



Combustion Quick Start Guide

All fossil fuel appliances should be tested annually with a digital combustion analyzer like the AccuTools® BluFlame™ to assure safe and optimal combustion and efficiency. The information contained in this guide illustrates typical sampling points for testing and provides typical combustion readings expected for specific equipment.

When available, always refer to and adhere to the manufacturer's specifications and requirements. In the absence of manufacturer's information, the typical readings included here are generally considered safe and reasonable guidelines for desired and expected equipment operation*. Safety is always the primary concern. Appliances producing carbon monoxide air free (or undiluted) ("COaf") at a level in excess of those in Table 1 (Carbon Monoxide Thresholds) should be shut off until repairs are made. If necessary, due to high COaf levels combined with flue gas spillage, provide an alternative heat source like electric heaters and contact the gas utility to red tag and disable the appliance.

Worst-Case Draft and Pressure Testing

Draft pressures are very low and can easily be overcome by mechanical fans like kitchen and bathroom exhausts, clothes dryers, or leaking ductwork. Worst case pressure testing is a method to identify if the combustion air zone (CAZ) has a high potential for flue gas spillage.

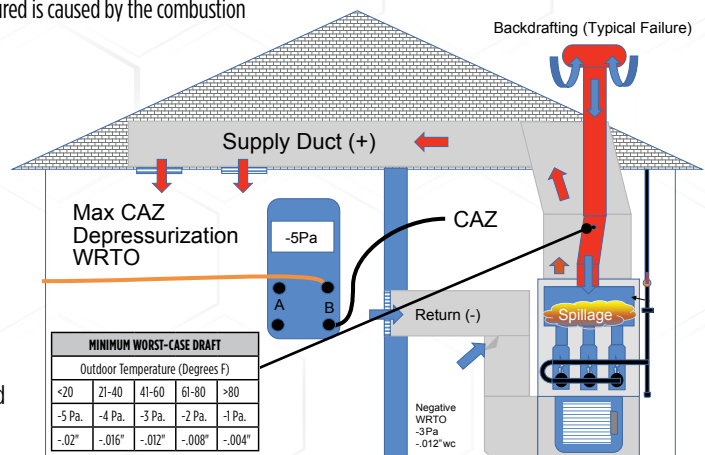
1. Measure and record the CAZ with respect to outdoor (WRTO) pressure difference with the CAZ door open. Then close the door and measure the pressure difference again. The negative pressure measured is caused by the combustion appliances and exhaust appliances.

2. Next, turn on the air handler; measure the CAZ-to-outdoors pressure difference again—first with the CAZ door closed, then with it open. Negative pressure or increased negative pressure (compared to Step 1) is caused by the furnace blower and return ducts. Verify the furnace base pan is sealed.

3. Now, close all interior doors; measure the CAZ-to-outdoors pressure difference again—first with the CAZ door closed then with it open. Negative pressure or increased negative pressure (compared to Step 2) is caused by imbalanced airflow between supply and return registers.

4. Finally, recreate the conditions observed in steps 1 through 3 above that produced the highest negative pressure. Test the appliances for safety and spillage under these conditions.

When there are multiple combustion appliances, operate them separately and together. Measure draft in each appliance and compare the negative draft to the values in the table shown above.



Follow BPI recommendations assuring safe levels of COaf (page 2), that there is no spillage at draft hoods (after 5 minutes cold and 2 minutes warm) and assure that the CAZ pressures are not exceeded.

*This guide is intended to assist trained HVAC technicians with convenient quick tips and is not a substitute for their professional judgment or education. Core Enterprises Inc. hereby disclaims all liability for misuse of this information.

STEPS TO A PROPER COMBUSTION ANALYSIS	
1. Verify safe levels of ambient CO	
2. Start appliance and check for spillage (Atmospheric draft or if connected to an atmospheric draft appliance)	
3. Set fuel pressure to manufacturer's specification	
4. Verify correct input (clock meter)	
5. Adjust manifold pressure as needed within allowable limits (3.2-3.8" typical)	
6. Combustion test	
7. Verify adequate draft	
8. Verify acceptable temperature rise (set blower speed)	
9. Verify maximum CAZ depressurization is within allowable limits	

