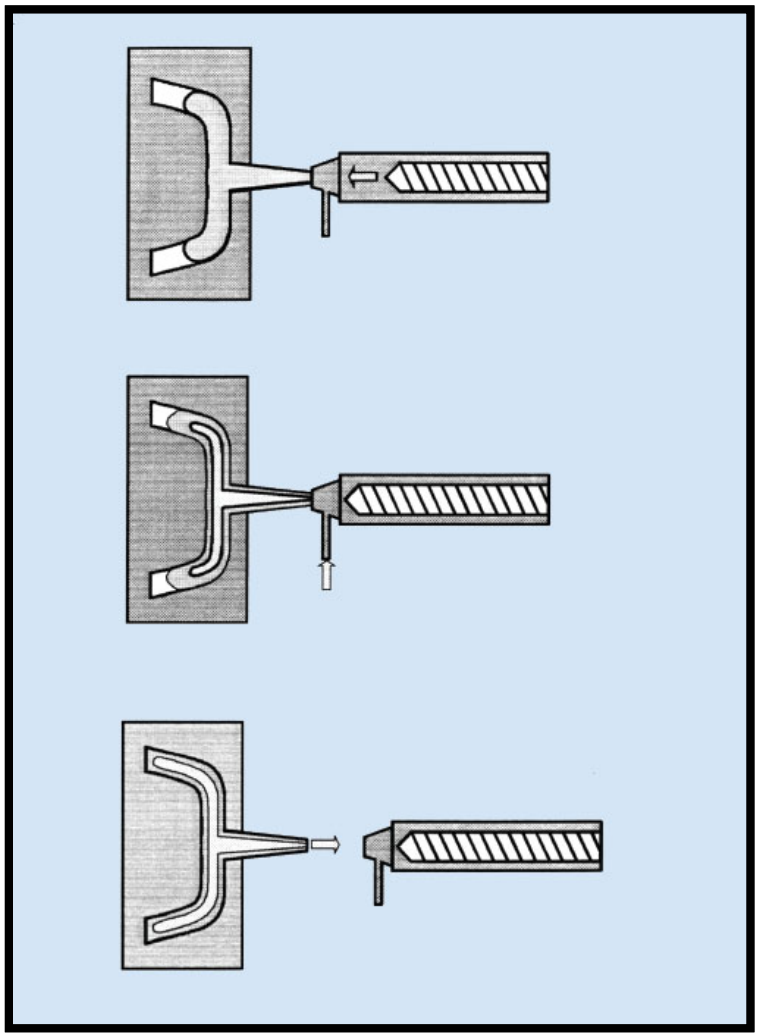
Supporting the Plastics Industry

Application Capability: Gas Assist Injection Molding

The GAIM Process

1. Slug of plastic is injected
2. Part of slug in contact with mold crusts and hardens
3. N2 is injected and takes path of least resistance
4. Pressure is held till polymerization is cured
5. N2 is released



GAIM Advantages

Increase:

- Design Freedom
- Productivity
- Efficiency
- Strength
- Rigidity

Decrease:

- Clamp Tonnage
- Energy Required
- Machine Size
- Cycle Time
- Part Weight
- Needed Plastic
- Cooling Time
- Oxidation
- Scrap

Quantifiable Advantages

Clamping Pressure Reduction	Plastic Weight Reduction	Reduction in Cycle Times
• 3000 psi vs. 25000 psi for conventional injection	• Thin-walled parts: 1-2% reduction • Thick parts: Up to 40% reduction	• Up to 50% due to plastic reduction, increased convection cooling and decreased clamping pressure

