Cold Heath Melting Techniques.

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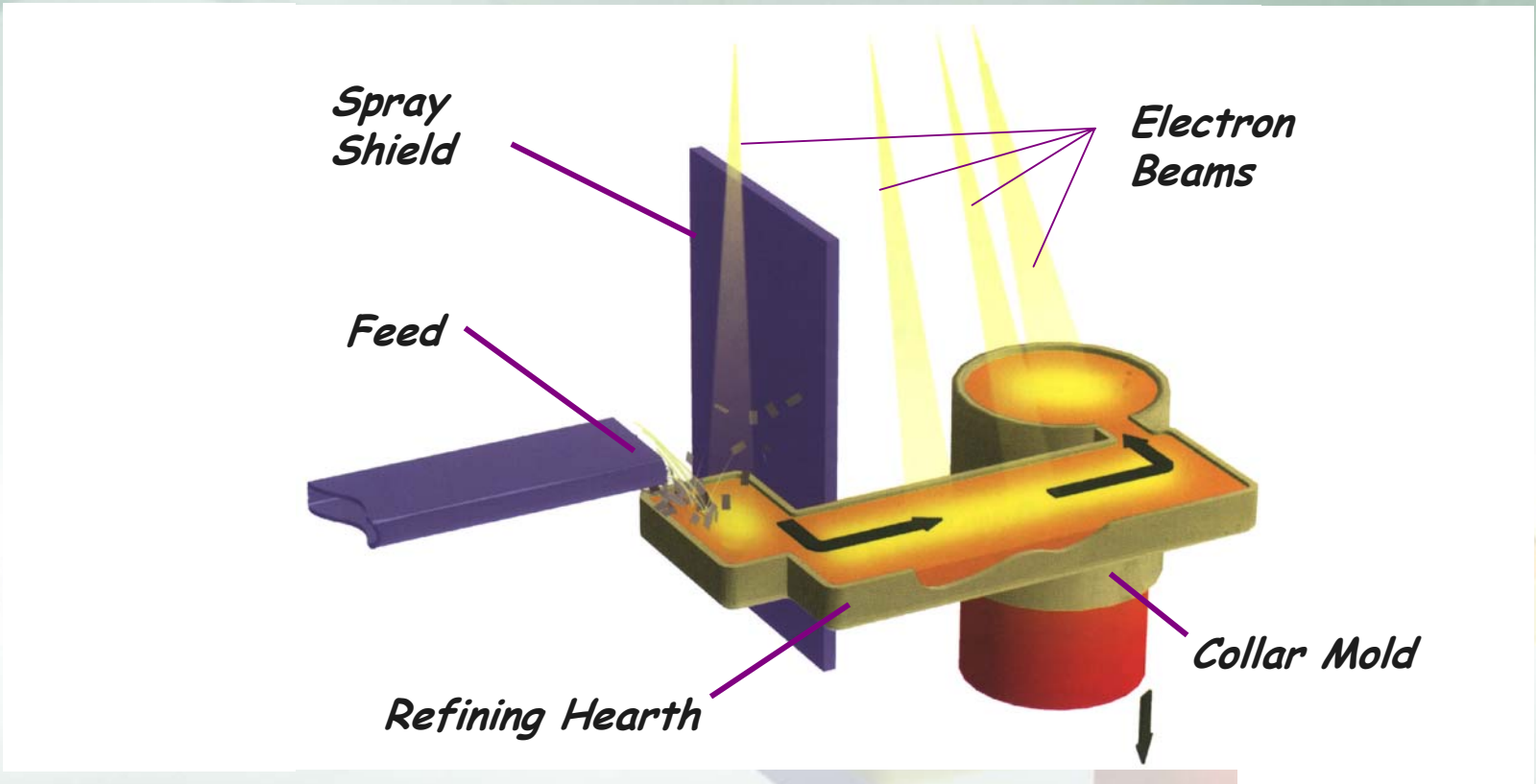
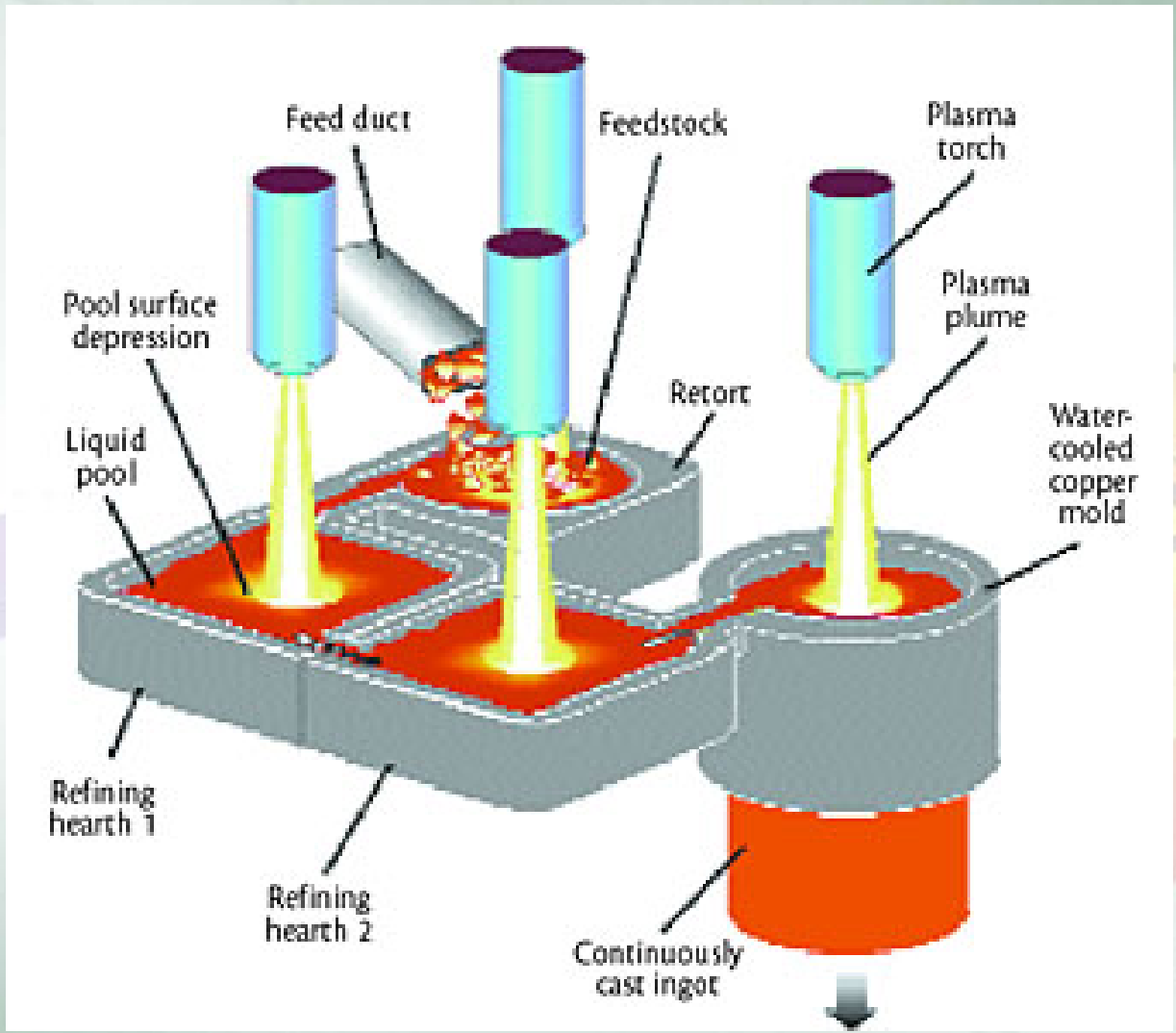
Introduction

