Additive Manufacturing and Gas Applications Technology

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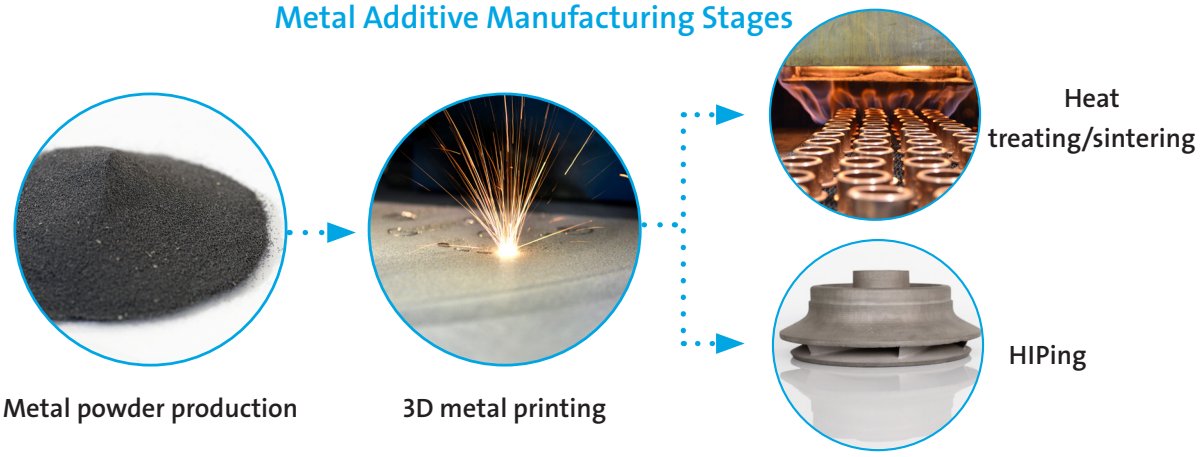
Contents

Industrial gases are advancing 3D printing processes

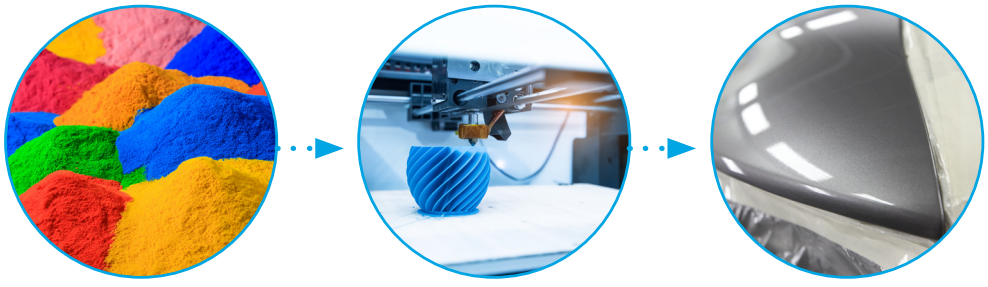
In the world of rapid prototyping and production of metal and plastic components, it is imperative to have the proper gas atmosphere to produce quality parts. To meet the high-tolerance standards required in Additive Manufacturing (AM), argon, nitrogen and helium are commonly used to provide inert atmospheres. Industrial gases are used every step of the way from powder production to the various additive manufacturing techniques to the finishing processes such as heat treating or HIPing (Hot Isostatic Pressing).

At Air Products, we have extensive applications knowledge in surface/bulk treatment of metals and plastics to help additive manufacturers optimize the gas selection, supply mode, and purity for improved part processing. This brochure highlights industrial gas usage for the steps before, during and after AM processing.

Metal Additive Manufacturing Stages



Plastic Additive Manufacturing Stages



Metal Additive Manufacturing

Metal Powder Production

Inert gas atomization is the best method to obtain dense, spherical particles, which are best for additive manufacturing applications, where the desired particle size is less than 100 microns. In addition, gas atomization greatly reduces risk for oxidation, providing a high level of powder purity and quality, resulting in more spherical powders. Table 1 lists the recommended gases for the powder atomization for specific metals. Helium provides the best results where its superior heat transfer capabilities are needed.

