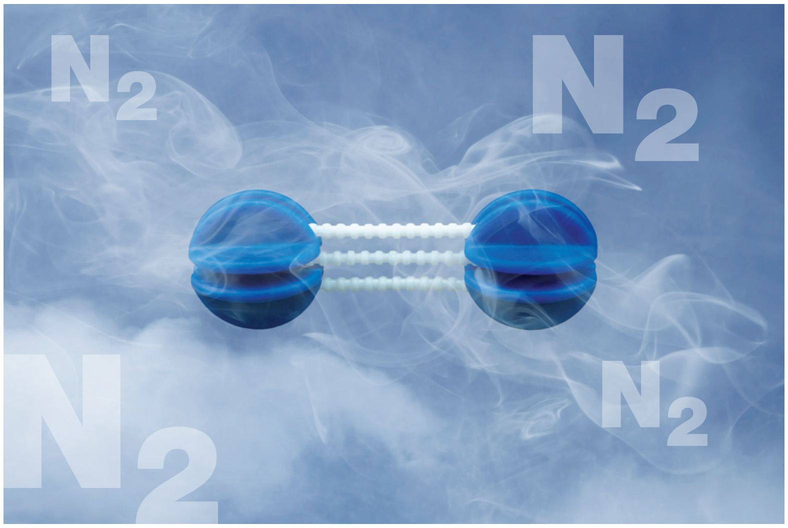
industry: semiconductor
author: **rob johnston**

WATLOW®
Powered by Possibility

Abatement of Waste Gases in Semiconductor Fabrication Using Nitrogen Heated with ***FLUENT®***



Summary:

Semiconductor fabrication creates a number of waste gases, many of which are corrosive, pyrophoric or potentially explosive. Often, diluting these gases with nitrogen gas (N_2) is an early step in the abatement process to make sure they either stay below the lower explosive limit or to reduce corrosive effects. Mixing colder nitrogen gas with waste gases has been known to accelerate condensation, and when deposits build up, it can lead to unplanned downtime. Heating the nitrogen gas is a better option, but only if this can be done in a way that does not introduce new points at which the nitrogen gas can leak from the system. Watlow's ***FLUENT®*** heating technology achieves this, meaning that semiconductor manufacturers no longer need to trade off between safety concerns and possible downtime caused by the need to flush clogged exhaust systems.

The Problem

In a sub-fab design, waste gases—typically hydrochloric acid, hydrofluoric acid, glycol ethers, methanol, xylene and various VOCs (volatile organic compounds)—are evacuated from the chamber via forelines using vacuum pumps. Most of these gases are hazardous in some way: Either corrosive, pyrophoric or potentially explosive, with the potential to cause substantial harm to people, equipment and the environment.

In addition, semiconductor fabs in the United States must comply with federal safety and environmental regulations, enforced by OSHA and the EPA. These regulations are outlined in legislation including the Occupational Safety and Health Act, Toxic Gas Ordinance and the Clean Air Act. Part of the regulations require that these gases be abated down to a given threshold level.

Dilution with Nitrogen: An Initial Solution, with Complications

One way to abate hazardous gases in process exhaust streams is to dilute them using a relatively harmless gas. In semiconductor fabs, nitrogen gas is often used because it is readily available and effective at diluting more hazardous gases prior to other abatement steps.

A good example of this solution comes from looking at potentially explosive gases, such as hydrogenated gases. These have an explosive range: A specific range of gas concentrations where explosion is likely to occur. Gas concentrations must be kept below the Lower Explosive Limit (LEL), which is the minimum concentration of gas needed to reach this explosive range.

The gases released from semiconductor fabrication are often over the LEL; mixing the gases with nitrogen lowers the ratio, making the gas too "lean" to pose an explosion risk.