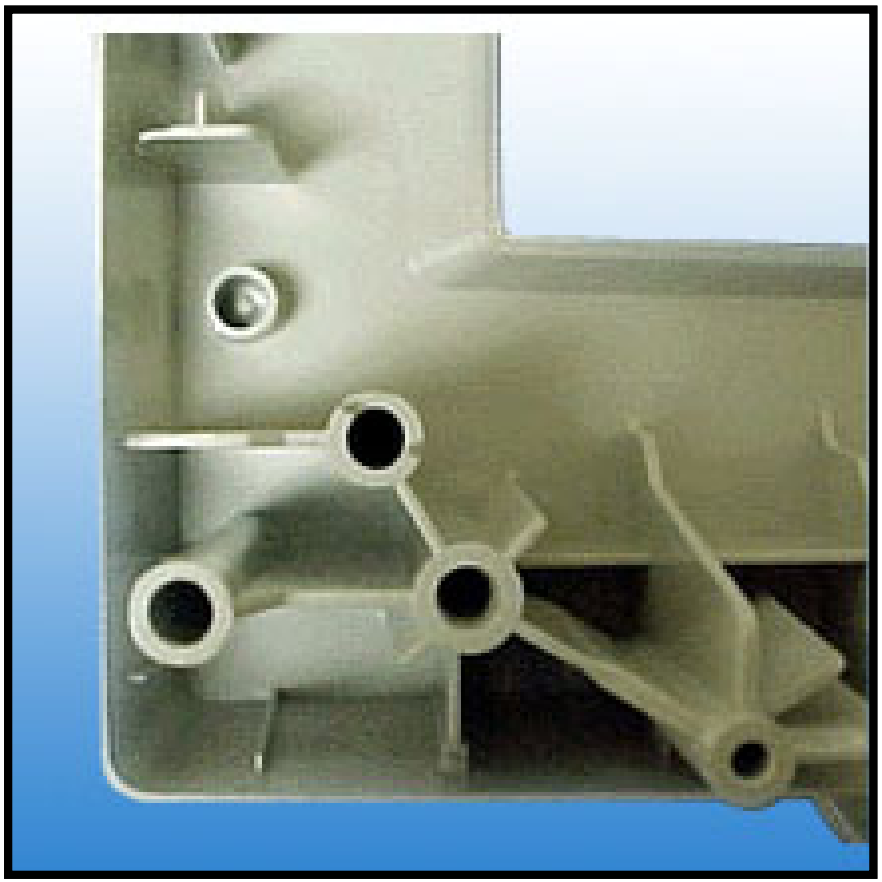
Why Use Nitrogen?

- Required to combat oxidation at polymer melt temperatures
- Extent of oxidation will dictate required nitrogen purity – nitrogen available in a wide range of purities to supply requirements

- **Other Benefits:**
  - Inexpensive
  - Easily compressible
  - Dry
  - Can be delivered easily at cooler temperatures

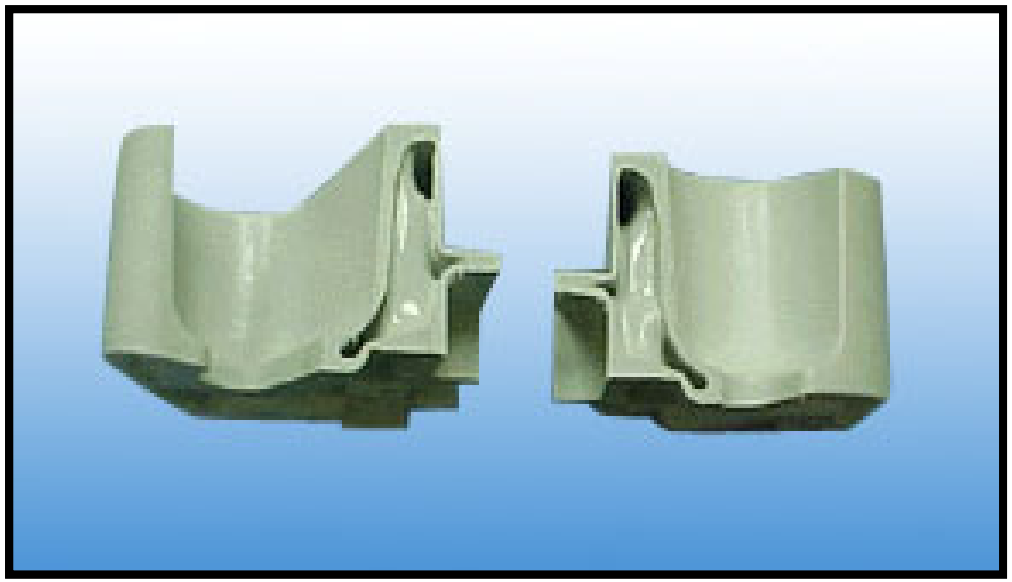
Application Examples

- Heavy ribs and bosses can be incorporated in your design without fear of sinks on the part surface. The ribs may actually be thicker than the nominal wall



