DISTRIBUTOR SUMMIT

BILBAO

NOVEMBER 2022

WELCOME TO BILBAO!

CORRECTION ON COUPLINGS AND HARDWARE

Antonio Soler (Product & Project Manager)

David Jiménez (Technical Director)

Piedmont GENESYS PWT™

DISTRIBUTOR SUMMIT

NOVEMBER 13-17, 2022

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

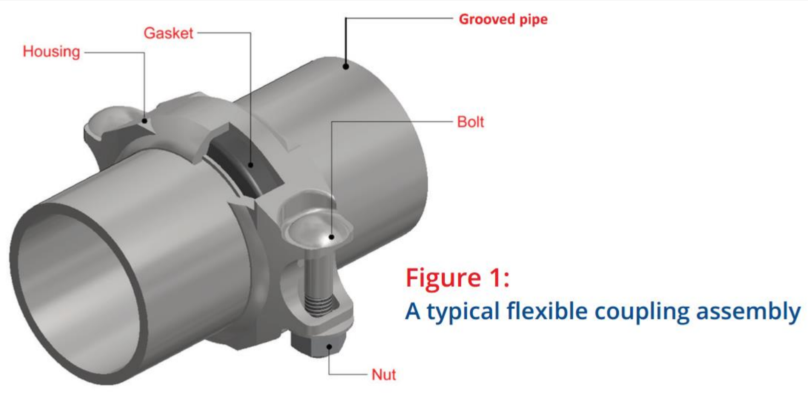


Figure 1:
A typical flexible coupling assembly

Corrosion Mechanisms:

a. Crevice corrosion

b. Pitting corrosion

c. Stress corrosion cracking (SCC)

d. Galvanic corrosion

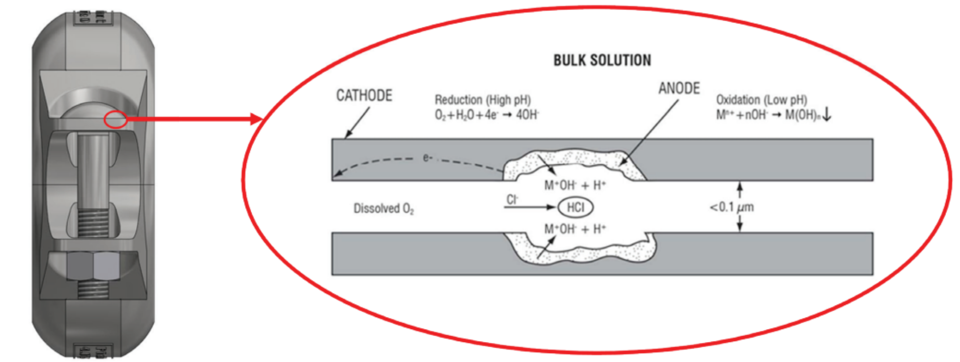


Figure 2:
The surface between the round head and the coupling exhibits a gap known as crevice, which is vulnerable to crevice corrosion under environmental effect.

SCC happens because of the combined effect of the microstructure cracks in austenitic stainless steel and the torque/pressure combination of the grooved coupling. Under torque and pressure, the microstructure crevices are forced open by the stresses and propagate through the material. Most fasteners are cold-worked, which means they inherently have internal residual stress within the structure. Furthermore, they are subjected to the stress caused by the torqueing required to close the assembly. SCC can happen at stresses that are below the yield stress of the metal. Vibration, and thus fatigue, may lead to acceleration of the phenomenon.

SCC is difficult to eliminate and premature failure of bolts is difficult to predict. Piedmont recommends that its clients follow the torque guidelines provided in the operation manual and regularly inspect the coupling assembly for premature signs of corrosion.

DISTRIBUTOR SUMMIT
BILBAO

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

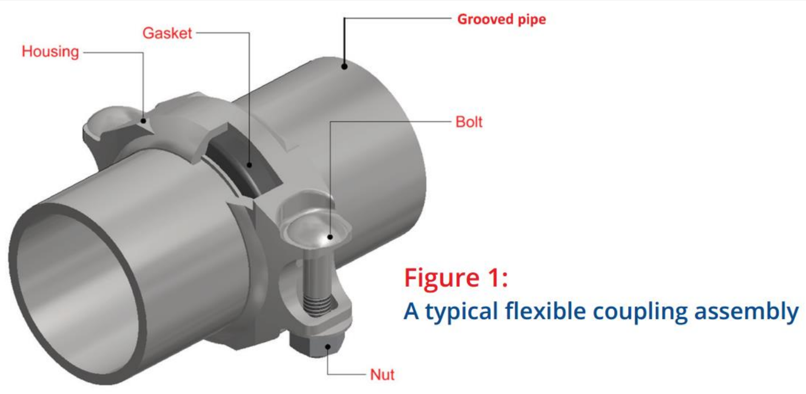


Figure 1:
A typical flexible coupling assembly

Typical materials used in couplings:

For stainless steels in chloride solutions there is a linear relationship between pitting and crevice corrosion resistance and alloy chemistry as defined by the Pitting Resistance Equivalent number (PREN) and the Crevice Factor (CF).

