News Trends in Selection of Metallic Material for Desalination Industry

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Abstract

This paper gives two examples of the recent use of new stainless steels in desalination water industry. The first concerns the materials used for the walls of thermal process evaporation cells. In the past, carbon steel, clad steels, copper-nickel alloys, or austenitic stainless steel grades such as 316L were the primary recommended materials. More recently the duplex grades UNS S32304 and UNS S32205 have been selected for this application. This paper provides some of the technical reasons, which brought about this change in the choice of materials selected. Initially, the results of an extensive corrosion study, performed in a representative environment for evaporation cells and including both duplex and austenitic grades, are presented and discussed. Then a joint corrosion testing program conducted in cooperation with a well established desalination plant designer and run under actual plant conditions is outlined. The results of these field tests led to the development of a new concept for evaporation cells based on utilizing duplex stainless steels. In the second part of the paper, the properties of the new lean duplex UNS S32202 are presented and compared with those of 304L. Potential applications in moderately aggressive environments, such as potable or drinking water, are discussed.

I. INTRODUCTION

The major thermal processes of desalination are Multi Stage Flash distillation (MSF) and Multi Effect Distillation (MED). These processes of desalination can generate aggressive conditions in some parts of the equipment, which can cause corrosion problems. As a consequence, highly corrosion resistant stainless steels must be selected in order to insure the continuous operation of the system. The selection of material has to be done with an excellent understanding of the process parameters.

A brief description of the mechanisms of pitting and crevice corrosion, and the risks encountered in both evaporation and post-treatment, are discussed. Then the technical reasons, which resulted in the recent selection of duplex stainless steel grades for the walls of the evaporators, are given. This includes an extensive electrochemical study performed in the lab and a joint corrosion testing program conducted in industrial MED plant in cooperation with a well established desalination plant designer (SIDEM, Veolia Water group). In addition, the corrosion resistance properties of the new lean duplex UNS S32202 are presented and compared with those of 304L. The aim is to evaluate the technical potential for the duplex material for the austenitic in the less aggressive part of distillates post-treatment and storage or transport of potable water.

I. CORROSION IN DESALINATION INDUSTRY

1.1 Mechanisms of localized corrosion

In chloride containing near neutral solutions, two main mechanisms of corrosion have to be considered for stainless steels: pitting and crevice corrosion.

Pitting corrosion [1-6] is a form of extremely localized corrosion that leads to the creation of small holes in the metal (see Figure 1) that are able to progress quickly in depth. It occurs on a very constricted surface zone, which loses its passivity and dissolves rapidly, while the rest of the surface remains protected by the passive film. This area becomes anodic while the area with an excess of oxygen becomes cathodic, leading to very localized galvanic corrosion. Pitting of a given material requires the presence of an aggressive species in the environment and a sufficiently oxidizing potential (e.g., chloride ion in neutral and aerated aqueous solution). Several mechanisms are linked to the presence of chloride which break through the passive layer locally and induce the initiation of a pit. The main steps are: the adsorption of chloride on the passive layer, the penetration of the passive film by the chloride, the formation of metal chloride and the acceleration of anodic dissolution under the influence of the metal chloride.

Crevice corrosion [5, 6] occurs when discrete areas on an alloy are physically isolated. This situation often occurs under deposits and at joints of fabricated components. The crevice corrosion process of stainless steels in chloride containing solutions can only occur if the medium is aerated, that is in the presence of an oxidizer or simply of dissolved oxygen. This phenomenon can be described in four stages: deoxygenating, increase of the salt and acid concentrations, depassivation and propagation (see Figure 2). In an oxygenated medium containing chloride ions, inside the crevice the exhaustion of the oxidant species occurs and they are insufficiently renewed. With the exhaustion of the oxidant, there is an increase in metallic ions (Cr^{3+}, Fe^{3+}) inside the crevice and mobile anionic species (e.g. Cl^{-}) are attracted inside the crevice to maintain charge neutrality. The crevice solution becomes concentrated with metallic chloride, which hydrolysed by water, form hydrochloric acid and result in a "progressive acidification" of the crevice. Active metallic dissolution occurs when the pH of the crevice solution is sufficiently low and the concentration of chloride is high enough to break down the passive film. The development of a critical crevice solution is controlled by alloy composition, crevice geometry and bulk solution chemistry.

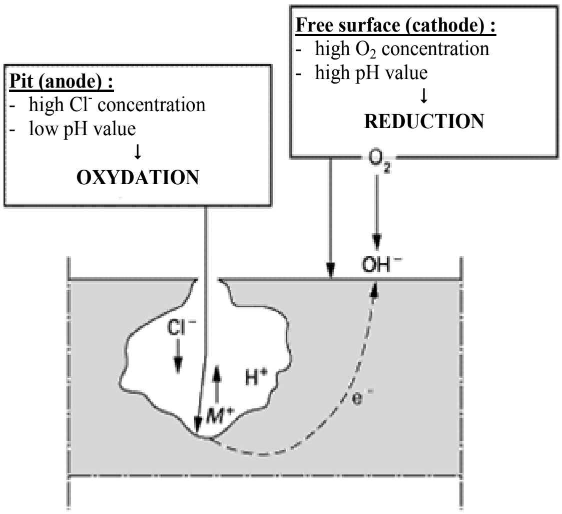

Figure 1: pitting corrosion mechanism [6].