Application Examples

- This part was originally molded in structural foam. With gas assist, the producer was able to reduce the shot weight by 1 pound, reduce cycle time by 34%, and limit the paint process to 1 coat.



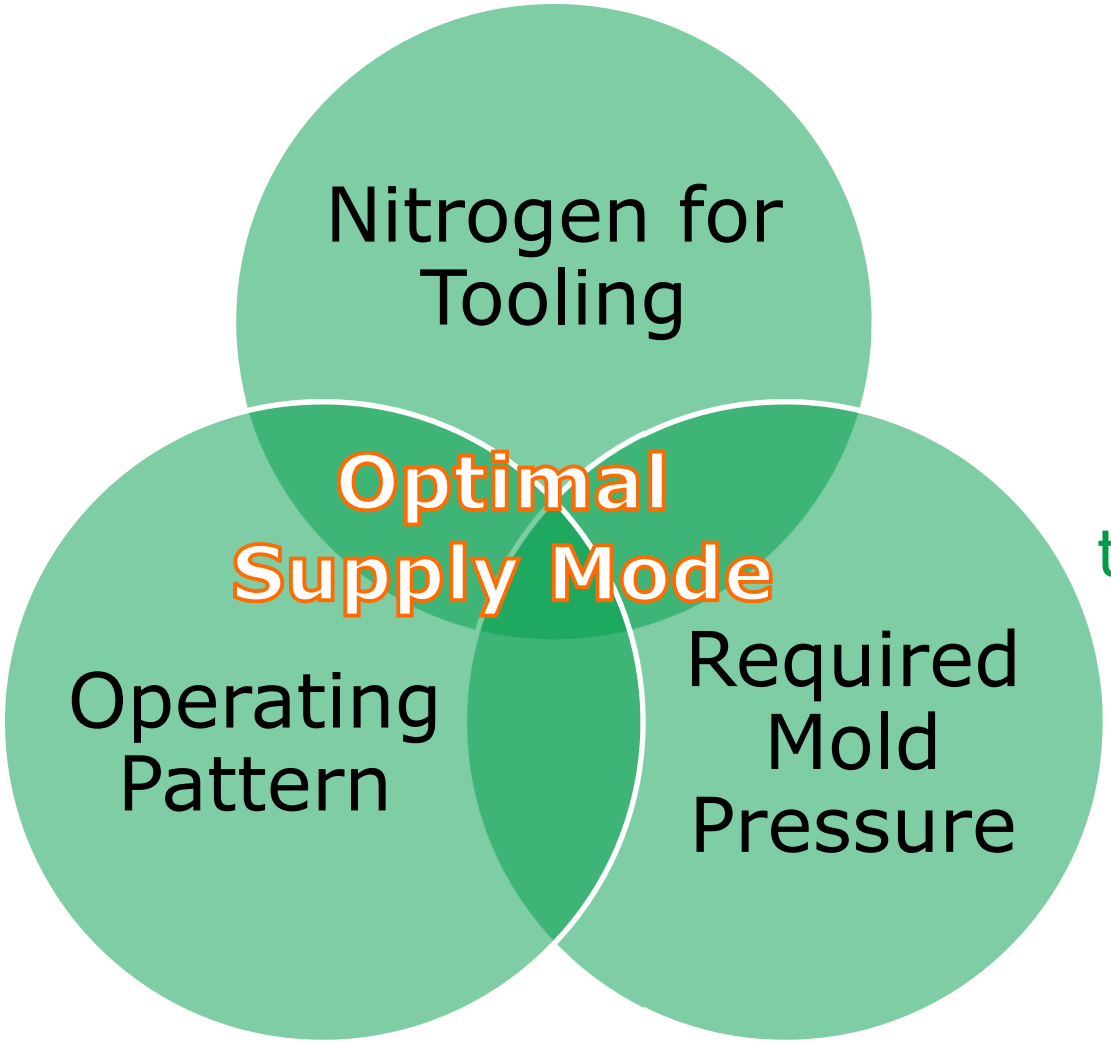
Applications and End Goals

Molding Type	Tube-and rod-like parts	Large, sheet-like, structural parts with a built-in gas-channel network	Complex parts consisting of both thin and thick sections
End Goal	Save material, reduce the cycle time, and incorporate the hollowed section with product function.	Reduce part warpage clamp tonnage, enhance rigidity and surface quality	Decrease manufacturing cost by consolidating several assembled parts into one single design