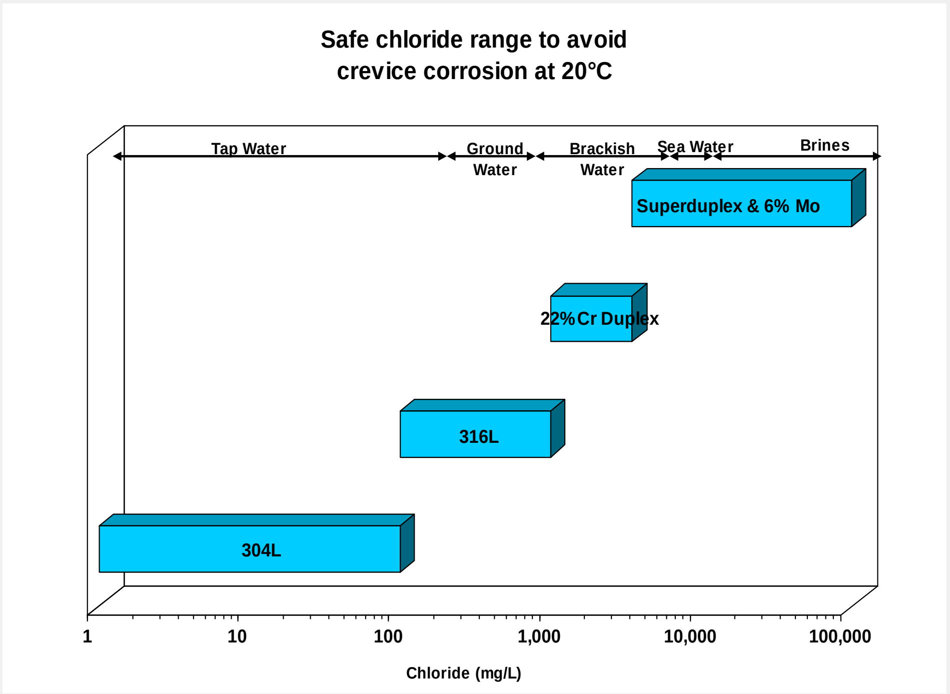
PREN = %Cr + 3.3*%Mo +16*%N

CF= %Cr +3*%Mo +15*%N

To attain a CCT of 35°C in ferric chloride and therefore resist crevice corrosion in seawater, for duplex materials:

-- the PREN needs to be at least 40

--the CF needs to be at least 35



Standard Rules

Stainless Steel	Maximum Recommended Chloride Level	PREN:
304/304L	200 ppm	
316/316L	1000 ppm	~25
317LMN, 904L, & 2205	3000 - 5000 ppm	~ 35
6% Mo grades & 2507	Resist seawater (20,000 ppm)	>40

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

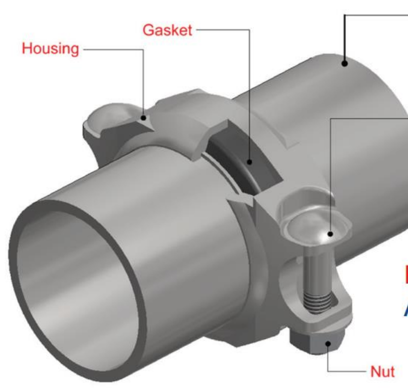


Figure 1:
A typical flexible coupling assembly

Typical materials used in couplings:

Corrosion effects of chlorinated seawater after 60 days exposure:

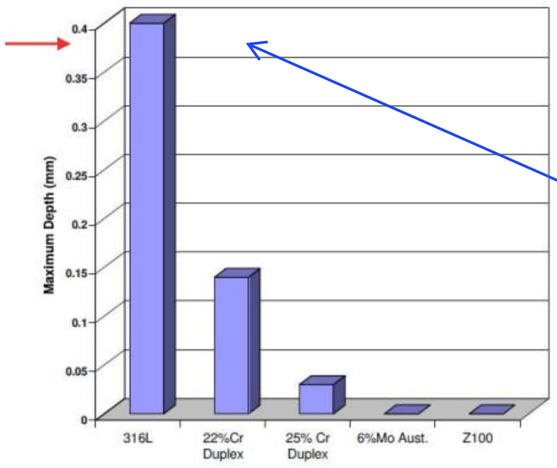


Figure 4 Depth of crevice corrosion in seawater at 16°C with 1mg/L chlorine[6].

