



**Atmosphere solutions  
for metals processing**  
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## About us

Air Products touches the lives of consumers around the globe in positive ways every day. The company is recognized for its innovative culture, operational excellence and commitment to safety and the environment. Our aim at Air Products is to develop lasting relationships with our customers and communities based on human qualities: an understanding of their needs, integrity and honesty in the way we do business, and a passion for exceeding expectations.

### Air Products today

- More than 18,000 employees around the world
- Operations in more than 40 countries

## Metals processing

For over 50 years, metals processors 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. We offer industrial gases, gas handling equipment and technology, additives, global supply capability and—most importantly—unmatched industry experience and technical know-how to help you succeed.

## Air Products' technical services and equipment make us different

Metals processors need innovative ways to improve sintering, brazing, annealing, carburizing and neutral hardening operations. That's why more and more are turning to Air Products' Atmosphere Solutions.

We ensure that each Atmosphere Solution is right for each customer. Our experienced industry specialists and field support personnel can:

- Help you choose the right atmosphere composition
- Select and provide blending and flow control equipment
- Perform on-site atmosphere analyses for consistent dimensional control, carbon control, and physical and metallurgical properties
- Optimize your furnace process to lower operating costs
- Perform state-of-the-art metallographic and chemical analyses (SEM, ESCA, SAM, ISS, SIMS)
- Provide safety training
- Test atmospheres using your parts in our lab furnaces
- Demonstrate our system at your facility



Air Products' specialists are ready to help you with atmosphere solutions for metals processing.

# Annealing

Gas atmospheres for annealing can range from nitrogen-based blends with hydrogen for carbon steels (to improve microstructure, surface appearance and reduce residual stresses) to 100% hydrogen (for stainless steels or for faster batch processing of carbon steel components).

For virtually any annealing operation, Air Products has an atmosphere that's ready to perform. Whether you are annealing ferrous or nonferrous metals, our wide range of atmosphere solutions can ensure that your special atmosphere requirements can be fully satisfied.

Nitrogen, typically the main atmosphere component, provides the inert base that prevents undesirable reactions from occurring. Often, a reducing agent such as hydrogen or a hydrocarbon is added to adjust atmosphere reducing potential.

Since many of our atmospheres contain none of the unreacted hydrocarbons that are typically found with traditional exothermically-generated atmospheres, the improvement in surface quality often allows for a significant reduction in post-heat-treatment cleaning or pickling costs, sometimes by as much as 80%.

Air Products offers a complete range of atmosphere systems that excel in a wide variety of annealing applications.

## Stainless steel annealing

Our nitrogen/hydrogen atmospheres and pure hydrogen atmospheres provide the highest possible atmosphere quality for stainless steel strip, wire and tube applications.

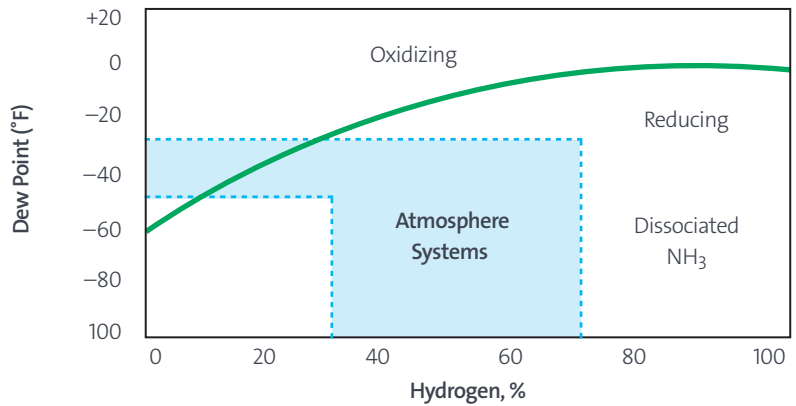
Any nitrogen-containing atmosphere such as dissociated ammonia can allow chrome-nitride formation in many stainless steels. Although the surface appearance may be acceptable, resultant intergranular nitrides may reduce corrosion

resistance of the material. Our 100% hydrogen atmospheres achieve the low dew point, strong reducing potential, and control necessary for superior surface cleanliness without nitride formation. (See Figures 1 and 2)