CARBON MONOXIDE THRESHOLDS (FROM ANSI/BPI 1200-S-2017 SECTION 7.95 TABLE 1)	
Appliance Threshold Limit	
Central Furnace (All Categories)	400 ppm air free (COaf)
Floor Furnace	400 ppm air free
Gravity Furnace	400 ppm air free
Wall Furnace (BIV)	200 ppm air free
Wall Furnace (Direct Vent)	400 ppm air free
Vented Room Heater	200 ppm air free
Vent-Free Room Heater	200 ppm air free
Water Heater	200 ppm air free
Oven/Boiler	225 ppm as measured (CO)
Top Burner	25 ppm as measured (per burner)
Refrigerator	25 ppm as measured
Gas Log (Gas Fireplace)	25 ppm as measured in vent
Gas Log (Installed in Wood-Burning Fireplace)	400 ppm air free in firebox

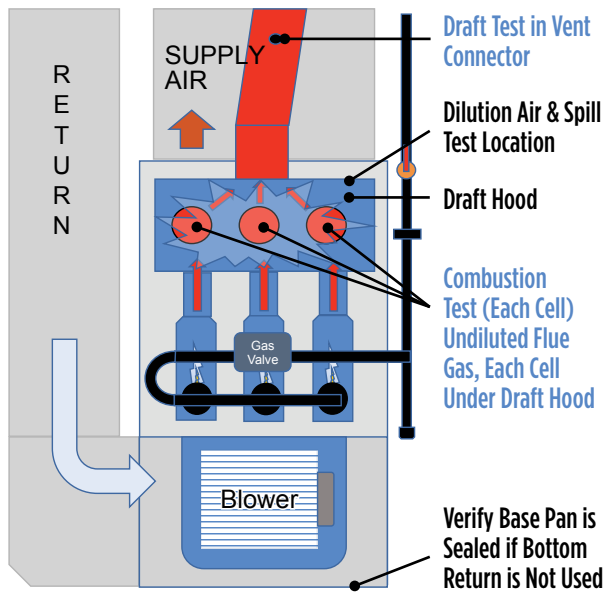
GENERAL GUIDE TO AFUE GAS APPLIANCE FEATURES	
Low Efficiency 50-60% AFUE	Standing pilot, draft diverter, gravity or belt drive, single upshot burner, cast iron heat exchanger, single wall flue pipe, operator set to 180° bonnet temperature
Standard Efficiency 70-75% AFUE	Intermittent pilot or hot surface ignition, draft diverter, with/without flue damper, direct drive blower, multi cell construction, ribbon or slotted port burners, single wall flue without chimney liner
Mid Efficiency 80+% AFUE	Intermittent pilot or hot surface ignition, induced draft, direct drive blower, multi stage or variable speed, in-shot burners, single or double wall chimney, if masonry, chimney must be lined
High Efficiency 85 to 90+% AFUE (May not always condense below 90%)	Intermittent pilot or hot surface ignition, induced or forced draft, direct drive blower, single stage, ribbon or in-shot burners, secondary heat exchanger, plastic vent pipe, medium to high temperature rise
Ultra High Efficiency 90 to 98.5+% AFUE (Condensing)	Intermittent pilot or hot surface ignition, induced draft, direct drive blower, single, multi-stage, or variable speed, in-shot burners, secondary heat exchanger, plastic vent pipe, lower temperature rise

APPROXIMATE STANDBY LOSSES TO COMPARE GROSS SSE* TO APPROXIMATE AFUE	
Minimum Stack losses based on max efficiency of 98.7%	1.30% gross and net loss
Stack Losses 80-120°F	-3 to -10% gross and net losses
No secondary heat exchanger	-10% to -18% gross and net losses
Draft Hood w/o flue damper	-5 to -10% gross, net, and standby losses
Standing Pilot	-10% standby loss
No circulation blower	-10% distribution loss
Uninsulated or leaking ducts	-10-30% distribution losses
Uninsulated cabinet losses	-5% distribution loss
For most condensing appliances, the net efficiency will be close to the AFUE All calculations based on AHRI Standard 1260 (I-P), Appendix E (Air-Conditioning, Heating, and Refrigeration Institute, 2017)	

