SUSTAINABLE STAINLESS

Cooling with Heat

A Case Study about Solar Cooling

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introduction

Stainless steel plays a key role in a new generation of adsorption chillers, the heart of environmentally friendly cooling equipment. A significant percentage of the energy consumed in our industrialised societies is used to keep rooms within a specific temperature range. Cooling accounts for much larger a percentage of global energy consumption than heating. Much of the energy used for cooling is consumed by air conditioning of homes and offices in summer and in hot climates; and by the many commercial and industrial processes – such as food handling – that depend on a controlled level of temperature. Conventional cooling systems utilise a compressor, which is usually electrically driven and hence energy-intensive to operate.

WHAT MAKES STAINLESS STEEL A SUSTAINABLE MATERIAL?

Before we can determine whether stainless steel is a sustainable material, we should first define what we mean by sustainability in relation to what is known as the triple bottom-line: People, Planet and Profit.

1. People

The material, in its use or in its production process, respects the human being, especially in terms of health and safety. A sustainable material does not harm the people working to produce it, or the people who handle it during its use, recycling and ultimate disposal.

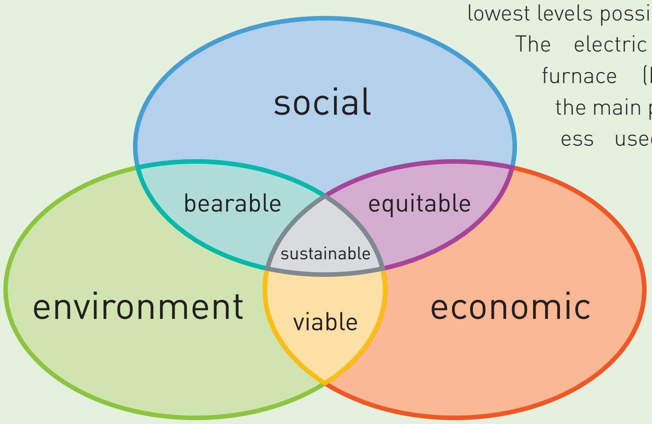
Stainless steel is not harmful to people during either its production or use. A protective layer forms naturally on all stainless steels because of the inclusion of chromium. The passive layer protects the steel from corrosion – ensuring a long life. As long as the correct grade of stainless is selected for an application, the steel remains inert and harmless to the people who handle it and the environment. These characteristics have made stainless steel the primary material in medical, food processing, household and catering applications.

2. Planet

The emission footprints of the material, especially those related to carbon, water and air, are minimised. Reuse and recyclability are at high levels. The material has low maintenance costs and a long life, both key indicators that the impact of the material on the planet is at the lowest levels possible.

The electric arc furnace (EAF), the main process used to make stainless steels, is extremely efficient. An EAF has a low impact on the environment in terms of both CO2 and other emissions. The EAF is also extremely efficient at processing scrap stainless, ensuring that new stainless steel has an average recycled content of more than 60%.

Stainless steels are easily recycled to produce more stainless steels and this process can be carried on indefinitely. It is estimated that about 80% of stainless steels are recycled at the end of their life. As stainless steel has a high intrinsic value, it is collected and recycled without any economic incentives from the public purse.



Source: Wikipedia

3. Profit

The industries producing the material show long-term sustainability and growth, provide excellent reliability and quality for their customers, and ensure a solid and reliable supply-chain to the end consumer.

Choosing stainless steel for an application ensures that it will have low maintenance costs, a long life and be easy to recycle at the end of that life. This makes stainless an economical choice in consumer durables (such as refrigerators and washing machines) and in capital goods applications (such as transportation, chemical and process applications).

Stainless steels also have better mechanical properties than most metals. Its fire and corrosion resistance make stainless a good choice in transportation, building or public works such as railways, subways, tunnels and bridges. These properties, together with stainless steels' mechanical behaviour, are of prime importance in these applications to ensure human beings are protected and maintenance costs are kept low. Stainless also has an aesthetically pleasing appearance, making it the material of choice in demanding architectural and design projects.

Taking into account its recyclability, reuse, long life, low maintenance and product safety, the emissions from the production and use of stainless steels are minimal when compared to any other alternative material. A detailed and precise analysis of the sustainability of stainless steel makes the choice of stainless a logical one. This might explain why, as society and governments are becoming more conscious of environmental and economic factors, the growth in the use of stainless steel has been the highest of any material in the world.

