

Answer: The short answer is that CO air-free is a carbon monoxide measurement that assumes that there is just enough oxygen in the combustion process to perfectly burn the fuel with no oxygen left over. In other words, no excess (extra) air is available. Because this is not realistic during normal combustion appliance operation, CO air-free must be calculated from the as-measured CO number and oxygen reading. As-measured CO is a direct measurement of the carbon monoxide in the flue products (which does contain excess air) during the normal combustion process.

Depending on your level of expertise, that answer may be a bit confusing. Consider the following for clarification.

Excess air:

In order to have complete combustion, excess air is required to ensure that there is enough oxygen present in the combustion process to completely burn all the fuel. Imagine that you have a high school dance and there are 50 girls on one side of the gym and 50 guys on the other side. What are the chances that there will be 50 couples on the dance floor? Not likely, right? It is the same with fuel and oxygen in a furnace. It is not likely that if you supply the exact amount of oxygen required for perfect combustion to the fuel that they will all find each other and burn nice and cleanly. But, in the dance analogy, if you had 75 guys on their side of the gym, the likelihood that all the girls are on the dance floor is pretty good. This is the same with combustion. If we supplied extra oxygen (excess air) to the process, the likelihood that all the fuel will be burned is much better.

So, when you perform combustion analysis, the oxygen number that shows up on your analyzer is a direct correlation to the % of excess air being supplied to that combustion process. You are reading the number of guys left over after all the girls are on the dance floor. Or, from a furnace perspective, the amount of air left over after we made sure all the fuel has been burned.

Air-free versus as-measured:

Carbon monoxide is typically measured in parts per million – PPM. If the volume of flue products is changed, it makes sense that the PPM concentration of CO in the flue products would also change. Since there is excess air being added to and diluting the flue products during normal operation, the as-measured CO number will always be lower than an air-free (no excess air) measurement because the volume of flue products would be greater. Also, this is hard to predict because the amount of excess air will vary from unit to unit. To try and help understand this concept let's compare two identical cups of black coffee.

To the first cup, we add two spoons of cream. The second cup gets four spoons of cream. (The coffee is the CO and the cream is the excess air). They are now different volumes and concentrations. I can measure the amount of coffee (CO) in each cup but the concentrations – PPM – will be different. This is as-measured CO. In order to know exactly how much coffee (CO) is in the cups, we need to remove the cream (excess air).

Air-free CO is what the PPM measurement would be if there was no cream in the cups. This means no excess air. This is an oxygen reading on your analyzer of 0%. Again, this is not realistic in actual operation so it must be calculated.

The combustion analyzer uses a mathematical formula to calculate this and gives us the air free reading. This formula is based on the oxygen and as-measured CO reading from your analyzer.

$$CO_{AFppm} = \left(\frac{20.9}{20.9 - O_2} \right) \times CO_{ppm}$$

Where:
CO_{AFppm} = Carbon monoxide, air-free ppm
CO_{ppm} = As-measured combustion gas carbon monoxide ppm
O₂ = Percentage of oxygen in combustion gas, as a percentage

In conclusion, understanding excess air and CO air-free is important because we have a better idea of how our combustion appliances operate and because BPI 1200 uses an air-free standard in its specifications for their operational testing procedures. ANSI design standards for manufacturers also use air-free in the standard. So, if you wish to communicate with a manufacturer about a CO problem you might be having, speaking "air-free" will add credibility to your inquiry.