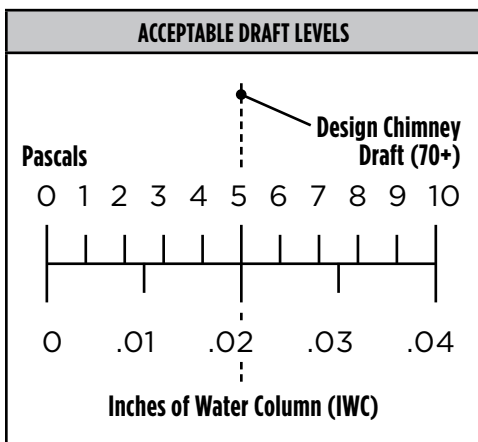
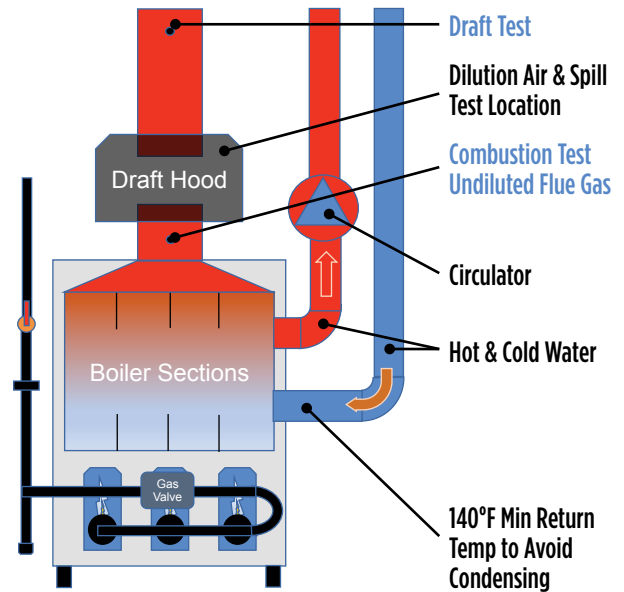
Standard Efficiency Atmospheric Appliances 70+% AFUE

Standard efficiency appliances have a draft hood or draft diverter to provide dilution air to dry flue gasses and prevent condensing in the chimney. In addition, the diverter physically disconnects the appliance from the draft source to prevent rollout if the chimney becomes blocked, and to prevent nuisance pilot outages in the case of a down draft. Primary air is entrained at the burner venturi, and secondary air entrained at the heat exchanger inlet by the natural rise of the hot combustion byproducts pulling in air behind them.

70+% Efficient Upflow Atmospheric Draft



Atmospheric Draft Hot Water or Steam Boiler



For a more precise level of acceptable minimum draft use the following formula

$$(ODT/40) - 2.75 = \text{draft Pa.}$$

Where ODA is Outdoor Air
Example: $(35/40) - 2.75 = -1.875 \text{ Pa.}$

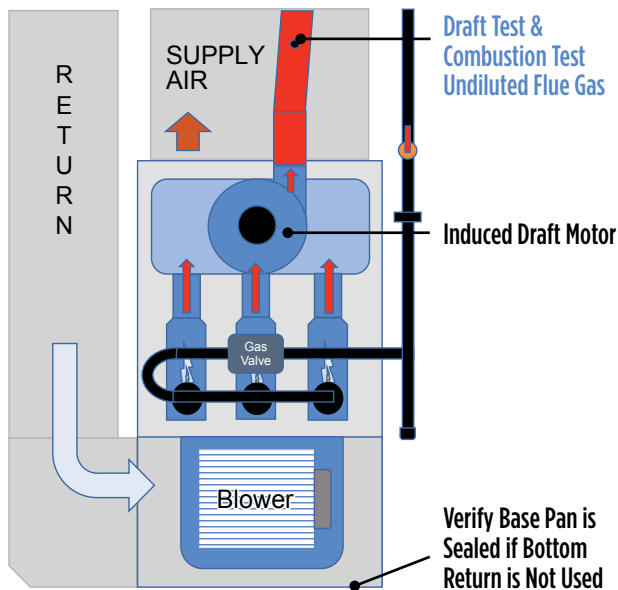
TYPICAL GAS APPLIANCE COMBUSTION TEST RESULTS	
Fuel Pressure**	3.2-3.8" WC
Excess Air	31-91%
O2 Reading	5-10%
Carbon Monoxide Air Free (COaf)	≤ 100*ppm
Stack Temperature (°F) Furnace/Hot Water	325-500°
Temperature Rise** (°F)	40-100° / 20°
Combustion Steady State Efficiency (SSE, Gross)	75-84%
Draft ("WC)	-0.02 to -0.04"
Max Combustion Air Zone (CAZ) depressurization	-4 Pa
*COaf below 100 PPM is typically always attainable, and should always be the goal in optimizing a unit for safe combustion. If 100 ppm COaf or less cannot be attained, it is permissible to leave the system in operation so long as the "Carbon Monoxide Threshold" (ANSI/BPI 1200-S-2017 Section 7.95 Table 1) is not exceeded.	Sample flue gasses in each combustion chamber before the draft diverter. Measure draft in the vent connector.
** Set per manufacturers' instructions. Ranges typical.	