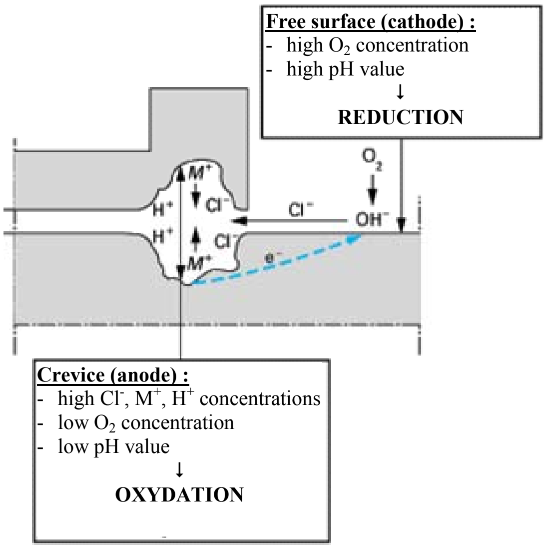

Figure 2: crevice corrosion mechanism [6].

1.2 Corrosion risks in evaporation part of MED process

In a neutral or slightly basic environment, such as seawater, localized corrosion is possible if some oxygen or another oxidizing species (able to be reduced) are present. If the evaporators of a MED installation are well monitored, the localized corrosion (pitting or crevice) of stainless steels cannot occur because the solution is deaerated.

On the other hand, corrosion can be observed during installation shutdowns or during accidental air inlets. In fact, the localized corrosion can be initiated as soon as the concentration in oxygen reaches a value typically equal to or greater than 1 ppm. In addition crevice corrosion requires the existence of a confined zone in which the solution is not renewed (under a deposit as calcium sulphate, in bottom of cell during a shutdown).

1.3 Corrosion risks in post-treatment, storage and transport of potable water.

Distillates produced by thermal desalination plants have very low salinity (< 10ppm), a low pH (around 6) and an alkalinity, which is practically negligible. As a consequence, water may have a poor taste and may be unhealthy. Severe corrosion problems may also be encountered in the water distribution system. The major objective of post-treatment (alkalinisation, remineralisation and chlorination of the distillate) is to meet national or international drinking water standards and to meet corrosion guidelines. After these post-treatments, potable water is stored in tanks and later transported in large pipes to be distributed. Again localized corrosion is the main concern for stainless steel but the conditions are much less aggressive than in the evaporation process.

II. MATERIALS AND CHEMICAL ANALYSIS

The stainless steels considered in this study are both austenitic and duplex (austeno-ferritic) grades. All stainless steels tested are hot rolled materials. Table 1 gives the typical chemical analysis and tensile properties of the materials.

Trademarks	UNS/AISI	EN	C	Cr	Ni	Mo	N	PREN	0.2YS (MPa)	UTS (MPa)
CLC18.10L	304L	1.4306	< 0.030	18.5	10.5	-	-	>18	200	500
CLC17.12.2L	316L	1.4404	< 0.030	17	11.5	2.1	-	>24	225	520
UR2202	S32202	1.4062	< 0.030	22.5	2	-	0.20	>26	450	650
UR2304	S32304	1.4362	< 0.030	23	4	-	0.10	>24	400	600
UR2205Mo	S32205	1.4462	< 0.030	22.5	6	3.1	0.17	>35	480	680

Table 1: typical chemical analysis (weight %) and mechanical properties of materials tested (0.2YS: Yield Strength at 0.2%, UTS: Ultimate Tensile Stress, PREN=%Cr+3.3%Mo+16%N).

The austenitic grade 316L is commonly used in the evaporation process in a desalination plant and 304L is more commonly used in the post-treatment, storage or transport of potable water.

Duplex grades contain high chromium, high nitrogen and low nickel contents and increased mechanical properties (yield strengths twice the value of austenitic grades). The UNS S32202 and UNS S32304 are the lean duplex grades produced by Industeel, and do not contain molybdenum additions. UNS S32205 is a more corrosion resistant grade due to the addition of molybdenum.

The PREN (Pitting Resistance Equivalent Number) formula was defined in ferric chloride solution testing ($FeCl_3$, ASTM G48-03), which is a chloride containing oxidising acid solution. The ranking of stainless steels obtained with this index is only valid in this type of medium. In neutral chloride ions containing solution, the conditions are different and we will see later that the ranking is not valid anymore.

III. MATERIALS FOR EVAPORATORS

3.1 Electrochemical lab study

As explained previously, the major factors for localized corrosion of stainless steels are: high chloride concentrations, elevated temperature and the presence of oxygen. During plant shutdowns, the venting of the installation is usually performed when the internal temperature reaches 40-50°C. The solution, always present in the installation, is mostly brine. The objective of this study is to evaluate the pitting and crevice corrosion resistance of both austenitic and duplex (austeno-ferritic) stainless steels using lab tests carried out in an environment simulating aerated brine (50g/L NaCl, pH=6.4) at 50°C.

