Molybdenum in the Water Industry

Desalination Plants

INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Molybdenum's contribution to sustainable development in:

- **Stainless steels**
- Alloy steels
- Superalloys
- Cast iron
- Mo metal
- Chemicals

MoRE FOR LESS

www.imoa.info

Molybdenum makes an important contribution to sustainable development as a metal, as an alloying element, and as a constituent of chemical products. IMOA's 'MoRE FOR LESS' case studies explore, in more depth, how molybdenum is contributing to sustainable development, a pattern of growth in which resource use aims to meet human needs while preserving the environment.

In particular we will look at how a specific use or application is contributing to the three pillars of sustainability:

ECOLOGY — Environmental performance, resource use, energy efficiency & production and recycling

ECONOMY — Supply chain, lifecycle and materials performance

SOCIETY — Health, safety and wellbeing

This case study explores the sustainability benefits of using molybdenum-containing stainless steel in the construction of seawater desalination plants. Molybdenum greatly increases resistance to corrosion, enabling cost-effective, reliable operation providing safe, clean drinking water to an increasing global population.

The challenge

Fresh, clean water is essential for life and yet 97% of the earth's total reserves are too salty for human consumption. In fact, less than 1% of the earth's accessible water is fresh and safe.[1] Currently some three billion people – about 40% of the global population – live in water-scarce regions, with more than three quarters of a billion – approximately one in ten – without access to safe water.[2]

As well as water to drink, we need vast amounts to grow our food. Agriculture accounts for around 70% of global freshwater withdrawals and up to 90% in some fast-growing economies.[3] We also need clean water to stay healthy and to protect us from disease. The UN estimates that 88% of diarrhoeal deaths are due to inadequate sanitation, water for hygiene and unsafe drinking water.[4]

Water scarcity already affects more than 40% of the global population. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water-stressed conditions.[4]

The solution

As with any shortage, the solution lies in reducing demand and increasing supply, involving a combination of water conservation, reuse and the development of new sources of fresh water. Per capita water consumption varies dramatically by country. Conservation strategies work best where water is already available and poor usage habits have led to higher than necessary consumption. Reusing water reclaimed from primary applications (principally wastewater) is another way to stretch scarce water resources and must increase greatly in future if water supply is to be sustainable. However, both strategies are most effective in areas with established water infrastructures and do not address burgeoning demand in arid areas.

Desalination is an established technology for delivering fresh water. In use for many decades, it has grown rapidly in response to population growth and higher living standards. Some 17,000 desalination plants around the world supply 81 million cubic metres of fresh water every day.[5] More than half of this global capacity is located in the Middle East. Saudi Arabia is the world's largest producer of desalinated water, supplying more than 70% of its urban requirements.[6]

Desalination plants operate using thermal distillation or reverse osmosis. In thermal distillation plants, salt water is heated and evaporated to produce fresh water. The most common methods are multistage flash (MSF) and multiple effect distillation (MED).

Reverse osmosis (RO) systems use high pressure pumps to force water through a membrane which allows water molecules to pass through, but blocks dissolved solids such as salts. Most RO plants operate at very high pressures, some up to 8000 kPa.

How molybdenum can help

The high temperatures and high salinity in thermal distillation plants produce extremely corrosive operating environments. Early plants were constructed with mild steel but corrosion was a significant problem and later evaporators

Figure 1: High-pressure couplings from a 40,000 m^3/day seawater RO plant in the mediterranean basin. The 6% molybdenum coupling was in service for 7 years compared to only 6 months for the 316L coupling.

were built using carbon steel clad with molybdenum-containing stainless steel such as Type 316L. Molybdenum improves the corrosion resistance of stainless steel in chloride-containing environments.

