From prototype to serial production
manufacturing hydrogen fuelling stations

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Linde Vienna – ATZ

Technology development

Linde hydrogen refuelling systems

Linde small serial production of hydrogen fuelling stations
The ATZ develops and brings **breakthrough innovations** to market in a **unique collaboration** with internal and external customers. It is renowned as a world leading competence center for **advanced hydrogen & CNG fuelling** and for its thermodynamic- and compression solutions.

Since 2012 the ATZ has had a department that deals with production transfer into serial and the related **small serial production**.
ATC projects – worldwide

More than **120 H2 compressors** and over 380 compressors for other gases like CNG, Ar or N2 worldwide
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Ionic compressor: development history

- **2002**: Idea of ionic compressor
- **2005**: Low speed ionic compressor
- **2007**: Middle speed ionic compressor
- **2008**: H2 refuelling 700bar (IC90 v1.0)
- **2009**: IC90 v1.1 (pre-serial)
- **2010**: H2 refuelling 700bar (IC90 v1.0)
- **2011**: IC90 v1.2 (pre-serial)
- **2012**: IC90 v1.3 (serial)
- **2013**: Natural gas purification (CIC30)
- **2014**: High speed IC prototype

- **2002**: CNG refuelling (IC30)
- **2005**: H2 forklift refueling (IC45)
- **2007**: H2 process gas Japan (HG90)
- **2008**: H2 process gas (HG50)
- **2009**: H2 process gas Japan (HG120)
- **2010**: Very small
Ionic compressor 90MPa - IC90 functionality

Input 5-10bara

Stage 1
Stage 2
Stage 3
Stage 4
Stage 5

14bara 40bara 113bara 318bara 900bara

Coalescer for ionic liquid

Hydrogen 5 to 900bara
Ionic liquid

Hydraulic oil

Hydraulic/radial piston engine

Output 900bara (1,000bara max.)
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Layout – 700bar hydrogen fuelling with compressor
Overview

Supply
- Hydrogen source
- Inlet line
- Hydrogen compressor
- Bank control valves
- High pressure buffer storage

Compressor station
- Outlet line
- Gas conditioning unit

Dispenser
- Dispenser line
- Dispenser valves
- Temperature compensation unit
- Fuelling equipment
- Vehicle
**Options:**

**Gaseous supply**

— Onsite 45bar standard tank
— Onsite 200bar/200kg tubes (Fig. 1)
— GH2 trailer supply (Fig. 2)
— Onsite steam reformer
— Onsite electrolyser

**Liquid supply**

— Liquid tank
— LH2 trailer supply
Options:

— **Very small:** Downsized IC90 (Fig. 1)

— **Small:** 1 standard IC90 in one standard container (Fig. 2)

— **Medium:** 2 standard IC90s in one standard container (Fig. 3)
Basic layout
Bank control valves

Options:
— Modular 3 Bank block for one dispenser line (Fig. 1)
— Modular 3 Bank block for two dispenser lines (Fig. 2)

Fig. 1: 3 Bank block for one dispenser line
Fig. 2: Bank block for two dispenser lines
Basic layout
High pressure storage

Options:

— Modules of 5 or 8 cylinders for 1000bar (Fig. 1)
— Up to 26 cylinders in one standard IC90 container (Fig. 2)
— External bundle container

Fig. 1: Bundle for 8 bottles
Fig. 2: Installed bottles – EU standard station
Basic layout
Gas conditioning unit (Cold Fill)

**Patented layout:**

— Standard cooling unit with option for temperature compensation unit (Fig. 2)

— Maintenance free solid cold accumulator (Aluminium) with several heat exchanger lines (Fig. 1)

Fig. 1: Solid coldfill heat exchanger module (w.o. Aluminium)  Fig. 2: Standard cooling unit
Options:

— Dispenser: 1 hose – 700bar (Fig. 1)
— Dispenser: 2 hoses – 700bar (Fig. 2)
— Dispenser: 1 hose – 700bar; 1 hose – 350bar

Fig. 1: Dispenser 1 hose-700bar
Fig. 2: Dispenser 2 hoses-700bar
Basic layout
Temperature compensation unit (TCU)

**Patented layout:**

— Used to compensate the warm dispenser line up to 50m (with standard TCU)

— Supplied by standard cooling unit in container (minimal losses)

— Maintenance free solid cold accumulator (Aluminium) for 1 dispenser line (Fig. 1)

![Fig. 1: 3D model - standard TCU (without Aluminium)](image-url)
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Hydrogen fuelling station for serial production

Example: New design of IC90 (US+EU Version)

- Small footprint: 2,7m x 4,3m
- Connected load: 105kW
- Compressor type: Ionic compressor for H2 – IC90
- Noise emission: <75dB(A)
- Supply: gaseous or liquid
- Option for capacity upgrade (33,6kg/h => 67,2kg/h)
- Fuelling protocol: SAE J2601-A70
- Same container for US and EU model
Ionic compressor 90Mpa
“IC90”

Performance

- Ionic compressor for H2
- **5-stage** compression
- Stage compression ratio: **1:2.8**
- Max. delivery rate: **370Nm3/h ~ 33,6kg/h**
- Min. input: **5bar**
- Max. output: **1.000bar**
- Power consumption at 5bara inlet pressure: **75kW**
- Stroke frequency: **5.8Hz**
- **Specific energy consumption:** **2.7kWh/kg**
  H2 (= energy saving of around 40%)\(^1\)

1 compared to conventional dry running piston compressor for 90Mpa
### Benchmark
Hydrogen compressor of competitor and Linde IC90

#### Hydrogen compressor of competitor
- **Manufacturer:** ---
- **Technology:** 4-stage piston compressor
- Delivery rate: **100 Nm³/h**
- Max. outlet: **440bar**
- Inlet range: **4 – 7bar**

#### Linde ionic compressor – IC90
- **Manufacturer:** Linde Gas – Austria
- **Technology:** 5-stage ionic compressor
- Delivery rate: **370 Nm³/h**
- Max. outlet: **900bar**
- Inlet range: **3,3 – 200bar**

### VS.
Small serial production of hydrogen fuelling stations

Overview and Outlook

**Actual**:  
- Capacity: 50 stations/a  
- Avg. lead time: 8 months  
- Testing capacity: 2 boxes on test stand for testing activities

**Outlook**:  
- Capacity: 100 stations/a (second shift)  
- Avg. lead time: 5 months  
- Testing capacity: 4 boxes on test stand

1 based on EU stations with similar scope of supply
Cost reduction potential

Advantage of small serial production

Production costs [%]\(^1\)  

-15.9% \quad -33.1%

100  
84  
67

<table>
<thead>
<tr>
<th>Production Type</th>
<th>Equipment</th>
<th>Labor</th>
<th>Commissioning</th>
</tr>
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<tbody>
<tr>
<td>Single production(^2)</td>
<td>20</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Serial production downside case</td>
<td>63</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Serial production upside case</td>
<td>52</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

1 based on EU stations with similar scope of supply
2 base is production cost of IC90 stations in 2010, costs are inflation adjusted
Economies of scale
Labor input

Labor input [%]\(^1\)

- **Station 1**: 100
- **Station 3**: 90
- **Station 6**: 75
- **Station 9**: 72
- **Station 19**: 53
- **Station 20**: 49
- **Station 21**: 48

Legend:
- **Dark blue**: using original infrastructure
- **Light blue**: at new production facility

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\(^1\) Labor for assembly only, based on EU stations with similar scope of supply
Thank you