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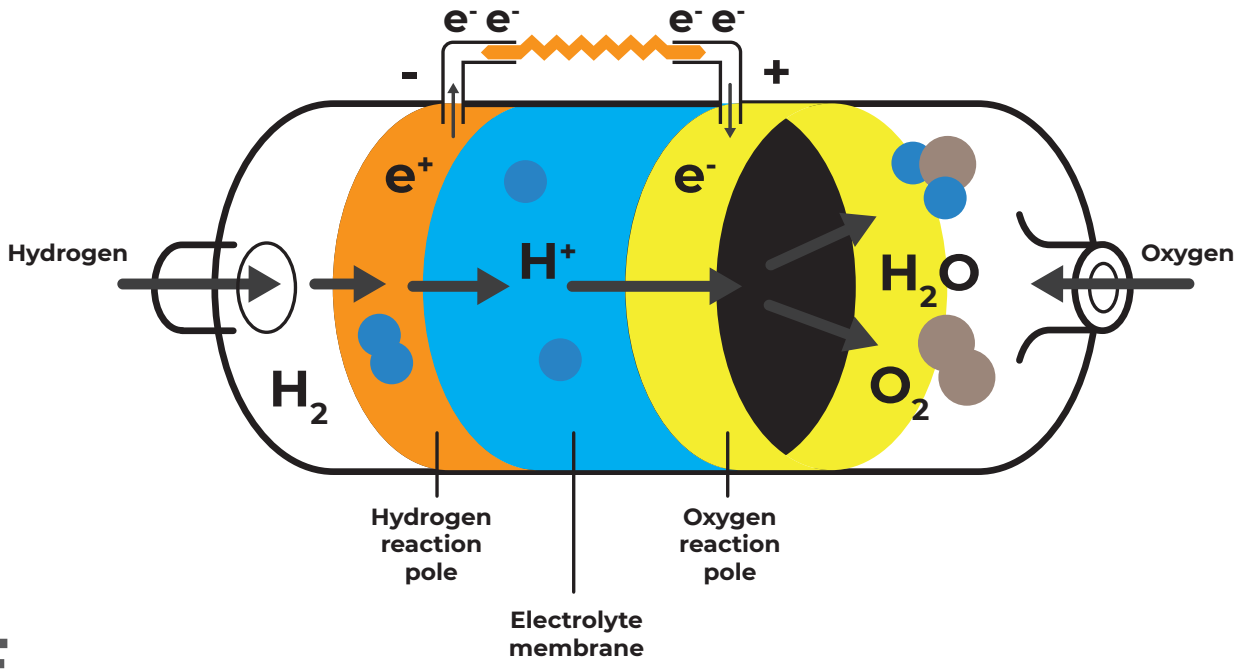

PCHE

H2 high temp/pressure field of application

TECHNICAL SHEET

T PLATE PCHE

printed circuit heat exchangers

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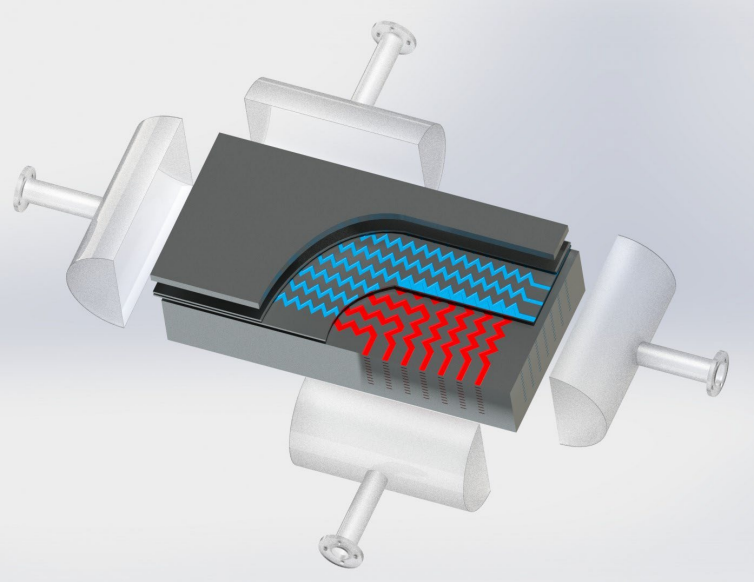
Printed Circuit Heat Exchanger - PCHE

High efficiency compact heat exchanger (~98%) operating at very high temperatures and pressures.



