MAN Turbo

Engineering the Future – Since 1758.
The MAN Group
250 Years MAN

250 years of experience, knowledge, competence

250 years of innovation, technology and progress

250 years of reliability, profitability and economic success
# Milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1758</td>
<td>Founding of the St. Antony iron works</td>
</tr>
<tr>
<td>1782</td>
<td>Establishment „Gute Hoffnungshütte“ (GHH) steel in Sterkrade</td>
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<tr>
<td>1805</td>
<td>Establishment of the Sulzer-Escher Wyss mechanical engineering works of Zurich</td>
</tr>
<tr>
<td>1814</td>
<td>Start of GHH steam engine production</td>
</tr>
<tr>
<td>1857</td>
<td>First BORSIG compressors</td>
</tr>
<tr>
<td>1877</td>
<td>Establishment of Blohm+Voss Shipbuildung</td>
</tr>
<tr>
<td>1903</td>
<td>First Sulzer turbocompressor</td>
</tr>
<tr>
<td>1904</td>
<td>First GHH steam turbine</td>
</tr>
<tr>
<td>1906</td>
<td>Start of Blohm &amp; Voss steam turbine production</td>
</tr>
<tr>
<td>1915</td>
<td>First process-gas turbine and first isotherm compressor</td>
</tr>
<tr>
<td>1934</td>
<td>First Sulzer axial compressor (air blower)</td>
</tr>
<tr>
<td>1950</td>
<td>First GHH axial compressor</td>
</tr>
<tr>
<td>1952</td>
<td>Production of GHH screw compressors</td>
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<tr>
<td>1977</td>
<td>First BORSIG Multi-shaft compressor</td>
</tr>
<tr>
<td>1991</td>
<td>Development of the MOPICO sealed turbocompressor product line</td>
</tr>
<tr>
<td>1994</td>
<td>Delivery of the first FT8 industrial gas turbine made by GHH</td>
</tr>
<tr>
<td>1996</td>
<td>Establishment of GHH BORSIG Turbomaschinen GmbH (integration of the turbocompressor activities of Deutsche Babcock AG)</td>
</tr>
<tr>
<td>2001</td>
<td>Takeover of the Sulzer AG turbomachinery activities by MAN Turbomaschinen AG GHH BORSIG</td>
</tr>
<tr>
<td>2004</td>
<td>New centre for the assembly and testing of large machine sets</td>
</tr>
<tr>
<td>2006</td>
<td>Integration of MAN DWE GmbH into MAN Turbo Group</td>
</tr>
<tr>
<td>2006</td>
<td>Acquisition of steam turbine division of B+V Industrietechnik GmbH</td>
</tr>
</tbody>
</table>
Company Headquarters & Main Locations

Berlin

Employees (28.02.2009) : 522

Products
Division Oil & Gas

- Small / medium centrifugal compressors
- Multi-shaft compressors

Competence centre for:
- Refining & CO₂ Applications
Locations
Sales and Service Centres

Location with production
MAN Turbo sales office
Major representative office
MAN Turbo Service Shop
Service Shop (cooperation)
Compressors

- Axial compressors
- Integrally geared compressors
- Isotherm compressors
- Pipeline compressors
- Process-gas screw compressors
- Centrifugal compressors
- Vacuum blowers
- MOPICO / HOFIM
## Compressors

### Technical data

<table>
<thead>
<tr>
<th>Turbo-compressors</th>
<th>Max. suction flow rate (m³/h)</th>
<th>Max. discharge pressure (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial compressors</td>
<td>1 500 000</td>
<td>25</td>
</tr>
<tr>
<td>Single-shaft centrifugal compressors, horizontally split</td>
<td>660 000</td>
<td>80</td>
</tr>
<tr>
<td>Single-shaft centrifugal compressors, vertically split</td>
<td>230 000</td>
<td>300</td>
</tr>
<tr>
<td>High-pressure barrel compressors</td>
<td>35 000</td>
<td>1 000</td>
</tr>
<tr>
<td>Multi-shaft centrif. compressors</td>
<td>350 000</td>
<td>225</td>
</tr>
<tr>
<td>Isotherm compressors</td>
<td>660 000</td>
<td>20</td>
</tr>
<tr>
<td>TURBAIR® vacuum blowers</td>
<td>200 000</td>
<td>Vakuum</td>
</tr>
<tr>
<td>Pipeline compressors</td>
<td>85 000</td>
<td>130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process-gas screw compressors</th>
<th>Max. suction flow rate (m³/h)</th>
<th>Max. discharge pressure (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw compressors</td>
<td>100 000</td>
<td>50</td>
</tr>
</tbody>
</table>
Integrally-geared compressor

- Suction flow rates up to 350,000 m³/h
- Max. discharge pressure up to 225 bar

- Ammonia
- Fuel gas
- CO₂ compression
- Fluid catalytic cracking
- Urea
- Air separation

- Refinery / Petrochemicals
- Nitric acid
- Oxygen
- Terephthalic acid
- Air separation
Integrally-Geared Centrifugal