Mid-Efficiency Gas Appliances

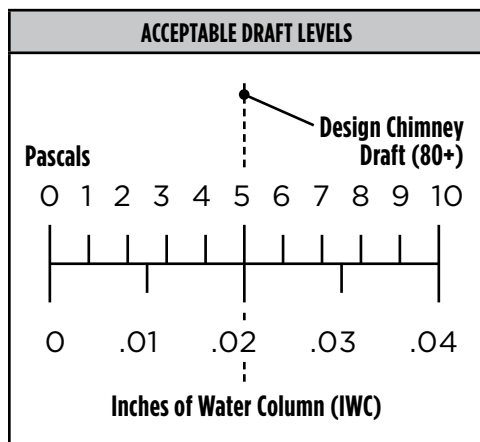
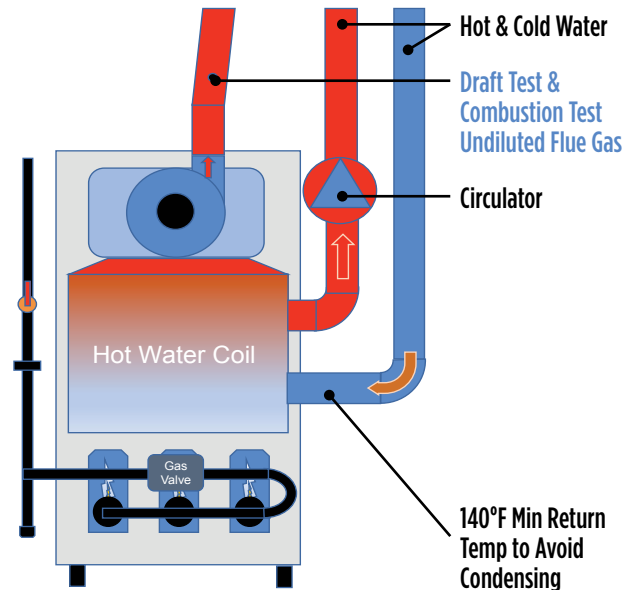
80+% AFUE

Mid efficiency appliances are equipped with a draft inducer fan to create a draft equivalent to the natural draft and air entrainment of a typical atmospheric appliance. This is required due to a more complex heat exchanger design which does not allow for the natural free flow of combustion gasses. Pressure and rollout switches are used assure draft, and to shut off the burner if rollout occurs.

80+% Efficient Upflow Induced Draft



80+% Hot Water Boiler



For a more precise level of acceptable minimum draft use the following formula

$$(ODT/40) - 2.75 = \text{draft Pa.}$$

Where ODA is Outdoor Air
Example: $(35/40) - 2.75 = -1.875 \text{ Pa.}$

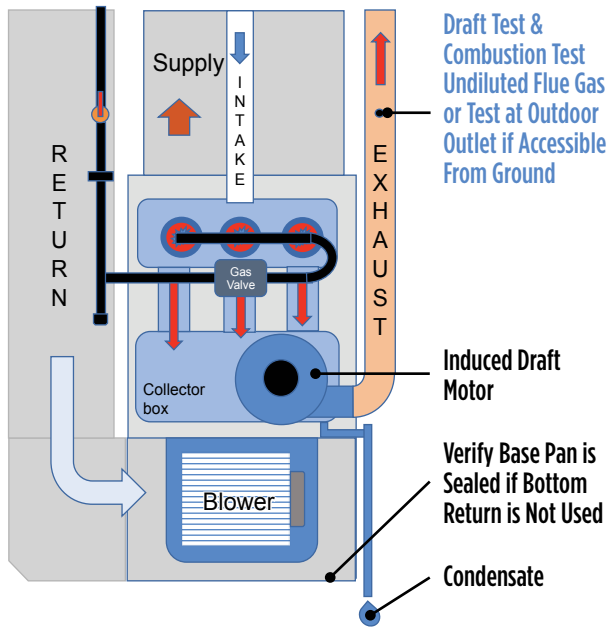
TYPICAL GAS APPLIANCE COMBUSTION TEST RESULTS	
Fuel Pressure**	3.2-3.8" WC
Excess Air	25-75%
O2 Reading	7-9%
Carbon Monoxide Air Free (COaf)	≤ 100*ppm
Stack Temperature (°F) Furnace/Hot Water	325-450°
Temperature Rise** (°F)	40-70° / 20°
Combustion Steady State Efficiency (SSE, Gross)	78-82%
Draft ("WC)	-0.02 to -0.04"
Max Combustion Air Zone (CAZ) depressurization	-5 Pa
*COaf below 100 PPM is typically always attainable, and should always be the goal in optimizing a unit for safe combustion. If 100 ppm COaf or less cannot be attained, it is permissible to leave the system in operation so long as the "Carbon Monoxide Threshold" (ANSI/BPI 1200-S-2017 Section 7.95 Table 1) is not exceeded.	Sample flue gas and measure draft in the vent connector 12-24" away from the induced draft motor.
** Set per manufacturers' instructions. Ranges typical.	