Example Applications	Clothes hangers, grab handles, chair armrests, shower heads	Automotive panels, business machine housings, outdoor furniture	Television cabinets, computer printer housing bezels, and automotive parts.

Typical Installation Process

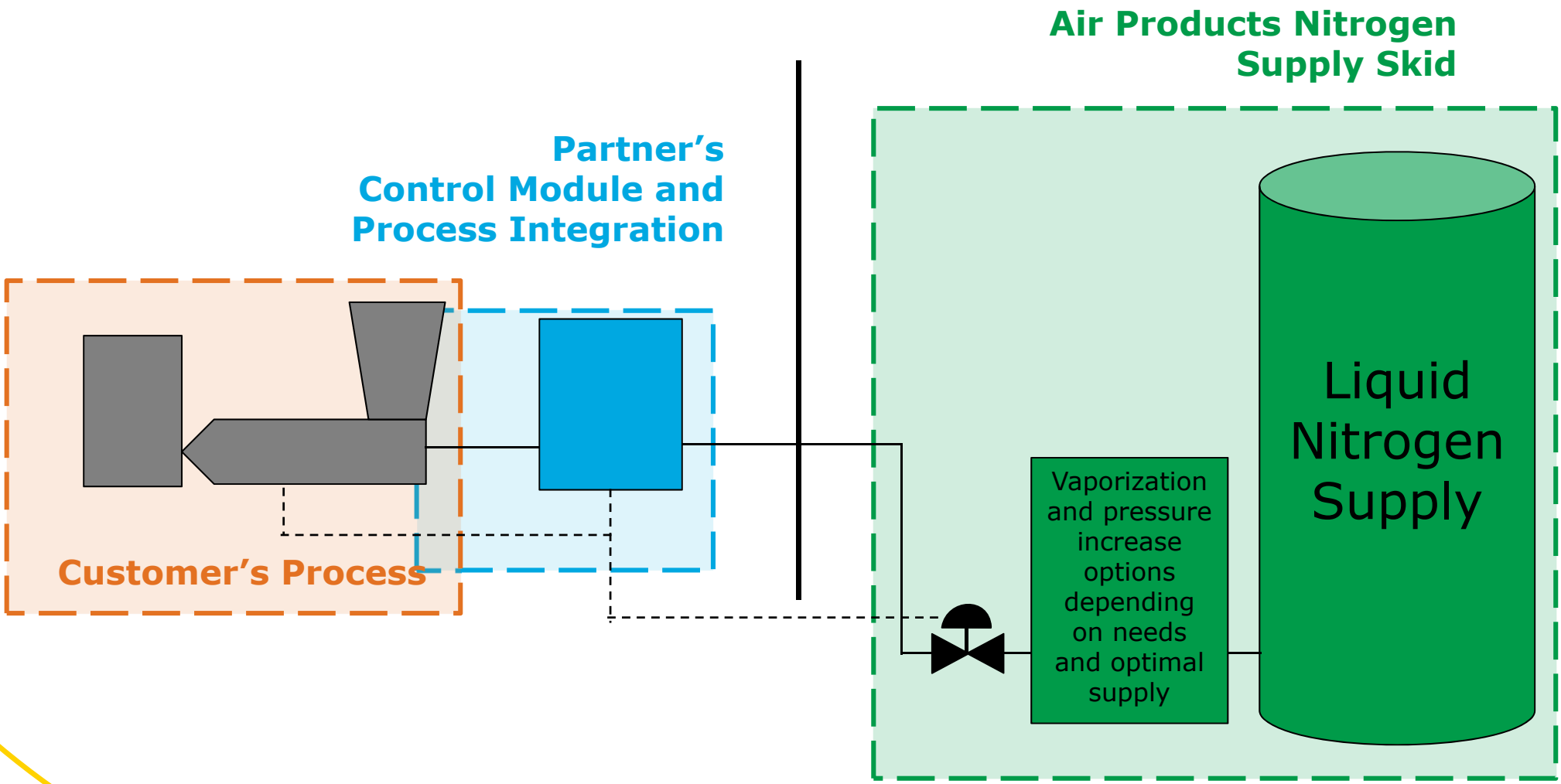
1. Initial meeting to assess customer needs
2. Consultation with technical experts to determine GAIM feasibility based on injection goals
3. Collaboration between Air Products, equipment manufacturer, and customer to optimize process conditions, nitrogen supply and tooling requirements
4. Project management, installation and start up
5. Continued process optimization after installation