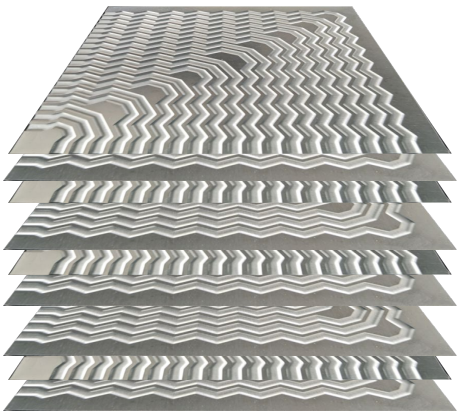
Thanks to the particular production process PCHE heat exchangers result:

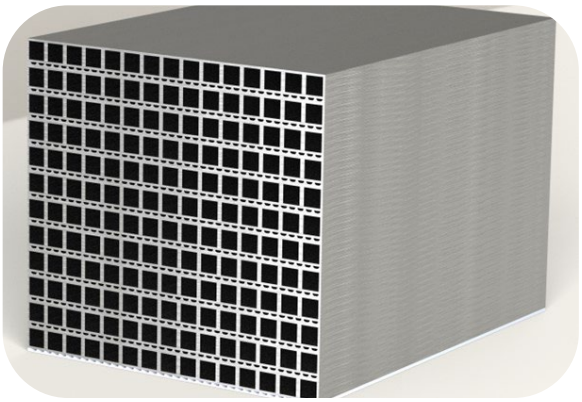
- More compact (85% smaller and lighter than traditional heat exchangers)
- With very complex internal circuit networks
- With high structural integrity
- Capable of working at pressures above 900 bar
- Capable of working at temperatures from -200°C to 900 °C
- Featuring low operating and maintenance costs

The main Processes – HIP Diffusion bonding («HIP DB»)

Stacked plates welded all over the contact surfaces into a monolithic block

- High quality joints: strength and ductility equivalent to those of the parent material
- No brazing, no external welds, no gaskets
- Joining of different materials
- High precision components with complex shapes
- Possibility to have Integrated collectors
- "HIP" DB Furnace larger than in Hot Uniaxial Pressing (HUP) DB → **Larger cores**





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Tempco PCHE exchangers for hydrogen applications

Innovative applications for a sustainable future in the nascent hydrogen industry require equally cutting-edge technological solutions. In the specific case of cooling and temperature management technologies for hydrogen and fuel cells, Tempco already has a series of applications developed thanks to the use of PCHE exchangers.

PCHE exchangers (Printed Circuit Heat Exchangers) are a new type of plate heat exchangers capable of satisfying the challenging operating conditions imposed by new hydrogen and fuel cell applications.

In fact, these solutions present extreme working conditions that involve very high pressures and temperatures, making it impossible to use cooling and thermal management systems that use traditional heat exchangers.

PCHE EXCHANGERS

In the hydrogen industry, Tempco collaborates in particular with technology partner Microchannel Devices (µCD), an innovative SME based in Setti-mo Torinese that develops and manufactures PCHE heat exchangers. The peculiarity of this type of printed circuit exchanger lies in the Diffusion Bonding (DB) process used by µCD for the construction of the exchangers. Diffusion Bonding is an innovative solid state welding technique that allows the joining of metallic materials, even of different types, by subjecting the two coupled objects, the exchanger plates in our specific case, to high pressure and temperature simultaneously.

