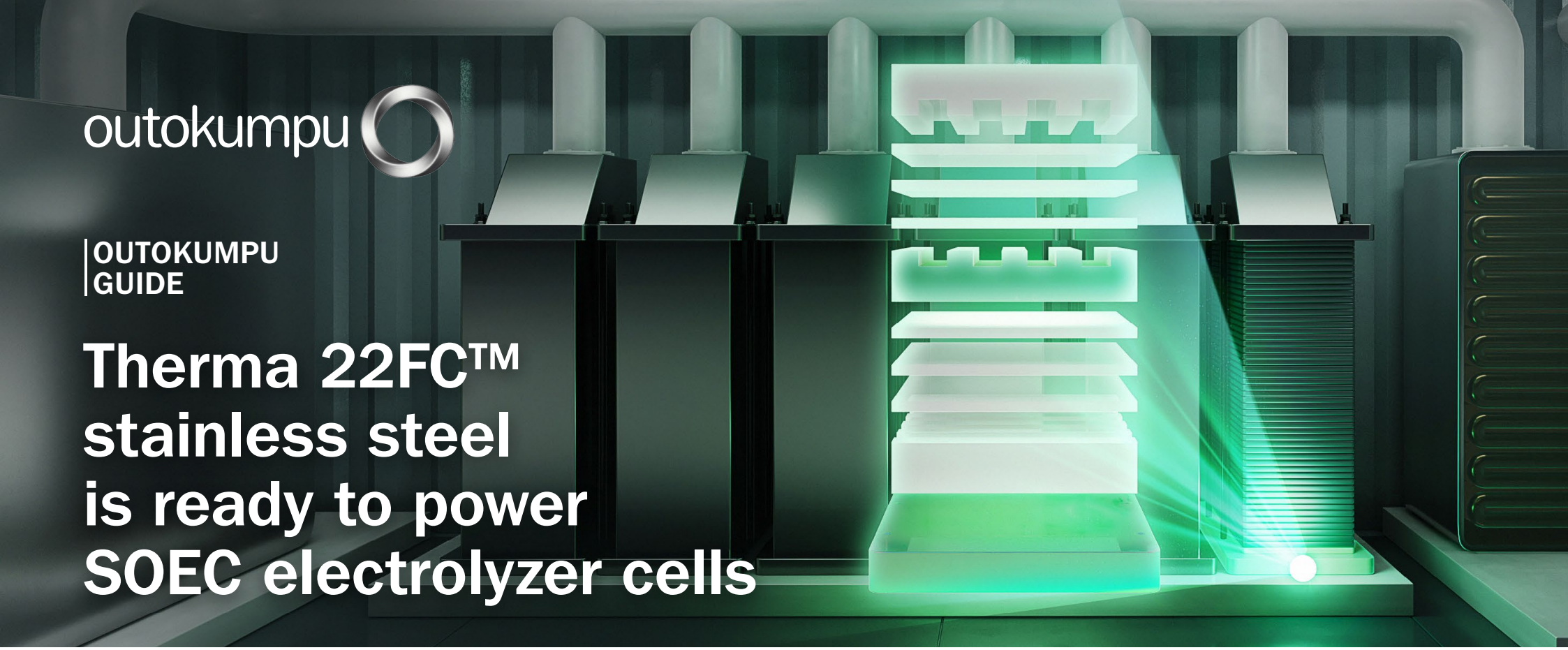

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OUTOKUMPU GUIDE

Therma 22FC™ stainless steel is ready to power SOEC electrolyzer cells

As the hydrogen economy expands globally, it is driving the development of Solid Oxide Electrolyzer Cells (SOEC) that produce hydrogen from water and use it as a fuel to generate electricity.