3.1.1 Pitting corrosion resistance - Pitting corrosion resistance was evaluated by measuring the pitting potential. The electrochemical test consisted of plotting a potentiodynamic curve in order to measure the pitting potential (E_{pit}, see Figure 3). An electrochemical cell with a capacity of 250mL was used. Only 1 cm^2 of one side of the coupon was exposed to the electrolyte. All samples (25 × 50 × thickness mm) were mechanically polished with silicon carbide (SiC) papers to a 600 grit finish, followed by cleaning with ethanol. The electrochemical tests began 24 hours after sample preparation in order for the passive film to form naturally as a result of electrochemical reactions with the atmosphere. A platinum sheet was used as a counter electrode. The reference electrode was a saturated calomel electrode (SCE). The electrolyte was prepared using deionised water and an analytic chemical grade of NaCl.

After 1 hour at free potential, the potentiodynamic curve was plotted at a scanning rate of 900mV/hour from the free (potential–50mV)/SCE in the anodic direction until the current density reached $500\mu A/cm^2$. During the electrochemical test, the solution was stirred using air. The pitting potential was measured at a current density of $100\mu A/cm^2$. After the completion of the electrochemical test, the stainless steel samples were examined by means of an optical microscope in order to confirm that pits were developed on the sample surface.

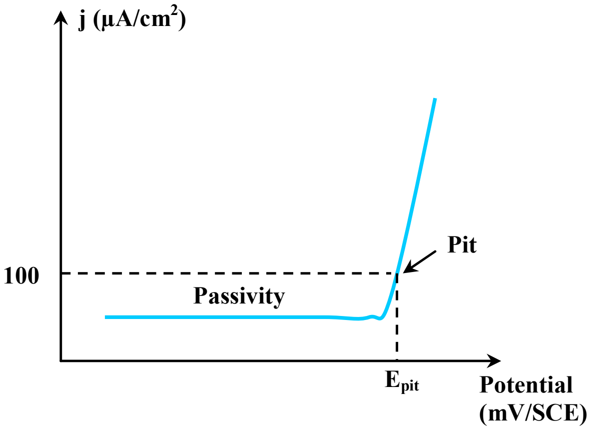

Figure 3: polarisation curve plotted in neutral chloride medium and the pitting potential measurement.

The measurement of the pitting potential in synthetic brine (NaCl 50g/L, pH 6.4 and 50°C / 122°F) provides a good idea of the pitting corrosion resistance. The higher the pitting potential, the greater the pitting corrosion resistance. Figure 4 indicates that pits are observed for both the 316L austenitic grade and for UNS S32304 but a slightly higher pitting potential for the duplex grade. On the contrary, grade UNS S32205 does not exhibit a pitting potential because no pits are developed and the measured potential corresponds to the oxidation of the water. We can expect, therefore, that the pitting corrosion resistance for austenitic grades will be slightly lower than for UNS S32304 and significantly lower than UNS S32205. Figure 5 presents the values measured in a synthetic solution with slightly lower chloride content (30g/L instead of 50 g/L NaCl). Nevertheless at 50°C, the pitting potentials of the UNS S2304 and 316L are rather similar (see Figure 4 and Figure 5). For lower temperatures, the difference between the two grades increases in favour of the duplex stainless steel grade. For temperatures higher than 50°C, similar low values are reported. These results obtained with UNS S32304 show that 23% chromium in a duplex microstructure is at least as beneficial for pitting corrosion resistance as 17% chromium and 2% molybdenum in an austenitic microstructure. In addition to the high chromium content, a molybdenum addition significantly increases the corrosion resistance of duplex family (see UNS S32205 in Figure 4).

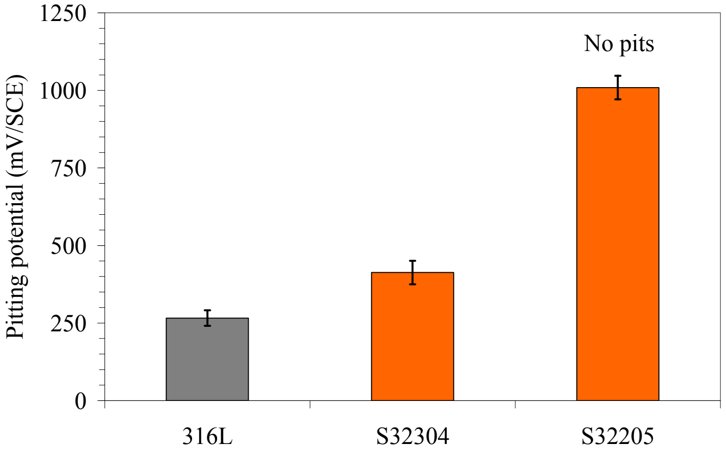

Figure 4: pitting potential in 50g/L NaCl solution at pH=6.4 and 50°C.