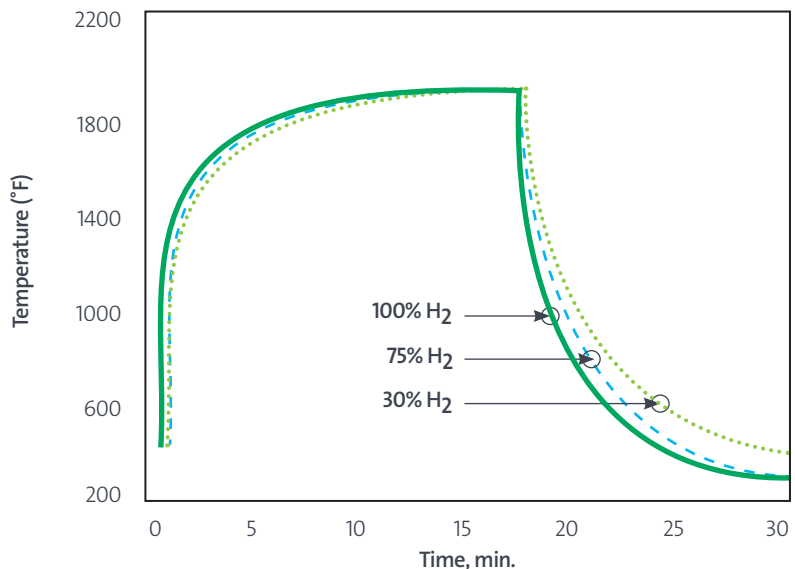
**Figure 1: Stainless steel annealing atmosphere composition**

Atmosphere Component	Dissociated Ammonia	Air Products' Atmospheres
N <sub>2</sub> %	25	0–70
H <sub>2</sub> %	75	30–100
O <sub>2</sub> ppm	10–35	5
Dew Point °F	–20 to –60	–90
NH <sub>3</sub> ppm	5–100	—

**Figure 2: Oxidation reduction for 18% chromium stainless steel at 2000 °F**



**Figure 3: Effect of atmospheric composition on heating and cooling rates**



The higher thermal conductivity of pure hydrogen over other atmospheres provides improved product and heating efficiency.

# Annealing (continued)

## Carbon and alloy steel annealing

When annealing sheet or coil product in high convection bell furnaces, the use of 100% hydrogen can reduce cycle time by as much as 50%, allowing for potential production increases (see Figure 3). And the extremely low density of pure hydrogen atmospheres reduces furnace fan power needs, allowing power cost savings as high as 35%.

For superior quality and control, our nitrogen-based atmospheres perform for virtually any type of ferrous product, including sheet, strip, and wire. A 4%–10% hydrogen level provides the reducing potential to prevent oxidation and decarburization. Detrimental carbon deposits are eliminated. Harmful carbon monoxide emissions are minimized. Small, controlled amounts of hydrocarbon maintain the carbon potential necessary for consistent quality. (See Figure 4)

## Nonferrous annealing

Our atmosphere systems for nonferrous annealing can maintain the consistency necessary for oxide-free surfaces and consistent metallurgical properties for nonferrous materials, such as aluminum or copper and brass tube, wire, and strip products. A 1%–10% hydrogen level in a nitrogen base provides the necessary reducing potential for maximum surface quality and minimum cleaning. (See Figure 5)

**Figure 4: Carbon and alloy steel annealing atmosphere composition**

Atmosphere Component	Endothermic	Exothermic	Air Products' Atmospheres
N <sub>2</sub> %	40	70–98	90–100
H <sub>2</sub> %	40	2–15	0–10
O <sub>2</sub> ppm	10–150	10–75	5
Dew Point °F	+10 to +50	–30 to +50	–90
CO%	20	2–12	—
CO <sub>2</sub> %	<1	1–10	—
CH <sub>4</sub> %	<1	<1	0–1

**Figure 5: Nonferrous (i.e., Cu) annealing atmosphere composition**

Atmosphere Component	Exothermic	Dissociated Ammonia	Air Products' Atmospheres
N <sub>2</sub> %	70–98	25	90–100
H <sub>2</sub> %	2–15	75	0–10
O <sub>2</sub> ppm	10–75	10–35	5
Dew Point °F	–30 to +50	–20 to –60	–90
CO%	2–12	—	—
CO <sub>2</sub> %	1–10	—	—
CH <sub>4</sub> %	0.02–0.10	—	—
NH <sub>3</sub> ppm	—	50–100	—