In these process conditions, the interfacial atoms of the plates move, exchanging and bonding with each other: the migration of the particles fills the asperities and porosities present in the interface areas of the two welded pieces, effectively making the joint between the two components disappear, obtaining a single monolithic block without visible joints, not even at a microstructural level between the plates. The resulting stable metallurgical bond means that exchangers made for Diffusion Bonding have exceptional structural integrity, with properties in terms of strength, microstructure and resistance equivalent to those of the original massive materials. The solid state welding process therefore allows us to eliminate the use of traditional brazing and welding operations with the addition of molten material, as well as eliminating the use of gaskets. As a result, PCHE exchangers are extremely compact, up to 85% smaller and lighter than traditional solutions of the same capacity, and offer significantly reduced operating and maintenance costs for end users.

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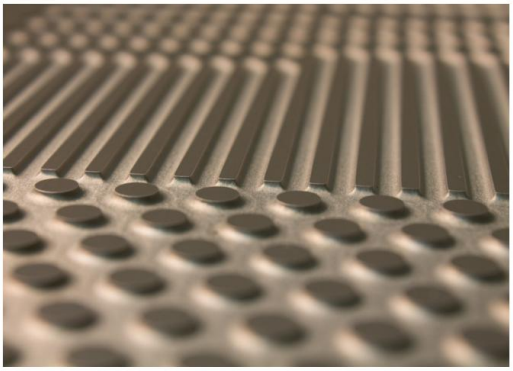
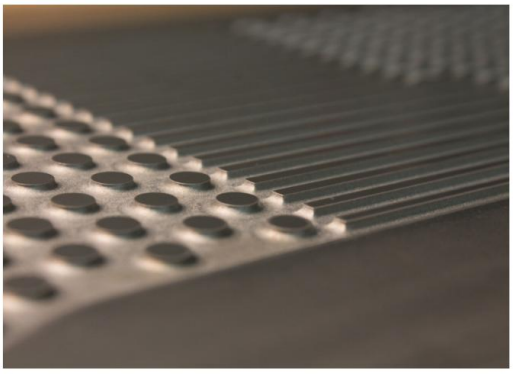




EXTREME PRESSURES AND TEMPERATURES

The very high structural integrity of the plate pack welded with the Diffusion Bonding process therefore allows the PCHE exchangers to operate in the extreme conditions that characterize hydrogen applications and in the cooling of the fuel (hydrogen) in fuel cells: the PCHE exchangers can in fact manage pressures up to 900 bar, working in a temperature range that goes from cryogenic situations, at -250° C, up to +400° C, being able to go even further by using very particular alloys.

Printed circuit plate exchangers are normally built in AISI 316L, with the possibility of creations that also use titanium, aluminum and other special alloys.

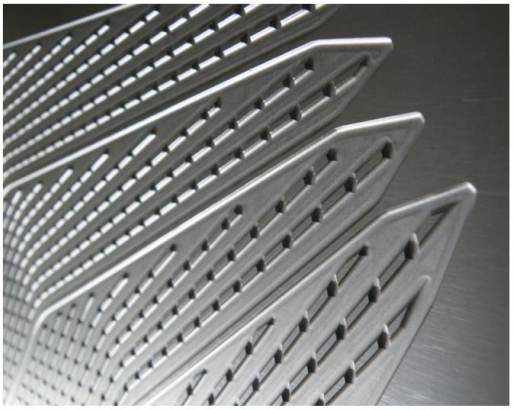
Another peculiar and innovative feature of the PCHE exchangers produced by µCD therefore consists in the molding technique of the plates themselves, in which the heat exchange channels are created through a special chemical engraving process (chemical etching) in which the company specializes. The particular methodology allows the creation of networks of highly complex microchannels, with highly customizable exchanger designs, which provide extremely high heat exchange coefficients, guaranteeing very high thermal efficiencies in cooling applications for the hydrogen industry.

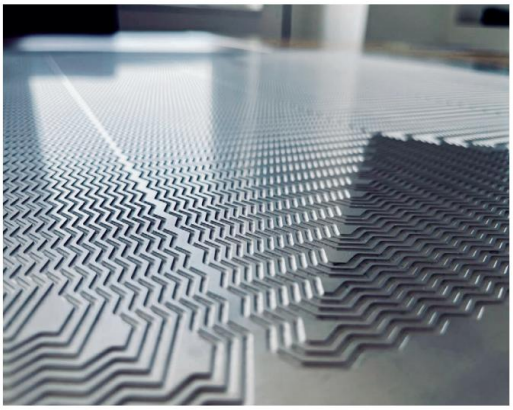
The PCHE exchangers that Tempco offers for hydrogen applications therefore belong to the range of full welded FULL INOX exchangers, made with the aforementioned Diffusion Bonding technology.
The technology allows you to have exchangers with customizable channel design and number of streams, design temperatures up to 400° C and pressures up to 700 bar. Characteristics that make them very attractive for the operational limit cases typical of fuel cell applications, but not only.