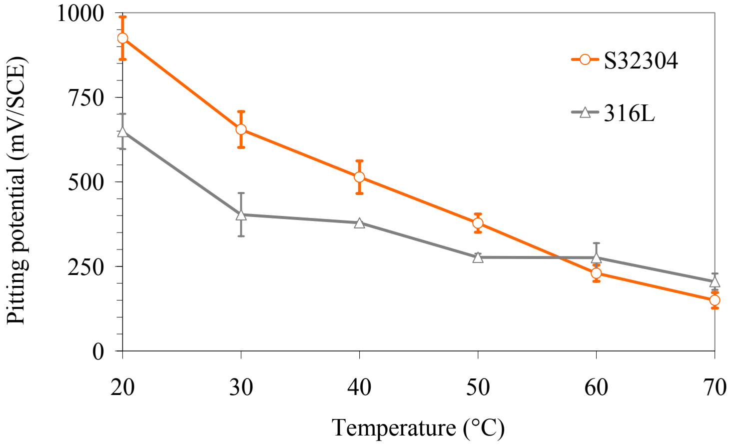

Figure 5: pitting potential versus temperature in 30g/L NaCl solution at pH=6.5.

3.1.2 Crevice corrosion resistance - Specimens were immersed in stirred synthetic brine solution containing 50g/L NaCl, at pH=6.4 and 50°C. A multi crevice assembly (MCA) (see Figure 7) was used to simulate a crevice configuration on the sample surface. It consists of two TFE-fluorocarbon segmented washers (see Figure 6), each having a number of grooves and plateaus (see Table 2). A TFE-fluorocarbon tubular sleeve (for electrical isolation), and a bolt, a nut, and flat washers of UNS N10276 have been used to fasten the crevice washers to the specimen. A torque of 1.6 Nm was applied on the bolt.

The duration of the test is about 1000 hours and potential was plotted as a function of time. The stability and the value of the free potential allow the behaviour of the passive film to be observed and to provide an idea of the crevice corrosion resistance under the MCA. After completing the immersion test, the MCA was removed and the stainless steel sample was weighed and examined by means of an optical microscope to determine the number and the depth of the crevice attacks.

The coupons have a dimension of 25 × 50 × thickness (mm) with a hole drilled and chamfered in the centre of the specimen sufficient to accommodate the bolt and insulating sleeve used to attach the crevice device. They were mechanically polished with silicon carbide (SiC) papers to a 600 grit finish, followed by cleaning with ethanol. The electrochemical tests began 24 hours after sample preparation in order for the passive film to form naturally as a result of electrochemical reactions with the atmosphere.

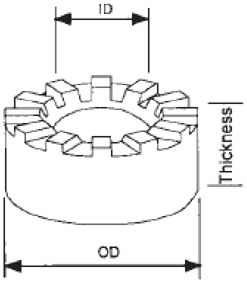

Figure 6: TFE-fluorocarbon washer [7].

Figure 7: photography of a multi crevice assembly (MCA).

ID (mm)	OD (mm)	Thickness (mm)	Slots		
			Number	Depth (mm)	Width (mm)
10	19	6.3	12	0.8	1.6

Table 2: specific dimension of the crevice block.

Figure 8 shows the threshold of the corrosion potential as a function of time for the different stainless steel grades. A high value of potential (+ 150mV/SCE) indicates that the material is in the passive state. On the contrary, a low value of potential (– 200mV/SCE) indicates that the material is in an active state (dissolution of the passive film) and that crevice corrosion is occurring under the MCA. Only 316L and UNS S32304 show low potential values during the test. Nevertheless, 316L stays at low potential value twice as long as the UNS S32304. Making the hypothesis of a similar propagation rate at 50°C [8], this indicates that attack will be more pronounced on the 316L sample than on the UNS S32304. Conversely, the potential of UNS S32205 does not present any stable decrease of potential, and stays at a high potential value during the whole test.

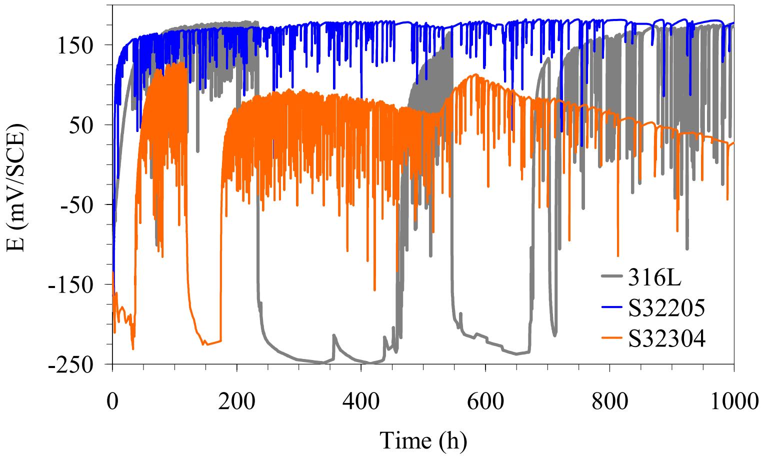

Figure 8: corrosion potential versus time in 50g/L NaCl solution at pH 6.4 and 50°C.