High Efficiency Condensing Appliances

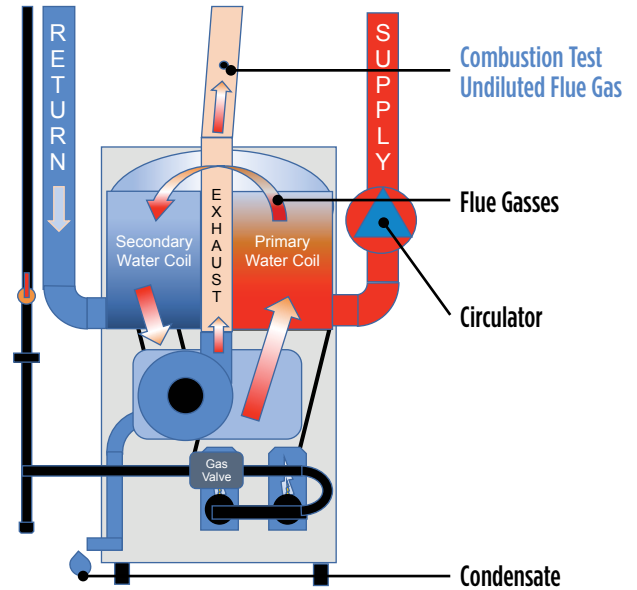
90+% AFUE

High efficiency appliances are equipped with a more powerful draft inducer fan due to extremely complex and restrictive heat exchanger designs that do not allow for the free flow of combustion gasses. With similar safety controls as the 80+ equipment, condensing furnaces are equipped with a secondary heat exchanger to lower the stack temperature which both condenses water vapor from the flue gas and decreases the stack losses capturing additional heat (sensible and latent). These features increase the overall net efficiency of the appliance.

90+% Efficient Upflow Induced Draft



90+% Condensing Boiler

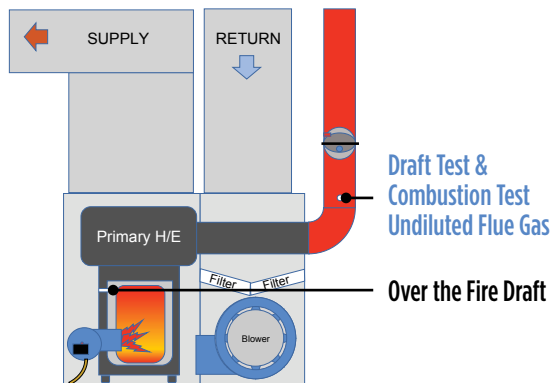


TYPICAL GAS APPLIANCE COMBUSTION TEST RESULTS	
Fuel Pressure**	3.2-3.8" WC
Excess Air	25-75%
O2 Reading	4.2-9%
Carbon Monoxide Air Free (COaf)	≤ 100*ppm
Stack Temperature (°F)	80-120°
Temperature Rise** (°F) Furnace/Hot Water Boiler	30-65° / 20°
Combustion Steady State Efficiency (SSE, Net)	89-98.5%
Draft ("WC)	+0.02-0.08"
Max Combustion Air Zone (CAZ) depressurization	-10 Pa
*COaf below 100 PPM is typically always attainable, and should always be the goal in optimizing a unit for safe combustion. If 100 ppm COaf or less cannot be attained, it is permissible to leave the system in operation so long as the "Carbon Monoxide Threshold" (ANSI/BPI 1200-S-2017 Section 7.95 Table 1) is not exceeded.	Sample flue gas and measure draft in the vent connector 12-24" away from the induced draft motor, or sample outside when vented horizontally.
** Set per manufacturers' instructions. Ranges typical.	

