



Desalination in Stainless Steel

A sustainable solution for the purification of salt water

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Publisher

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ISBN 978-2-930069-63-0

introduction

Current efforts to make our world more sustainable are increasingly focussed on the lack of available fresh water. Increasing the use of desalination plants will help to protect the world's supply of fresh water while guaranteeing a dependable water supply.

Successful desalination requires a material that can resist the aggressive corrosion caused by seawater and brine. Utilising stainless steel to create fresh water further increases the sustainability profile of the desalination industry. The durability and minimal maintenance requirements of stainless make it a good choice economically. The high-level of recycled content and 100% recyclability at the end of its life are the cornerstones of stainless steel's environmental profile. High performance stainless steels, including duplex grades, are the perfect choice for desalination.

1



*MED type evaporator
of Marafiq IWPP in
Saudi Arabia
(Photo : Sungjin Geotech. Co.)*

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.

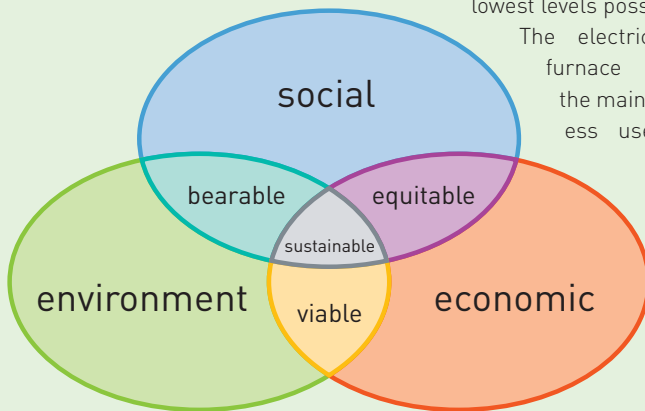
1. People

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



Source: Wikipedia

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.

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.

DESALINATION IN STAINLESS STEEL

History of Desalination

Water is our most precious resource. Water scarcity is already a problem in many parts of the world due to increasing populations, greater demands for water, and diminishing freshwater resources.



Global production of desalinated water has increased exponentially since then. Yet worldwide, only 1% of drinking water is produced by desalination plants, despite the fact that there are more than 12,500 plants in over 120 countries. Just under half (47%) of the commissioned global desalination capacity is located in the Middle East.¹ Considering that almost one quarter of the world's population lives less than 25 km from the coast, seawater has the potential to become one of our main sources of fresh water.