- This presentation will summarize cold hearth techniques for melting of titanium, with a particular emphasis on electron beam melting.
- The Timet melting facility operated at Morgantown, PA will be described and the current situation of electron beam single melt.

Electron Beam Process Description



Plasma Melting Process Description



Electron Beam Cold Hearth Melting At Morgantown

- Five EB cold hearth melting furnaces situated at Morgantown PA, USA.
- ‘A’ furnace 4 guns – 2.4MW

  ‘B’ furnace 5 guns – 3.0MW

  ‘C’; ‘G’; ‘H’ furnaces 6 guns – 3.6MW
- Each EB gun has own region of focus: melting, hearth or crucible.
- Monitoring of power input - near IR thermography to check refining area temperature.
- EB melt pressure ~10-20microns versus plasma melting at near atmospheric pressure.
- Volatilization issues with EB melting, but capability demonstrated for EB single melt, which is now approved for standard quality applications such as armour.
- Proven capability for melting CP Ti, Ti 6-4 and other alloys.
- Ability to recycle into premium quality product via EB-VAR.

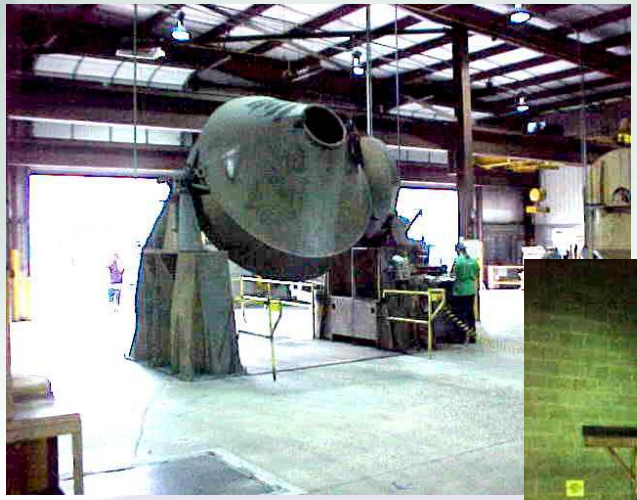
Electron Beam Melting Introduction.