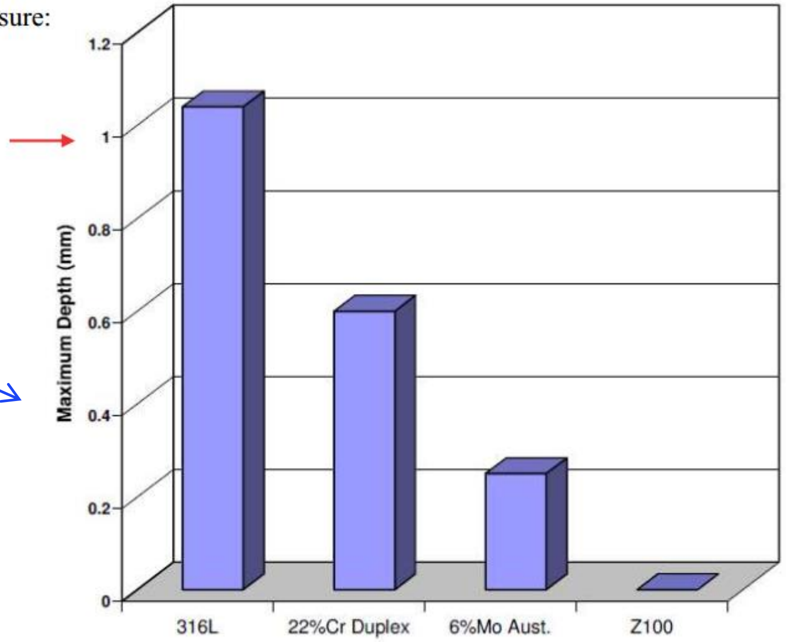


Figure 5 Depth of crevice corrosion in seawater at 40°C with 1mg/L chlorine[6].

CORROSION IN FLEXIBLE COUPLINGS

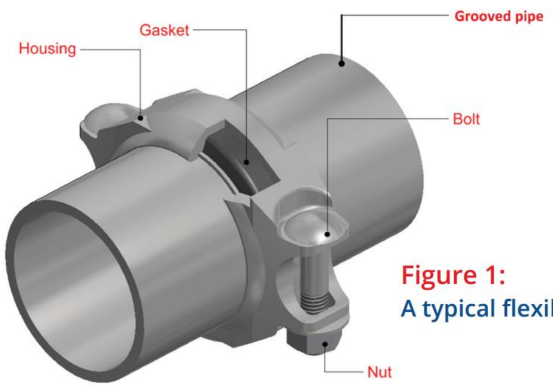
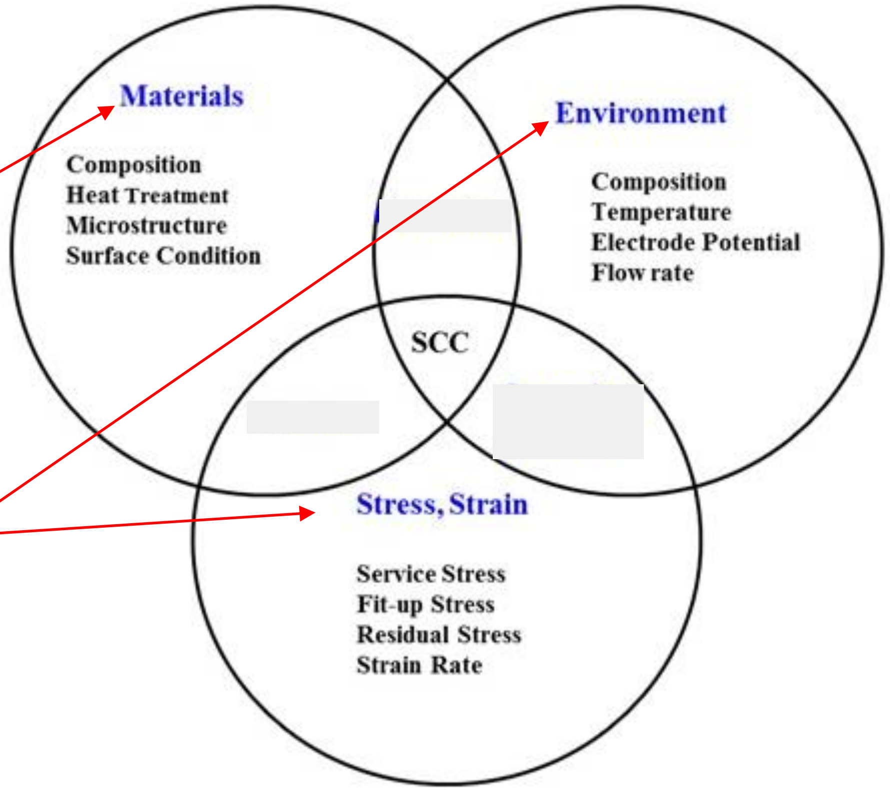


Figure 1:
A typical flexible coupling assembly

Chloride Stress corrosion cracking (CSCC):

Main factors



Human factor:

