Clean Aluminium Production Process

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MODULAR PRIMARY ALUMINIUM PLANTS
BASED ON
BECK CELLS WITH INERT ANODES AND
CATHODES

CARBON NEUTRAL AND ZERO EMISSION OF
CARBON DIOXIDE AND OTHER GREENHOUSE GASES

The Beck Cell is named after the inventor; Dr. Theodore R. Beck, professor in electrochemistry at the Washington University in Seattle, WC, USA.

Patented process (Patent No. US 8,480,876 B2, July 9, 2013)
Environmental Comparison

The Beck Cell is a « Game Changer »
Environmental and energy friendly aluminium reduction process for a sustainable aluminium industry.

**EXISTING HALL HÉROULT CELL TECHNOLOGY**

$$2 \text{Al}_2\text{O}_3 + 3 \text{C} \Rightarrow 4 \text{Al} + 3 \text{CO}_2$$

$$2 \text{t Al}_2\text{O}_3 + 0.4 \text{t C} + 14 \text{ MWh} =$$
$$1 \text{t Al} + 1.40 \text{t CO}_2$$

Carbon anodes replaced every 30 days.

**NEW BECK CELL TECHNOLOGY**

$$2 \text{Al}_2\text{O}_3 \Rightarrow 4 \text{Al} + 3 \text{O}_2$$

$$2 \text{t Al}_2\text{O}_3 + 11 \text{ MWh} =$$
$$1 \text{t Al} + 1.0 \text{t O}_2$$

Inert anodes and cathodes
The Business Deal

Delivery of low cost turn-key modular primary aluminium plants

Price €90 million per plant producing 50,000 ton aluminium per year

Arctus

Aluminium Manufacturers

Oxy – Fuel Power Plant

O₂, CO₂ → Al
In the year 2016 some 50 million tons of aluminium are produced worldwide.

**Beachhead market:**
Twenty old (30-50 years) Primary Aluminium Smelters in Europe which can be upgraded.
World Primary Aluminium Production since the beginning of the XXth Century

Aluminum is a young metal

Various sources
Main areas of growth are in Non-OECD countries. e.g. China, Gulf States, Southern Africa and Brazil.
World Primary Aluminium Production 2005 and projected 2020

Figure 1. The world consumption of primary aluminum, in millions of tonnes.\textsuperscript{1,4,10}
Some 600 Aluminium downstream manufacturers in Europe, providing

1 million jobs, and producing products from
11 million tons of aluminum per year,
thereof 5 million tons Al imported.
Conventional, 130 years old, Hall Héroult Aluminium Production Technology with Carbon Anodes.

- **Conventional Hall Héroult Technology**
  \[
  2 \text{Al}_2\text{O}_3 + 3 \text{C} \Rightarrow 4 \text{Al} + 3 \text{CO}_2
  \]
  \[
  2 \text{t Al}_2\text{O}_3 + 0.4 \text{t C} + 14 \text{MWh/t} =
  \]
  \[
  1 \text{t Al} + 1.40 \text{t CO}_2
  \]

- **Inert Anodes Comparison**
  - **Horizontal Carbon Anode.** Some 30 days in the cell.
  - **Horizontal Graphite Cathode.** Some 6 years in the cell.

- **Electrolyte at 950 °C.**
- **Liquid aluminium metal in the bottom of the cell.**
Beck Cell process emits valuable $O_2$ instead of $CO_2$

In the year 2020 some 70 million tons of aluminium will be produced worldwide with emission of 100 million tons of $CO_2$.
Revolutionary energy-efficient and clean aluminium production process

Main Product:

Turn-key modular aluminium smelter.

based on:

Beck Cells with multiple vertical inert anodes and cathodes to produce aluminium.

Consumables:

- Inert anodes
- Inert cathodes

Aluminium oxide $\Rightarrow$ Aluminium + Oxygen

$2 \text{Al}_2\text{O}_3 \Rightarrow 4 \text{Al} + 3 \text{O}_2$
The Inert Cathode of the Beck Cell Technology

A half section of a porous cathode

TiB$_2$ wetted with aluminium

Al$_2$O$_3$ plate with molten aluminium

Alumina Header Pipe

Surface of the Cathode is coated with alumina for preventing oxygen attack above the bath level.

Electrolytic Bath
SIDE BY SIDE BECK CELLS
Anode and Cathode Beams, Risers and Busbars

100 kA Electrolytic Cell with 57 vertical inert anodes and cathodes

Busbars + to Anodes
Anode Beam +
Aluminium Container 32 kg/hour
Cathode Beam -
Busbars - from Cathodes

Busbars + to Anodes
Busbars - from Cathodes
The Beck Cells have multiple vertical inert anodes and wettable inert cathodes in low temperature (750°C) electrolysis process.
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Competitive Advantages

Our „Game Change“ Beck Cell aluminium process compared to a conventional Hall Héroult process:

• Zero emission of $CO_2$ and other greenhouse gases.

• Zero compliance costs for smelters due to carbon dioxide emission regulations.

• **Instead 1 ton $O_2$ generated** for each ton Aluminium produced which can be used for different industrial applications nearby or oxy-fuel power generation.

• 20% less energy.

• 60% less space.

• 40% less investment cost.

• Improved health and safety for the employees.

• Higher aluminium quality (99.95% vs 99.7%).

• Patented process (*Patent No. US 8,480,876 B2, July 9, 2013*)

Smelter based on Hall Héroult Cells  
Plant based on Beck Cells
The business potential for Beck Cell „Game Changer“is great!