This process achieves all the following properties:

- Dense, spherical particles
- High quality and purity metal powders
- Narrow size distribution around 100 microns

In addition to various gas atmospheres, Air Products can also provide high pressure gases for powder atomization and hydrogen-based atmospheres for powder reduction.

Table I: Industrial Gas Recommendations for Powder Atomization of Specific Metals

Material	Preferred*	Alternatives
Aluminum	Ar	N_2 He
Carbon Steel	N_2	—
Cobalt	Ar	He
Copper	N_2	Ar
Magnesium	Ar	He
Nickel	Ar	He
Stainless Steel	N_2	Ar
Titanium	Ar	He

* Specific atomization gas selection depends on materials, process and equipment factors. Our experts at Air Products can help you make the best selection.

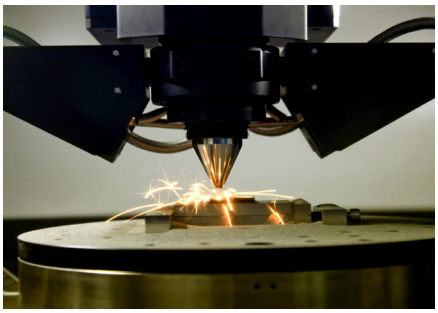
Metal Additive Manufacturing

3D Printing Process

To meet the high-tolerance standards required in additive manufacturing, nitrogen and argon are commonly used to provide inert atmospheres. The use of helium—with its high thermal conductivity—offers an interesting option for minimizing the thermal distortion of elongated parts during printing. Helium is often used for post-build quenching of operationally critical aerospace and medical components that are processed under vacuum in electron beam melting applications.

An inert atmosphere provides numerous benefits on a printed part by:

- Reducing oxidation of printed parts by lowering the oxygen content during the printing process
- Improving safety through the inerting of combustible dust during powder handling and sieving
- Creating a stable printing environment by maintaining constant pressure in the print chamber
- Mitigating powder clumping in the feed tube
- Preventing part deformation by controlling thermal stress through cooling



Gas requirements differ based on the process and the material being printed. For example, a direct metal laser sintering machine printing with cobalt chrome may require nitrogen, while a selective laser melting machine using the same material may require argon. Table II illustrates recommended gases for commonly used metal powders and printing technologies.

Table II: Gases Used for Common 3D Printing Processes

Manufacturing Method	Recommended Gases*
Laser Powder Bed Fusion	Ar, N_2
Electron Beam (Powder) AM	N_2, He
Electron Beam (Wire) Melting	Ar, N_2, He
Wire Arc Additive Mfg (WAAM)	Ar, He
Binder Jet Printing	Ar, He

*Gas used is dependent on process materials. Our experts at Air Products can help you make the best selection.

Metal Additive Manufacturing

Post Processing Treatment

Often, 3D printed parts require additional processing to achieve desired final properties. This is done mainly in the form of heat treating, sintering, or HIPing (Hot Isostatic Pressing). All three processes have industrial gas requirements to prevent oxidation. Table III lists the gases used in each process and the advantages of each of them.