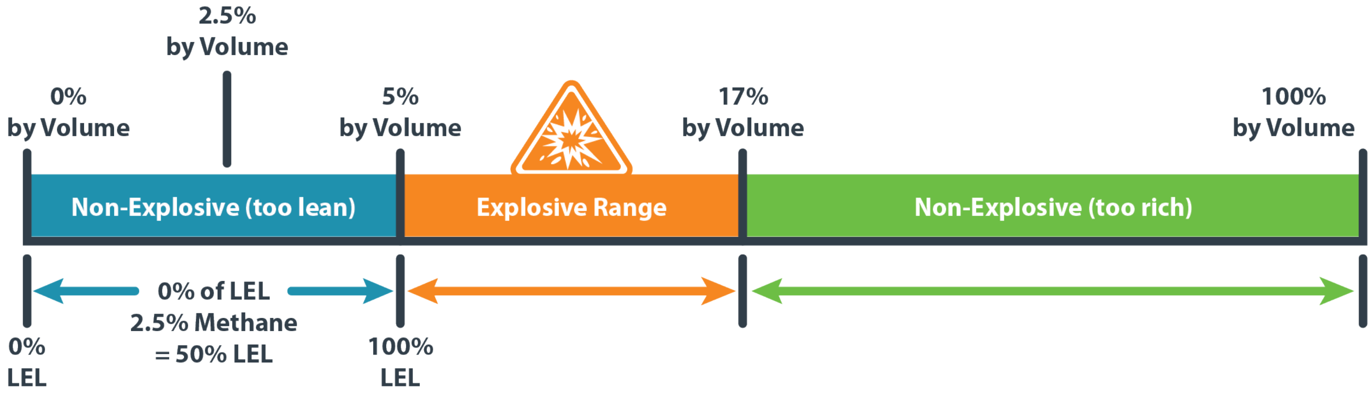


Figure 1: Explosive range of an air/methane mixture in semiconductor fab exhaust

That said, condensation is a potential issue when introducing a new gas into the exhaust stream. The waste gases coming from a typical fab floor are at a much higher temperature than the surrounding environment; adding room-temperature nitrogen effectively cools these gases, which can cause them to condense on the interior of the system, causing deposition. This eventually creates clogging, leading to unplanned downtime. Additionally, if combustion is used in the abatement system, adding cooler nitrogen will lower the temperature in the combustion unit and make it less efficient.

Thus, the addition of nitrogen poses something of a dilemma, forcing plants to choose potential line shutdown in order to ensure safety—a tradeoff no one wants to make.

[1] For a comprehensive look at exhaust management in semiconductor fabrication, see Sherer, Michael J. (2005). Semiconductor Industry Wafer Fab Exhaust Management, New York: Taylor and Francis.

[2] See the EPA's National Emission Standards for Hazardous Air Pollutants: Semiconductor Manufacturing from 2002 (***https://www.federalregister.gov/documents/2002/05/08/02-11298/national-emission-standards-for-hazardous-air-pollutants-semiconductor-manufacturing***); Final Rule ***amendments*** were made in 2008.

A Better Solution: Heated Nitrogen

If adding room-temperature nitrogen into a waste stream causes problems, such as increased condensation, heating the nitrogen is sufficient to avoid the problem. Getting nitrogen to temperature has, however, proved to be a tricky engineering problem.

One of the biggest issues is with nitrogen leaks. Introducing a heater into the system can potentially introduce another place where nitrogen gas can leak out, meaning that not all nitrogen gets into the waste stream for abatement. If the leak is severe enough, the hazardous gases will not be diluted enough for safety's sake—for example, a potentially explosive gas might still be well within its explosive range.

Space is an issue, too. There is limited space that can be taken up within an existing an abatement system, which in turn, limits the number of components, controllers and wires that can be added to the system, especially in multi-chamber setups.