Implementation Through Optimization



We match **your process needs** with the **supply capabilities** of Air Products and the equipment vendor to develop the **best and most economic** solution for you.

System Process Flow Diagram with Typical Scope Split



Supply Mode Options

Cylinders

Microbulk

Liquid Bulk

On-Site Generation - Membranes

On-Site Generation – Pressure Swing Adsorption (PSA)

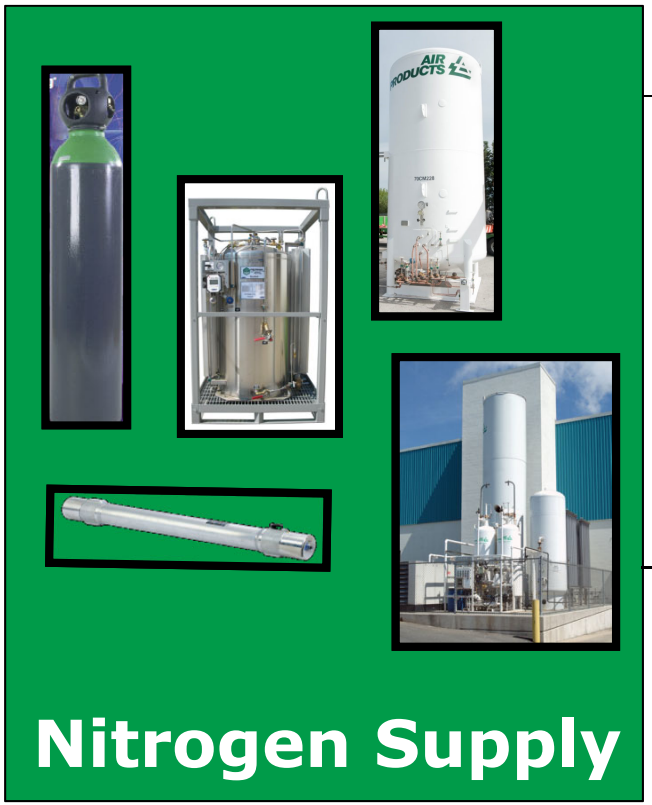
Increasing Volume Usage

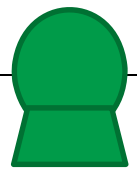
AIR PRODUCTS

Supply Mode Options

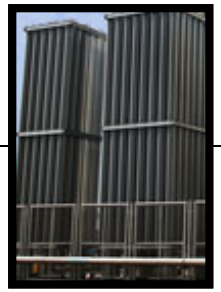
Outside Customer's Walls

Inside Customer's Walls



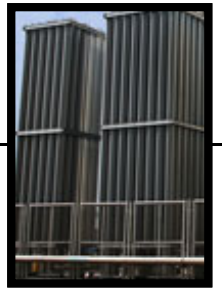


Air Products' Cryogenic Pump



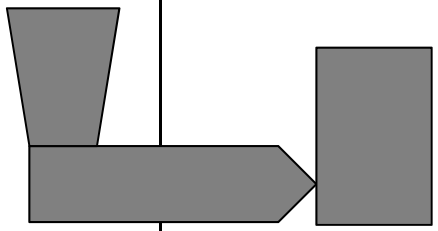
Vaporizer

Gas Controller and Pressure Boost



Vaporizer

Gas Controller and Full Compressor



Molding Machine

System Scope Split

Customer

- Define Process Needs
- Install piping inside battery limits (*)
- Provide access to install nitrogen injection in tooling

Air Products