--Bolt Material selection in RFQ ($$):
2205 duplex/2507 super duplex Vs SS316

--Bolt assembly torque

--Couplings maintenance &
racks leakings at SWRO site

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

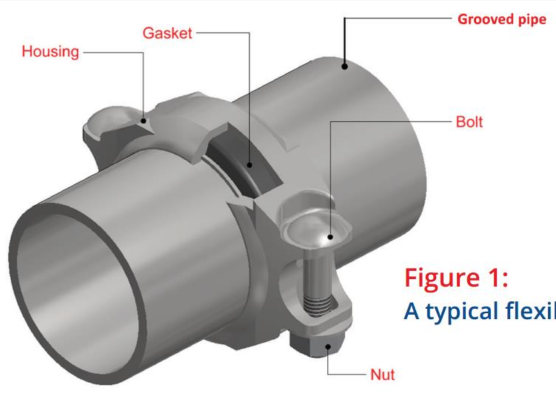
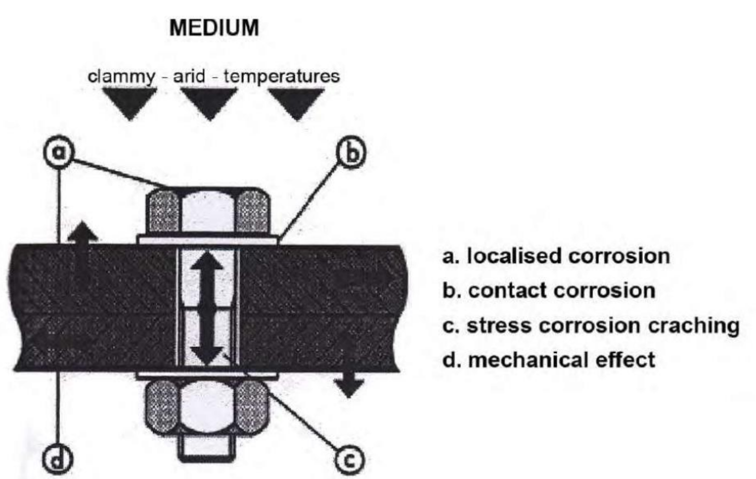


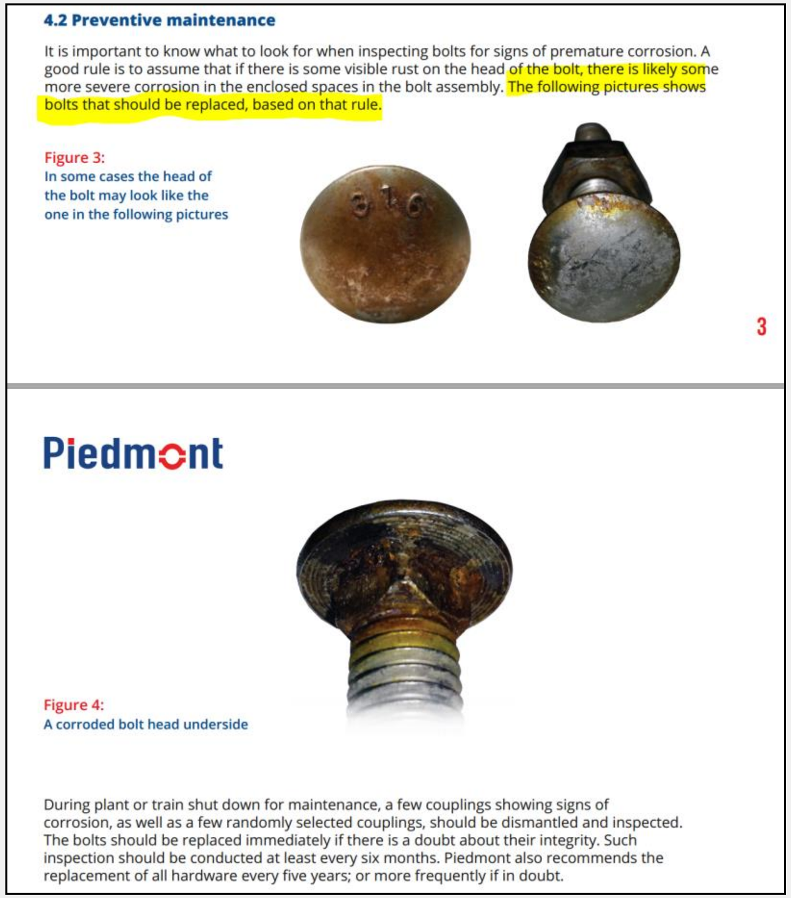
Figure 1:
A typical flexible coupling assembly

Factors influencing negatively into the corrosion:

a. Chloride
b. Temperature
c. Humidity
d. Condensation
e. Biofouling
f. Tension control + Torque

Diagram of the most common types of corrosion in screw connections





4.2 Preventive maintenance

It is important to know what to look for when inspecting bolts for signs of premature corrosion. A good rule is to assume that if there is some visible rust on the head of the bolt, there is likely some more severe corrosion in the enclosed spaces in the bolt assembly. The following pictures shows bolts that should be replaced, based on that rule.