Turnings
(swarf)

Wash Line
(incl magnetic separator).

Turnings
(Washed)

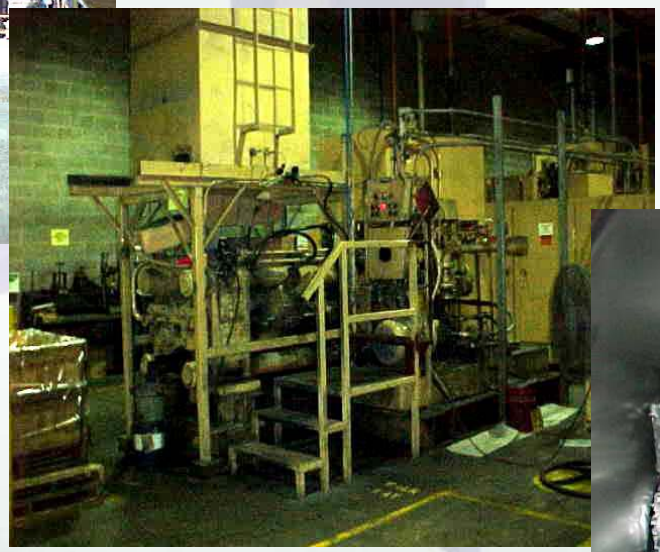
Electron Beam Melting Introduction.



Sampling and testing of swarf. Formulation.

Blending with RM's

Briquetting Press



Finished Blend

Status of Qualification of Single Melt Material

- CP strip for industrial applications supplied for ~20years
- Casting stock supplied for ~10 years [Ti 6-4; 6242].
- Armour plate: > 5Mlbs supplied in ~ 7 years to MIL DTL 46077 and ASTM B265.
- Automotive forgings [Ti54M and Ti6-4] supplied for ~ 4years
- SAE published AMS 6945 (Cold Hearth Only Ti-64 Sheet & Plate) in 2005.
- MMPDS (MIL-HNDBK) published design allowables for CH only sheet and plate.
- Military aircraft: applications approved. Drawings modified and metal is being consumed.
- Civil airframe: corporate specification approval in hand.
- Engine Manufacturers evaluating CH only, both to allow AMS 6945, and in qualification for corporate specifications.

Why Electron Beam Single Melt?

- Generally Cold Hearth Only will produce a material that is equivalent to current production methods in performance
  - Chemistry and mechanical properties

Chemistry + Processing → Structure → Properties → Performance

- So why go through the time and effort to develop the technology?

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Why Electron Beam Single Melt?

- Defect Abatement
  - Defects can be introduced during handling and processing of the melt electrode
  - Elimination of a melt step eliminates potential for defect introduction
- Cost Reduction
  - Efficient manufacture of nearer-net shape input stock reduces the
    - Number of operations
    - Processing time

