Master Alloys: production, raw material situation and influences on future supply
CAUTIONARY NOTE

- This document is strictly confidential and is being provided to you solely for your information by AMG Advanced Metallurgical Group N.V. (the "Company") and may not be reproduced in any form or further distributed to any other person or published, in whole or in part, for any purpose. Failure to comply with this restriction may constitute a violation of applicable securities laws.

- This presentation does not constitute or form part of, and should not be construed as, an offer to sell or issue or the solicitation of an offer to buy or acquire securities of the Company or any of its subsidiaries nor should it or any part of it, nor the fact of its distribution, form the basis of, or be relied on in connection with, any contract or commitment whatsoever.

- This presentation has been prepared by, and is the sole responsibility of, the Company. This document, any presentation made in conjunction herewith and any accompanying materials are for information only and are not a prospectus, offering circular or admission document. This presentation does not form a part of, and should not be construed as, an offer, invitation or solicitation to subscribe for or purchase, or dispose of any of the securities of the companies mentioned in this presentation. These materials do not constitute an offer of securities for sale in the United States or an invitation or an offer to the public or form of application to subscribe for securities. Neither this presentation nor anything contained herein shall form the basis of, or be relied on in connection with, any offer or commitment whatsoever. The information contained in this presentation has not been independently verified. No representation or warranty, express or implied, is made as to, and no reliance should be placed on, the fairness, accuracy or completeness of the information or the opinions contained herein. The Company and its advisors are under no obligation to update or keep current the information contained in this presentation. To the extent allowed by law, none of the Company or its affiliates, advisors or representatives accept any liability whatsoever (in negligence or otherwise) for any loss howsoever arising from any use of this presentation or its contents or otherwise arising in connection with the presentation.

- Certain statements in this presentation constitute forward-looking statements, including statements regarding the Company's financial position, business strategy, plans and objectives of management for future operations. These statements, which contain the words "believe," "expect," "anticipate," "intends," "estimate," "forecast," "project," "will," "may," "should" and similar expressions, reflect the beliefs and expectations of the management board of directors of the Company and are subject to risks and uncertainties that may cause actual results to differ materially. These risks and uncertainties include, among other factors, the achievement of the anticipated levels of profitability, growth, cost and synergy of the Company's recent acquisitions, the timely development and acceptance of new products, the impact of competitive pricing, the ability to obtain necessary regulatory approvals, and the impact of general business and global economic conditions. These and other factors could adversely affect the outcome and financial effects of the plans and events described herein.

- Neither the Company, nor any of its respective agents, employees or advisors intend or have any duty or obligation to supplement, amend, update or revise any of the forward-looking statements contained in this presentation.

- The information and opinions contained in this document are provided as at the date of this presentation and are subject to change without notice.

- This document has not been approved by any competent regulatory or supervisory authority.
AMG ADVANCED METALLURGICAL GROUP N.V.

- approx. 3,000 employees
- US$ 1.060 billion annual revenues in 2017

<table>
<thead>
<tr>
<th>AMG Business Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMG Critical Materials</td>
</tr>
<tr>
<td>Conversion, mining and recycling business</td>
</tr>
<tr>
<td>- AMG Lithium (BR)</td>
</tr>
<tr>
<td>- AMG Titanium Alloys &amp; Coatings (DE)</td>
</tr>
<tr>
<td>- AMG Superalloys (UK)</td>
</tr>
<tr>
<td>- AMG Vanadium (US)</td>
</tr>
<tr>
<td>- AMG Aluminum (US)</td>
</tr>
<tr>
<td>- AMG Antimony (FR)</td>
</tr>
<tr>
<td>- AMG Brazil (BR)</td>
</tr>
<tr>
<td>- AMG Graphite (DE)</td>
</tr>
<tr>
<td>- AMG Silicon (DE)</td>
</tr>
<tr>
<td>AMG Engineering</td>
</tr>
<tr>
<td>Vacuum systems and services business</td>
</tr>
<tr>
<td>- AMG Engineering (DE)</td>
</tr>
</tbody>
</table>

Innovative metallurgical solutions for the global markets of:

- Energy
- Transportation
- Infrastructure
- Specialty Metals & Chemicals

Peter Baumeister, Master Alloys

May 14-16, 2018 • Melia Sevilla • Seville, Spain

3
A **Master Alloy** contains two or more alloying elements for the final Ti alloy or grade with a defined composition.

### Number of Elements:

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of Elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary</td>
<td>2</td>
<td>VAI (for Ti 6-4), MoAl, NbAl</td>
</tr>
<tr>
<td>Ternary</td>
<td>3</td>
<td>VAIFe MoAlTi (for Ti 6-2-4-6)</td>
</tr>
<tr>
<td>Multinary</td>
<td>&gt;3</td>
<td>AlSnZrMoCr (for Ti 17), AlMoVCrTi (for Ti 5-5-5-3)</td>
</tr>
</tbody>
</table>
Titanium Alloys are used to