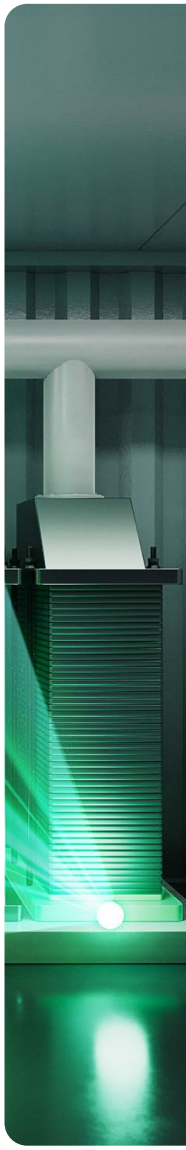
To meet this demand, Outokumpu has developed Therma 22FC™ as a specialist high-chromium ferritic stainless steel grade for the construction of SOEC stacks. It offers the ideal combination of electrical, mechanical and corrosion resistant properties to ensure high performance and long life in applications operating between 550 °C and 900 °C.

SOEC technology – Converting water to hydrogen

Solid Oxide Electrolyzer Cells (SOEC) will play a key role in the future energy mix by producing green hydrogen through the electrolysis of water, with oxygen the only byproduct. This will become increasingly important as the hydrogen economy builds momentum, with electrolyzers running on low-carbon electricity, from wind or solar energy plant for example, using hydrogen as a way of storing and/or transporting energy. SOECs benefit from thermal energy, which can be sourced from industrial waste heat or renewable sources like concentrated solar power, making SOECs the most efficient technology for clean hydrogen production in such cases. This makes them ideal for integration into energy-intensive sectors aiming to decarbonize operations.

The process works in reverse in Solid Oxide Fuel Cells (SOFC) that oxidize either pure hydrogen or a hydrocarbon fuel to generate electricity, with water the only emission. Thanks to their high combined efficiency, long-term stability, fuel flexibility and increasingly competitive cost, SOFCs are fast emerging as an option for stationary high-power generation applications from kilowatts to megawatts.

Historically, one main disadvantage of SOEC technology has been the high operating temperature – up to 1000 °C – since this requires specialized and costly construction materials such as zirconia, composites and highly-alloyed stainless steel to ensure reliability over a long service life. However, the new generation of SOECs are capable of operation at less demanding temperatures of around 650 °C to 900 °C. This has opened up the possibility to utilize more competitively priced and easier to fabricate stainless steel grades. That is why Outokumpu has developed a customized grade - Therma 22FC™. One of its most important advantages is its increased electrical conductivity that it can sustain over a long service life. This new grade can also be applied to SOFCs.