History

- 3 STAGES
  - 6 bar
  - 1977

- ONE BULL GEAR

- ONE BULL GEAR

- TWO BULL GEARS

- ONE BULL GEAR

- 4 STAGES
  - 15 bar

- 5 STAGES
  - 25 bar

- 6 STAGES
  - 40 bar

- 7 STAGES
  - 64 bar

- 8 STAGES
  - 80 bar

- 10 STAGES
  - 200 bar

- 8 STAGES
  - 187 bar

- COMBI DESIGN

- 1977
- 1998
Typical 4-Stage Arrangement
Integrally-Geared Centrifugal
Basic Design
Integrally-Geared Centrifugal
Basic Design
Integrally-Geared Centrifugal
Basic Design

Volute
Diffuser Diaphragm
Inlet Guide Vane
Impeller Seal
Impeller
Pinion Shaft
Carbon Ring Seal
Gearbox Flange
Impeller Fastening
Inlet Diaphragm
Integrally-Geared Centrifugal Basic Design
Integrally-Geared Centrifugal
Basic Design

- main motor
- coupling
- central gear box
- compressor stages
- interconnecting gas pipings
- lube oil system
- baseframe
- intercoolers
Integrally-Geared Centrifugal
Basic Design
Integrally-Geared Centrifugal
Inlet Guide Vanes
Integrally-Geared Centrifugal
Typical Shaft Seals

Source: Espey
Integrally-Geared Centrifugal
Typical Design of a Carbon Ring Seal

DACOPIPE Stage 8 (2350 psia)

1 Return to suction end
   Stage 4 (161 psia)
2 Return to suction end
   Stage 1 (17 psia)
3 Nitrogen barrier gas (19 psia)
4 Atmospheric vent

- Swirl breaker
- Chambers
- Carbon rings
- Casing
- Sealing pockets/seal gas chambers
Integrally-Geared Centrifugal
Thrust Collar
Integrally-Geared Centrifugal
Performance

Urea Synthesis Process

- RG 40-8
- Gas Wet CO₂ Mix
- Flow 7,500 acfm
- Pressure 15 – 2,320 psia (r = 160)
- Power 5,700 HP
Typical 8-Stage Arrangement

Pinion 1

Pinion 2

Pinion 3

Pinion 4
Integrally-Geared Centrifugal Performance

**Wet CO₂ Compressor**

- Model: RG053-10
- Inlet Volume: 13,800 acfm
- Pressure: 15-2,900 psia \((r=200)\)
- Speed: 11,000-50,000 rpm
- Power: 6,200 HP
CO₂ High Pressure Geartype Compressors
First steps in the early 90s

- World’s first double bull-gear multishaft geartype compressor patented
- 1st 10 stage compressor for wet CO₂ service designed, fabricated and in operation for AZOT Nowomoskowsk
Integrally-Geared Centrifugal
Typical Installation
Case Study – High Pressure CO\textsubscript{2} Compressor
Case Study – High Pressure CO₂ Compressor
Integrally-Geared Centrifugal
8 Stages

**CO₂ Compressor**

- Model: RG080-8
- Inlet Volume: 34,242 acfm
- Pressure: 17-2,717 psia ($r = 160$)
- Speed: 7400-26,400 rpm
- Power: 15,150 HP
Integrally-Geared Centrifugal Impellers:
Stages 1 through 8
Integrally-Geared Centrifugal
8 Stages
Integrally-Geared Centrifugal Compressor
DGC - Beulah, North Dakota
Integrally-Geared Centrifugal Compressor
DGC - Beulah, North Dakota
**CO₂ High Pressure Geartype Compressors**
Thermodynamic Design

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<table>
<thead>
<tr>
<th>hp [kJ/kg]</th>
<th>Ts [°C]</th>
<th>ps,log [bara]</th>
<th>Zs [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>150</td>
<td>100</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>120</td>
<td>80</td>
<td>0.8</td>
</tr>
<tr>
<td>30</td>
<td>90</td>
<td>60</td>
<td>0.6</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td>40</td>
<td>0.4</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>20</td>
<td>0.2</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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![Graph showing stage number and related parameters](image-url)
CO₂ High Pressure Compressors
Sensitivity of Real Gas Factors for Various Gases

![Graph showing the sensitivity of real gas factors for various gases with molar mass in kg/kmol on the x-axis and compressibility factor on the y-axis. Different gas types are indicated with distinct markers, including natural gas, water vapor, nitrogen/air, and flash gas. CO₂ is also plotted with a specific marker.]
Integrally-Geared Centrifugal Compressor
Compression Path in Temperature-Entropy-Diagram
CO₂ High Pressure Compressors
Thermodynamic Design

![Diagram of CO₂ high pressure compressors with thermodynamic data and stage numbers.](image)
Integrally-Geared Centrifugal
8 Stages
EnCana
Weyburn Oilfield Receiving Terminal

MAN Turbo AG
CO2 Compr Pres
09.04.2009
Integrally-Geared Centrifugals

The first two compressors in North Dakota have been in operation since 1997; the third machine was installed in 2006.
Thank you for your attention

Engineering the Future – Since 1758.