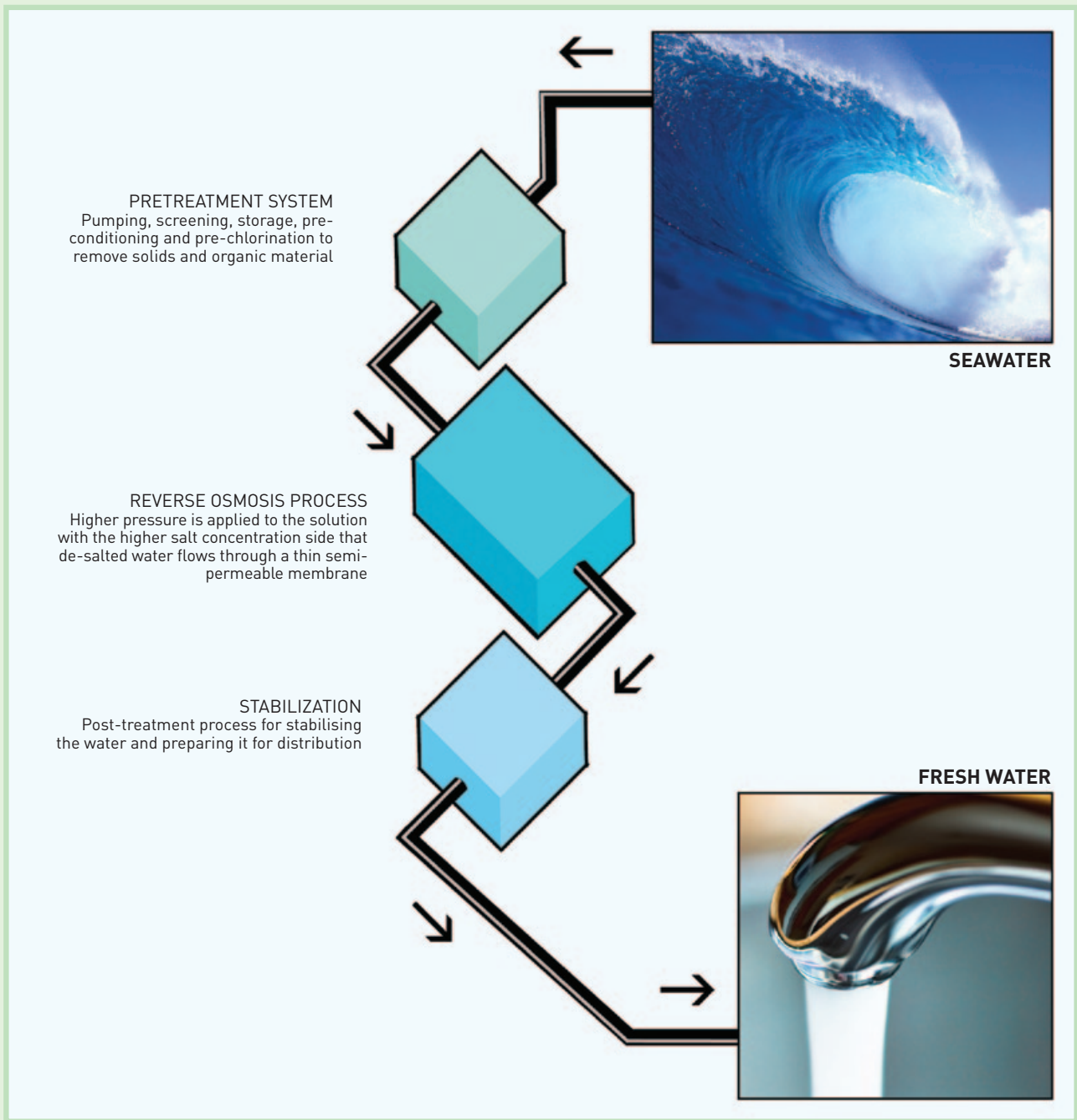
Why Stainless Steel?

Thermal and membrane technologies are the two main methods used to desalinate water. Thermal methods of desalination include Multi-Stage Flash Distillation (MSF) and Multi-Effect Distillation (MED) while membrane technologies include Reverse Osmosis (RO) and Electro-dialysis/Electro-dialysis Reversal (ED/EDR). Stainless is used in all of these technologies, primarily because of its corrosion-resistance properties.

All desalination processes work in the same way. The incoming salt water is separated into two parts: treated and concentrate. The treated water has a very low level of salt while the concentrate has a higher level of salt than the raw seawater. An absolute necessity for the process to work is the use of corrosion-resistant materials in the construction of the plant. Material selection and design criteria are affected by the specific operating conditions the material will be exposed to during its lifetime. Many of these criteria are perfectly met by stainless steel. Stainless should be utilised wherever corrosion resistance and durability are key requirements.



Shuaibah Desalination plant in Saudi Arabia
(photo : Doosan Heavy Ind. Co)



Which Stainless Steel?

Although there are over two hundred stainless steel grades on the market, only a handful are utilised in desalination applications. The primary property required from any material used in desalination is corrosion-resistance in a wide variety of aqueous environments.

Austenitic stainless steels in the ASTM 300-series (316L/EN1.4404 and 317L/EN1.4438) are the predominant material used to make the components of a desalination plant. Type 316L is useful in environments with a marine atmosphere. However, if it is immersed in seawater it can suffer pitting and crevice corrosion.

The tendency to pit in chloride-containing environments may seem to rule out the use of stainless in distillation plants which handle hot, concentrated seawater. Although hot seawater lacks oxygen, which reduces the tendency of stainless to pit, most modern MSF plants do not use grade 316L/1.4404. Historically, 316L/1.4404 has been the material of choice for the evaporators. However, most desalination technology providers have now switched to using duplex alternatives for this application.²

A particular sub-group of stainless steels, known as duplex grades, are becoming available to the desalination industry. Duplex stainless steels exhibit good resistance to corrosion, especially to stress corrosion cracking (SCC). SCC is the unexpected

sudden failure of normally ductile metals which have been subjected to a tensile stress in a corrosive environment, especially at elevated temperature. Duplex stainless grades have twice the strength of austenitic grades and are particularly cost-effective because of their mechanical properties. They are also excellent engineering materials. Duplex grade 2205/1.4462 has already been utilised in MSF evaporator shells. Both the Melittah plant in Libya and the Skikda plant in Algeria (constructed in 2004 and 2005) utilise grade 2205 /1.4462.