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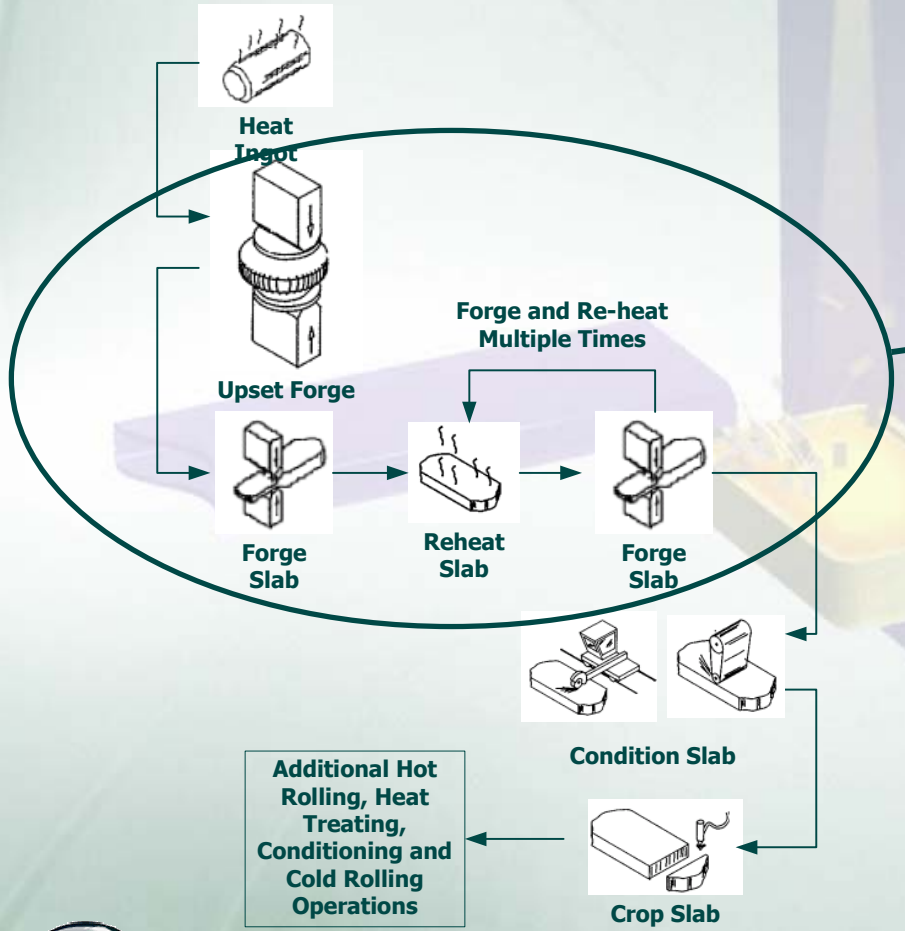
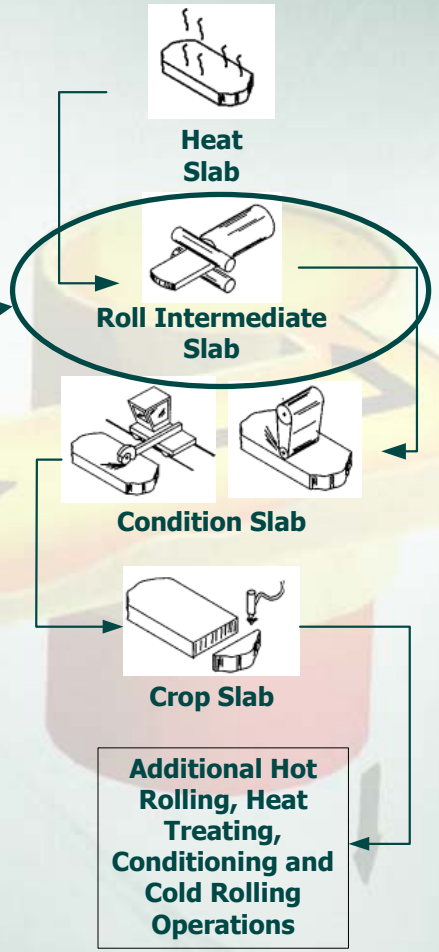
Flat Product Conversion

Conventional Processing of Standard Ingot



Processing of EBSM Slab



Long (Bar) Product Conversion

- Starting with a nearer-net shape (i.e. smaller diameter ingot) allows
  - Elimination of a melt step
    - Yield improvement associated with elimination of VAR remnant
  - Reduction in number of forging operations
    - At minimum, elimination of full-size ingot to current cast size
  - Utilization of alternative equipment
    - Possible utilization of rotary forge equipment (GFM) or alternative (RUMX)

Thermal Mechanical Processing Design

Chemistry + Processing → Structure → Properties → Performance

- **Need to ensure that equation holds**
- **Design TMP from the starting point to**
  - **Minimize cost**
  - **Minimize time (≡ money)**
  - **Utilize alternative equipment**
  - **Produce equivalent structure**

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Long Product Conversion Processes

- 34” ∅ Ingot
- Ingot Breakdown
  - Ingot Soak
  - Open Die Press to Intermediate
- Forge to Rolling Bloom
- Additional Rolling Processes
  - Roll, test, package

- 17”-20” ∅ Ingot
- Ingot Breakdown
  - Soak
  - Rotary Press to Intermediate
- Forge to Rolling Bloom
- Additional Rolling Processes
  - Roll, test, package

With smaller as-cast structure in EB only, it may be possible to reduce the amount of work required to produce equivalent microstructure

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TIMET EBSM RQ Ti-6Al-4V Trial

- EB Melt 17” Diameter
  - Use process for manufacture of RQ EB-VAR electrode
  - Equivalent raw materials
  - Three heats (~5,000 lb each)
  - Characterization of chemistry
    - EB Dip Samples
    - Product Chemistry Characterization
- Conversion
  - Manufacture of 3 bar sizes at Witton (Birmingham) and Waunarlwydd (Swansea)

Conclusions

- TIMET has demonstrated the ability to manufacture titanium alloys using Electron Beam Single Melt
- Chemistry and mechanical properties are consistent with traditionally melted alloy material
- Chemistry evaluated using dip sampling of the liquid melt is representative of that obtained from the intermediate product
- Electron Beam Single Melt (EBSM) can be used to manufacture material suitable for production of RQ compressor blade bar
- Processing routes must be designed to produce appropriate microstructure for desired performance