Modern plants are constructed using duplex stainless steel, typically grades 2205 and 2304. These steels both contain molybdenum and have emerged as the optimal grades for thermal desalination plants because of their high corrosion resistance and mechanical strength. The strength of duplex stainless steel means that the thickness and weight of the evaporator vessel can be reduced by as much as 30%. These vessels require less steel, less welding and cost less than alternative corrosion-resistant materials.[7]

In RO plants, the combination of high pressure and seawater requires exceptional strength and corrosion resistance. Early RO plants in Saudi Arabia and Malta used Type 316L stainless steel for high pressure pipe components, but even with this enhanced corrosion resistance, high pressure couplings suffered extensive crevice corrosion requiring replacement after as little as two years.[8]

Figure 2: The Ashkelon RO desalination plant in Israel. © IDE Technologies

Intermediate grades of stainless steel such as 317L, 904L and 2205 duplex were trialled but plants continued to report pitting and crevice corrosion. To achieve the necessary degree of corrosion resistance, 6% molybdenum stainless steel has been specified for many seawater RO plants, including some of the biggest facilities in the world, such as Fujairah in the United Arab Emirates.

The difference in corrosion resistance between Type 316L and 6% molybdenum stainless steel is shown in **Figure 1**.

More recently, super duplex stainless steels have become the materials of choice for this application, such as the 2507 grade specified in the construction of the Ashkelon RO desalination plant in Israel, completed in 2005 (pictured in **Figure 2**).

This grade has very similar corrosion resistance to the 6% molybdenum grades and has the additional benefit of higher strength and improved fatigue resistance. The composition of stainless steels most commonly used in desalination plants are shown in **Table 1**.

Table 1: Stainless steels commonly used in brackish and seawater desalination plants (nominal compositions in weight %, balance iron)

Grade	UNS No.	EN No.	C (max.)	Cr	Ni	Mo	N	Other
Austenitic Stainless Steels								
316L	S31603	1.4404	0.03	17	11	2.1	–	–
317L	S31703	1.4438	0.03	18	12	3.1	–	–
904L	N08904	1.4539	0.02	19.5	24.5	4.5	–	–
6% Moly grades	S31254 N08926 N08367	1.4547 1.4529 –	0.02 0.02 0.03	20 19.5 20.5	18 24.5 23	6.1 6.1 6.1	0.20 0.20 0.20	Cu - 0.70 Cu - 0.70 –
Duplex Stainless Steels								
2304	S32304	1.4362	0.03	21.5	3	0.3	0.16	–
2205	S32205	1.4462	0.03	22	5	3.3	0.16	–
2507	S32750	1.4410	0.03	25	7	3.7	0.27	–

Key sustainability benefits

Benefit	Sustainability attribute		
Desalination is a reliable, mature technology utilising abundant resources to keep the supply of water sustainable in a growing world	ECOLOGY		SOCIETY
Desalination plants bring reliable supplies of fresh water to water-scarce regions, improving health and quality of life	ECOLOGY		SOCIETY
Molybdenum alloyed steels resist the corrosive environment of desalination plants, making them economically viable and avoiding the prohibitive cost of regular refurbishment		ECONOMY	SOCIETY
Thermal desalination evaporator vessels made from molybdenum-containing stainless steels last longer, saving resources and expense	ECOLOGY	ECONOMY	
Thinner, lighter vessels manufactured from stronger molybdenum-containing stainless steels save resources and energy in construction and transportation	ECOLOGY	ECONOMY	

Summary

Global water supplies are under pressure from population growth and may be unable to sustain total demand by 2025. Desalination provides reliable, sustainable supplies of fresh water, offering a partial solution. Modern plants use molybdenum-containing stainless steels to protect these strategic assets from the inherent problem of corrosion, which would otherwise render them uneconomic due to the frequency and prohibitive cost of refurbishment and replacement.

1 'The Future of Water', Fortune Magazine, October 2009
2 WHO/UNICEF JMP Report update 2013
3 World Water Development Report 2012
4 UN Water, 2014
5 World Desalination Association, 2013
6 Royal Embassy of Saudi Arabia website, 2013
7 'MSF chambers of solid duplex stainless steel', Olson J, Jägerström V, Resini I, Acom 4/2003
8 'Stainless steels for SWRO plants high-pressure piping, properties and experience', Olson J, Cosic K, Acom 4/2003

International Molybdenum Association
info@imoa.info · www.imoa.info

 IMOA/06/14