The observations (see Figure 9 and Table 3) reveal one crevice on each sample of the 316L and UNS S32304. For 316L the maximum depth and weight loss are a little bit higher than for UNS S32304. These results are in good agreement with the recorded values of the corrosion potentials. For UNS S32205, no crevice attack is observed after the completion of the test.

Grade	Weight loss (mg)	Number of crevices	Maximum depth (µm)
316L	3	1	97
S32304	2	1	44
S32205	0	0	0

Table 3: observations of the samples after the immersion test

Figure 10 shows a preferential dissolution of the ferrite phase for the duplex grade. The ferrite phase, which contains less Nickel, than the austenite is probably less resistant to uniform corrosion in the reducing acidic conditions developed in crevice area.

a) 316L b) S32304 d) S32205

Figure 9: pictures of coupon surfaces after the immersion test in 50g/L NaCl solution at pH 6.4 and 50°C (white arrows indicate crevice attacks).

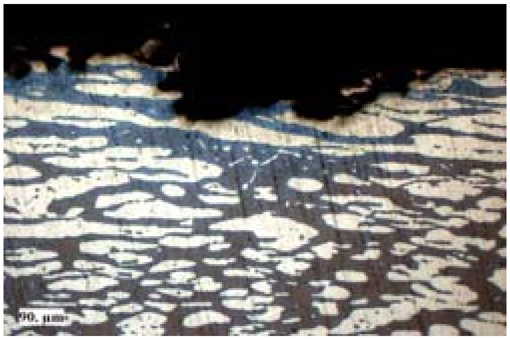

Figure 10: picture of a UNS S32304 cross section sample in the crevice corroded area under the MCA after 1000h immersion in 50g/L NaCl solution at pH 6.4 and 50°C (NaOH etching).

For crevice corrosion resistance, UNS S32304 and 316L offer the same limited resistance to crevice initiation whereas UNS S32205 presents a much better behaviour.

3.2 Field tests

A joint corrosion testing program in actual plant conditions was run in cooperation with a well established desalination plant designer (SIDEM, Veolia Water group). Exposures were performed in two MED type evaporators, the first one in Saint Barthelemy and the second one in Saint Martin Island.

3.2.1 Saint Barthelemy Site - Two UNS S32304 plates of 600 × 600mm were welded in the bottom of both a hot and a cold 316L evaporator cell. This desalination plant was in operation almost continuously during the 2 years of exposure, from December 2001 to November 2003. The field test conditions are representative of a well-controlled evaporator, with a practically continuous operation. Figure 11 shows the surface of the UNS S32304 welded onto 316L parts in two different cells. No corrosion attacks were observed on the two UNS S32304 plates. The duplex grade seems to have at least a similar pitting resistance behavior compared to the 316L. In fact, only two pits were observed and those were on the 316L near the weld (see Figure 11 and Figure 12).

Figure 11: photograph of UNS S32304 welded onto 316L surface (arrows shows pitting attack)

Figure 12: photograph of pitting attack on 316L, shown by arrow on Figure 11

3.2.2 Saint Martin Site - To ensure that the UNS S32304 material was continuously wetted by brine, specimens were fabricated using the design shown in Figure 13. These specimens were placed in the first cell (n°1, 60°C / 140°F) and in the last cell (n°12, 40°C / 104°F) under a bundle of sprayed tubes in order to also be sprayed and constantly filled by deaerated brine (60g/L NaCl). During shutdown periods, brine was stagnant inside the 316L equipment, so the duplex specimen was always in contact with the aggressive solution even in aerated conditions. To avoid a galvanic coupling phenomenon, Teflon was used to insulate the test materials from the bottom of the evaporator. The coupon exposed in cell 1 was tested in the following conditions: 8745 hours (59%) in deaerated brine at 60°C / 140°F (10-20 ppb O_2), 5450 hours (37%) in partially deaerated brine at 40°C / 104°F and 600 hours (4%) in aerated brine at 30°C / 86°F. The coupon exposed in cell 12 was tested in the following conditions: 11120 hours (53%) in deaerated brine at 40°C / 104°F (10-20 ppb O_2), 8800 hours (42%) in partially deaerated brine at 30°C / 86°F and 1000 hours (5%) in aerated brine at 30°C / 86°F. This field test was begun in December 2000 and stopped in October 2003.

