/\text{CCF}}{100,000}$$

$$\text{Therms} = 924$$

## Worst-Case Draft Testing

### Introduction

As dwellings have become tighter over the years, testing conventionally vented combustion appliances for proper and safe venting has become important. The federally funded low-income weatherization program, operated by the Department of Energy, sometimes requires worst-case draft testing as part of the weatherization process. This is because tightening a dwelling to reduce energy consumption may influence the proper flow of combustion gases in a vent system. This can result in hazardous conditions for the occupants.

Most installers of combustion appliances who are not working within the low-income weatherization program are not aware of the importance of worst-case draft testing. It would be beneficial to their clients and their risk of liability to regularly use this testing procedure.

The purpose of worst-case draft testing is to ensure the proper venting of all interior air-coupled combustion appliances in a dwelling when worst-case conditions are simulated.

Interior air-coupled combustion appliances are defined as combustion units having vent systems that are connected to the air inside a building. Examples include atmospherically vented units and fan assisted Category I units. Direct-vent units are not a concern because they are connected only to the *outdoor* air.

The procedure for worst-case draft testing measures the difference in pressure between outside and inside the house at one or more combustion device(s) in the combustion appliance zone (CAZ) and verifies adequate vent system draft at all interior air-coupled combustion appliances. If vented combustion appliances are located in different areas of the house, a test must be performed for each area.

### Tools Required

The tools required for this test include a manometer (either analog or digital) and a pressure hose about fifty feet long. The manometer must measure in units of Pascals which is 1/250th of an inch of water column. This equipment is available from The Energy Conservatory, 2801 21st Avenue South, Suite 160, Minneapolis, MN 55407, (612) 827-1117, <http://www.energyconservatory.com>. The pressure hose is 1/8 inch (3.175 mm) inside diameter.

***Dwellings Requiring Testing***

Experts in the fields of indoor air quality and safety recommend that this test be performed 1) immediately after conventionally vented combustion equipment is installed or 2) immediately after any conditions affecting air pressures in a dwelling are altered (examples include installation of new exhaust fans, alteration of ductwork, or sealing air leaks in a building exterior surface).

If a dwelling has no conventionally vented combustion appliances, the worst-case draft test is not necessary. For example, if the dwelling has all electric appliances or all the combustion appliances are direct-vent, the test is not necessary.

***Test Procedure***

Worst-case is defined as the configuration of the house that results in the greatest negative pressure in the combustion appliance zone (CAZ).

1. Consideration must be given to the following:
  - a. The types and locations of the heating systems.
  - b. The location and strength of all exhausting equipment (bath fans, dryers, kitchen exhaust devices, etc.).
  - c. The location of wood stoves, fireplaces and water heaters.
  - d. The volume of the area where the combustion devices are located.
  - e. The location of the forced-air system returns.
2. Place the building in the wintertime condition with all windows and exterior doors closed. If it is not practical to close or install existing storm windows, latch or lock primary window units.
3. Record the outdoor temperature.
4. Deactivate all combustion appliances by turning them off or setting the control to pilot.
5. Close all operable vents, for example, a fireplace damper.
6. If there is a furnace, replace or clean the filter if it is dirty.
7. Check and clean the lint filter in the dryer.
8. Adjust the pressure gauge to 15 Pascals if using an analog manometer gauge. If using a digital manometer, no adjustment is needed.
9. Set up pressure hoses so that the pressure differential from CAZ with reference to the outdoors can be easily measured.