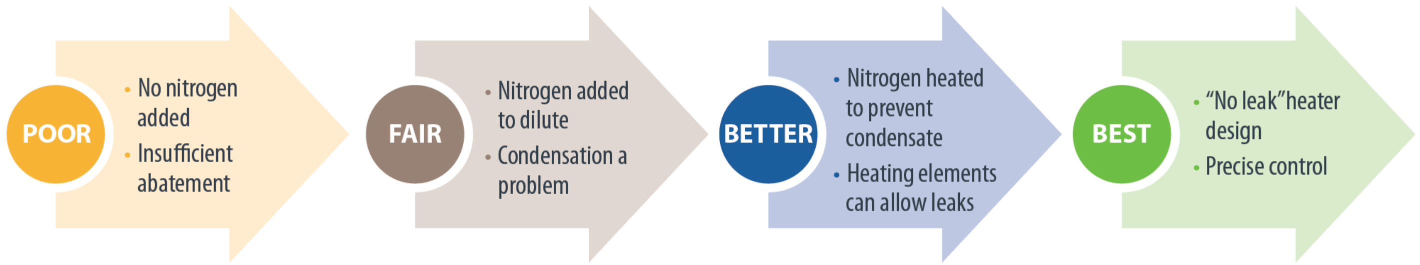


Figure 2: Stages in the problem-solution space of semi-fab exhaust abatement

The Best Solution: No-Leak Heater Design

A compact, no-leak heater design is needed to ensure the reliability of exhaust abatement systems in semiconductor fabrication. An example would be Watlow's ***FLUENT*** in-line heater, which is designed to allow movement of a fluid or gas over the heater surface without any loss of the fluid or gas through the outer shell.

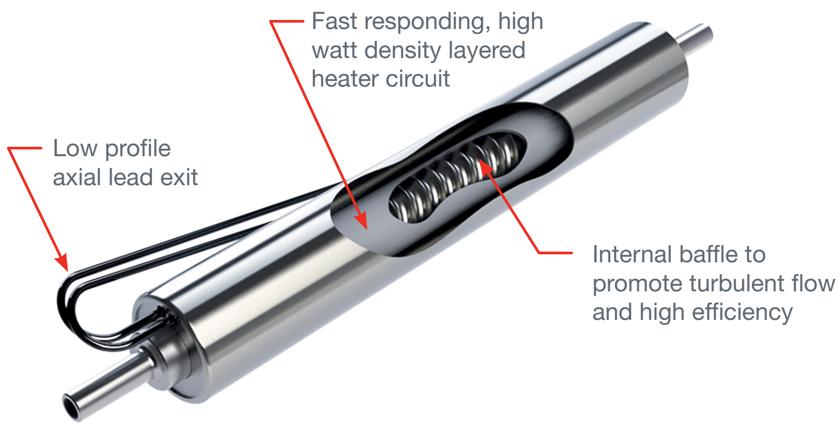


Figure 3: A look inside a Watlow FLUENT in-line heater

This no-leak design not only includes a seamless stainless steel outer protection tube, it also has the heating elements sitting outside of the fluid flow path. This means that neither the elements nor the wiring penetrate the gas flow path, mitigating the need to weld components in place and thereby create areas where gas can escape. This design thus ensures that all nitrogen gas is passed along into the process (and none escapes into the sub-fab).

With no leaks present, the correct mixture of gases can be assured. Furthermore, this design has been extensively tested in-line to verify that there is no loss of gas—i.e., 100% transmission.

To gain the most from Watlow's ***FLUENT*** in-line heater, it is best to pair it with an ***F4T***® touch-screen programmable controller. This is a single drop controller appropriate for multi-chamber tools that provide modular, scalable control of connected heaters.

Takeaways

A first step in the abatement of waste gases in semiconductor fabrication should be dilution with nitrogen gas. The best way to add said nitrogen is to heat the gas before it reaches the waste stream. This can create an additional issue, as traditional heaters can leak, throwing off the proper ratio of nitrogen to waste gas. A no-leak design, like that used in Watlow's ***FLUENT*** in-line heater, is thus an ideal way to add the appropriate amount of heated nitrogen gas, preventing condensate build-up and appropriately diluting hazardous gases.

Further information is available at: www.watlow.com