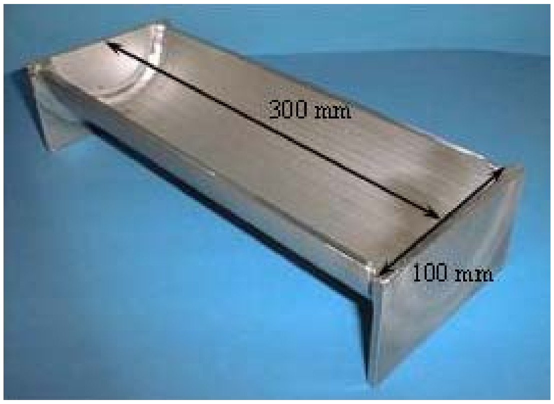

Figure 13: photograph of a UNS S32304 specimen exposed in a Saint Martin desalination plant.

According to SIDEM, this field test appears to be very aggressive due to the long and repeated operational shutdown periods. The UNS S32304 is in contact with either the deaerated brine or the aerated brine for approximately equal periods. Figure 14 shows the sample after the exposure in cell n°1 with lots of saline deposits and only one corrosion attack observed on the whole surface. For the sample exposed in cell n°12, no corrosion products are observed on the surface. These observations were confirmed after cleaning. The sample exposed in cell n°1 shows only one corrosion site of 4mm diameter (see Figure 15) and no corrosion is observed on sample exposed in cell n°12 (see Figure 16). Based on the experience of the desalination plant designer, the behavior of UNS S32304 is at least as good as that of 316L.

Figure 14: photograph of UNS S32304 sample after exposure in cell n°1

3.3 Applications

By taking into account the lab and field tests, a dual concept was developed by the desalination plant designer with UNS S32304 for less corrosive parts and UNS S32205 for the most corrosive parts of the evaporators.

In 2004, SIDEM used the 2 duplex grades for the first time in a small unit in Qatar (2640 m^3/d). In 2005, the first high capacity unit (36000m^3/d) was erected for Layyah plant in the emirate of Sharjah. Then 10 units (27500 m^3/d) for Al Hidd plant in Bahrein in 2006, 8 units (22000m^3/d) for Zawiya, Derna and

Susa plants in Libya in 2007, 27 units (29630 m^3/d) for Marafiq plant, Al Jubail, KSA in 2008 and 12 units (38640 m^3/d) for Fujairah, UAE in 2008 were built with these materials.

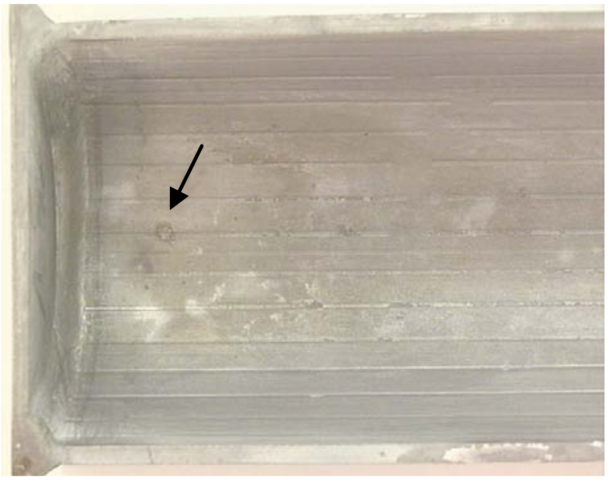

Figure 15: photograph of cleaned UNS S32304 after exposure in cell n°1 (arrow shows pitting attack).

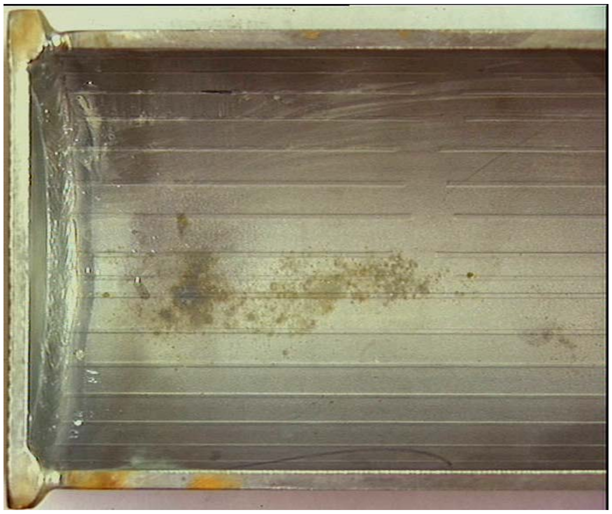

Figure 16: photograph of cleaned UNS S32304 after exposure in cell n°12.

IV. MATERIALS FOR POST-TREATMENT AND POTABLE WATER SYSTEMS

Distillates produced by thermal desalination plants are very low salinity (< 10ppm), a near neutral pH (around 6) and an alkalinity, which is practically negligible. As a consequence, water may have a poor taste and may be unhealthy. Severe corrosion problems may also be encountered in the water distribution system. The major objective of post-treatment (alkalinisation, remineralisation and chlorination of the distillate) is to meet national or international drinking water standards and to meet corrosion guidelines. After these post-treatments, potable water is stored in tanks and then transported in large pipes to be distributed. Once again localized corrosion is the main concern for stainless steel but with conditions, which are much less aggressive than in the evaporation process.

