INCITE

Final report
INCITE participation to the Swedish Metals & Minerals event at Jernkontoret (Stockholm – 12th September 2024 + site visits to First-of-A-Kind (FOAK) industrial installations (11th and 13th September 2024)

Sector: Iron and Steel
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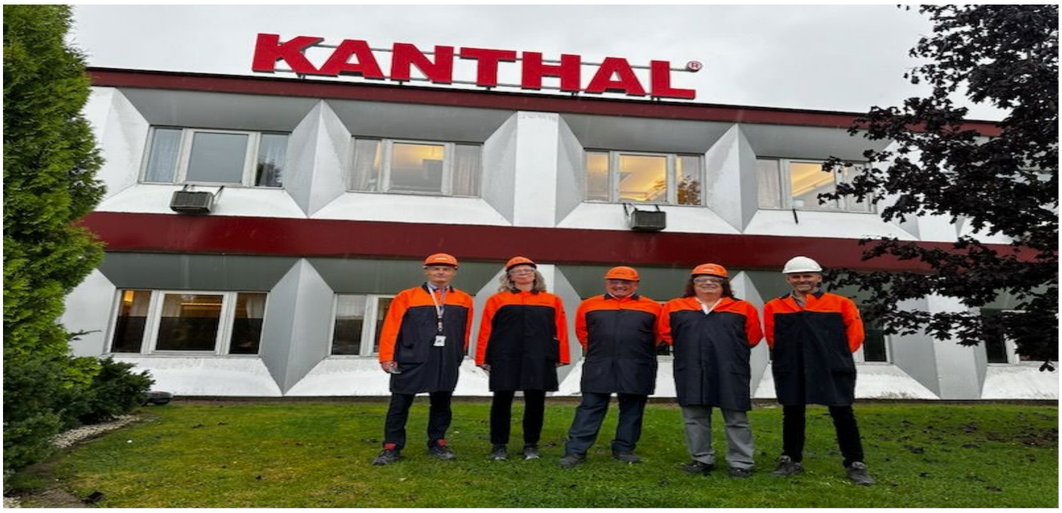
Site visit at Kanthal (Hallstahammar – 11/09/2024)

The INCITE team (Eric Aries, Panagiotis Karlis) accompanied by Eva Blixt (Jernkontoret) and Nicolai Schaaf (Kanthal, Sustainability Manager, Kanthal) performed a site visit at the Kanthal plant located in Hallstahammar.



Kanthal is a brand for products and services in the area of industrial heating technology and resistance materials. Kanthal provides solutions for the electrification of various processes in several energy intensive industrial sectors (e.g. iron and steel, ceramics, aluminium, automotive, glass). Kanthal produces around 800 different alloys that can be used to produce a wide range of heating elements that can operate up to 1 850ºC in e.g. electric furnaces.

An electrified hot rolling installation was visited in Hallstahammar. The installation has been operating for more than 30 years. It consists in a walking beam furnace for reheating of ingots which is entirely electric. The ingot rolling mill produces billets, which are hot rolled in the rod rolling mill into wire rods (diameters between 5.5-12.5 mm). Prior to rod rolling, the billets are passing through an electric walking beam furnace, where they are heated up to 1.300ºC. Traditionally either gas or oil is used in reheating furnaces such as walking beam furnaces, with relatively low thermal efficiency and generation of significant amounts of CO_2 emissions. Electric reheating furnaces generates far less noise and dust emissions, in addition they do not need any exhaust gases abatement systems leading to significant gains in terms of energy consumption.

Kanthal®Super heating elements, which are based on molybdenum disilicide ($MoSi_2$), are used for heating the waling beam furnace. When heated, a protective layer of silica is formed on the surface of the elements which prolongs their service life and reduces the need for maintenance and repairs.

Presentation were also given by the R, D and T team of Kanthal, highlighting several applications in the field of electric heating for energy intensive industries which could be relevant to INCITE.

This included, for example, the following:

- Kanthal®Tubothalmetallic heating element: Can be used for holding furnaces within primary aluminium smelters (furnaces up to 100 tons) leading to zero carbon emissions, a reduction in overall energy consumption and reduced metal loss due to 0.5 – 1% less dross formation. Can also be used in steel heat treatment furnaces such as e.g. roller hearth furnaces. For instance, OVAKO converted 14 roller hearth furnaces in one of its plants in Finland leading to CO_2 savings between 1 400 to 2 000 tons of CO_2 per year per furnace.
- Kanthal®Globar: Can be used in particular in the glass manufacture industry, for example in the production of float glass.
- Kanthal®APM radiant tubes: These are radiant tubes that can be used in electrical e.g. continuous galvanizing furnaces, holding furnaces and dosing furnaces in the aluminium, zinc, lead industries.