The key financials for our aluminium plants and products based on the European market only are:

- € 90 million per modular aluminium plant for 50.000 tpy Al.
- € 170 million per modular aluminium plant for 100.000 tpy Al.
- Sales target after 5 years of commercial operation is at least three turn key aluminium plants per year.
- 25% profit margin on sales.
- Consumables: € 20 million in inert cathodes per smelter and year.
- Royalty license fee
The Beck Cell’s “Blue Box” Risk Analyses

Where is Beck Cell today?

2009  2016  2020

Funds Available

RISK

Tests

USA

VRD

Test 1

180A

Test 2

1,800 A

Test 3

9,000 A

Test 4

100,000 A

Test 5

Commercialization

The Blue Box
The drawings show the set up for the Bench Top Test of the 120 A Beck cell at VRD in Sweden in June 2009. The crucible is at the same time the anode and made of inert or non-consumable Cu-Ni-Fe material and the porous cathode of SiC with Titanium diboride coating. The circular, porous and hollow vertical cathode is connected to a TiB2 bar inside the headpipe.

In the first test the aluminium penetrated partly the porous cathode as seen.
Trials by the Commonwealth Science and Industrial Research Organization (CSIRO) and Comalco with horizontal Inert Anodes in Conventional Hall Héroult Aluminium Production Cells

Dr. Mark Cooksey leader at CSIRO, Melbourne has informed Arctus that CSIRO, “believe more in the success of multiple vertical inert anodes and cathodes in low temperature electrolyte (750°C) like the Beck Cell concept”, than trying to develop inert anodes and cathodes for conventional Hall Héroult cells. after 20 years research project 1990-2008, without any commercial success!

(Melbourne, February 2013)
**Time Schedule and Funding**

**Arctus Metals completed R&D project**
- **2008-2009**  Vattenfall R&D Laboratory, Sweden  
  Bench Top Test at 120 Amps
- **2007-2013**  Patent process

**Arctus Metals planned R&D Project in Horizon 2020**
- **2016-2017**  Bench top test at 180 Amps  
  **€ 500,000**
- **2017-2018**  Full size cathode test at 1,800 Amps  
  **€ 1,000,000**
- **2018-2019**  Multiple full size cathode test at 9,000 Amps  
  **€ 1,500,000**

**Pilot Plant in cooperation with an Aluminum Producer.**
- **2019-2020**  Prototype test of three full size Beck Cells at 100,000 Amps.

**Arctus Metals planned Commercialization**
- **2020-**  First modular aluminum smelter in operation with 20 cells  
  for 5,000 tpy production.
- **2022-**  First aluminum smelter in operation with 100 cells  
  for 25,000 tpy production.
Arctus Partners:

- Innovation Center Iceland
- EFLA Engineering Ltd, Iceland
- LeFebvre Engineering FZC, UAE
- Ultramet Inc.

R&D
- Power System Engineering
- Environmental Issues
- Aluminium busbars and risers
- TiB2 coating of cathodes

Potential Partners?

- KIC InnoEnergy Sweden
- ABB, Sweden
- Uppsala Universitet & KTH
- Vattenfall AB, Sweden
- EU Horizon 2020

Venture Capital and Network
- High Power Rectifiers and Systems
- TiB2 coating of cathodes
- Electrochemistry and low temperature electrolyte
- Pilot plant power, etc.
- SME Funds
Experienced management team:

Eng. Jon H Magnusson, MScEE.
Director Arctus Metals Ltd., Reykjavik, Iceland
Director MetalTech Ltd., Reykjavik Iceland
30 years experience in product development in the aluminium industry

Eng. Rolf M. G. Falkenberg, MScME.
Director Arctus Metals Ltd., Reykjavik, Iceland
Former CEO Vattenfall Engineering Ltd, Stockholm, Sweden
30 years experience in the power industry

Dr. Lennart Billfalk, PhD. Hydraulic Engineering
Partner and Technology Advisor
Former CTO Vattenfall Ltd, Stockholm, Sweden
30 years in the power industry

Dr. Theodore R. Beck, PhDEC.
Partner and Process Inventor, President, ETCI LLC, Seattle, WA
Professor Emeritus, Electrochemistry
University of Washington, Seattle, WA, USA
50 years experience in R&D in the aluminium industry

Our Vision:
“Create a profitable business providing energy-efficient and environmentally friendly process for aluminium production.”
KIC InnoEnergy Sweden:

The Beck Cell Aluminium Process supports EIT KIC InnoEnergy’s goal to achieve a “sustainable energy future for Europe. New ideas, products and solutions that make a real difference, new businesses and new people to deliver them to market.”

The Beck Cell Aluminium Process support EIT KIC Raw Material’s goals by, “developing aluminium raw materials into a strategic strength for Europe by boosting competitiveness and the attractiveness of the raw materials sector.”
Arctus 2nd price in the European ClimateLaunchpad 2015 with 700 participants from 28 European countries.

2003 JHM awarded Honoray Professor at SIM (JUST) University, China

2003 JHM awarded the Innovation Price of the Icelandic Export Council and the Research Foundation

2002 JHM awarded as the Innovator of the year in Iceland
“We want to provide the power intensive aluminium smelters in Europe and world wide, with more attractive and energy saving processes, reduce the environmental impact of their operations, improve their efficiency and profitability and contribute at the same time to sustainable development of industries world wide.”
Questions and Answers

Has prepared answers to some technical questions as follows.

We welcome more questions!