10. With the interior doors open and all combustion appliances and exhaust devices off, record the baseline pressure in the CAZ with reference to the outdoors.
11. Turn on all exhaust devices and record the pressure in the CAZ with reference to the outdoors.
12. If the house contains a furnace, activate the blower. Record the pressure reading in the CAZ with reference to the outdoors. Caution: If the only way to activate the blower is to fire the furnace, extreme caution must be used due to the potential of combustion backdrafting or flame rollout.
13. Close interior doors and measure the pressure difference between the main body of the house and the room you are closing off when standing on the main-body side of the door with your pressure gauge. If this pressure is negative, leave this door open. If this pressure is positive, close this door.
14. Close the door to the CAZ (this is often the basement door). If closing this door results in a negative pressure in the CAZ with reference to the outdoors of a greater magnitude (for example, from a -2 to a -4), leave this door closed. If closing this door decreases the magnitude of the pressure (for example, from a -4 to a -3), leave this door open.
15. Determine whether the furnace air handler fan contributes to depressurization. This is done by turning the air handler fan off and then on again while watching the CAZ pressure with reference to outdoors.
16. Record the worst-case depressurization, that is, the most negative pressure in the CAZ with reference to outdoors.
17. Under these worst-case conditions, fire the combustion appliance and determine if the appliance is drafting properly after two minutes.
18. Under these worst-case conditions, fire the combustion appliance and measure its draft. After two minutes, the draft should comply with the draft values in the table on the next page. If an acceptable draft is not obtained, the draft problem must be corrected, even if the CAZ pressure is within normal range.
19. If more than one appliance is located in the zone, fire the combustion appliance with the lowest Btu output first. Measure the draft at the ap-

pliance. The draft for atmospheric gas appliances should comply with the appropriate values in the table below. Shut down the appliance. Fire all remaining appliances, one at a time in order of output (smaller to larger), testing each one for draft. If the appliances vent into the same chimney or vent connector, test each one individually. If the appliances vent into different chimneys or vents, test with each successive unit running. All appliances must achieve acceptable draft within two minutes of firing.

20. If draft is unacceptable, correct the problem with one of the following (listed in order of preference):
  - a. Check for vent system blockage and correct if found,
  - b. Increase CAZ air volume by connecting CAZ to other conditioned areas (see NFPA 54, the *National Fuel Gas Code*),
  - c. Duct outdoor air directly to the combustion supply air port of burner(s), or
  - d. Increase CAZ air volume by connecting CAZ to outdoors (see NFPA 54).
21. If the dwelling has other combustion appliance zones, repeat the sequence of activating exhaust equipment, door closure, furnace blower activation, and recording pressure readings.
22. When all worst-case draft testing has been completed, turn off all exhaust equipment and return doors and combustion appliances to their normal settings.

Acceptable Draft Test Readings for Various Outdoor Temperature Ranges Atmospheric Gas Appliances Only					
F <sup>0</sup>	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column Inches	-0.02	-0.116	-0.012	-0.008	-0.004
Note: for proper draft values for fan-assisted Category I appliances, see manufacturer's recommendations.					

Conversion Factors

<i>Multiply</i>	<i>By</i>	<i>To Obtain</i>
Btu	777.649	ft-lb
Btu	251.9957	calories, gm
Btu	0.000029	hp/hr (boiler)
Btu	0.2931	W/hr
Btu	0.2520	Calories, kg
Btu	1,055.06	Joule
Btu	0.0002931	kWh
Btu	1.055	kJ
Btu/hr	0.2931	Watt
Btu/hr	0.0002931	kW
Calories, kg	3088	ft-lb
Calories, kg	3.9683	Btu
Calories, kg	1000	calories, gm
Calories, kg	4187	Joule
calories, gm	0.00396832	Btu
calories, gm	0.001	Calories, kg
calories, gm	4.187	Joule
Celsius	(1.8°C) + 32	Fahrenheit
centimeter	0.3937	inch
COP	3.367	EER
dekameter	10.0	meter
dekatherm	10.0	therm
EER	0.297	COP
Fahrenheit	(°F - 32)/1.8	Celsius
feet	0.3048	meter
feet	304.8	mm
feet	0.3048	meter
Ft-lb	0.001285	Btu
ft-lb	3.766 x 10 <sup>-7</sup>	kW/hr
ft-lb (work)	1.35582	Joule
ft/min	0.00508	m/s