4.1 Corrosion resistance

Pitting corrosion resistance of both 304L and UNS S32202 have been evaluated by means of pitting potential measurements and long term immersion at the corrosion potential.

4.1.1 Pitting potential. Experimental setup and operating conditions were described in paragraph 3.1.1. Figure 17 shows the results obtained in a 250ppm chloride containing solution at pH 5.5. This concentration was chosen because 250ppm of chloride is the maximum concentration allowed in drinking water standards [9-11]. No pitting potential has been measured on the UNS S32202 coupon at 25°C whereas pits do initiate around 800mV/SCE on 304L coupon.

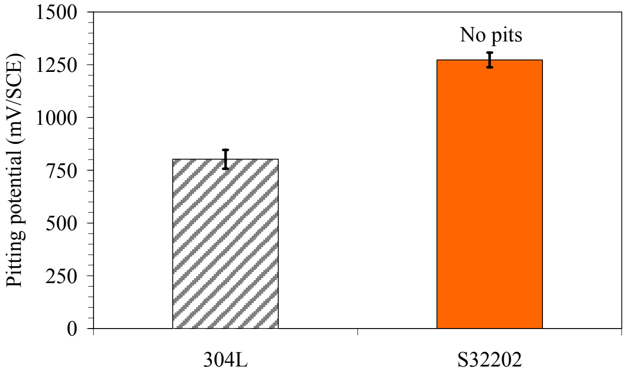

Figure 17: pitting potential in 250ppm chloride containing solution at pH 5.5 and 25°C / 77°F.

When pH loses one unit and chloride concentration increases up to 1000ppm, the pitting potential of 304L decreases to 670mV/SCE whereas UNS S32202 is still not prone to pitting (see Figure 18). At 50°C and then 80°C, the pitting potential measured on the duplex grade is slightly higher than that of the 304L.

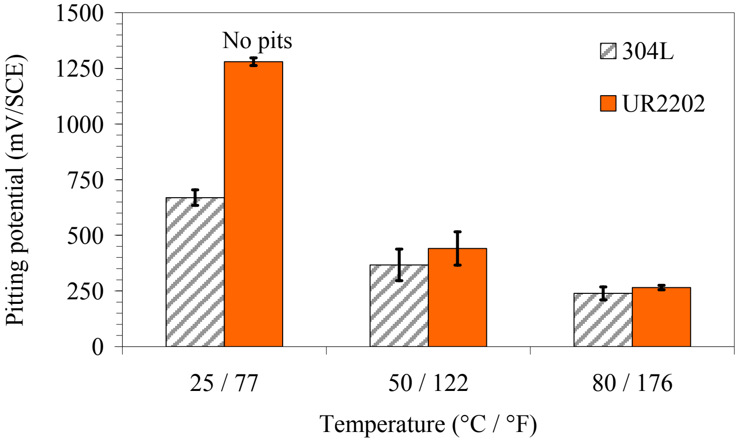

Figure 18: pitting potential in 1000ppm chloride containing solution at pH 4.5.

When chloride content increases up to 5000ppm, the pitting potential of the lean duplex grade still decreases but it remains higher in all cases than that of the austenitic grade (see Figure 19).

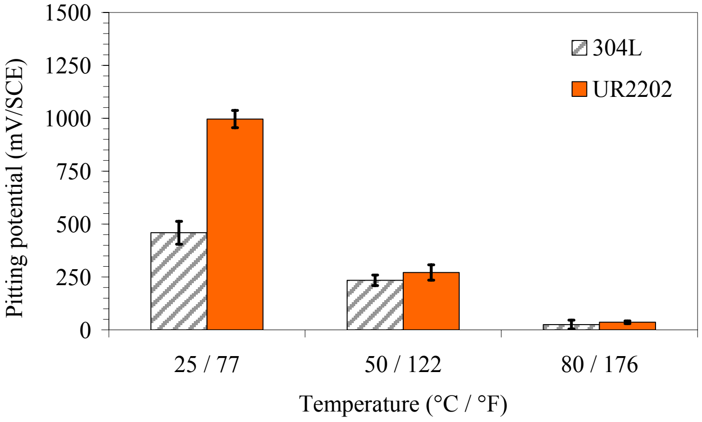

Figure 19: pitting potential in 5000ppm chloride containing solution at pH 4.5.

In summary, at ambient temperature, the pitting corrosion resistance of UNS 32202 is much better than that of 304L whereas when the temperature increases up to 50°C and 80°C, it is at worst similar.

4.1.1 Immersion test at the open circuit potential (OCP). UNS S32202 and 304L specimens were immersed in a stirred 1000ppm chloride containing solution at pH 4.5 and 25°C. The duration of the test was 720 hours and potential was observed as a function of time. The stability and the value of the free potential allow the behaviour of the passive film to be observed. The coupons 20 - 25 × 50 × thickness (mm) were mechanically polished with silicon carbide (SiC) papers to a 600 grit finish, followed by cleaning with ethanol. The electrochemical tests began 24 hours after sample preparation in order for the passive film to form naturally as a result of electrochemical reactions with the atmosphere. After the completion of immersion test, the stainless steel samples were weighed and examined by means of an optical microscope.