SPECIALIZATION IN GREEN TRANSITION

Microchannel Devices was founded in 2019 as a spin-off of STV Italia to develop and create solutions dedicated to combating climate change and promoting the energy transition, thanks to the use of microchannel devices born from a series of R&D projects. Operational areas include the hydrogen industry (production and storage) and fuel cells, renewable energy, oil & gas and liquefied natural gas applications, thermal management in the nuclear and battery sectors, chemical industry and CO2 capture . µCD is a member of the Piedmontese innovation technological hub Mesap and of the H2.IT association, and has a series of collaboration agreements with the Polytechnic of Turin, the Environment Park and the Turin branch of the Italian Institute of Technology (IIT).

The Diffusion Bonding technology used by the company for the production of heat exchangers allows the creation of high precision components with complex and highly customized shapes. The specialization in the chemical etching process to create even complex designs of the internal exchange circuits in the plate pack allows





furthermore, it is possible to work without mechanical stress on metal plates of considerable thickness, between 0.1 and 5 mm, and of large format, with dimensions up to 850 x 3,000 mm. The company has the certifications of ASME U, ASME U2 and ISO 9001 process.

HYDROGEN COOLING

Among the application cases developed with µCD, Tempco has recently created a solution for cooling pure hydrogen compressed at high pressure, using a mixture of water and glycol, which uses a PCHE heat exchanger made up of a stack of metal plates in a pattern that includes a series of hot fluid plates / cold fluid plates stacked together.

On each 'active' (non-neutral) plate, a series of grooves forms a network of microchannels where one of the fluids involved in the thermal exchange process flows.

my. All channels are fed from an inlet manifold and pour fluid into an outlet manifold.
The particular device used in this specific application is a counter-current heat exchanger. The exchanger is housed inside a compressor which has two compression stages, arranged in series. The heat exchanger was designed to cool the hydrogen flows coming from the two compression stages in the same device.

This function is achieved by creating two series of separate and sealed channels on each 'hot' plate, which is possible precisely by virtue of the ability of µCD to create both photo-etched plates and PCHE exchangers internally, thus being able to have heat exchangers which cool multiple flows at the same time. In each hot plate, two streams of hot hydrogen will flow simultaneously at different pressures from the 1st and 2nd stages. The circuits that can be obtained allow for considerable customization which guarantees a customized design depending on the type of circuit.

The exchanger is not equipped with any purge valve or refrigerant drainage valve and is also without any safety valve for the pressurized circuits: all these functions are in fact present in the respective compressor circuits connected to the heat exchanger.

The particular Multistream heat exchanger designed and created specifically for this hydrogen cooling application differs from the parent exchanger due to the presence of a series of bypass channels that short-circuit the input and output ports on each cold plate, to allow the minimum hourly flow rate required by the end user.

All equipment is made of AISI 316L stainless steel. Considering the material of construction, its interaction with the operating fluids and the installation environment, no corrosion margins are considered. Finally, the design pressure in this specific case can exceed 700 bar, while the operating temperatures can vary from cryogenic conditions up to over 200° C.

Printed circuit heat exchanger

SCAMBIATORI H_2 FULL INOX / PCHE

Soluzioni di valore per una efficiente transizione energetica

Settori di applicazione principali:

- H_2 Storage & Delivery
- LNG and other Oil&Gas
- CO_2 trapping (bioreactors) and bio-sensors
- H_2 Production & Usage (Bipolar plates for fuel cell and hydrolysers stacks)
- Battery thermal control (cold plates and heat pipes)
- Nuclear plants heat management

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