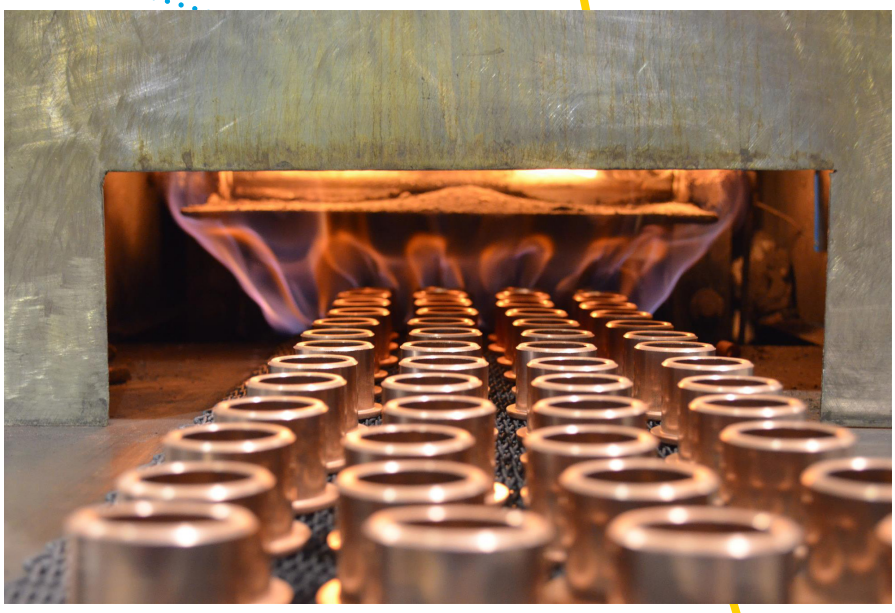


Table III: Gases Used for Post Processing Methods and Process Benefits

Process	Gases Used	Benefit
Sintering	N_2 Ar H_2 (H_2 used in forming gas blend)	• Near-net shape parts • Increased strength • Increased uniformity
Heat Treating	N_2 Ar H_2	• Relieved internal stresses • Increased strength • Increased ductility • Increased hardness
HIPing	Ar	• Fully dense parts • Increased strength • Increased reliability

Improve your heat-treating efficiency with Air Products' atmosphere supply and process management systems. These state-of-the-art systems monitor composition parameters to ensure your furnace is running with the desired gas atmospheres, and provide alerts for any needed maintenance or adjustments. They feature Air Products' Process Intelligence—our IIoT (Industrial Internet of Things) driven approach to process optimization, applying decades of metals processing experience in gas supply, applications knowledge, and safety. Table IV outlines Air Products' atmosphere management equipment, and their benefits.

Table IV: Air Products' Atmosphere Management Equipment Features

Equipment	Features
Precision Gas Blending Systems	• Real-time flowrate, pressure, and composition control • Built in human-machine interface • Control of 2- and 3-part gas mixtures
Intelligent Furnace Atmosphere Measurement Systems	• Real-time monitoring and control of furnace gas density, temperature, pressure, and purity • Manages dew point, oxygen level, hydrogen and/or carbon monoxide percentage, and carbon potential
Smart Nitrogen-Methanol Lance	• Real-time pressure and temperature updates for predictive maintenance • Improved atomization for increased efficiency
Process Data Acquisition System	• Stores all process parameters in one convenient location
Tank Monitoring System	• Tracks pressure, liquid level, and flowrate of bulk tanks • Remote data access

Plastic Additive Manufacturing

Cryogenic Grinding

PolarFit® Cryogenic Grinding Solutions for Efficient Size Reduction

Some materials that do not respond well to ambient milling may benefit from cryogenic milling or grinding. The temperature of thermoplastic materials or even some metal powders can be lowered to a point below their glass transition, for example, to allow for easier processing. Materials that might melt, oxidize or discolor with heat generated during grinding may benefit from the cooling provided by liquid nitrogen or carbon dioxide used with cryogenic milling in order to produce uniform particles at smaller sizes for use in 3D printing.

Air Products PolarFit size reduction systems use the cooling power of liquid nitrogen to remove heat produced in your grinding process, as well as control the temperature of your product or mill in an inert atmosphere. This can enable you to achieve finer, more consistent particle size distribution and higher throughputs. Cryogenic grinding offers many benefits over conventional grinding methods, including the following:

- Higher yield of particles in your target range
- More uniform particle size distribution
- Higher production rates
- Improved product quality
- Improved process safety due to inerting with nitrogen.