Duplex grades were also specified for large plants engineered by FISIA, an Italian company that specialises in building desalination plants. Built examples include the Taweelah B extension in Abu Dhabi, the Jebel Ali L plant in Dubai and the Ras Abu Fontas desalination plant in Qatar.² These projects utilise the “dual duplex” concept where grade 2205 /1.4462 is used in the more hostile environments in the plant while lean duplex is used in less corrosive applications.

Lean duplex is a cost-effective duplex stainless steel which has lower nickel and molybdenum content than 2205 /1.4462. Corrosion resistance is very close to that of grade 316L/1.4404. The high strength of Lean duplex makes it possible to reduce the gauge by up to 50% compared with austenitic 300 series grades. However, restrictions in design codes limit the real savings to around 35 to 40%.³



MSF evaporator made of solid duplex stainless steel, 2205, for Melittah (Photo: Reggiane)



MSF evaporator made of solid duplex stainless steel, 2205, for Skikda (Photo: Aquatech)



*MED type evaporator of Marafiq IWPP in Saudi Arabia
(Photo: Sungjin Geotech. Co.)*

6 The dual duplex concept has already been implemented in large MED plants. The first such example was erected by Sidem in Sharjah, United Arab Emirates (UAE). The grades used in the plant are 2205/1.4462 in combination with 2304/1.4362.²

Experience from 27 seawater reverse osmosis (SWRO) plants already in service confirm that there is a risk of corrosion if the wrong stainless grade is used in the high-pressure piping. Neither grade 316L/1.4404 or 317L/1.4438 possess sufficient corrosion-resistance properties. Not even highly alloyed grades (such as 2205/1.4462 and 904L/1.4539) show reliable service performance in this application. However, no corrosion has been reported for new super-austenitic stainless grades (such as S31254/1.4547) which have been used in more than 30 full-strength SWRO plants and several plants using brackish water with high salinity.⁴

STAINLESS DESALINATION IN OPERATION

Doosan Heavy Industries based in Changwon, Korea is one of the few companies in the world that has proprietary technologies for all three desalination methods (that is, MSF, MED and RO). "Doosan recently built the world's largest desalination plant in Saudi Arabia. Known as Shuaibah Phase 3, the plant has a daily desalination capacity of 880,000 tons. We have also built the world's first hybrid desalination plant in Fujairah, UAE. The plant combines both MSF and RO systems," says Kyungkoo Kim who manages the Water Process Piping department.

"We use duplex stainless steels for the pipes and fittings of various water systems. Duplex stainless steels account for about 30% of the stainless used in these applications," explains Kyungkoo. "The duplex stainless steel matches the specifications of the plant's owners and is less costly than nickel-based alloys and cladding materials. In addition, duplex stainless steels resist pitting and crevice corrosion and are suited for high-chloride environments. We also use duplex grades for high-pressure piping lines, where the required mechanical strength is higher than austenitic stainless grades can provide. If delivery times for duplex stainless steels compare favourably with those of 300 grade, and maintain their cost-advantage over nickel-based materials, we will be very satisfied and will extend their use."⁵



*A desalination evaporator
(Photo: Doosan Heavy Ind. Co.)*



MED type evaporator of Marafiq IWPP in Saudi Arabia Photo: Sungjin Geotech. Co.]

Sungjin Geotec based in Ulsan, Korea is a major manufacturer of plant, marine and power facilities. Yongho Lee, Director of Technology, Marketing and Sales, stresses his company's potential need for lean duplex: "We are interested in using lean duplex stainless steels to build desalination plants. We expect cost competitiveness compared with conventional 300 series and a reduction in the construction period for the plant due to shorter material lead times than for other materials.

The most important benefits of using lean duplex compared to conventional cladding materials are its low cost and high quality. As these are key factors in our business, I have no doubt that lean duplex will continue to be used in our new projects."⁶

CASE STUDY: DESALINATION PLANTS

Sasakura Engineering Co., Ltd. for MED desalination plants and Mitsubishi Heavy Industries, Ltd., for RO plants, are two of the leading builders of desalination plants in Japan. Both companies are experienced in utilising stainless steel in the plants they construct. They mention the advantage of stainless steel as follows.