<i>Multiply</i>	<i>By</i>	<i>To Obtain</i>
ft <sup>2</sup>	0.0929	m <sup>2</sup>
ft <sup>3</sup>	0.0283	m <sup>3</sup>
ft <sup>3</sup>	28.32	liter
ft <sup>3</sup> /min, cfm	0.4719	L/sec
ft <sup>3</sup> /sec, cfs	28.32	L/sec
gallon (US) H <sub>2</sub> O@60°F	8.32823	lb of H <sub>2</sub> O
gallons (US) liquid	3.7853	liter
gallons	8.0	pint
gph	1.05	mL/s
gpm	0.0631	L/s
grain	0.000142857	pound
gram	0.0022046	pound
horsepower (boiler)	13.337	hp (metric)
horsepower (boiler)	9.809	kW
horsepower (boiler)	9809.5	Joules/sec
horsepower (boiler)	33,479	Btu/hr
horsepower (boiler)	13.149 hp	(electric)
horsepower (boiler)	13.149 hp	(water)
horsepower (boiler)	13.155	hp (mech)
horsepower (mechanical)	2542.48	Btu/hr
horsepower (mechanical)	745.7	Joules/sec
horsepower (mechanical)	1,980,000	ft-lb/hr
in H <sub>2</sub> O	0.036127	lb/in <sup>2</sup>
in H <sub>2</sub> O	249.08	Pascal
in H <sub>2</sub> O	0.249	kPa
inch	25.4	mm
inch	2.54	cm
Joule (abs)	0.73756	ft-lb
Joule	0.0009478	Btu
Joule	1.0	Watt/sec
Joule	0.2388	calories, gm
Joule	0.000239	Calories, kg
Joule/sec	0.0001	hp (boiler)

<i>Multiply</i>	<i>By</i>	<i>To Obtain</i>
kg	2.2046	pound
kilometer	0.621	mile
kiloWatt	1000	Watt
km	0.621	mile
kW	0.102	hp (boiler)
kW	3.6 x 10 <sup>6</sup>	Joule/hr
kW	1000	Joule/sec
kW	3412.14	Btu/hr
kW/1000 cfm	2.12	J/L
kW/hr	3.6	MJ
kW/hr	3412.14	Btu
kW/hr	3,600,000	Joules
kW/hr	2,655,222	ft-lb
L/sec	2.119	ft <sup>3</sup> /min, cfm
L/sec	15.8478	gpm
L/sec	0.0353	ft <sup>3</sup> /sec, cfs
liter	1.0567	quart
liter	0.2641	gallon
liter	0.03531	ft <sup>3</sup>
liter	0.001	m <sup>3</sup>
liter	0.264	gallon (US)
m/s	196.85	ft/min
m <sup>2</sup>	10.7643	ft <sup>2</sup>
m <sup>3</sup>	1000	liter
m <sup>3</sup>	35.3357	ft <sup>3</sup>
meter	39.3701	inch
meter	3.28084	feet
meter/sec	2.2369	mile/hr
mile	1.61	km
miles/hr	1.466	ft/sec
miles/hr	88	ft/min
miles/hr	0.447	m/s
mL/sec	0.9524	gph

<i>Multiply</i>	<i>By</i>	<i>To Obtain</i>
mm	0.00328	ft
mm	0.03937	inch
parts/million, ppm	0.0001	percent
Pascal	1.0	N/m <sup>2</sup>
Pascal	0.001	kPa
Pascal	0.000145	lb/in <sup>2</sup>
Pascal	0.00401463	in H <sub>2</sub> O
pound	7000	grain
pound	453.6	gram
pound	0.45359	kg
pound/in <sup>2</sup>	6.89476	kPa
pound/in <sup>2</sup>	6894.76	Pascal
pound/in <sup>2</sup>	27.68	in H <sub>2</sub> O
quart (U.S.)	0.946	liter
therm	100,000	Btu
therm	105.505	MJ
tons of refrigeration	12,000	Btu/hr
tons of refrigeration	3.52	kW
Watt	0.0002843	tons refrig.
Watt/hr	3.41214	Btu
Watt	0.0001	hp (boiler)
Watt	3.41214	Btu/hr
Watt	1.0	Joule/sec
Watt	0.001	kiloWatt
Watt/sec	1.0	Joule
year	8765.81277	hours