Air Products has decades of laboratory and plant experience in cryogenic grinding. As a leader in cryogenic applications, we offer complete technical service from our experienced staff and fully equipped facilities. Our cryogenic specialists can work with you to meet your product and process needs. At our trial facilities in Allentown, Pennsylvania, we can run your product on production-scale equipment to help determine the feasibility of using cryogenics in your process and also help quantify the benefits versus the cost.

Whether you have an existing cryogenic or ambient milling system that you need to upgrade, or plan to install a new system, our cryogenic specialists can help you design and implement the optimal solution to grind more effectively and efficiently. For more information about our cryogenic grinding solutions, visit **airproducts.com/grind**.

Industrial Gas Modes of Supply

Microbulk, Liquid Bulk and Onsite

Air Products has multiple supply options to fit your company's needs. Depending on the required flow rate and purity, our engineers can size a system that's right for you. Table V below lists the options we offer for specific flowrates.

Table V: Industrial Gas Modes of Supply

Gas	Microbulk	Liquid Bulk	Onsite
N_2	Flowrate: 250–5,000 SCFH Purity: ≥99.998%	Flowrate: 5,000–20,000 SCFH Purity: ≥99.998%	Flowrate: 5,500–150,000 SCFH Purity: 93-99.999%
Ar	Flowrate: 250–5,000 SCFH Purity: ≥99.997%	Flowrate: 5,000–20,000 SCFH Purity: ≥99.997%	—
He	Flowrate: 0–1,500 SCFH Purity: 99.995%	Flowrate: 5,000–20,000 SCFH Purity: ≥99.995%	—
H_2	Flowrate: 0–1,500 SCFH Purity: 99.95%	Flowrate: 5,000–20,000 SCFH Purity: ≥99.999%	Flowrate: 2,000–31,500 SCFH Purity: ≥99.999%

Industrial Gas Modes of Supply

PRISM® Membranes Built-In Solution

Builders of 3D printers can design membrane separators into the printer housing for convenient and continuous nitrogen inerting. This built-in solution prevents end users from the hassle of exchanging cylinders or coordinating their own inert gas supply.

Very small membrane separators fit counter-top printers while large membrane separators feed multiple printer banks. With many sizes in between, Air Products is known to offer the widest portfolio of membrane products across the broadest operating ranges, which means that system builders have the design flexibility to optimize their 3D printing application. Learn more at **airproducts.com/membranes**.

PA1010-N1 Membrane Separator for Small Printers

Product Flow Rate (SCFH) / Feed Air Flow Rate (SCFH)*						
	Nitrogen Purity (%)					
Pressure (BARG)	**99.5%**	**99%**	**98%**	**97%**	**96%**	**95%**
5	0.6/6	1.2/6.6	1.8/7.2	2.4/7.8	3.0/8.4	3.6/9.6
9	0.18/12	3.0/12.6	4.2/14.4	5.4/15.6	6.6/17.4	7.8/18.6
15	3.6/20.4	5.4/22.2	7.8/25.2	10.2/27.6	12.6/30	15/33

*Feed air temperature 55°C

PA4050-N1 Membrane Separator for Large Printers

Nitrogen Flow (SCFH) / Feed Air Flow (SCFH)*						
	Purity					
Pressure (BARG)	**99.5%**	**99%**	**98%**	**97%**	**96%**	**95%**
5	120/811	168/860	243/938	310/1,013	377/1,084	449/1,155
9	284/1,566	392/1,682	561/1,873	721/2,045	878/2,213	1,047/2,389
15	550/2,725	751/2,957	1,081/3,327	1,383/3,660	1,690/4,000	2,011/4,336

*Operating temperature 55°C.

Depend on a worldwide leader

For 75 years, customers around the world have come to rely on Air Products' industrial gases, gas atmospheres, equipment and technical support to help improve product quality, reduce operating costs, and increase productivity. To learn more about how Air Products can help additive manufacturers optimize their 3D printing processes, visit airproducts.com/3Dprinting.

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