- Determine optimal nitrogen compression pressure
- Determine low cost supply mode
- Ensure deoxygenation specifications
- Use of CFD modeling for tooling design
- Size, install and maintain nitrogen storage system
- Supply nitrogen

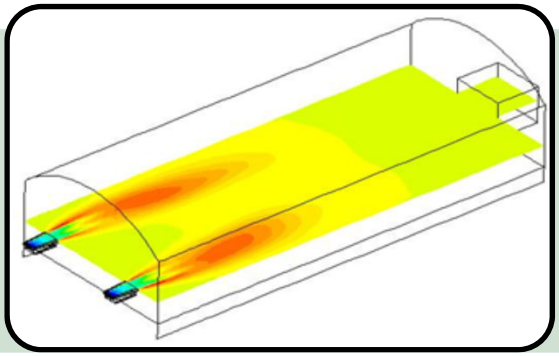
GAIM Partner

- Determine injection feasibility based on tooling
- Design controls scheme with nitrogen and molding process
- Supply appropriate nitrogen injection equipment and retrofit tooling
- Start up controls and injection equipment

Why Air Products?

Patented Cryogenic Pumping Technology

- Higher efficiency than typical cryogenic pumps
- Lower cost and power usage (10-20% reduction) than compressor



Industry Leading Computational Modeling Center

- First in industry – started in 1985
- World class, used to optimize and conceptualize applications

Collaborative Supply Approach to Drive Value

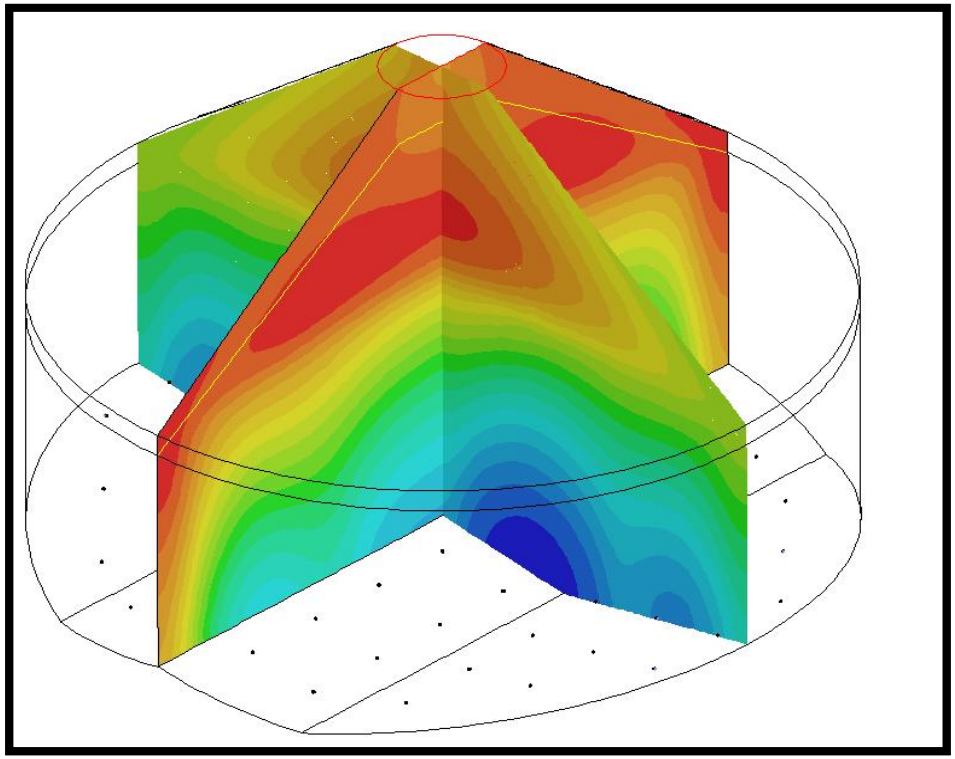
- Best in class research experts and engineers specializing in plastics
- Only Industrial Gas Company on Forbes' Top 100 Innovative Companies