Figure 3:
In some cases the head of the bolt may look like the one in the following pictures

3

Piedmont

Figure 4:
A corroded bolt head underside

During plant or train shut down for maintenance, a few couplings showing signs of corrosion, as well as a few randomly selected couplings, should be dismantled and inspected. The bolts should be replaced immediately if there is a doubt about their integrity. Such inspection should be conducted at least every six months. Piedmont also recommends the replacement of all hardware every five years; or more frequently if in doubt.

DISTRIBUTOR SUMMIT
BILBAO

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

Preventing failures due to corrosion:

a. Material Selection for each component (housing, hardware, gasket)

b. Bolts design:
Oval neck instead of carriage square neck to avoid stress concentration:

c. Coatings

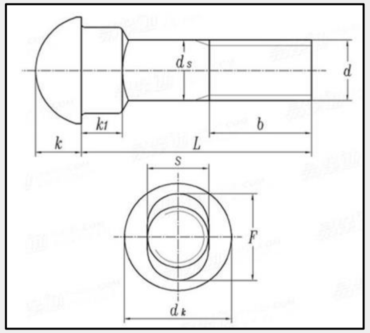
d. Surface quality at the gasket seating area
Machined pipe ends, and use peroxide cured EPDM gaskets

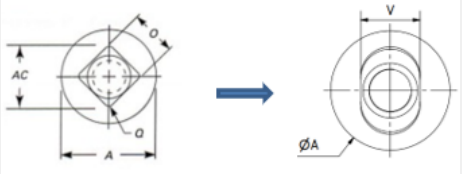
e. Installation procedure / tips:
Respect max gaps & displacements, avoid pipe centerline misalignments, and bolts over torques

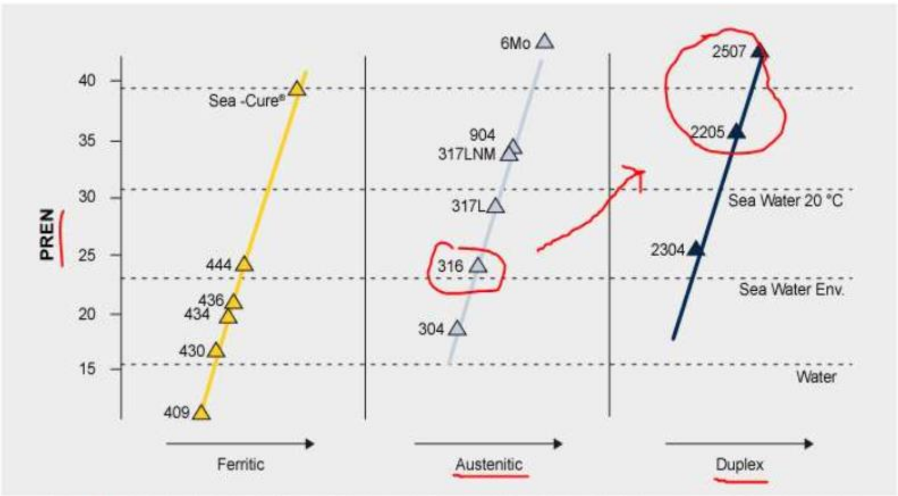
f. Preventive maintenance:
cleaning and replace when corroded

g. Reuse of Fasteners:
not recommended

h. Further measures:
Replace consumable parts (hardware and gaskets) as needed.







Source: International Molybdenum Association – PREN Comparison of Stainless Steel and Duplex Steel Materials

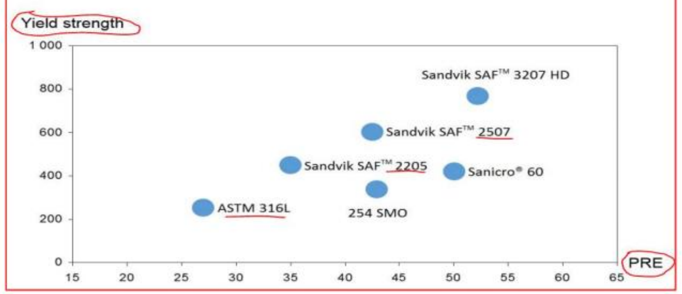
Stainless steel material in contact with seawater or seawater concentrate shall have an actual Pitting resistance equivalent number (PREN) of at least 40 and a Crevice factor (CF) of at least 35; to be calculated as follows:

For super austenitic alloys:

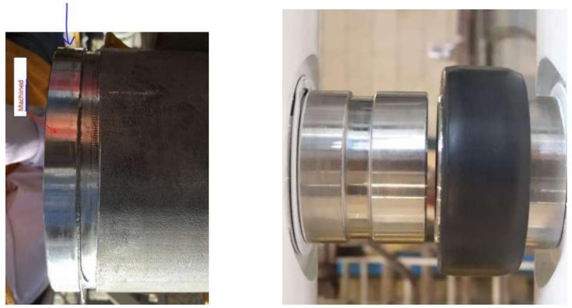
PREN = %Cr +3.3x %Mo+16x %N.