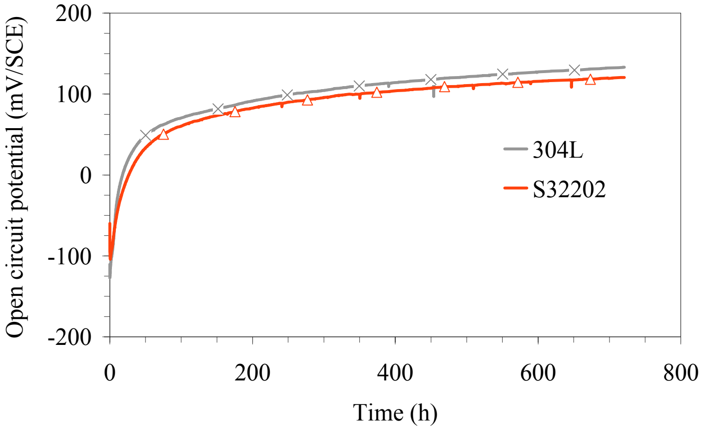

Figure 20: corrosion potential versus time in 1000ppm chloride containing solution at pH 4.5 and 25°C.

The corrosion potentials of the two stainless steels increase quickly during the first 4 days then reach a relatively stable value around 100 – 120mV/SCE. A limited number of potential instabilities were observed during the one month immersion showing that the passive layer built in this environment is relatively stable. After one month, no pits were observed and the calculated uniform corrosion rate is lower than 0.5µm/y (see Figure 21).

a) 304L – Side 1 b) 304L – Side 2 S32202 – Side 1 c) S32202 – Side 2

Figure 21: pictures of surfaces after the immersion test in 1000ppm chloride ion solution at pH 4.5 and 25°C.

Based on these results, the new lean duplex UNS S32202 appears to be a substitution candidate for 304L in mildly aggressive environments such as potable or drinking water.

3.2 Applications

Regarding the others metallic materials used for decades in potable water applications, ductile iron or cast iron, selecting stainless steels may offer several advantages. First of all, due to their extremely low corrosion rates in a wide range of waters, stainless steels seem more hygienic. The leaching rates of stainless steels are in agreement with different drinking standards as shown for 316L in a solution simulating drinking water [12]. Stainless steels have been used for more than fifteen years for manufacturing, storage and transportation of beer, juice soda and wine. Due to this excellent corrosion resistance, monitoring of water chemistry to mitigate corrosion attack is not necessary. Another point to be considered in the material selection is the mechanical characteristics. Using high strength grades allows a reduction of the wall thickness for pipes, especially in the case of higher design pressures (10 bars and more), or for storage tanks. Among the stainless steels family, the duplex materials exhibit much higher mechanical properties than the austenitic grades (about twice the yield strength, see Table 1). So, compared to other materials used for pipes or storage tanks in a potable distribution network, duplex grade can help reduce investment costs. Moreover, as stainless steels are not coated (internal and/or external), modifications of water systems are more easily and quickly achieved.

IV. CONCLUSIONS

For evaporators in thermal desalination plants, the risk of localized corrosion can be estimated based on: previous experience, the temperature, the oxygen concentration and the presence of stagnant brine. The duplex grade UNS S32304 has a pitting corrosion resistance equivalent or slightly better than the austenitic grade 316L. However; it is potentially as low as 316L for crevice corrosion resistance. The use of this economical duplex is better adapted to the zones where the risk of crevice is small. High chromium, molybdenum and nitrogen contents and a duplex microstructure allow UNS S32205 to offer a better resistance to the various forms of localized corrosion than the austenitic grade 316L. The risk of localized corrosion during shutdown operations, even if air enters the equipment, is minimized. Thus, the corrosion safety margin is higher and the costs for maintenance and inspection are reduced. The first reports of industrial applications show that pit initiation may occur depending on the operating conditions. These have no consequence on the reliability of equipment and do not call in question the choice of materials. However, an annual inspection with a local passivation treatment of any initiated pits is recommended in order to keep corrosion completely under control. The higher mechanical properties of the duplex grades may allow a reduction in the thickness of some parts of the installation. Therefore, the material costs, the erection costs and the welding time can be reduced. Finally, thanks to the low nickel content of the duplex grades, the market price of these materials is less volatile compared to 316L. This situation is even more important considering the extended time required for design and construction of large projects like desalination plants. Consequently, duplex grades UNS S32304 and UNS S32205 have been selected by the plant design engineers and delivered by Industeel for several desalination plants built recently in the Middle East.

It was also demonstrated than the new lean duplex UNS S32202 has a better pitting corrosion resistance than the standard 304L in a wide range of pH, temperature and chloride concentrations. For the same reasons shown above (less sensitive to fluctuations in raw material prices and higher tensile properties)

UR2202 is not only a cost effective alternative to 304L but also to coated or galvanized carbon steel and concrete in post-treatment, transport and storage of potable water.

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