



Council for Mineral Technology



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metallurgical innovation

The History of DC Arc Furnace Process Development

June 2009

TR Curr

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ELECTRIC FURNACES

- 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

SLAG RESISTANCE FURNACE

- 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

OPEN ARC FURNACE

- 3 AC-electrodes in a circular shell
- Steel scrap melting
- Pre-baked electrode sections
- Open-arc into solid scrap or molten slag

SUBMERGED – ARC FURNACE

- 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

High
> 1500°C

**Operating
Temperature**

Low
1000°C - 1500°C

Open-Arc	Submerged-Arc
Slag resistance Reverberatory Flash furnace	Blast furnace Cupola

Fine

0,01 – 10mm

Coarse

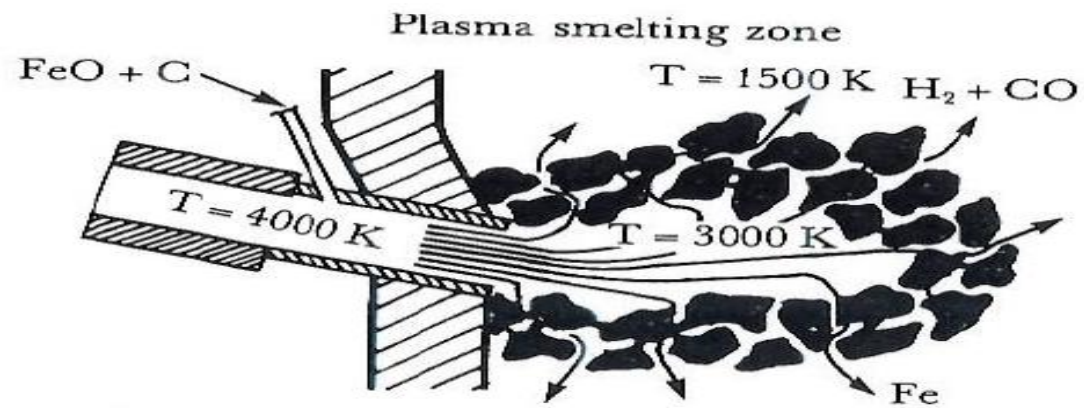
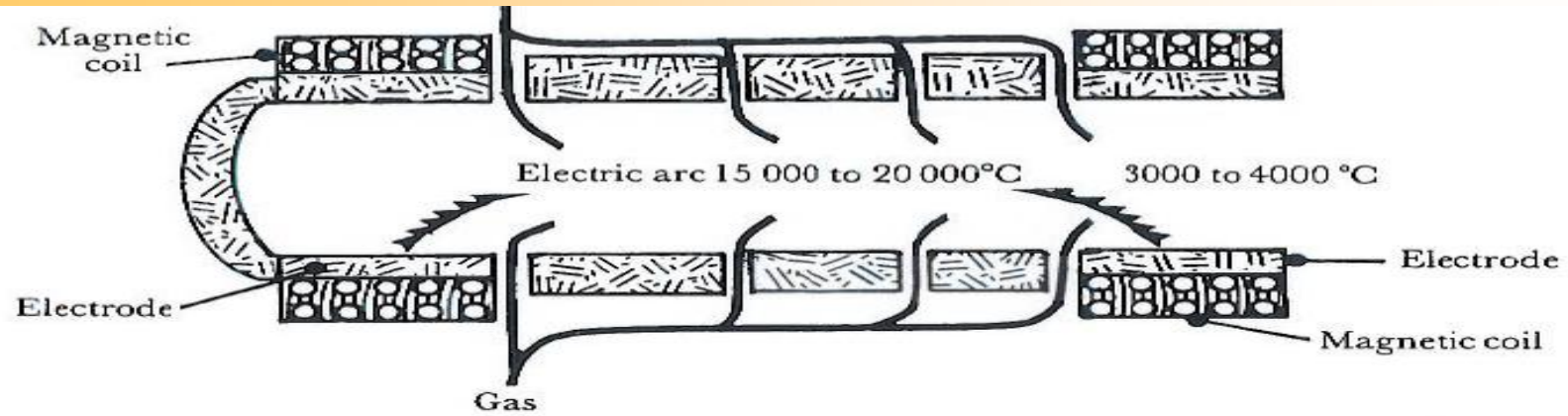
10mm – 200mm