**Figure 6: Electrical steel annealing atmosphere composition**

Atmosphere Component	Exothermic	Air Products' Atmospheres
N <sub>2</sub> %	70–98	84–100
H <sub>2</sub> %	2–15	0–16
O <sub>2</sub> ppm	10–75	5
Dew Point °F	–30 to +50	–50 to +70
CO%	2–12	—
CO <sub>2</sub> %	1–10	—
CH <sub>4</sub> %	0.02–0.10	—

## Electrical steel annealing

Our nitrogen/hydrogen atmospheres with controlled oxidant additions provide optimum electrical properties in motor, transformer, and generator lamination grade steels. Superior atmosphere quality and consistency allow for improved lamination quality or equal lamination quality from lower grade feedstock material. (See Figure 6)

Both electrical properties like core loss and permeability and insulating properties provided by oxide bluing can be maximized through the precise monitoring of the atmosphere blend. Our atmosphere solutions have achieved up to a 15% improvement in electrical quality over other atmospheres.

# Brazing

Our brazing Atmosphere Solutions maintain atmosphere composition to optimize part strength and integrity. Product surfaces remain clean without sacrifice to product quality. Wettability can be controlled.

Nitrogen is used as the carrier gas with small percentages of hydrogen as the reducing agent. Small additions of hydrocarbon may be added to control and reduce the dew point to compensate for decarburization if required. Stringent control over the dew point-to-hydrogen ratio allows for the brazing of high-carbon steels, stainless steels, and nonferrous metals (see Figure 7). Improvements in the mechanical strength of the brazed joint and part surface quality are achieved through the consistent control of filler metal flow.

## Braze wettability is optimized

Because of furnace dew point flexibility and hydrogen content, atmosphere reducing potential can be controlled to vary braze wettability. In cases where minimum braze flow is desired, such as wide-gapped joint brazing, the reducing potential can be decreased with high dew points and reduced hydrogen levels. For narrow-gapped joints or high wettability needs, the atmosphere reducing potential can be increased with low dew points and increased hydrogen levels.

Figure 7: Brazing atmosphere composition

Atmosphere Component	Exothermic	Dissociated Ammonia	Air Products' Atmospheres**
N <sub>2</sub> %	70–98	25	98
H <sub>2</sub> %	2–20	75	2
O <sub>2</sub> ppm	10–75	10–35	5
Dew Point °F	–30 to +50	–20 to –60	*
CO%	2–10	—	—
CO <sub>2</sub> %	1–6	—	—
CH <sub>4</sub> %	0.02–0.10	—	—
NH <sub>3</sub> ppm	—	50–100	—
Base Material	Special Consideration	H <sub>2</sub> %	Dew Point
Iron	—	2	Low
Iron	Oiled Parts	3	Controlled
Iron	High Carbon	2	Low
Iron	Wide Joint Gap	2	Controlled
Stainless Steel	—	30–100	Controlled
Brass	Low Melting Point	5–25	Low

\* Controlled at different levels, depending upon application.

\*\* Typical

## Brazing surfaces are clean

Cutting oils and other residues often interfere with proper braze flow. Air Products' Atmosphere Solutions can produce atmospheres humidified to eliminate these carbonaceous materials from the brazing surface. With the change in dew point, the reducing potential of the nitrogen-based atmosphere still remains superior to that of an exothermic gas system due to the presence of small amounts of hydrogen. Product quality is not sacrificed. Flux can be eliminated. Cleaning operations are usually unnecessary.

## Decarburization is prevented

For brazing medium- or high-carbon parts, decarb caused by excessive dew point can be a major problem. The dew point of nitrogen is less than minus 90 °F, and oxygen and carbon dioxide levels are below 5 ppm—conducive to decarburization prevention.

