High Altitude Affects on Gas Fueled Water Heaters

All gas appliances need fresh air (containing oxygen) for complete combustion. When a water heater is designed in the research lab, it is designed for sea level applications. During the design process, the fuel flow rate is balanced with the available oxygen (at seal level) to produce a flame. The flame pattern is a steady, even, blue flame. The balance of the fuel-air mixture assists in the efficiency of the water heater and ensures a clean burn of the fuel.

Think of this process like the carburetor on a car. A normal carburetor has a fuel mixing valve and an air mixing valve. The mechanic adjusts these two valves to get the maximum revolutions per minute (which means maximum power and fuel efficiency) at a given idle speed. During the design of a water heater, the same idea applies. The difference, in the case of a water heater, is that you cannot control the air mixture.

Proper operation of a gas water heater requires air for combustion and ventilation. Fresh air provides the oxygen necessary for the pilot and main burner flame. To better understand, you must first start with the basic understanding of the combustion process itself. Combustion is a chemical reaction that occurs so fast it generates both heat and light. The three key ingredients of combustion are a fuel source, a supply of oxygen and a source of ignition (pilot, spark or match). As a rule of thumb, the mixture of fuel to air is approximately 1:10. Natural gas, for example, will require 10 cubic feet of air for every one cubic foot of gas to achieve a controlled combustion. The combustion by-products (heat, light, carbon dioxide, and water vapor) rise and vent to at outside atmosphere. When there is an inadequate fresh air source, incomplete combustion occurs and carbon monoxide is produced. Carbon monoxide is a lethal gas that is colorless, odorless and tasteless. It combines with the body's blood and prevents the absorption of oxygen.

In concentrations in air below four percent and above 14 percent, natural gas will not burn. When natural gas is used in a properly adjusted burner with an adequate air supply, its primary byproducts are carbon dioxide and water vapor. These are the same substances that are exhaled when we breathe. When not enough air is available to support proper combustion, less carbon dioxide is produced and carbon monoxide is produced instead.

OK, now that we have a background in combustion, let's talk about what happens when a water heater is installed in an application above sea level. The higher you go above sea level, the less oxygen content in the air. When we talk about high altitude problems with a water heater, the cause is not the heater, but the surrounding atmosphere. High altitude affects on a heater do not normally occur until the heater is installed in an application that is at or above 2,000 feet.

The trick is to balance the fuel-air mixture of the water heater in a high altitude application. Remember, you cannot control the available air - so your only choice is to control the fuel. The amount of fuel required at sea level for a *clean burn* is not the same amount of fuel required when the heater is installed in a high altitude application. Remember the careful balance of the fuel-air mixture at sea level? Well, the same must be done in a high altitude application. Remember, we said there was less air density (and therefore less oxygen) at higher altitudes? This means we will also need less fuel to produce the same ideal fuel-air mixture.

Balancing the fuel-air mixture is accomplished by doing one of two things: **derating the water heater** or **devaluing the gas fuel**. Derating the water heater affects only the heater and is accomplished by replacing the orifice in the burner assembly. Devaluing the gas fuel affects only the gas and is accomplished by the local gas utility. In some areas of the country, such as Denver, CO., the local gas utility derates the BTU value of the fuel from 1050 BTUs (the BTU value at sea level) to equal the normal average altitude of the area.

If a water heater is modified for high altitude, then either the heater must be derated or the fuel must be devalued. You must do one or the other - not both!

TECHNICAL SERVICE DEPARTMENT
Technical Service Bulletin
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The **main burner** orifice size controls the amount of fuel that is released into the combustion chamber of a water heater. If you reduce the orifice size, then you also reduce the amount of available fuel. This is exactly what we want to do in high altitude applications. The basic rule of thumb is this: For every 1,000 feet of altitude, you must reduce the main burner orifice size by four percent.

For example:

Main Burner Orifice size at:

sea level	2000 feet	3000 feet	4000 feet	5000 feet	6000 feet	7000 feet	8000 feet	9000 feet	10,000 feet
10	12	13	13	14	15	16	17	18	19

Reference: Table E.1.1(d) Equivalent Orifice Sizes at High Altitudes; NFGC 2012; p 54-137
(includes 4% input reduction for each 1000 ft above sea level)

Note: the smaller orifice sizes have larger number. Yeah, I know it is confusing!

High altitude = less oxygen; less oxygen = less fuel; less fuel = smaller orifice.

Another option to balance the fuel air mixture is to 'derate' the fuel. Gas utilities that service high altitude areas may have already compensated the fuel to provide a clean burn at higher altitudes. If the fuel has been derated, then you will not need to change the burner orifice in the water heater. Check with your local gas utility for their specific procedures on derating.

Symptoms of improperly adjusted combustion

Yellow flame
Sooting on the burner plate
Abnormal flame patterns (not clean, blue and steady)

All of these symptoms may indicate too much fuel present - and not enough oxygen for complete combustion.

Exceptions:

The exception to this procedure is the PowerVent water heater. PowerVent water heaters must have a high altitude blower motor. You can determine a PowerVent that has been manufactured for high altitude by finding the "H" in the model number. For instance - 21VP50**H**E-1A. The burner orifice has been changed to 5,000 feet on these ***high altitude*** PowerVents. If the user's altitude is higher than that, the heater must still be derated or the fuel devalued.

This technical bulletin does not discuss the pilot supply orifice. That is a totally different part. The pilot burner (supply) orifice is quite small – about the size of the sharp end of a sewing needle. Call technical support if you have questions about the pilot orifice.