Kanthal has also recently signed a partnership agreement with Danieli, a major supplier of Direct Reduction of Iron (DRI) technology. The objective is to develop an electric process heating solution for pre-heating hydrogen in the DRI process. This is one of the key hurdle to overcome for hydrogen steelmaking using DRI. Kanthal has tested and verified in a pilot scale the Prothal® DH direct electric-heating solution for high-temperature process gas heating, but this will need to be further developed full scale. Prothal® electric-heating solution will be developed for hydrogen, natural gas, and their combination, thereby also enabling retrofitting of existing DRI plants.

Kanthal is also working in the cement sector, as partner in the Horizon EU-Funded research project Electra which started in 2024, where a demonstration plant will be built in Finland.

Meeting at Greeniron headquarters (Stockholm - 12/09/2024)

The INCITE team (Eric Aries, Panagiotis Karlis) accompanied by Eva Blixt (Jernkontoret) participated on 12/9 in a meeting in the offices of the Greeniron company in Stockholm. Edward Murray (CEO) gave a presentation about the company and explained the innovative solutions it can offer.

The company can handle a variety of raw materials and recover the metal content to produce different fossil free metals. For iron, it can process virgin iron ore (mineral ore) as well as a large variety of residues generated in the steelmaking process (e.g. fabric filter dust, mill scale, slags). In short oxidic material that react with hydrogen and get reduced This technology is not only applicable to the iron sector but also to non-ferrous metal applications, e.g. GreenIron is also developing the recovery of copper for residues generated in copper mines. The technology is fully patented, the company currently holds in total 7 patents that were submitted in 2017 and approved.

An indicative list of the raw materials that the company can process is the following:

- Virgin ore (iron, copper, nickel, manganese)
- Mill scale (steel with alloys)
- Steel slag (iron, steel, alloys)
- Filter dust (iron, steel, alloys, zinc)
- Pickling Sludge, (iron, nickel)
- Sinter fines (iron)
- Roasted Pyrite (iron, copper and more)
- Catalyst waste (nickel, chrome and more)
- Smelter waste (copper and iron)

The production of the metals is taking place in a batch processing furnace (bell furnace) at a temperature of about 600°C. The internal atmosphere is flushed with nitrogen gas (N_2) and thereafter evacuated. In this step, the main goal is to control the internal environment, where elimination of the oxygen gas (O_2) is of great importance. Hot hydrogen gas (H_2) is then introduced into the chamber and the reduction process starts. There are no air emissions from this process. Wastewater emissions are handled by an external company or reused (depending on their purity) in the electrolytic cell for production of hydrogen. The entire process lasts only one hour. A 10 MW electrolyser is typically required for supplying green H_2 to a bell furnace.

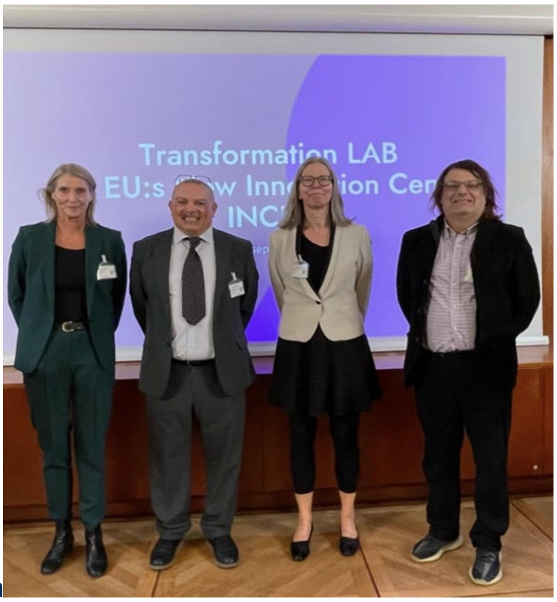
The company will operate first in Sweden (Sandviken) after having secured more than 100 million SEK additional financing last April 2024. Construction of the facility is now ongoing, and GreenIron is expecting to start commercial production of fossil-free iron by the end of 2024 at this plant. Another plant is also currently in a planning phase in Australia with a production capacity of 160 000 tonnes per year. Globally, the company is planning to scale up all over the world, with the commissioning of more than 300 furnaces currently planned by 2030 as a goal.

GreenIron will invite the INCITE team to the inauguration of the plant in Sandviken.