Stainless steel is used in applications such as pumps, evaporators, and for high-temperature piping in desalination plants. Stainless steel components and parts account for around 20 to 30% of the equipment, although it varies depending on the client's specifications.

Carbon steel is not usually utilised in the applications that become wet with seawater. Carbon steel coated with epoxy resin or lined with rubber was used for components and parts that were occasionally exposed to seawater. However, regular maintenance of the resin coatings or rubber linings was required.

On the other hand, diverse types of fibre-reinforced plastic (FRP) are used, mainly for pipes in sections that become wet with low-temperature seawater. Since they do not corrode,



*Desalination plant / Rabigh in Saudi Arabia
(Photo: Sasakura Engineering Co., Ltd)*



*Desalination plant / Rabigh in Saudi Arabia
(Photo: Sasakura Engineering Co., Ltd)*

there is no problem with their reliability in this application. To date they have not been used for other applications such as evaporator vessels, pumps or large storage tanks. Plastic pipes are not used for high-pressure piping since their pressure- and heat-resistance properties are not high enough.

That is why stainless steel is used in these applications instead. In addition, the use of duplex stainless steel is increasing due to its superior corrosion resistance against seawater. Different types of stainless steel are used for different pieces of equipment in each plant.

Carbon steel, clad with stainless steel, was used for the evaporator vessels. Recently though, duplex stainless grades S32304 (also referred to as 2304) and S31803 (also referred to as 2205) have been used more often than clad carbon steel. Super austenite and super duplex stainless steels are used for parts that come into contact with high salt concentrations as they have excellent corrosion resistance. This makes them ideal for use in distillation-process plants or RO plants.

Stainless has high levels of reliability, durability, cleanliness and aesthetics if the proper type of stainless steel is selected for the application. The operating rates of desalination plants are generally high and stainless steel has a performance level to match.

As mentioned earlier, stainless is utilised in desalination plants to make pumps, evaporators, pressure vessels for heat exchangers, tanks and pipes that transport high-temperature and high-pressure seawater. The characteristics required of these components and parts include corrosion resistance, durability and pressure resistance. Stainless steel is used mainly due to its strong corrosion resistance against fresh and condensed seawater. Resin pipes do not have sufficient pressure- or heat- resistance for these applications.

The outlook for stainless steel is bright in desalination plants. The use of stainless is expected to increase in those parts of a desalination plant where its high corrosion resistance is needed.

CASE STUDY: SINGSPRING DESALINATION PLANT IN SINGAPORE

The SingSpring desalination plant in Singapore constructed by Hyflux is a reverse osmosis plant with the capacity to produce 136,000 cubic metres of freshwater each day. At the time of its opening in 2005, the facility was the largest seawater desalination plant and one of the most energy efficient desalination plants in the world.

Stainless steel is still helping the plant to meet around 10% of Singapore's daily freshwater needs. The incoming seawater first passes through a seawater reverse osmosis (SWRO) pass where super-duplex stainless is utilised in high-pressure piping. This grade of stainless steel can resist the high-levels of corrosivity of seawater and the pressures required. After the level of salt in the seawater has been lowered in the SWRO, the water moves through the brackish water reverse osmosis (BWRO) pass. Pipes in the BWRO utilises a standard 300-series grade of stainless. For the energy recovery systems, ensuring energy efficiency of the plant, super duplex grade 2507/1.4410 was utilised for its high-strength and corrosion-resistance properties.

According to the plant's operators stainless steel performed well after five years of continuous service.⁷

REFERENCES

1. <http://ec.europa.eu/environment/etap>
2. J.Olsson & M.Snis, "Duplex-A New Generation of Stainless Steels for Desalination Plants", Science Direct, Desalination 205(2007). pp104-113
3. J.Johnson, Stainless steel design stresses in EN and ASME pressure vessel codes, Proc. Stainless Steel, Italy, 1999
4. J.Nordstrom and J.Olsson, "Stainless Steel for High Pressure Piping in SWRO Plants. Are there any options?", Avesta acomNo.3-95
5. <http://www.doosanheavy.com>
6. <http://www.sgtkor.com>
7. Source: Outokumpu

www.worldstainless.org

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ISBN 978-2-930069-63-0