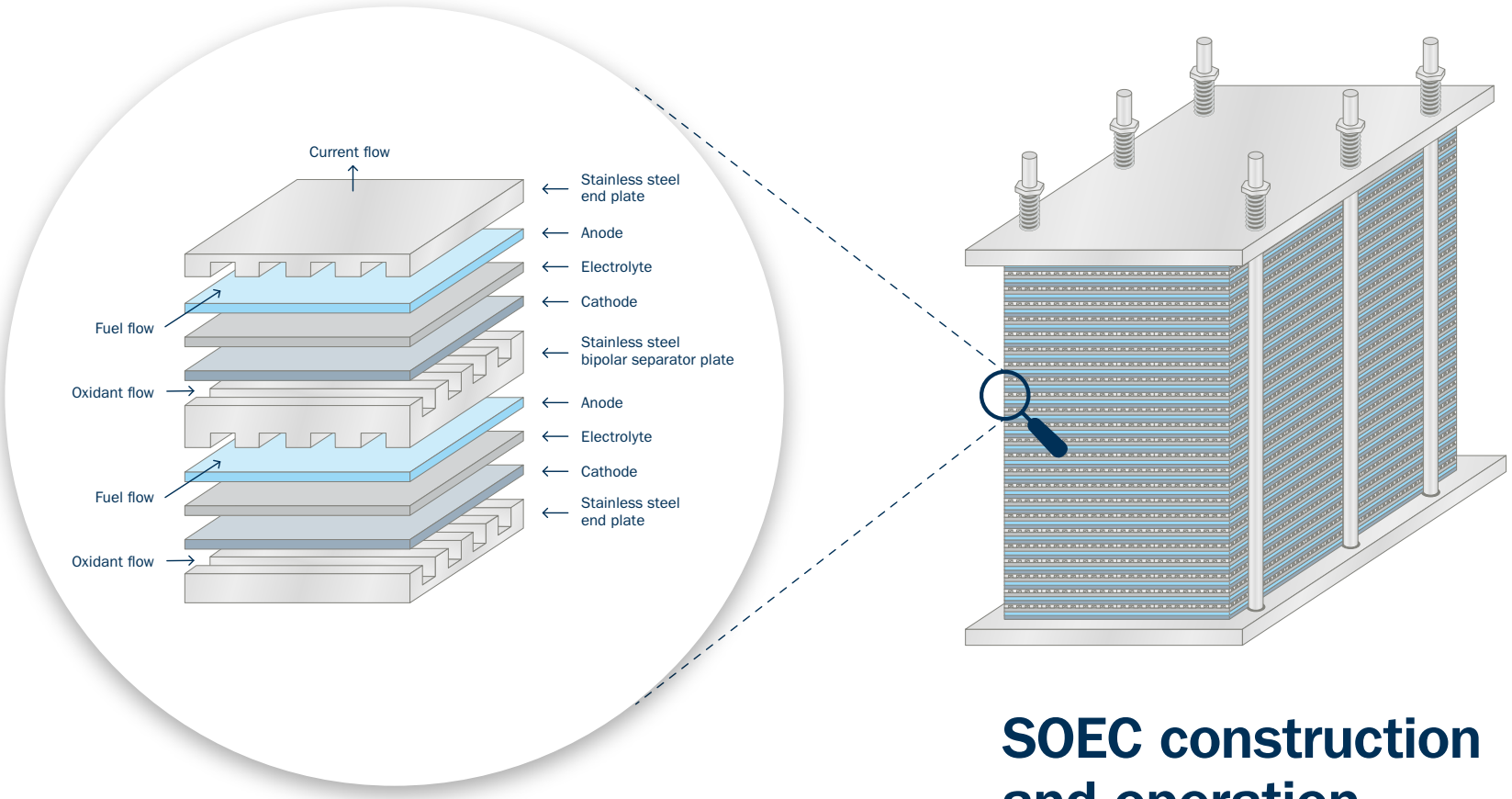
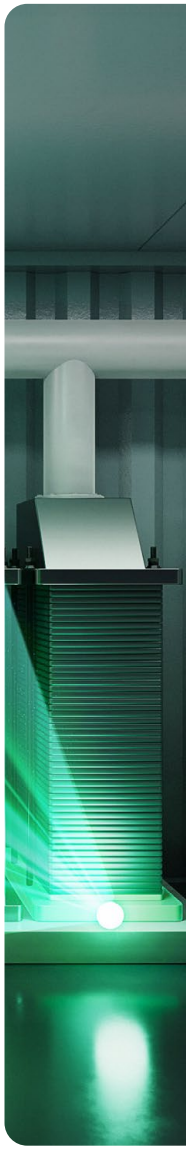


Fig. 1. Solid oxide electrolyzer cell (SOEC)

SOEC construction and operation

Figure 1 shows the typical construction and operating principle for a basic SOEC unit. It comprises a porous anode and cathode, each made of different types of ceramic. In between them is a solid electrolyte.

The SOEC enables electrical current to be applied to a supply of water. This causes the water (H_2O) to breakdown to produce hydrogen and oxygen.



Building the stack

In Figure 1 we see just one cell. In practical applications, “stacks” of multiple cells are connected in series to achieve the required system voltage. A crucial element in this stacked design is the interconnector plate that provides the electrical connection between the anode of one cell and the cathode of the next cell in the stack. It has to perform a dual role in maintaining the structural integrity of the stack, while at the same time preventing contact between the hydrogen at the anode and the oxygen at the cathode. A similar component is also used as the endplate of the stack.