GreenIroon is also involved in an EU-Funded project (in association with ArcelorMittal Espana, in particular), as part of the Clean Steel Partnership. The project is entitled ZHIRON.

Participation in the Swedish Metals and Minerals workshop on INCITE (Jernkontoret – 12/09/2024)

The workshop took place on 12/9 in Stockholm in the offices of Jernkontoret. Around 100 participants representing SE authorities, industry, technology providers, academia attended it in person. Moreover, there were around 200 online participants.

n 

The objective of the workshop was to introduce and give visibility to INCITE to a wide range of SE stakeholders (including research and technology organisations, industry, governmental authorities, technology providers). Eva Blixt, Jernkontoret was moderating the event.

Annika Roos, (CEO, Jernkontoret) gave an opening speech highlighting the importance of INCITE for transformation and innovation of the iron and steel industry.

Eric Aries (INCITE, European Commission) gave the opening presentation, summarising information on the revised Industrial Emissions Directive and focusing on the objectives of INCITE. The talk was well received and triggered some questions about the working procedures of INCITE, especially in relation to the analysis of innovative techniques. There were also questions about the definition of an innovative technique.

Afterwards a panel discussion took place in relation to new projects from research and technology providers among the following panellists:

- Pontus Sjöberg, CEO, Swedish Metal Research Institute, Swerim
- Adam Andersson, Director European Affairs, RISE, Research Institutes of Sweden
- Lars J Nilsson, professor, LTH at Lund University
- Nicolai Schaaf, Sustainability Manager, Kanthal

The second part of the workshop took place in Swedish, with some presentations in relation to the link between INCITE and the *Sevilla* process and two more panel discussions about innovation research in SE and working methods of SE stakeholders with INCITE.

The INCITE team was active during all the workshop responding to several questions arising from the audience and the panellists, giving further explanations about the mission of INCITE and some practical information about the INCITE workflow. The INCITE team invited the relevant stakeholders to upload their innovative techniques in the INCITE platform (when it will be ready).

At the end of the workshop all in person participants said a few works about their understanding of INCITE. The majority expressed their support to the project, highlighting that the Workshop was key to understand better the mission and working methods of INCITE.

Hybrit pilot plant site visit (Luleå – 13/09/2024)

The INCITE team (Eric Aries, Panagiotis Karlis) accompanied by Eva Blixt / Christer Ryman (Jernkontoret), Markus Odevall, LKAB and Nicolai Schaaf (Kanthal) performed on 13/9 a site visit at the Hybrit pilot plant (semi-industrial scale) located in Luleå.

The HYBRIT initiative was launched in 2016 by SSAB, LKAB and Vattenfall with the aim of creating a completely fossil-free value chain from mine to fossil-free steel, with fossil-free pellets, fossil-free electricity and hydrogen. The aim of the initiative is to phase out the use of coal and to virtually eliminate carbon dioxide emissions for the steel industry, corresponding to about 10% of Sweden's total CO_2 emissions. On August 2020, the pilot plant for the direct reduction of iron ore with hydrogen was first commissioned and in August 2022, the pilot plant for storage of fossil-free hydrogen was commissioned.

An overview of the results obtained during the past 6 years of the Hybrit pilot scale project was provided by the Hybrit development team represented by Gunilla Hyllander (General manager).

The pilot plant consists of a direct reduction process of iron oxides for the production of iron (sponge iron). Hydrogen is used as the reducing agent in the process. The production of hydrogen is taking place by using 100% fossil free electricity. The process has a footprint of 25 kg CO_2/ton of steel (the related footprint for the traditional blast furnace process is 2 200 kg CO_2/ ton of steel). It should be noted that this process has not yet be implemented in an industrial scale.

The pilot plant has a capacity of producing 1tn/h of iron and operates since 2020. The related industrial capacity will exceed 100 t/h. The plant has a height of 50 m. The choice of process settings and technologies are validated through pilot scale trials throughout the value chain from ore to steel.

In the direct reduction process, iron ore pellets are converted into iron using only hydrogen as follows:

- Iron ore pellets are fed into the top of a shaft furnace and the bed of pellets slowly moves downwards. An upward stream of hot hydrogen gas reacts with the oxygen in the pellets and leaves the shaft at the top as water vapour.
- The reduced iron does not melt but remains in its solid original pellet form.

- The product leaves the shaft in either hot or cold condition. Hot sponge iron can be compacted into briquettes.