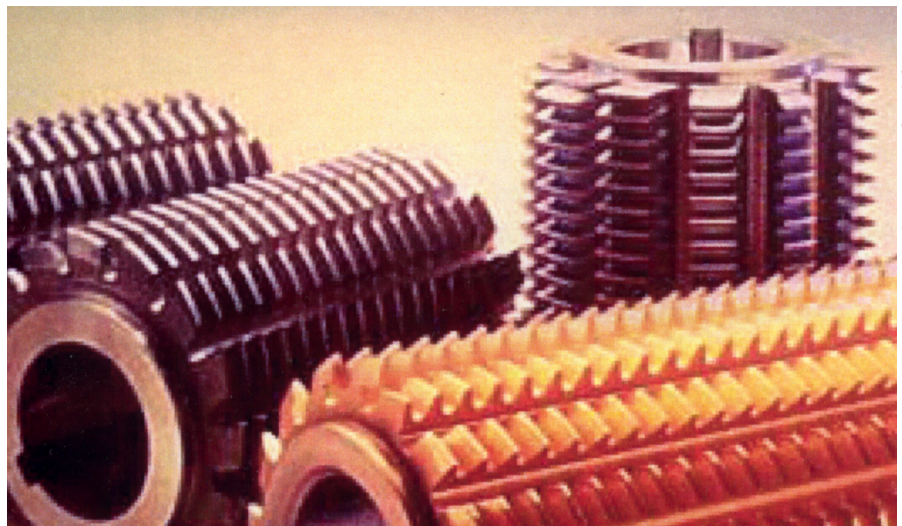


Photo courtesy of Handy & Harman

# Carburizing/neutral hardening

Air Products' Atmosphere Solutions are available for carburizing, neutral hardening, carbonitriding, nitriding and nitrocarburizing. Nitrogen, methanol, and a small amount of enriching gas are blended at the furnace to provide a furnace atmosphere essentially identical in composition to that of endothermic

gas—20% CO, 40% H<sub>2</sub>, and 40% N<sub>2</sub>. The benefit of Air Products' Atmosphere Solutions is superior atmosphere control for consistent part quality, operational cost savings, significant increases in operational productivity, and ease of operation. (See Figure 8)

## Atmosphere solutions can be controlled

With Air Products' Atmosphere Solutions, endogas composition is virtually duplicated by blending pure nitrogen with liquid methanol at the injection point of the furnace hot zone.

By varying the amount of enriching gas, the furnace carbon potential can be adjusted to meet your specific atmosphere requirements.

## Low-pressure vacuum carburizing

Air Products has developed high-pressure gas quenching solutions to meet the exacting demands of low-pressure vacuum carburizing technologies. Gas quench capabilities up to 40 bar using nitrogen, argon or helium can be provided. Specific equipment is recommended based on the type and volume of gas required. High-pressure gas storage can be custom designed and optimized to satisfy the specific requirements of the process and quench frequency.

## Atmosphere solutions are efficient

The elimination of endo-generation and its associated maintenance produces the greatest impact on cost reduction. With Air Products' Atmosphere Solutions, total gas flow and composition can be controlled easily and quickly to meet the requirements of each phase of the carburizing cycle. Because of the system's rapid turndown capabilities, compensation necessary for minimizing air infiltration is eliminated, allowing flow rate reductions of up to 50%. Air Products' atmosphere control system automatically increases flow with an inert nitrogen purge during charging, quenching, or furnace malfunction, enhancing operation efficiency and safety.