CF= %Cr +3 x %Mo+15x %N.

For marine applications PRE > 40 is recommended and the following diagram compares the PRE and yield strength for a number of currently used grades.



For instance, the surface machining of the gasket seating area has been reported to increase resistance against crevice corrosion attacks.



By machining a small amount of metal from the land for the gasket rubber seal is a simple, low cost operation and enhances the level of crevice corrosion resistance.

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

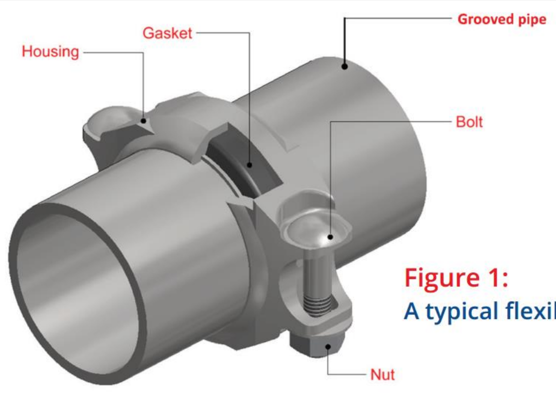


Figure 1:
A typical flexible coupling assembly

Lessons learnt:
Duplex 2205 & superduplex 2507 bolting:

Rule of a thumb / guideline to avoid fasteners corrosion:

-fasteners (bolts+nut+washer) should have greater corrosion resistance than items being joined (couplings housings cast).

-The fastener should be made of the same or a more noble metal than the part to be fastened in order to prevent failure of the fastener/bolt.

Because the fastener has the smaller surface area.

For a given T ºC, as CL- increases, crevice (grieta) corrosion takes place prior to pitting corrosion (surface)

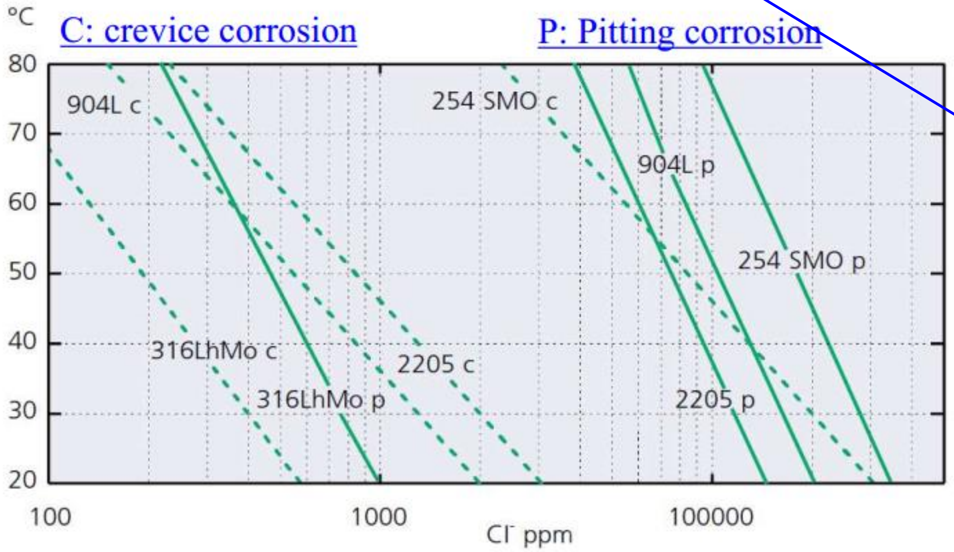
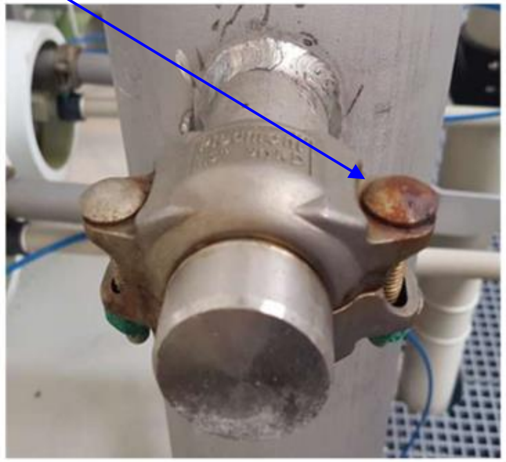


Fig 1. Maximum allowable service temperature in water as a function of the chloride content. Grade 316LhMo corresponds to EN 1.4432 (min 2.5% Mo). The risk of crevice corrosion is indicated by "c" while "p" stands for pitting.