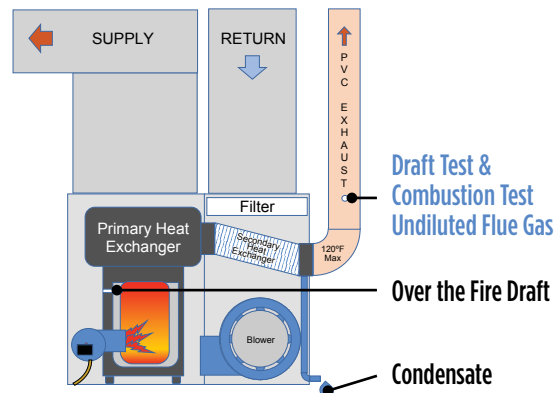
Fuel Oil Appliances Includes Boiler and Hot Water Tanks

Fuel oil appliances should be checked and adjusted annually to assure safe, reliable and efficient operation. Ideally the flame should be straw colored (carbon luminous), and smoke free at the highest safe CO₂. For the highest efficiency, oil furnaces should operate at their highest rated input. Because the primary heat transfer method is radiant, a larger flame closer to the combustion chamber walls will transfer the largest amount of heat the most efficiently. High CO_af can be caused from either too little or too much excess air. Too much excess air causes flame quenching or cooling resulting in unburned fuel.

Standard Oil Cast Iron Cone / Flame Retention Head Burner Lowboy Furnace



90+% High Efficiency FRH Burner Lowboy Furnace

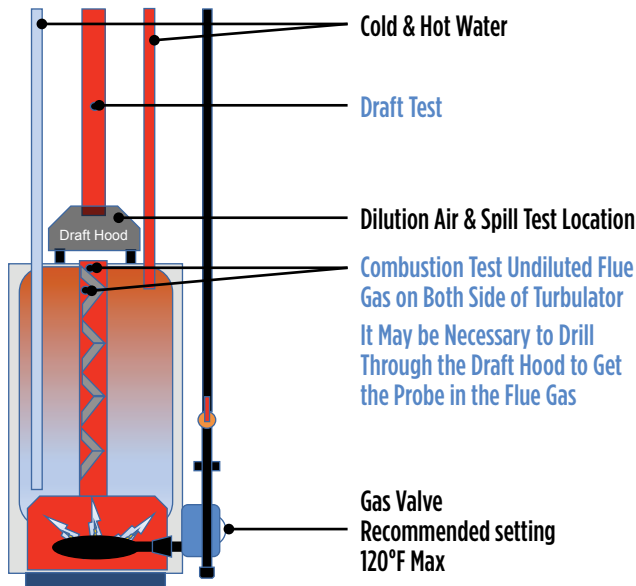


OIL APPLIANCE TEST RESULTS			
	Cast Iron Cone	Flame Retention Head (FRH)	FRH Condensing
Fuel Pressure**	100-150 psig**	100-150 psig**	100-150 psig**
Excess Air	30-75%	23.7-40%	23.7-40%
O ₂ Reading	5-9%	3-6%	4-6%
CO ₂ Calculated	8.9-11.9%	11.2-12.7%	11.2-12.7%
Carbon Monoxide Air Free (CO _a f) (ppm)	≤ 100*ppm	≤ 100*ppm	≤ 100*ppm
Stack Temperature (°F)	400-600°	330-450°	80-120°
Temperature Rise** (°F)	40-100°	40-70°	30-65°
Combustion Steady State Efficiency (SSE, Gross, Gross, Net)	73-79% Gross Eff	78-84% Gross Eff	89-98.5% Net Eff
Over the Fire Draft ("WC) (Sampled over the fire)	-0.02"	-0.02"	-0.02"
Stack Draft ("WC) (Sampled in the vent connector)	-0.02 to -0.04"	-.02 to -.04"	+0.02 to 0.08"
Max Combustion Air Zone (CAZ) depressurization	-4 Pa	-4 Pa	-10 Pa
Bacharach Smoke Spot#	#0 to #1	#0 to #1	#0 to #1
CO _a f below 100 PPM is typically always attainable, and should always be the goal in optimizing a unit for safe combustion. If 100 ppm CO _a f or less cannot be attained, it is permissible to leave the system on operation so long as the "Carbon Monoxide Threshold" (ANSI/BPI 1200-S-2017 Section 7.95 Table 1) is not exceeded. All calculations based on AHRI Standard 1260 (I-P), Appendix E (Air-Conditioning, Heating, and Refrigeration Institute, 2017) ** Set per manufacturers instructions. Ranges typical	Sample flue gas and measure draft in the vent connector or sample outside when vented horizontally.		