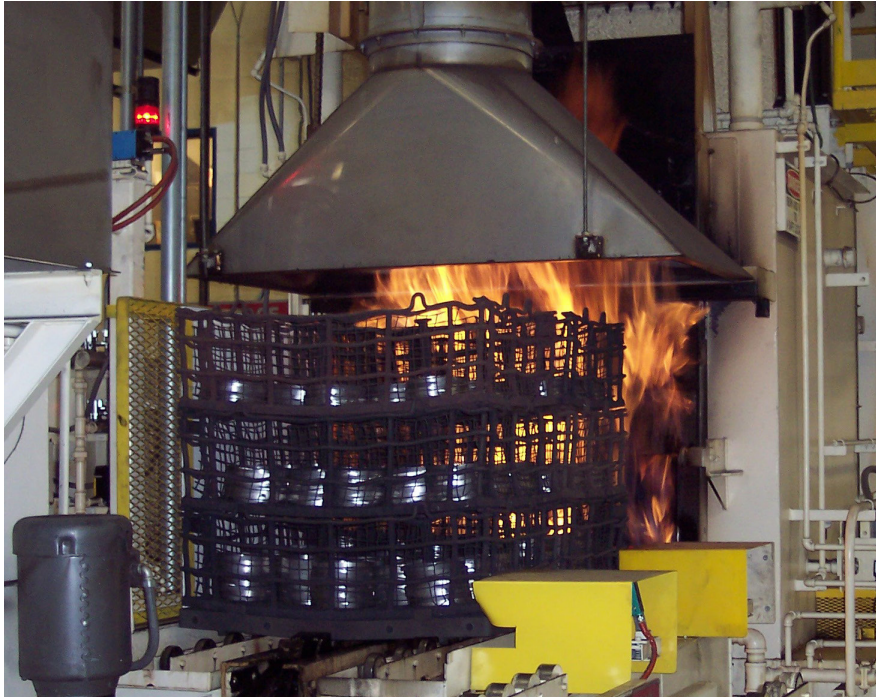


Photo courtesy of Surface Combustion

**Figure 8: Carburizing/neutral hardening atmosphere composition**

Atmosphere Component	Endothermic	Air Products' Atmospheres
N <sub>2</sub> %	40	40
H <sub>2</sub> %	40	40
CO%	20	20
CO <sub>2</sub> %	<1	<1
O <sub>2</sub> ppm	10–150	5
Dew Point °F	+10 to +50	-10 to +40

## Sintering

Air Products' Atmosphere Solutions for sintering provide an excellent means to improve the quality of the sintered components. Dimensional changes are minimized. The carbon levels in the core and surface of the powder metal part are better maintained, leading to improved hardness control. The atmosphere systems are also designed for improving lubricant removal.

The furnace atmosphere equilibrium is maintained through proper understanding of the furnace design, processing conditions, and the appropriate atmosphere composition and distribution in the furnace. Air Products' Atmosphere Solutions are primarily based on nitrogen, with small additions of reducing or oxidizing gases which provide the optimum atmosphere in each specific zone of the sintering furnace. These atmospheres are carbon-neutral and reduce adverse carburizing and decarburizing tendencies that are typical in endothermic type atmospheres. With Air Products' Atmosphere Solutions, the variations in atmosphere composition and dew point that are typical with endothermic atmospheres and dissociated ammonia are minimized. (See Figure 9)

### Ferrous sintering

For sintering typical iron-based parts, the nitrogen-based atmosphere system provides higher quality by carbon control and higher sintered strength. By adjusting the reducing and other enriching gases, we can tailor the atmosphere to better suit the specific requirements of the alloy and component being sintered. Small amounts of a hydrocarbon, such as natural gas, can be used to



Photo courtesy of St. Mary's Pressed Metals

**Figure 9: Sintering atmosphere composition**

#### Air Products' Nitrogen-based Atmospheres

Atmosphere Component	N <sub>2</sub> -H <sub>2</sub>	N <sub>2</sub> Dissociated Ammonia	N <sub>2</sub> -Endo**
N <sub>2</sub> %	0-100	85-100	85-100
H <sub>2</sub> %	0-100	0-10	0-10
CO%	—	—	—
Dew Point °F	-90 to -10	-70 to -10	-50 to +30
O <sub>2</sub> %	5	5	5
CO <sub>2</sub> %	—	—	—
CH <sub>4</sub> %	<1	<1	1

achieve additional control over dew points. By increasing the amount of reducing gas used, we can sinter stainless steel and other hard-to-sinter alloys such as higher alloyed sinter hardenable grades. Air Products has also developed proprietary solutions for more effective lubricant removal, copper infiltration and belt life extension.

### Nonferrous sintering

In nonferrous sintering applications, carbon control is not important and the sintered properties are more dependent on the reducing power of the atmosphere. By proper selec-

tion of the type and amount of these enriching gases, it is possible to obtain specific metallurgical properties, surface quality, and dimensional control.

### Powder treating

Air Products also provides gases and customized atmosphere solutions for a variety of other related technologies, such as powder atomization, powder annealing, hot isostatic pressing, metal injection molding and powder forgings.

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