The History of DC Arc Furnace Process Development

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TR Curr
Manager, Pyrometallurgy, Mintek
• Evolved from late 1880’s
• By early 1970’s there were three basic types
  - Slag resistance
  - Open-arc
  - Submerged-arc
• All using graphite electrodes
• Note: induction and muffle furnaces excluded
• Usually six-in-line electrodes, rectangular shell
• Non-ferrous industry Cu, Ni, PGM’s
• Self-baking electrodes dipped into molten slag
• Ohmic heating from 3 single phase AC transformers
• 3 AC-electrodes in a circular shell
• Steel scrap melting
• Pre-baked electrode sections
• Open-arc into solid scrap or molten slag
• 3 AC-electrodes in circular shell
• Ferroalloy industry (FeCr, FeMn, FeSi)
• Self-baking electrodes, choke-fed lumpy feed
• Arcs submerged, typically >3m deep in feed
## A SMELTING FURNACE CLASSIFICATION

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• Origins in the 1960’s space race
• Need to test re-entry materials at >4000°C
• Concept is to pass gas through an electric arc
• Precedent in a 1900’s process to produce $\text{NO}_x$
• Two plasma torch types were developed
• Characterized by using water-cooled metallic electrodes
TRANSFERRED ARC

Diagram showing components of a transferred arc setup including:
- Plasma torch
- Feed ports (6)
- Cast alumina
- Magnesia-chrome bricks
- Water-cooled roof
- Magnesite bricks
- Water sprays
- Taphole
- Tar-impregnated magnesite bricks
- Anode
- Metal
- Slag
- Delonized water
- Nozzle
- Nozzle cooling
- Cathode cooling
- Argon gas
MINTEK’S INVOLVEMENT IN PLASMA FURNACES

• Peter Jochens identified plasma furnaces as a possible solution to the “Chromite fines” problem.
• Chromite mining usually results in > 50% of < 6mm ore fines – not suitable for submerged-arc furnaces
• Mintek and Middleberg Steel & Alloys (now part of Samancor Chrome) conducted smelting trials on Tetronic’s pilot transferred-arc plasma furnaces in 1979/80
• Although metallurgically successful there were problems of scale-up
• Plasma torches could not be scaled up to > 5 MW, due to excessive electrode wear
THE ADVENT OF DC ARC FURNACES

- In the 70’s ASEA in Sweden developed high power thyrsistor rectifiers
- Sven-Einar Stenkvist investigated the conversion of AC open arc furnaces to DC, principally for steelmaking
- Identified a graphite cathode electrode arcing onto a slag/metal bath as the anode
- Devised an electrically conductive hearth and a hollow graphite electrode for finely sized iron ore smelting
ASEA’s DC ARC FURNACE
DC ARC SMELTING OF CHROMITE

• The metallurgy proven at Tetronics, plus
• The scale-up potential of ASEA’s DC arc furnace.
• This synergy was recognized by Nic Barcza
• It resulted in MS & A converting an existing AC furnace at Palmiet Ferrochrome (now Mogale Alloys) to a 12MW DC arc furnace of ASEA design in 1984
• It also resulted in Mintek building a 1,2MW DC arc furnace in 1983, to support this development and extend it to other applications
• The 12 MW furnace was upgraded to a 28 MW furnace in 1988
• A 42 MW DC arc furnace was built at Middleberg Ferrochrome in 1997 and was followed by a 60 MW DC arc furnace in 2009
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### Ore size
- Fine: 0.01 – 10mm
- Coarse: 10mm – 200mm
• In principle could use DC or AC for smelting ore fines in an open arc furnace
• In fact RBM operate 4 x 60 MW AC open-arc six-in-line furnaces to smelt ilmenite ore fines
ADVANTAGES OF DC OPEN ARC FURNACES VS AC

• No arc repulsion and hot spots

• Lower electrode consumption
• Higher current per electrode, “skin effect”
Ilmenite smelting

- Piloted at Mintek in 1990
- 25 MW DC furnace at Namakwa Sands 1995
- 35 MW furnace followed in 1998
- Two further DC furnaces in Empangeni
• Cobalt recovery from copper discard slags
  - Investigated since 1980’s
  - Piloted at Mintek in 1999 at 1.5 MW
  - 40 MW DC furnace in operation in Zambia, 2002
  - First commercial side-feeding DC smelter
• Nickel Laterite  
  - Piloted at Mintek from 1998 to 2006  
  - 2 x 80 MW DC arc furnaces planned for Xstrata’s Koniambo FeNi smelter in New Caledonia

• Lead blast furnace slag  
  - Piloted at Mintek from 1994 to 1998  
  - Recover 98% Zn metal via fuming & condensation  
  - Distillation to 99.5% purity also developed
PILOTED BUT NOT YET COMMERCIALIZED (continued)

- Magnesium metal
  - Fuming & Condensation
- PGM smelting (Conroast process)
  - Smelting roasted concentrates
FUTURE DEVELOPMENTS

- Improved arc stability
- DC self-baking electrode
- DC submerged-arc furnace
Technology development is not linear, it may have many roots and unexpected outcomes.
Thank you

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