The material used for the interconnector must meet some very demanding criteria:

- Low thermal expansion coefficient (TEC) compatible with the ceramic oxide components and sealing materials. This is essential to minimize thermal stresses during the heating up and cooling down stages when the SOEC starts and stops operation
- Corrosion resistance in a dual atmosphere, resistance to hydrogen and other fuel gases such as methane
- Low and stable electrical resistivity
- Long term durability to ensure reliable operation for many years
- Resistance to the evaporation of elements such as chromium that can “poison” the cell reaction and degrade its operation
- Good creep resistance at both operating temperatures and during stack manufacture
- Formability to enable the creation of gas transfer channels in sheet that can be as thin as 0.3 mm
- Compatibility with surface coatings applied for additional corrosion protection

Why Therma 22FC™ is the ideal stacking option

Outokumpu has developed Therma 22FC™ as a high-chromium ferritic stainless steel grade tailored for high temperature use in SOEC applications. It is used mainly for the interconnector plates and other metallic parts of the stack, where its physical and mechanical characteristics ensure a long lifespan.

Table 1 shows the chemical composition of Therma 22FC™ that is tightly controlled for optimized performance. It has a ferritic crystal structure, therefore the material is ferromagnetic.

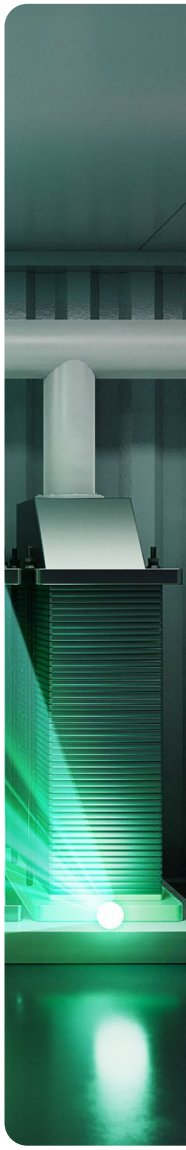
The thermal expansion coefficient (TEC) of Therma 22FC™ is comparable to the surrounding ceramic components and coatings. It can be used in combination with several different types of coating systems to provide outstanding performance with high electrical conductivity.

Table 1

Outokumpu grade	C	Cr	Ni	Mo	Stabilization	Others
Therma 22FC™	0.03	21	–	–	Ti+Nb	Cu: 0.3–0.8 V: 0.03–0.5

This grade has good creep behavior at high temperatures. It also offers higher heat transfer than austenitic grades resulting in less distortion.

Stabilization with titanium (Ti) and niobium (Nb) ensures a lower risk of sensitization. Sensitization of stainless steel can occur when it is heated to between 600 °C to 850 °C during heat treatment, welding or high temperature service. This causes chromium carbides to form on the grain boundaries. These carbides are hard and brittle, and they can make the steel susceptible to corrosion. The stabilizing elements help to keep the chromium in solution and prevent it from combining with carbon to form carbides.



Corrosion resistance

The 21% chromium content of Therma 22FC™ ensures good corrosion resistance and also reduces the risk of evaporation of chrome at high temperatures that could poison the SOEC.

Forming Therma 22FC™

Therma 22FC™ has good machinability due to its lower work hardening than austenitic grades. It can also be formed using typical forming processes like folding, bending, drawing, etc. to produce the flow field of the interconnector plates.

This grade has a slightly higher proof strength than the standard austenitic stainless-steel grade 304L (1.4307). Due to stabilization, its R-value (the plastic strain ratio that indicates the formability of steel) is higher than non-stabilized ferritic stainless steel. These characteristics ensure excellent formability.