- add alloying elements required to meet the performance targets of the final tailor made application
- improve the mechanical properties, the heat and corrosion resistance of base titanium
- improve and allow subsequent process steps (e.g., forging, forming, rolling)
- save costs by alloying Master Alloys instead of pure metals (e.g. V + Al)
**Master Alloys** are reducing the melting point inside VAR

Master Alloys allow to melt and include all raw materials close to the melting point of the base Ti material. (e.g. VAl65 melts at 1580 °C close to Ti)
Production process of Master Alloys

**Raw Materials**
- weighing
- mixing

**Melting**
- Aluminothermic Reduction ATR
- Vacuum Induction Melting VIM
- ATR → VIM two-step-process

**Crushing**
- crushing
- sizing

**Inspection**
- Magnetic separation
- Inspection (visual, x-ray, black light)
- Sampling
- Chemical analysis
- Screen analysis
- Quality release
With an **Aluminothermic Reduction** process (ATR) the alloy is produced via an aluminothermic (thermite) smelting process within a refractory-lined or copper vessel.

- Initial ignition
- Exothermic chemical reaction
- No additional supply of energy

Raw materials are metal oxides + aluminum as well as auxiliary materials which will be mixed/homogenized.
With the **VIM-Process** process the alloy is produced via a smelting process within a **Vacuum Induction Melting furnace**.

- endothermic chemical reaction
- supply of external energy necessary
- controlled process

Raw materials are metals and/or alloys, but no oxides.
Examples of titanium alloy applications

The ingot will be mechanically processed to a final part
Aerospace Master Alloys require **high purity raw materials** with aerospace quality requirements.

**Master alloy class:**
- V: Vanadium
- Mo: Molybdenum
- Nb: Niobium
- Cr: Chromium

**Raw material:**
- Vanadium Oxides (Pentoxide and variants)
- Molybdenum Oxides
- Niobium Pentoxide
- Chromium Trioxide
Vanadium prices hit highest levels for a decade.

- Sharp rise in Q1 2018
- The scale of the price rise has been unexpected
- Prices have not been this high since 2008
- Fundamental tightness in vanadium availability in China
- Robust demand on the consumption side with strong demand for ferro-vanadium and vanadium nitride from steel mills

Source: Metal Bulletin Vanadium Ore min. 98% Europe Monthly average $/lb V$_2$O$_5$
Molybdenum prices hit highest levels for more than three years.

- Sharp rise in Q1 2018
- Prices have not been this high since 2014
- Robust demand on the consumption side with strong demand for ferro-molybdenum steel mills

Molybdenum Oxide 57; Source: Platt’s
There are different influences on future demand of Master Alloys.

- **Market**
  - Number of new airplanes will increase – mainly driven by the Asian/Pacific region expansion

- **Technology**
  - New civil aircraft designs require much more titanium alloys per aircraft than past models
There are different influences on future demand of Master Alloys.

- The general tendency is to increase the use of Ti alloy scrap
- Technological changes in materials (composites, Ti Aluminides) will change the usage of master alloys
MASTER ALLOYS FOR TITANIUM ALLOYS – INFLUENCES ON FUTURE SUPPLY

- **Political**
  (trade barriers, duty, strikes, shortage in energy, etc.)

- **Pricing**
  Raw materials are depending on other industry sectors
  (e.g. Vanadium quotation is linked to the steel industry)

- **Currency** exchange rates
  (USD, EUR, RMB, REAL, etc.)

- **Supplier**
  Strategic focus of the approved and certified suppliers;
  New market participants not seen to date
There are **opportunities, challenges** and **risks** for the TITANIUM industry.
Raw material suppliers should

- provide clear strategic commitments supporting the titanium industry with sustained supply of consistent quality materials
- show flexibility regarding pricing
- balance the expectations of the customers and the capabilities while taking into consideration their own constraints
- be willing to share commercial risk
We, as *master alloy producers*, must

- **balance the expectations** of our customers and the capabilities of our raw material suppliers while taking into consideration our own constraints
- provide our products to **specification** and **on time**
- be **innovative** in developing technical solutions for present and future master alloy requirements as well as leading cost reduction programs
Customers should:

- balance purchasing orders within the approved and certified supplier base
- understand and accept market influences (currency exchange rates, raw material situation, duty, …)
- intensify cooperation by e.g.
  - early involvement in R&D activities
  - providing reliable mid/long term forecasts
- bringing us to a position of adjusting capabilities and capacities at the right time
Only a close alliance of the total chain will increase the **security of supply** for the **future**!
SUMMARY

A Master Alloy is not a commodity.

Master Alloys are essential for the titanium industry.

The titanium industry requires a healthy Master Alloy supplier base.
MASTER ALLOYS FOR THE TITANIUM INDUSTRY

TITANIUM MASTER ALLOYS

THANK YOU FOR YOUR ATTENTION