Patented Cryogenic Pumps

- Standard pump design adapted to increase pumping efficiency over industry norms
  - Average of 5% savings
- All pumps reworked by Air Products dedicated cryogenic machinery facility
- Available in several standard sizes

Computational Modeling Center

- Air Products is a leader in the industrial gas industry in Computational Fluid Dynamic (CFD) modeling
  - First use in 1985
  - One of the first industrial customers of Fluent
- Air Products accelerate CFD application to support R&D, engineering, and customer support in last decade due to
  - High Performance Computing established in early 2000
  - Established use case, calibration and validation of physics
  - Enhanced features for pre-processing (Geometry, meshing) and post-processing



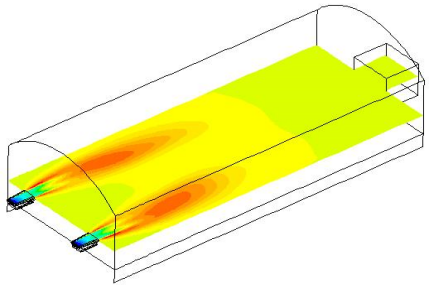
AIR PRODUCTS

Frequently Asked Questions

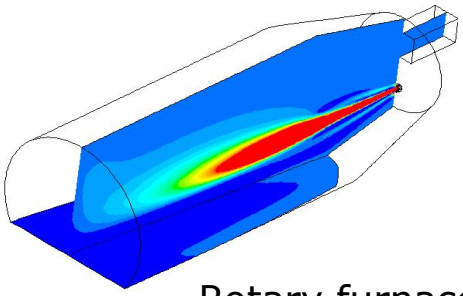
- What kinds of materials work with GAIM?
  - Virtually all thermoplastics with some limitations with heat sensitive materials
- Do I need a license?
  - No, this requirement went away many years ago. If a vendor is asking for a license, you're working with the wrong vendor.
- What GAIM technology partner do you recommend?
  - We recommend working with Nitrojection to assess GAIM design feasibility and control installation. They were the first company to commercialize the process and have 20 years of experience optimizing GAIM processes.
- How much nitrogen will I need?
  - This will depend on your required pressure and production rate. However, a go-by number is 2.2 SCF/tooling machine. One machine, running 24/7 would require about 90,000 scf/month.
- Can I run several tooling machines on one gas controller?
  - You can, but it creates a very complex control scheme. For better operational consistency, a gas controller/machine is the preferred approach.

