Dispelling 10 Myths About Nitrogen Reflow

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Abstract

In my twenty years in the electronics manufacturing industry, I have heard a lot of claims made about the use of nitrogen in inerted soldering processes—many of them completely wrong.

In this paper, we will talk about reflow in an enclosed oven, although many of these discussions may pertain to wave soldering and even vacuum soldering.

Let's start with the real reason assembly engineers use nitrogen in inert soldering: because it is the cheapest gas available that does not react with hot metal surfaces to form an unsolderable film. That's it, period. People who use nitrogen for reflow are not using it because it has any wonderful properties. They are using it because it has low oxygen and moisture levels, and can purge (in other words, dilute) oxygen down to a level low enough to prevent or slow the oxidation of metal surfaces during heating.

Background

To understand any process using inert (unreactive) gases, you need to understand the composition of air—the most abundant gas available to us. Air is approximately 78% nitrogen, 20.9% oxygen, and 0.9% argon, with small amounts of other gases (carbon dioxide, etc.), along with varying amounts of water vapor. Water vapor may be present at levels up to approximately 4%, and, at this level, it will dilute the other levels of gases by (96/100), just in case you think there is a problem with the math. The 20.9% oxygen level equates to 209,000ppm (parts per million). The ppm unit is a much more useful measure when you are at low percentage levels, for example, 0.01% = 100ppm. It is also important to note that the fractional measure (ppm or percentage) correlates to the amount by volume and, from the ideal gas equation, also the molar percentage.

Busting Myths

Myth 1: *"Nitrogen removes oxides."*

Fact: Nitrogen used at reflow temperatures has no fluxing properties whatsoever and does not chemically react with anything at these temperatures. Fluxes are oxide-removing or oxide-reducing materials, and nitrogen is not a flux. Nitrogen prevents or slows oxidation or, in the case of a flux-cleaned surface, re-oxidation, because it is not an oxidizing

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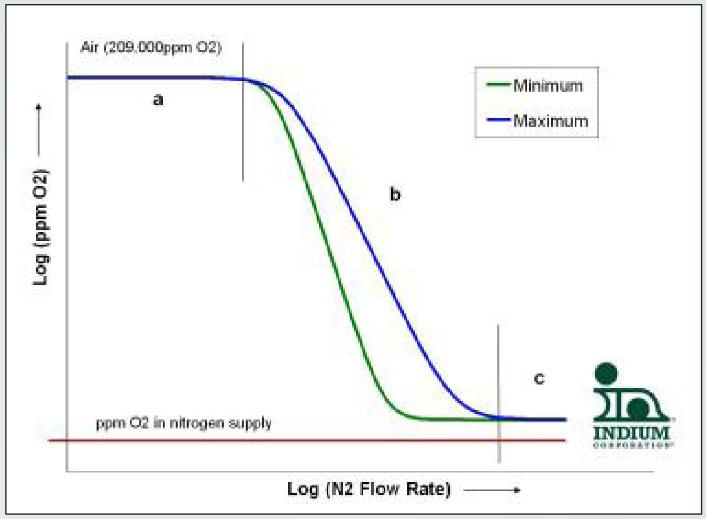
gas. Forming gas is a mixture of hydrogen and nitrogen, and is very different, as the hydrogen can act as a flux. I will discuss this in a subsequent note.

Myth 2: *"Nitrogen improves heat transfer."*

Fact: Nitrogen has no practical thermal effect on the soldering process. Heat transfer in gases at the same pressure and temperature is governed by the molecular weight of the gases—nothing else. Since nitrogen has a molecular weight of 28, and oxygen is almost the same at 32, the difference in heat transfer properties between air and nitrogen is minimal whether you are talking about laminar or turbulent flow.

Myth 3: *"If I measure the oxygen level in my incoming nitrogen, then I know the level in the oven."*

Fact: Even a seemingly well-sealed, inerted reflow oven is actually mixing ambient air with your nitrogen to some degree. It does this through simple diffusion (driven by the difference in the partial pressure of oxygen in air versus inside the oven) or by turbulent mixing of the nitrogen with air near an opening. What happens in a real oven is shown in the illustration on the right. Putting a low flow rate of nitrogen into the oven will have little or no effect (a). However, increasing the flow rate will reduce the level but will produce large variations (b). Finally, given a high-enough flow rate, the oxygen concentration will reach a plateau (c) where the minimum oxygen level possible is reached, but turbulent mixing is still introducing some oxygen from the outside air. As you increase the nitrogen flow rate, you are simply increasing the turbulence, and hence the rate of mixing.