Ore size

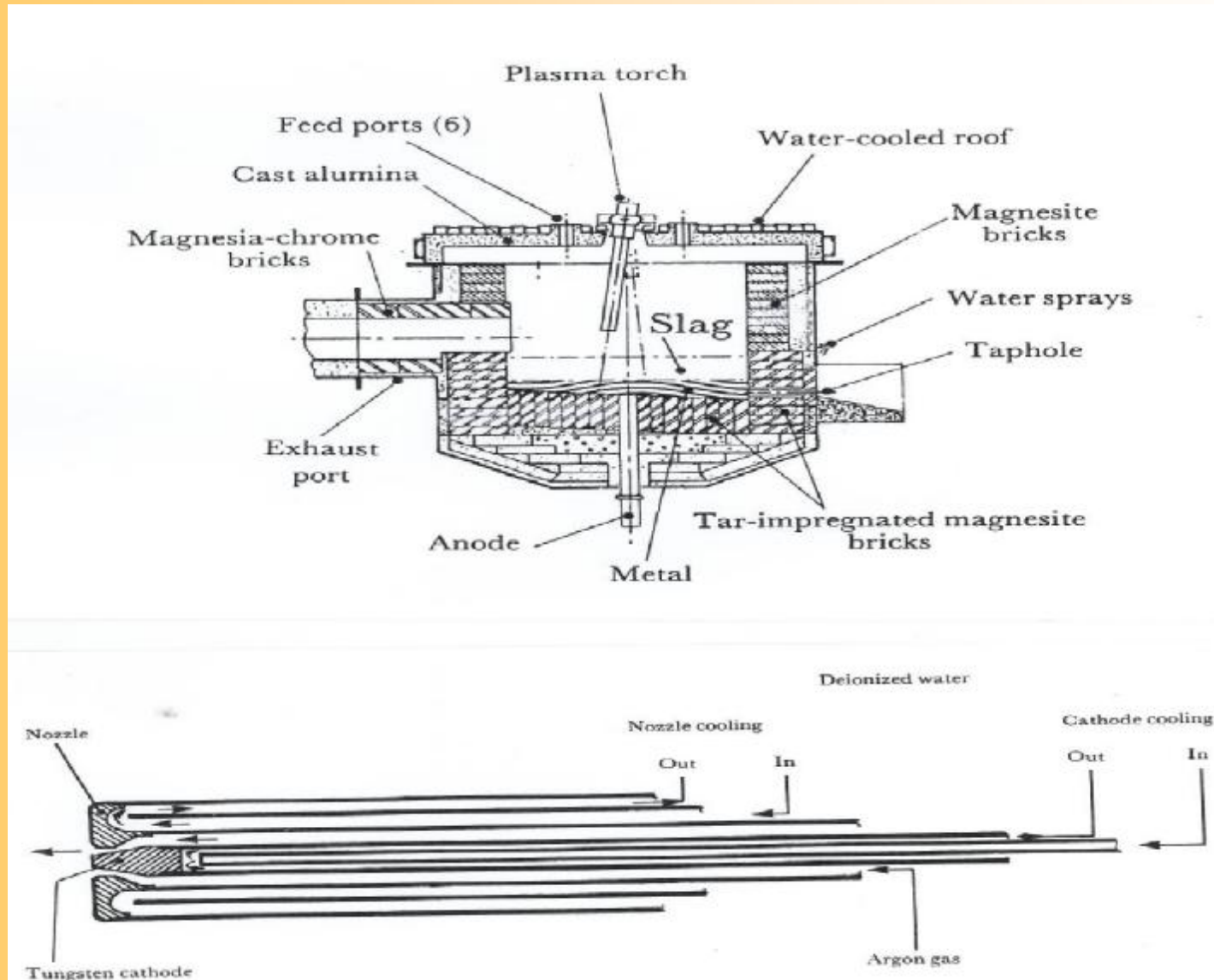
THE ADVENT OF PLASMA FURNACES

- Origins in the 1960's space race
- Need to test re-entry materials at $>4000^{\circ}\text{C}$
- Concept is to pass gas through an electric arc
- Precedent in a 1900's process to produce NO_x
- Two plasma torch types were developed
- Characterized by using water-cooled metallic electrodes