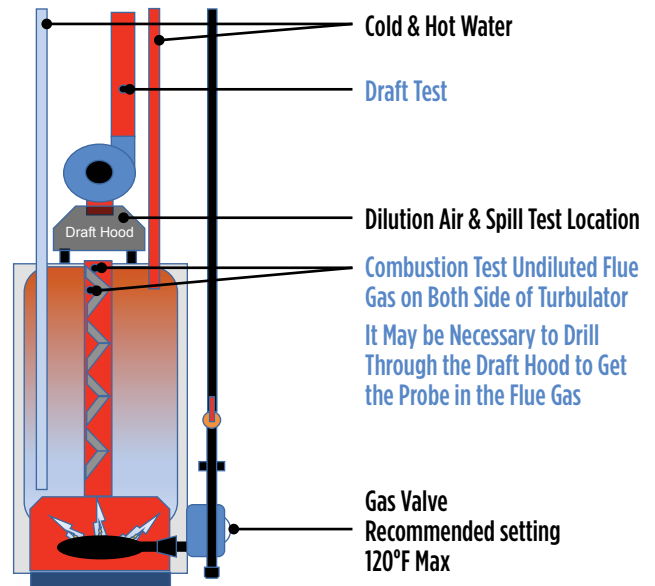
Domestic & Commercial Hot Water Tanks

Hot water tanks with standard and sidewall venting have a draft hood or draft diverter to provide dilution air to dry flue gasses and prevent condensing in the chimney or flue pipe. The diverter physically disconnects the appliance from the draft source which prevents rollout if the chimney or vent pipe becomes blocked, and nuisance pilot outages in the case of a down draft. Primary air is entrained at the burner venturi and secondary air entrained at the burner inlet by the natural rise of the hot combustion byproducts pulling in air behind them. When a hot water tank is under high demand or just filled with cold water flue gas condensing may occur until the water heats allowing the flue gasses to rise above the dew point temperature. Typically, the flue gas temperature should be no less than 270°F above the tank set point temperature.

Atmospheric Draft Hot Water Tank



Forced Draft Hot Water Tank



TYPICAL GAS APPLIANCE COMBUSTION TEST RESULTS	
Fuel Pressure**	3.2-3.8" WC
Excess Air	31-91%
O2 Reading	5-10%
Carbon Monoxide Air Free (COaf)	≤ 100*ppm
Stack Temperature (°F)	325-500°
Temperature Rise** (°F)	40-100°
Combustion Steady State Efficiency (SSE Net)	75-84%
Natural Draft / Forced Draft	-0.02 to 0.04 / +0.02-0.08"
Max Combustion Air Zone (CAZ) depressurization	-4 Pa
*COaf below 100 PPM is typically always attainable, and should always be the goal in optimizing a unit for safe combustion. If 100 ppm COaf or less cannot be attained, it is permissible to leave the system in operation so long as the "Carbon Monoxide Threshold" (ANSI/BPI 1200-S-2017 Section 7.95 Table 1) is not exceeded.	Sample flue gasses in each combustion chamber before the draft diverter. Measure draft in the vent connector.
** Set per manufacturers' instructions. Ranges typical.	