ADSORPTION CHILLER TECHNOLOGY

Another type of chiller, the adsorption chiller, uses thermal instead of electrical energy. This idea is not new. In 1878, French engineer Augustin Mouchot demonstrated the principle at the Paris World Exhibition, producing ice blocks using a solar-driven adsorption chiller.

For large-scale, stationary applications, solar hot water is an excellent source of thermal energy to drive the chiller. Electricity consumption is minimal. In a typical design for room air conditioning, 1 kilowatt (kW) of electricity can produce up to 10 kW of cooling performance.

Augustin Mouchot demonstrated the principal of solar cooling at the Paris World Exhibition of 1878

The combination of adsorption chillers and a solar thermal energy source is exceptionally attractive both economically and ecologically. The solar hot water panels yield the highest energy output exactly when the chiller requires the highest energy input, that is, during the hot and sunny hours of the day – an ideal situation.

Augustin Mouchot

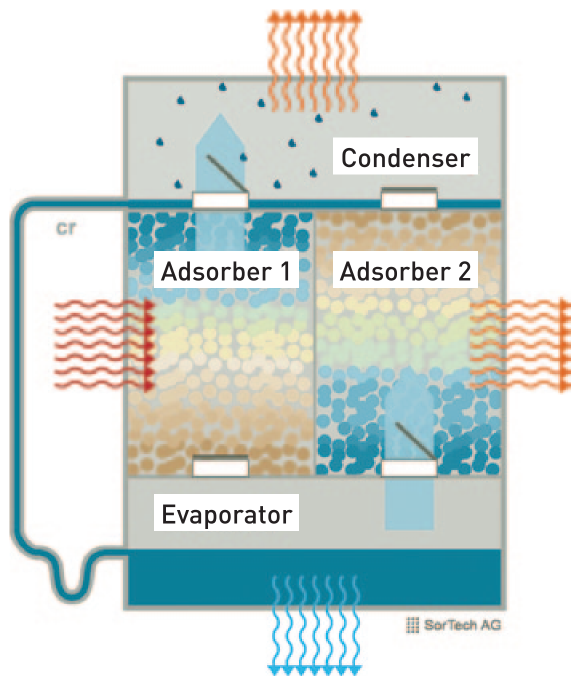
HOW DOES ADSORPTION COOLING WORK?

An adsorption cooling device consists of four chambers: a condenser, an evaporator and two adsorbers. This assembly is wrapped into an airtight, thermally insulated stainless steel skin. The two adsorbers contain silica gel, an extremely porous, chemically inert mineral which is instrumental for the adsorption process to work. The refrigerant is quite simply water.

The four process chambers are interconnected by self-operated vapour valves, which control the flow of the refrigerant vapour. In the first operating phase, heat (coming from, for example, hot water solar panels) is piped through adsorber chamber 1. It drives out the refrigerant, which had previously adhered to the huge porous surfaces inside the silica gel. The condenser transforms the vapour return into the liquid phase, thereby releasing waste-condensation heat.

The condensed refrigerant is piped back into the evaporator chamber for a new adsorption-desorption cycle. When adsorber chamber 2 opens, the refrigerant is sucked in and adsorbed into the silica gel. In this process, the refrigerant changes from liquid to gas, extracting thermal energy from a fluid which is piped through the chamber. The alternating operation of two adsorption chambers makes the system work semi-continuously.

Except for the valves of the adsorber chambers, there are no moving parts. This design contributes to durability and low maintenance. Noise and vibrations are also avoided.

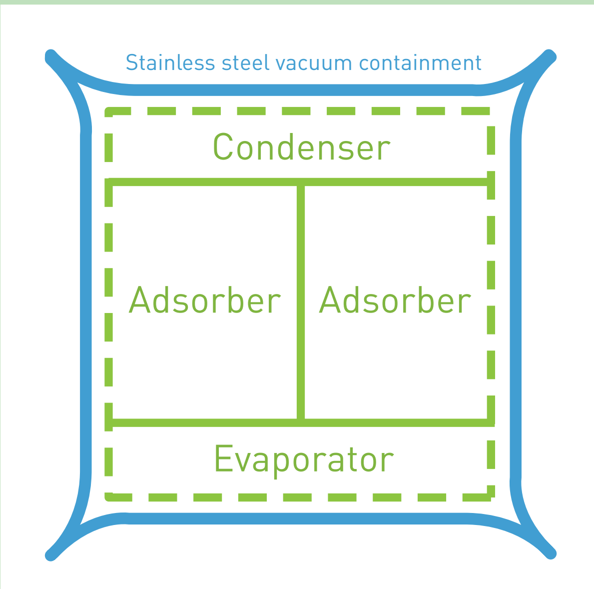


The adsorption chiller contains four chambers – one for each of the steps of adsorption and desorption, evaporation and condensation