Crevice corrosion takes place prior to any pitting corrosion and the



C: crevice corrosion

P: Pitting corrosion

DISTRIBUTOR SUMMIT
BILBAO

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

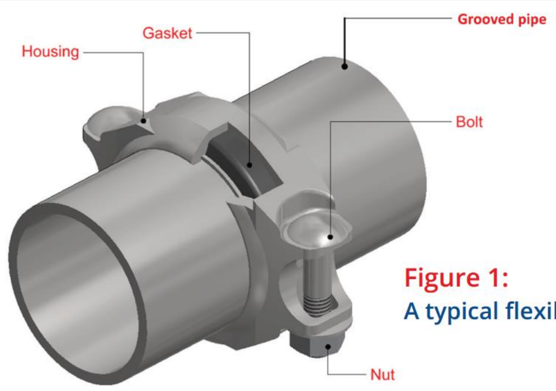


Figure 1:
A typical flexible coupling assembly

<u>Lessons learnt:</u>

<u>High pressure endcaps corrosion & piping:</u>

-crevice corrosion

-microbiology influenced corrosion (MIC)

-fluid velocity corrosion (at endcaps)

Once assembled, the coupling – pipe groove joint creates a tight crevice, and some customers reported experiences with lower alloy stainless steels piping (PREN < 40) which suffered severe crevice corrosion in SWRO plants, like the below photo examples:

Photo: High pressure S32205 duplex piping (PREN ~35) with crevice corrosion observed after coupling disassembled (Egypt) (not Piedmont coupling)

Corroded casted CE8MN-SD endcap (at high pressure seawater & brine):
To use instead superduplex CE3MN (casted) or S32750 (2507) forged

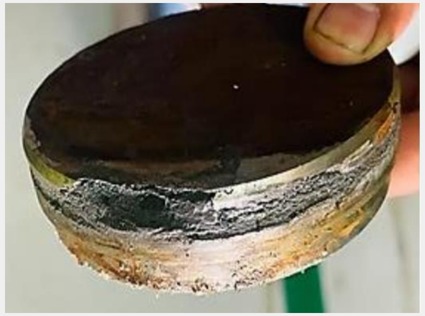


Photo: Crevice corrosion of 316L at high pressure coupling pipe joint

DISTRIBUTOR SUMMIT
BILBAO

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

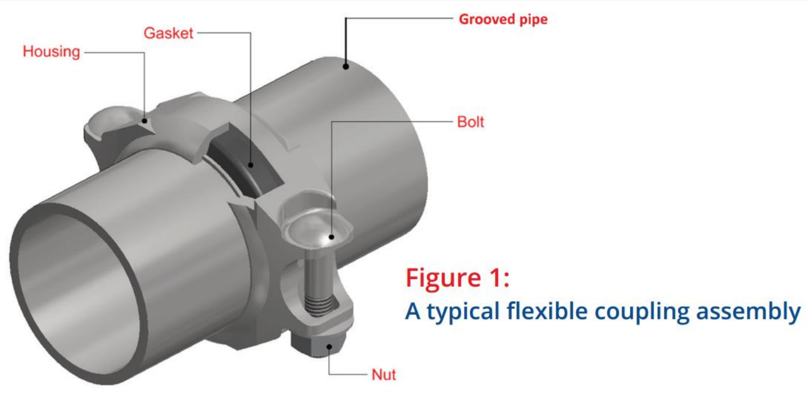


Figure 1:
A typical flexible coupling assembly

Lessons learnt:
High pressure endcaps corrosion & piping:
-crevice corrosion
-microbiology influenced corrosion (MIC)

In order to increase the resistance against crevice corrosion at the pipe cut groove surface area, specially at the SWRO high pressure couplings applications, Piedmont recommends to:

A) To use pipe materials with higher crevice and pitting resistance No (PREN > 40), such as:

a. Alloy 2507 (Superduplex S32750)
b. Zeron 100 (RA Alloys)
c. AL6XN (Allegheny-Ludlum)
d. 254SMO (6Mo) (Outokumpu)

That is why we usually provide our high pressure couplings (Style D, S, H) piping installation recommendations for SWRO applications to the quotations (attached).

The type 316, type 904L stainless, and alloy 2205 (S32205) duplex pipe material are not allowable piping materials for this high pressure rating in seawater.

As reference:

Photo: High-pressure coupling- pipe assembly from a 40,000 m^3/day seawater RO plant in the Mediterranean sea. The 6% molybdenum coupling pipe part was in service for 7 years compared to only 6 months for the opposite 316L coupling pipe part. [1]

DISTRIBUTOR SUMMIT
BILBAO

CORROSION IN FLEXIBLE COUPLINGS

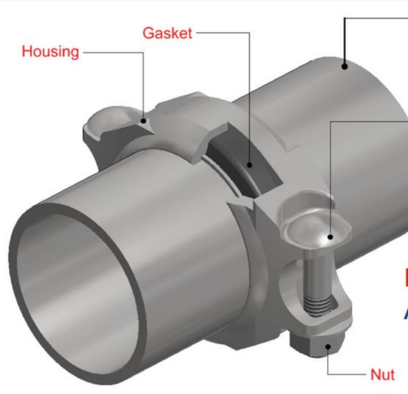


Figure 1:
A typical flexible coupling assembly

Final conclusion:

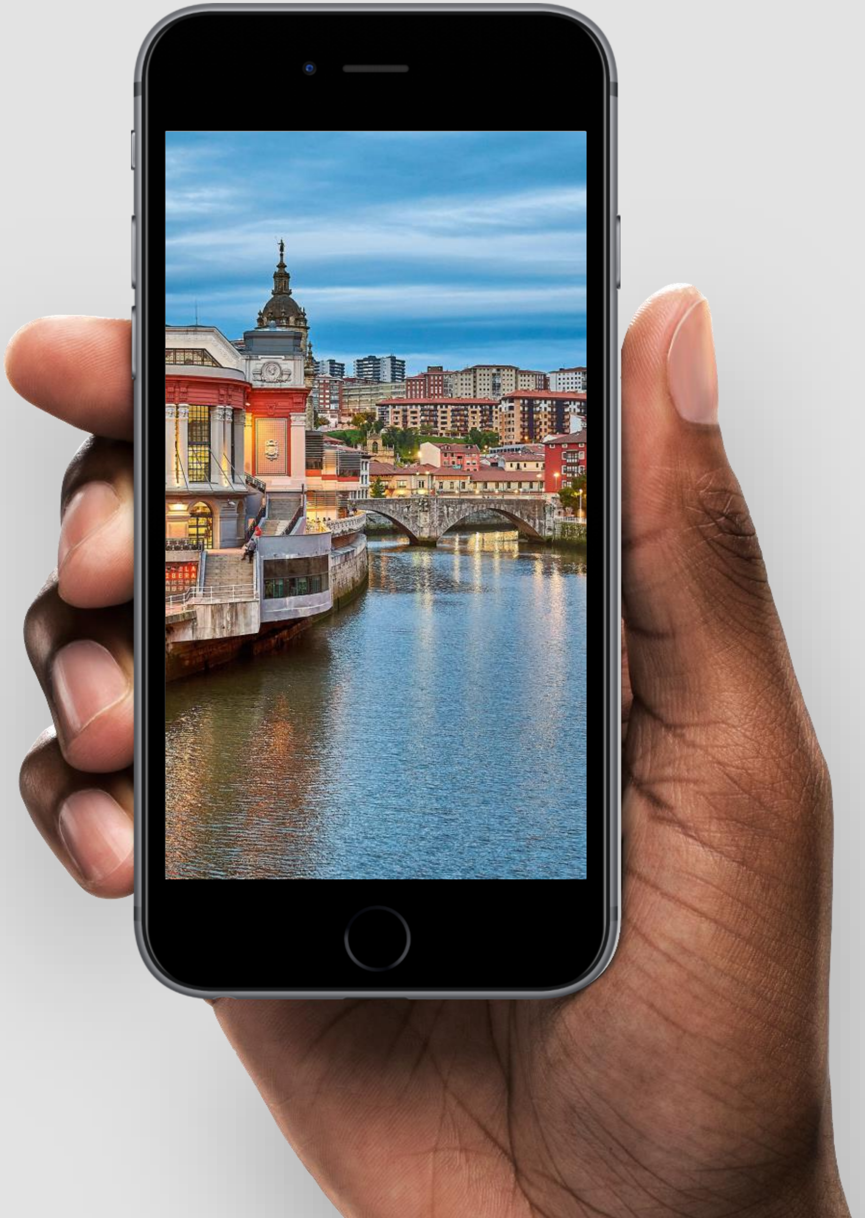
S3C

1) Let's take **CARE** of the couplings corrosion issues to improve our designs.

2) Let's **COMMUNICATE** the corrosion risks to our Customers

3) Let's get and **CELEBRATE** the spare parts PO to replace the corroded componts

QUESTIONS TO THE AUDIENCE:



DISTRIBUTOR SUMMIT
BILBAO

Piedmont

CORROSION IN FLEXIBLE COUPLINGS

EventMobi

QUESTIONS TO THE AUDIENCE (choose one):

1) In a coupling bolting assembly, which corrosion mechanism starts first?

a) Pitting corrosion (detected by visual check)

b) Crevice corrosion (not easily detected)

2) The coupling hardware components (bolts, nuts, washers) in SWRO plants, independendtly of the material used and maintenance performed...:

a) last for all the SWRO plant life (~25-30 years approx.) ?

b) Are consumable components, like the gaskets, and need to be checked regularly and replaced when corroded ?

3) In high pressure SWRO piping, which grooved endcap material would you recommend?

a) SS316 or duplex CE8MN /S32205

b) Super duplex 2507/S32750, CE3MN, or superior grade

DISTRIBUTOR SUMMIT BILBAO

WATER COMPANY
OF THE YEAR 2020

GLOBAL
WATER
AWARDS