Myth 4: *"Purer nitrogen will give me better results."*

Fact: Standard, cryogenic-quality nitrogen contains approximately 2-5ppm of oxygen. Even purging a well-sealed oven will not get you down to exactly the same level as the incoming gas. You will see no difference if you are using a nitrogen source at 10ppm or 10ppt (parts per trillion) oxygen. As you can see in the illustration (c), the effect of the highly pure gas is somewhat diminished due to its mixing with air.

Myth 5: *"Nitrogen reduces all soldering defects."*

Fact: Nitrogen can help with some wetting-related defects, and can often turn a marginally acceptable soldering process into an acceptable one. Note that the use of nitrogen may also create some undesirable consequences, including: increasing wetting ("wicking") uncontrollably onto lead frames or other surfaces; causing solder spattering; contributing to die tilt (power semiconductor assembly) or tombstoning (SMT).

Myth 6: *"I turned on the nitrogen flow, so my oven is now inerted."*

Fact: It takes time to purge an oven down (and yes, I have an equation to determine this). The final equilibrium oxygen level, as we have seen in the previous discussion, will be somewhere between that found in the incoming nitrogen gas and the 209,000ppm oxygen level found in air.

Myth 7: *"If I increase the nitrogen flow rate, I'll get a lower oxygen level."*

Fact: Yes you will, to a certain point. However, every reflow oven has a minimum oxygen level due to turbulent mixing (see Myth 3). You will never be able to reach the same oxygen level as that of the incoming gas because, by definition, it is impossible to hermetically seal an in-line reflow oven.

Myth 8: *"I have 26 identical reflow ovens using nitrogen gas, with the same inlet pressure, and I know the ppm oxygen level in one of the ovens, so the ppm will be the same in the others."*

Fact: I had a customer make this claim to me, then tell me that he had soldering defects in some ovens and not in others. Why? Because when we actually measured the oxygen levels, they were different in each oven—and not a small difference either. Measurements ranged from 80ppm oxygen up to 1% (10,000ppm) because the oven curtains were trimmed to different lengths.

Myth 9: *"I measured the oxygen level in my ovens once, so now I know exactly what it is."*

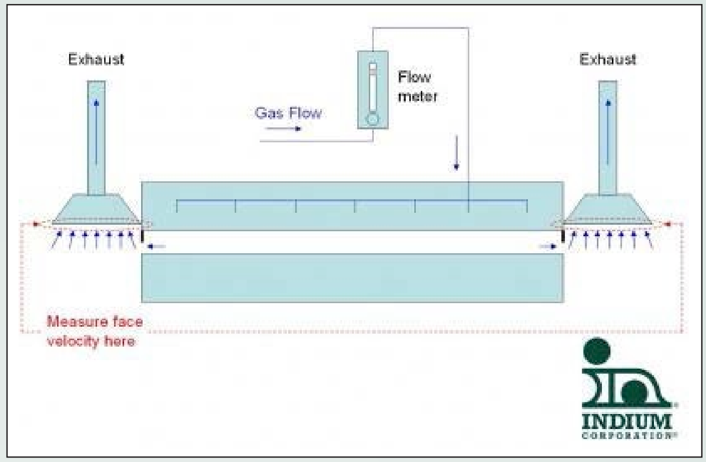
Fact: The "air tightness" of all reflow equipment changes over time. Among the factors causing these changes are:

- Flux residues may clog diffusers and block exhausts (blockage rates vary as the flux residues build up).
- Operators can trim curtains and adjust the oven exhaust balance.
- Copper-filled silicone gasket materials can lose pliability and harden so they no longer seal correctly.

One contract manufacturer I visited was having reflow problems. It was only when he disassembled the external exhaust system, and removed the two-foot-long (no joke here) piece of resin that was almost completely blocking his 4-inch duct, that he realized what was going on. Remember, flux "volatiles" only remain volatile if they are hot.

Myth 10: *"I can balance the reflow exhausts easily by having the inlet and outlet vents tied together."*

Fact: OK, this is from one engineer to another. The face velocity (gas flow rate, measured in units of ft/min or cm/min) at the exhausts at both ends of the reflow oven has to be the same (see diagram on right). Not the volumetric gas flow rates. Not the vent pipe inner diameter (ID). The reason is simple: if you have the same face velocity into the ducts at each end, you balance the Bernoulli Effect across the oven precisely, so that the pressure is the same. The minute you have a difference in the face velocity, you have a difference in the air pressure. This difference will drive air into the oven at a rate that is a function of the difference of the squares of the face velocities.



One final note: Inert or "nitrogen" soldering really should be renamed "low oxygen level" soldering to place emphasis on the control variable: the ppm oxygen (O_2). From an engineering perspective, it IS a critical control variable, and ppm levels within reflow ovens should be measured on a continuous basis.

Remember: "What gets measured gets managed." A variable that is not monitored cannot be controlled: just good engineering practice.