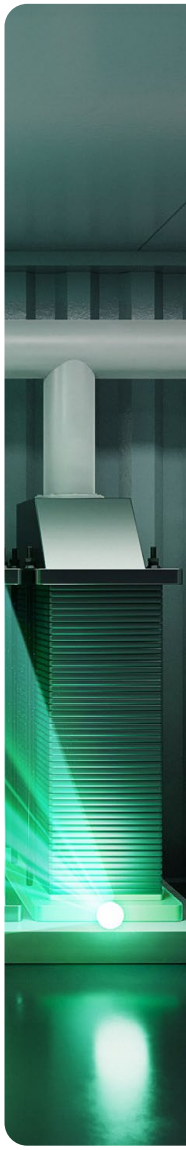
Welding Therma 22FC™

Therma 22FC™ can be welded using conventional welding methods with austenitic 316L filler metals. Shielding gases should be Ar/He based, mixed with a maximum of 2% oxygen to improve the arc stability. Hydrogen and nitrogen additions are forbidden.

The heat input should be minimized to reduce the grain growth in the heat-affected zone (HAZ). Stabilization prevents sensitization in the welds, while adequate corrosion resistance in the welds can be achieved using either mechanical descaling or pickling.

Product forms

Therma 22FC™ is available as cold rolled coil and sheets and in thicknesses of 0.3–3 mm with widths up to 1500 mm. Hot rolled products are also available on request.



Therma 22FC™ – summarizing its mechanical and physical properties

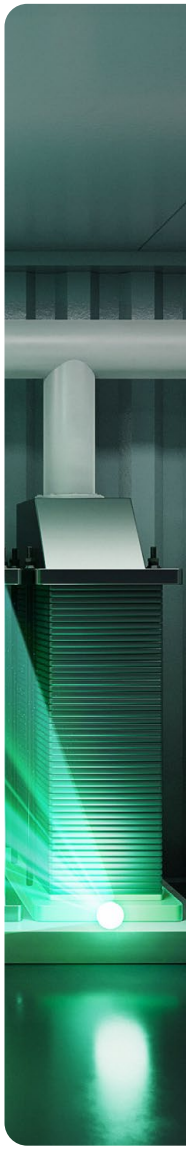
- Good creep resistance
- Density: 7,7 kg/dm^3
- Coefficient of thermal expansion: 10.5 x 10^{-6} 1/K (T = 20...100 °C)
- Coefficient of thermal expansion: ~12.0 x 10^{-6} 1/K (T = 25...700 °C)
- Thermal conductivity at 20 °C: 21 W/(m x K)
- Thermal capacity at 20 °C: 460 J/(kg x K)
- Electrical resistivity at 20 °C: 0.65 Ω x mm²/m
- Modulus of elasticity at 20 °C: 220 GPa
- Modulus of elasticity at 700 °C: 110 GPa

Therma 22FC™ is part of a broad range of stainless steels for the hydrogen economy

In addition to developing Therma 22FC™ for stacks, Outokumpu offers a broad range of other stainless steel grades that play an important role in the general construction of the overall electrolyzer system including structural components, housings and tubing. Our customers use them to create complete systems that range from 1.5 to 3 kW domestic fuel cells in the home to larger commercial installations providing 60 kW of electricity and 25 kW of heating. Even larger systems are anticipated, up to 1 MW, such as for data centers.

The high operating temperatures close to the stack call for grades that offer high creep resistance at elevated temperatures, resistance to temperature cycling and a highly stable microstructure. A variety of grades within the Outokumpu Therma range of steels are available, such as Therma 253 MA®, to satisfy this need and the specific choice of grade will depend on the exact conditions.

Stainless steel can also be employed in the broader infrastructure supporting the fuel cell or electrolyser. This includes transportation, storage and gas handling, and conditioning. Both corrosion resistance, resistance to hydrogen embrittlement and formability are important in these applications. Appropriate grades will include austenitic 1.4420 (Outokumpu Supra 316plus®) and 1.4435 (Outokumpu Supra 316L/4435).



Contacts and enquiries

Contact us

Our experts are ready to help you choose the best stainless steel product for your next project.

www.outokumpu.com/contact

General inquiries: **Contact**

Working towards a world that lasts forever

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: clean energy, clean water, and efficient infrastructure. Because we believe in a world that lasts forever.

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