NON-TRANSFERRED ARC



TRANSFERRED ARC



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

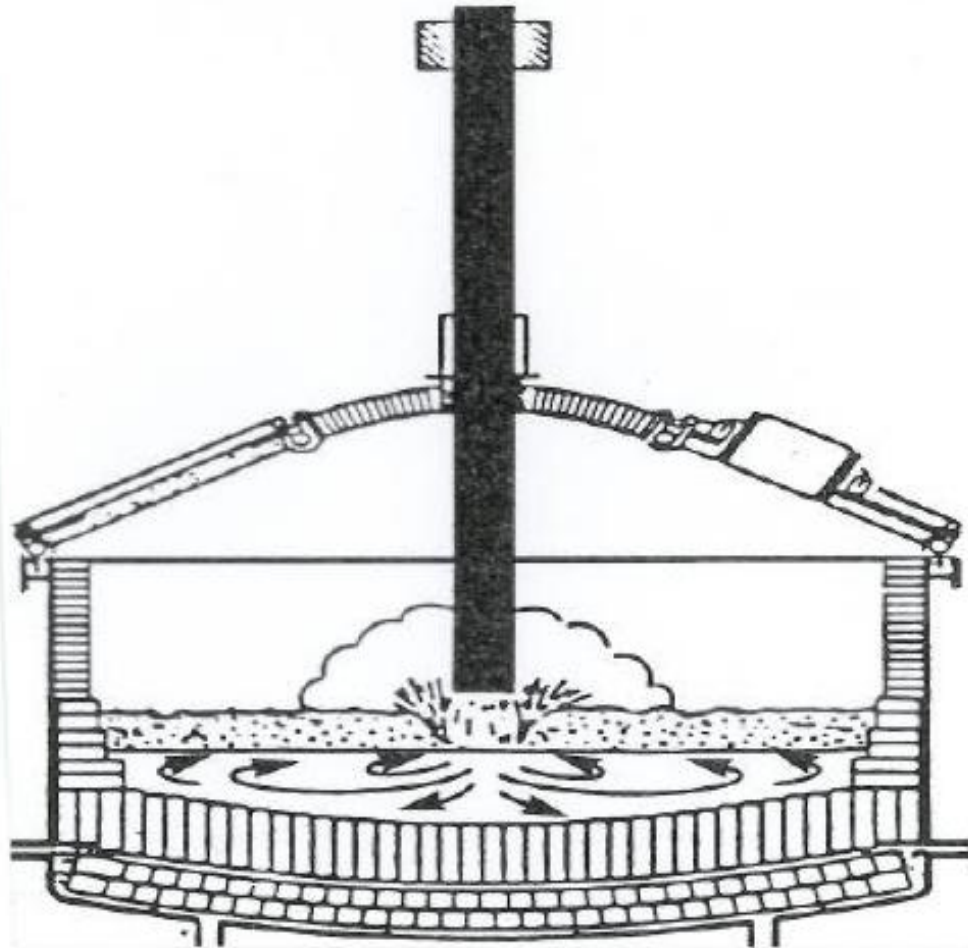
MINTEK'S INVOLVEMENT IN PLASMA FURNACES (Continued)

- 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 thyristor 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

DC ARC SMELTING OF CHROMITE (continued)

- 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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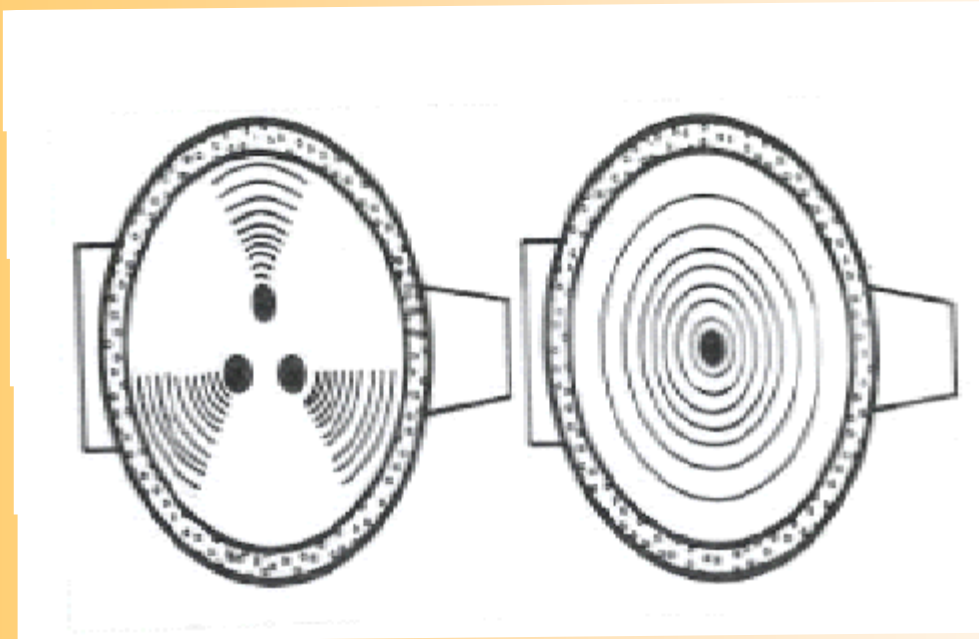
Ore size

WHY USE A DC ARC FURNACE

- 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”

SUBSEQUENT DC OPEN-ARC FURNACE APPLICATION

- 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

SUBSEQUENT DC OPEN-ARC FURNACE APPLICATION (continued)

- 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

PILOTED BUT NOT YET COMMERCIALIZED

- 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

CONCLUSION

- Technology development is not linear, it may have many roots and unexpected outcomes.

Thank you



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