Tests in the pilot plant are run around the clock for periods of 6-8 weeks at a time. The total time for testing until 2024 is 61 weeks. Reduction of iron ore pellets using only hydrogen has accounted for 75% of the operating time of the pilot plant so far. The parameters of the process have been characterised by testing more than 175 different process states. Sponge iron has been produced for a long time under stable process conditions. More than 5 000 tonnes of fossil-free sponge iron have been produced so far. Moreover, different methods for fossil-free heating of the reduction gas have been evaluated, with tests of gas-fired and electric heaters and partial combustion with oxygen. A lot of research is taking place is relation to the small cavities of the product. The structure of the cavities depends on the temperature of the direct reduction and have a direct effect on the quality of the product.

It was highlighted that sponge iron pellets reduced with hydrogen have significantly better transport, storage and melting properties compared to sponge iron reduced with conventional natural gas-based processes. Moreover:

- Low iron oxide content and 0% carbon give the sponge iron robust mechanical properties. The product is resistant to mechanical pressure, abrasion and drops Therefore, losses during handling and transport of the product are minimised.
- Tests also show that the product has very good and stable chemical properties. It ages very slowly and can therefore be easily stored for a longer time.
- A high degree of metallisation (98-99%) means that there is very little iron oxide remaining. This reduces losses in the value chain and results in lower energy consumption during melting.

The production of hydrogen is taking place in a full-scale facility. The nominal production capacity is 910 Nm^3/h which corresponds to an output of approximately 4.5 MW. The electrolysers have been in operation for more than 9 000 hours. There is also a pilot hydrogen storage facility in a lined rock cavern situated 3 km away from the plant. The hydrogen storage facility opens up the possibility to adapt hydrogen production to the price of electricity while meeting the hydrogen needs of the reduction process. This creates the conditions for cost-effectively managing fluctuations in the supply of renewable electricity based on, for example, wind and solar power. Hydrogen is stored in a 100 m^3 tank located 30 m below the ground surface. High pressure is required for the storage to be efficient and by constructing underground, this pressure is generated by the rock mass instead of by heavy pressure vessels above ground. Results from trials at the pilot plant show that storage can reduce the variable cost of hydrogen production by up to 40%.

Next steps:
A validated process concept has been delivered to LKAB and SSAB for full-scale implementation. Accordingly, a full scale HYBRIT plant is going to be built in Gallivare (North Sweden). The plant is foreseen to operate at full industrial scale in 2027. It will result in the avoidance of 14.3 million tons of CO_2 over the first 10 years of its operation. It will need around 5TWh/year of fossil-free electricity.

The DRI will be used for production of steel slabs after melting in an electric arc furnace at the SSAB Oxelösund site (South Sweden).

Site visit of the Stegra plant under construction (Boden – 13/09/2024)

The INCITE team (Eric Aries, Panagiotis Karlis) accompanied by Eva Blixt / Christer Ryman (Jernkontoret) and Nicolai Schaaf (Kanthal) performed on 13/9 a site visit at the (under construction) Stegra plant located in Boden.

Stegra is building its first plant for large-scale production of green hydrogen, green iron and green steel. The integrated steelworks will be entirely new. The company was founded in 2020 as H_2 Green Steel and changed its name to Stegra in September 2024. The plant was built in Boden because of the close availability of a 400 kV high power line for electricity supply nearby.

Anne Graf (Head of Regional Affairs) introduced Stegra and the site activities.

The plant will apply direct reduction of iron ore for the production of iron (sponge iron). Hydrogen will be used as the reducing agent in the process. The production of hydrogen will take place by using 100% fossil free electricity. The hydrogen plant will have the capacity to produce more than 100 000 tonnes of hydrogen per year. Moreover, a steel production plant (electric arc furnace process) will be built as well as hot and cold rolling steel processing lines.

Around 1 000 people are working for the construction. At the time of the site visit the related surface developments for supporting the plant were finalised and the installation of the skeleton of the reduction reactor was taking place.

The company has already signed contracts for steel products with different clients and around 50% of the future initial steel volumes are already sold. The production of steel is foreseen to take place in 2026 with a projected production of 2.5 million tonnes of hot and cold rolled steel per year. The production capacity is expected to rise to 5 million tonnes by 2028.

The company has also a funnel of potential projects outside of Sweden that are being explored as part of a longer-term outlook. They are characterised by locations where the company's customers need help with value-chain decarbonisation and which offer abundant access to renewable electricity and strong grid connections. Locations under consideration include Portugal, Canada and Brazil. In Portugal, where green power is readily available, Stegra is studying the possibility to install a DRI plant for production of HBI (standalone plant near Sines).