NOVEL DESIGN IN STAINLESS STEEL

Most adsorption chillers currently in operation are in the 200 kW performance range and are used for large operations. However, compact units for smaller applications are new. Engineers had to overcome one difficulty: if water is to be used as an environmentally friendly, non-toxic refrigerant, a vacuum is needed to make it evaporate at ambient temperatures. Normally this would require a thick-walled container to withstand the atmospheric pressure. This would drive up the size and weight of smaller installations to a point where it would become uneconomical.

Stainless steel gave engineers a solution. They sealed the assembly in a thin welded stainless steel envelope. Because of its mechanical properties, the sheet used to fabricate the airtight wrapping is only 1 mm thick.



A schematic view of the stainless steel container demonstrates how a vacuum-tight stainless steel skin serves as an envelope to the machine.

The pressure-tight envelope is produced by TIG welding. Low thermal conductivity, excellent weldability and durability make the classic chromium-nickel stainless steel grade 304 a good choice. This design makes the adsorber solution suitable for small applications in a performance range below 20 kW.

The stainless steel skin provides a vacuum-tight envelope to the four chambers forming the chiller unit

The fully air-tight design involves stainless steel valves and piping, which must resist atmospheric pressure

Outstanding weldability is among the assets of austenitic stainless steels like grade 304.

CASE STUDY: STAINLESS STEEL ADSORPTION COOLER IN A CANTEEN

Since the summer of 2007, solar-powered adsorption coolers in combination with geothermal probes have contributed to the air conditioning of the canteen of the Fraunhofer ISE research facility in Freiburg, Germany.

Fraunhofer ISE was selected as the location for a large-scale test of solar cooling

The kitchen of the institute's restaurant requires efficient air conditioning

The adsorption machine is essentially maintenance-free throughout its entire useful life

The heart of the installation is an adsorption machine which can operate as either chiller or heat pump. The soil is used as a storage medium, absorbing the excess heat in summer and providing thermal energy for heating in winter.

In summertime, solar hot water panels with a surface of only 20 m² help to power an adsorption chiller. Solar energy accounts for around 60% of the energy requirements. The adsorption device produces cold by evaporating water at an extremely low pressure of only 10 mbar. The chilled water that is generated in the device is used to cool the air that is fed into the institute's restaurant kitchen. The waste heat resulting from the process is "dumped" via three geothermal probes sunk 80 m into the ground.

Solar hot water panels just 20 m² in size are sufficient to provide energy for the cooling process

Another advantage of the adsorption device is that in winter, the process is reversed. Below a certain depth, the ground maintains a stable temperature throughout the year. Thermal energy can be extracted from the soil to heat a building. In winter mode, the adsorption device can operate as a heat pump.

80 metre deep holes were drilled into the ground to accommodate the geothermal probes

ENVIRONMENTAL BENEFITS

Including ancillary components, the adsorption chiller reduces electricity demand for room cooling by 80% compared with conventional cooling systems. As CO_2 emissions go down accordingly, adsorption chillers make a contribution to reducing our carbon footprint. Cooling, traditionally an energy-consuming process, becomes resource-saving.

To be faithful to the concept of sustainable solutions, the designers were aware that the materials and fluids used should be ecologically benign. The minerals used as adsorbate – silica gel or zeolite – are chemically inert. The refrigerant is quite simply water. Neither the adsorbent nor the refrigerant need to be replaced during the entire service life of the installation. The materials used for the assembly and its airtight skin are fully recyclable metallic alloys. Environmental responsibility goes beyond the useful life of an installation.

FUTURE PERSPECTIVES

Adsorber chillers can use a number of different heat sources. Solar hot water panels are only one solution. Waste process heat or biogas are others. Whatever the application – domestic, office or industrial – cooling can be carried out using natural, free sources of energy like the sun. Stainless steel as an exceptionally durable, formable, weldable and inert material is again making a contribution.

Because of their ability to function as both cooling and heating devices, adsorption machines have additional potential in regions of the world with marked differences between outside temperatures in summer and in winter.

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