Advanced argon management for HIP processes.

Matthias Bors
Sint-Niklaas, 11th February 2019
1. About Linde
2. The HIP (hot isostatic pressing) process
3. Cost drivers in HIP installations
4. Dimensioning argon supply systems
5. Options for efficient gas use in different customer cases
6. Summary
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The Linde Group.
A leading gases & engineering company.

- EUR 17.2 billion in sales in 2017
- 58,000 employees worldwide (2017)
- Global presence in more than 100 countries

The Linde Group

Gases Division  Engineering Division  Other activities

World map showing global presence.
Gases Division.
Wide range of gases & gas mixtures.

<table>
<thead>
<tr>
<th>Air gases</th>
<th>Other gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Nitrogen</td>
<td>- Acetylene</td>
</tr>
<tr>
<td>- Oxygen</td>
<td>- Helium</td>
</tr>
<tr>
<td>- Argon</td>
<td>- Propane</td>
</tr>
<tr>
<td>- Rare gases:</td>
<td>- Carbon dioxide</td>
</tr>
<tr>
<td>Krypton, neon, xenon</td>
<td>- Carbon monoxide</td>
</tr>
<tr>
<td></td>
<td>- Hydrogen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specialty gases</th>
<th>Medical gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Pure gases</td>
<td>- Medical oxygen</td>
</tr>
<tr>
<td>- Specialty gas mixtures</td>
<td>- Nitric oxide (NO)</td>
</tr>
<tr>
<td></td>
<td>- Nitrous oxide (N₂O)</td>
</tr>
</tbody>
</table>

Diagram showing various gases and their concentrations.
Gases Division.
Integrated gases model.

- **On site**
  - EUR 3.8 billion

- **Bulk**
  - EUR 3.6 billion

- **Cylinder**
  - EUR 3.8 billion

Value creation

- Filling sites
- Retailer
- Transport of liquefied gas
- Gas production plant e.g. air separation unit (ASU)

- Pipeline

~15% of volume
~1% of volume

04/03/2019
The new Linde.

Linde plc will be a leading industrial gas and engineering company with market capitalization of approximately USD 90 billion (EUR 78 billion) and 2017 pro forma sales of USD 27 billion (EUR 24 billion). The company will employ approximately 80,000 people globally and will serve customers in more than 100 countries worldwide.
Advanced argon management.

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Typical HIP targets
When operating HIP units, process owners have the following goals:

- **Material properties**
  Create the right recipe to ensure the perfect mix of material properties (e.g. density, hardness, strength and ductility) tailored to customer specifications

- **Continuous improvement**
  Incorporate the latest developments to combine different heat treatment steps into one HIP process

- **Customisation**
  Tailor the setup to individual pressure, volume and flow requirements – applies to the HIP furnace and to the gas supply system
Typical HIP requirements
When considering the most appropriate inert gas supply solution for HIP processes, operators typically have a number of key requirements:

- **Atmosphere control**
  During HIP, chemical reactions must be prevented as these could compromise the mechanical properties, fatigue performance and/or service life of the high-performance components being treated.

- **Ease of management**
  Reducing the complexity of the plant, particularly the gas supply and reuse system.

- **Cost efficiency**
  Optimising gas consumption and reusing vented gas, for instance.
# Advanced argon management.

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Advanced argon management. Cost drivers in HIP installations.

CAPEX
- HIP unit
- Associated gas supply

OPEX
- Electrical energy
- Gases
- Maintenance
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Supply scheme.
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Classification of HIP installations.

Pilot (small) HIP production furnace: Volume up to 100 l

Medium HIP production furnace: Volume up to 1,000 l

Large HIP production furnace: Volume more than 1,000 l
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Basic calculations.

- HIP furnace volume
  - 500 l

- Cycle time
  - 12 h

- Annual number of cycles
  - 500

- Process pressure
  - 1200 bar

- Process temperature
  - 1200°C

- Annual gas consumption
  - 93 t

HIP process

- Pilot system
  - Up to 100 l volume
  - Up to 30 tonnes of argon/year
  - Direct filling
  - 1 section using recaptured vented gas (optional)
  - Gas analyser (optional)

- Medium system
  - Up to 1000 l volume
  - Up to 150 tonnes of argon/year
  - 300-bar fresh argon buffer
  - Multi-section buffer tanks for used argon (optional)
  - Gas analyser

- Large system
  - Volume larger than 1000 l
  - More than 150 tonnes of argon/year
  - Multi-section buffer tanks
  - Gas analyser
  - Gas purification (optional)
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PFD case 1.

Case 1:
Direct Filling by Cryo Pump

1. First Filling
2. Pressure Holding
3. Recycle Buffering (equilibrium)
4. Blowing-Off (low pressure gas)
5. Re-Using (equilibrium)
6. Fresh Gas Filling
7. Blowing-Off (out-of-spec. gas)
8. Purging

![Diagram of argon management system]
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Basic calculations.

**HIP process**

**HIP furnace volume**
- 4000 l

**Cycle time**
- 22 h

**Annual number of cycles**
- 300

**Process pressure**
- 1200 bar

**Process temperature**
- 1200°C

**Annual gas consumption**
- 445 t

**Pilot system**
- Up to 100 l volume
- Up to 30 tonnes of argon/year
- Direct filling
- 1 section using recaptured vented gas (optional)
- Gas analyser (optional)

**Medium system**
- Up to 1000 l volume
- Up to 150 tonnes of argon/year
- 300-bar fresh argon buffer
- Multi-section buffer tanks for used argon (optional)
- Gas analyser

**Large system**
- Volume larger than 1000 l
- More than 150 tonnes of argon/year
- Multi-section buffer tanks
- Gas analyser
- Gas purification (optional)

04/03/2019
Case 2:
Filling from Fresh Gas Buffer

1. First Filling
2. Pressure Holding
3. Recycle Buffering (equilibrium)
4. Blowing-Off (low pressure gas)
5. Re-Using (equilibrium)
6. Fresh Gas Filling
7. Blowing-Off (out-of-spec. gas)
8. Purging

Cryo Vessel
Gas monitoring for new fillings
PBU
Cryo Pump

Air Evaporator (E. Heater on demand)
Fresh Gas Buffer

Compressor

HIP Reactor
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Advanced argon management. Options for efficient supply.

Customising argon supply systems using pre-defined components from a wide product range is key to cutting costs and ensuring plants are operated efficiently.
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Summary.

Gas supply concepts have a significant impact on total cost of ownership. Factoring all relevant parameters into the HIP process at an early stage of a customer project helps optimise cost control.

**Potential for cost optimization through**

– Analysing the size of the HIP system and its associated gas consumption
– Choosing hardware based on flow and pressure requirements
– Break-even calculations for investments in gas reuse systems
– Pre-configured and optimised argon supply schemes
– Rental models for gas supply components to minimise CAPEX
Thank you for your attention.

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