Thank you…
tell me more

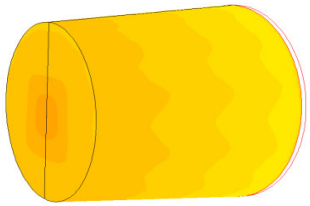
Successful Applications in Air Products…



Glass furnace

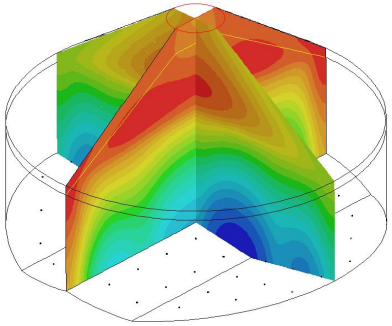


Rotary furnace

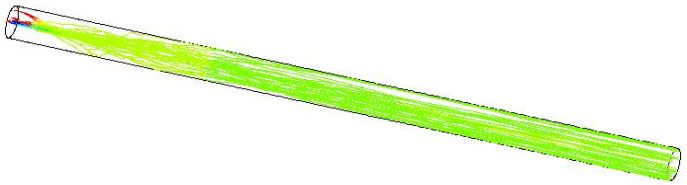


Ladle preheat

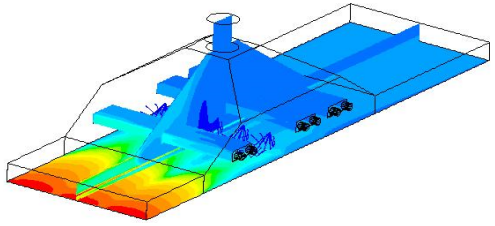
Cupola



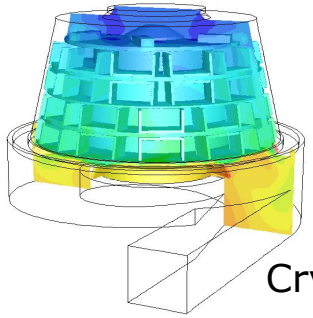
Biomass storage



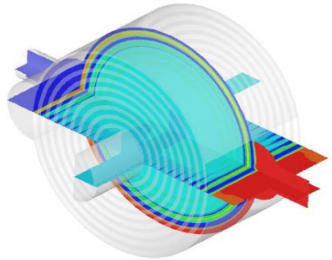
Inerting in powder transport



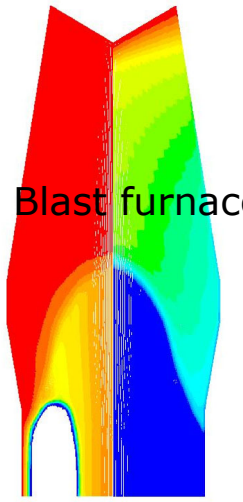
Sinter hardening



Cryogrinder



Cryo cooling



Blast furnace

Air Products High Pressure Pumps LIN/LAR

Mini-Cryo Pump (MCP)

- MAWP = 3000 psig(207bar)
- Flow = 5000 scfh
- Max monthly volume = 1MM/ month

Cryostar PD-3000 Pump (CVI)

- Multiple models
- MAWP = 3,000 psig(206bar), flow = 20,000 scfh
- MAWP = 10,000 psig (689bar), flow = 7000 scfh
- Not designed for continuous duty
- Max monthly volume = 6MM/ month

ACD - SGV-1 / SGV-2 Pump (SGV)

- Multiple models
- MAWP = 6,000 psig(414bar)
- Flow = 45,000 scfh
- Designed for continuous duty
- Max monthly volume = 20MM/ month

Example of Design Optimization

		Extent of gas penetration	Polymer skin thickness	Volumetric fill time
Material Properties	High thermal diffusivity	longer	thicker	longer
	Low thermal diffusivity	shorter	thinner	shorter
	High viscosity	longer	thicker	longer
	Low viscosity	shorter	thinner	shorter
Process variables	Higher gas pressure	shorter	thinner	shorter
	Lower gas pressure	longer	thicker	longer
	Higher melt temperature	*	*	shorter
	Lower melt temperature	*	*	longer
	Longer delay time	longer	thicker	longer
	Shorter delay time	shorter	thinner	shorter
	Longer gas injection time	longer	**	**
	Shorter gas injection time	shorter	**	**
	Higher polymer pre-fill	shorter	**	**
	Lower polymer pre-fill	longer	**	**

* Trend depends on other parameters
** Data not available or not applicable

Ref: http://www.dc.engr.scu.edu/cmdoc/ga_doc/B_Design.frm.html