Cubic Feet (Ft³) of Gas Per Revolution

Seconds Per Revolution	Size of Meter Dial			Seconds Per Revolution	Size of Meter Dial			Seconds Per Revolution	Size of Meter Dial			Seconds Per Revolution	Size of Meter Dial		
	1/2 Ft ³	1 Ft ³	2 Ft ³		1/2 Ft ³	1 Ft ³	2 Ft ³		1/2 Ft ³	1 Ft ³	2 Ft ³		1/2 Ft ³	1 Ft ³	2 Ft ³
15	120	240	480	32	56	113	225	51	35	71	141	80	22	45	90
16	112	225	450	33	55	109	218	52	35	69	138	82	22	44	88
17	106	212	424	34	53	106	212	53	34	68	136	84	21	43	86
18	100	200	400	35	51	103	206	54	33	67	133	86	21	42	84
19	95	189	379	36	50	100	200	55	33	65	131	88	20	41	82
20	90	180	360	37	49	97	195	56	32	64	129	90	20	40	80
21	86	171	343	38	47	95	189	57	32	63	126	94	19	38	76
22	82	164	327	39	46	92	185	58	31	62	124	98	18	37	74
23	78	157	313	40	45	90	180	59	30	61	122	100	18	36	72
24	75	150	300	41	44	88	176	60	30	60	120	104	17	35	69
25	72	144	288	42	43	86	172	62	29	58	116	108	17	33	67
26	69	138	277	43	42	84	167	64	29	56	112	112	16	32	64
27	67	133	267	44	41	82	164	66	29	54	109	116	15	31	62
28	64	129	257	45	40	80	160	68	28	53	106	120	15	30	60
29	62	124	248	46	39	78	157	70	26	51	103	130	14	28	55
30	60	120	240	47	38	77	153	72	25	50	100	140	13	26	51
31	58	116	232	48	37	75	150	74	24	48	97	150	12	24	48
				49	37	73	147	76	24	47	95	160	11	22	45
				50	36	72	144	78	23	46	92	170	11	21	42

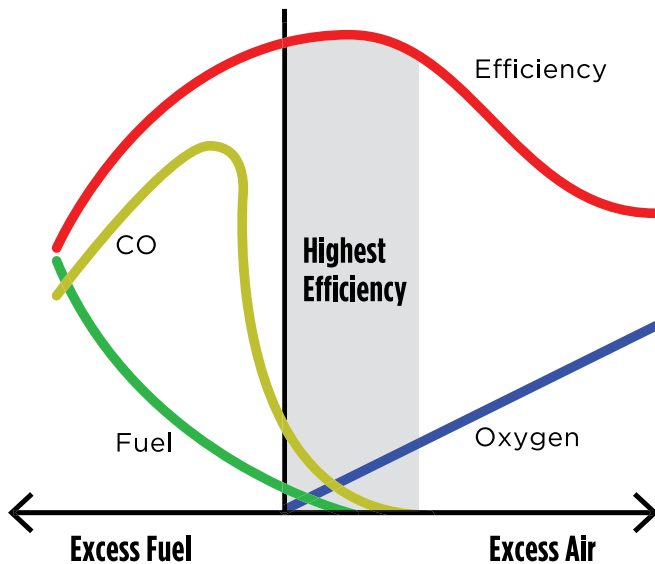
Heat Content Correction: (BTU Value From Supplier / 1000) x BTU/Hr From Table = Appliance Input

Verifying Correct Appliance Input

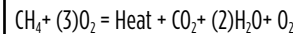
1. Time how long it takes for one revolution of 1/2, 1, or 2 cubic-foot dial. Find that number of seconds in the columns marked "Seconds per Revolution." Follow that row across to the right to the correct column for dial you timed. Note: that you must multiply the number in the table by 1000 to get the input.
2. If the measured input is higher or lower than input on the name plate by more than 10%, adjust manifold pressure up or down within a range of 3.2 to 3.8 IWC. (+/- 10% of 3.5 IWC nominal) to get the correct input
3. If the input is still out of range, replace or resize the existing orifices with orifices sized to give the correct input.

Note: The table assumes 1000 BTU/Ft³. If the heat content differs, use the formula below the table to correct for gas heat content.

Stoichiometric Combustion



THE IDEAL COMBUSTION PROCESS



Where

CH₄ = 1 cubic foot of methane gas (natural gas)

(3) O₂ = 3 cubic feet of oxygen

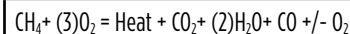
Heat = 1000 BTU's of heat energy produced by chemical reaction

(2) H₂O = two cubic feet of water vapor

CO₂ = 1 cubic foot of carbon dioxide (greenhouse gas)

O₂ = 1 cubic foot of excess air

TYPICAL COMBUSTION (CO ≤ 100 PPM COAF)



Where

CO = carbon monoxide (deadly gas)

Note: CO can be produced with or without excess oxygen



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