1. Introduction

Traditional pipe clamp designs supporting instrumentation and hydraulic tubes in a marine environment both upstream and downstream have been seen to be highly prohibitive with regards to an asset through life support costs.

Failures through tube leakage from a chemical process known as crevice corrosion or under clamp corrosion utilizing this clamp design are reported on a global scale and this design of pipe clamp should be avoided at all costs.

2. Process of crevice corrosion

The trapped seawater atmosphere between tube support and pipe clamp is enclosed in a chamber where no oxygen is present, therefore changing the chemical formula of the atmosphere to an acid.
At the points of contact the acid formula then attacks the tube being supported.

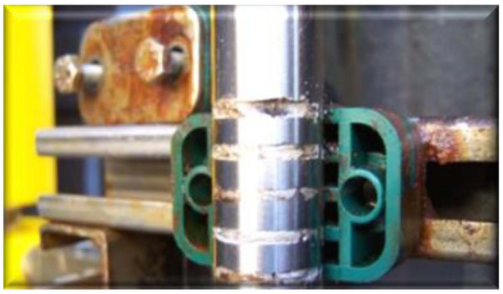
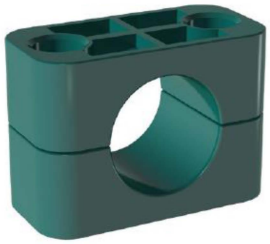


Fig 1 – Tube showing signs of crevice corrosion



Note: The alternative design of a completely smooth inside profile is also wholly unsuitable and in all cases offers even more severe corrosion. The contact area with the smooth bore design and tube has increased therefore giving a larger contact area of the acidic formula repetitive.

Fig. 2 – Clamp with smooth inside profile

3. Tube material

Utilising a higher grade tube was commonly believed to overcome this issue but reports from owner / operators globally have reported this is not the case. Some improvement with regard to lifetime of the tube can be expected but with the premium cost of more exotic tube materials this is offering no benefit when considering through life costs when combined with a traditional pipe clamp design.

In summary the pipe clamp design is the cause of the problem and an alternative style must therefore be considered.

4. Anti-corrosion paste

Whilst using anti-corrosion paste at the point of contact between the tube and traditional pipe clamp offers a short term preventative cure of between 12-18 months, this is again deemed as unacceptable to the owner / operator.

The overall quantity of pipe clamps used on a typical project and the inaccessibility of many of the pipe clamps makes this solution unmanageable and impractical to operations and will therefore not be considered.

5. Requirements

In order to consider an alternative design to overcome the issue of crevice corrosion the owner / operator must be shown that an alternative design does in fact mitigate against the risk of crevice corrosion.

A series of accelerated corrosion and temperature / humidity tests has therefore been compiled in order to satisfy the owner / operator as to the long term benefits when using an alternative design proposal.

The test program compiled is a minimum requirement any product design proposed must be shown to achieve. Documentary evidence and some external laboratory / independent testing must be included in any test reports submitted to prove validity.

6. Overview Specification Tests

Specific test specifications are listed under the following chapters:

7 Tube Material / Clamp Performance in a salt spray chamber
8 Environmental testing
9 High temperature, high humidity (Onshore terminal test)
10 Accelerated corrosion test
11 General performance criteria
12 Extended life performance
13 Sub Sea Performance

7. Tube Material / Clamp Performance in a salt spray chamber

a. Test Description
Continues hot salt spray test for a period of 2000 hours.

b. Test Standard
ASTM B1117

c. NaCl concentration
5% w/v sodium chloride solution

d. Chamber temperature
Continuous 35°C

e. Tube Material
316L

f. Number of test pieces 4

g. Analysis
Any evidence of corrosion should be inspected using an optical digital microscope with the following resolution:
Resolution and analysis direction x, y: max 10 µm (horizontal)
Resolution and analysis direction z: max 1 µm (vertical, depth)

h. Inspection process
One sample to be removed at 500 h intervals with analysis following point g.

i. Acceptance criteria
No crevice corrosion to be observed using the analysis as shown in point “g”.

8. Environmental Testing

a. Test Description
4-week cyclic salt spray test ASTM G85 + 7 days BS EN 60068-2-52

b. Test Standard
ASTM G85 / BS EN 60068-2-52

c. Test specification / procedure

Test	Modified G85-A3 test during first three weeks	Modified BS-EN test during final 7 days
NaCl concentration	5 wt%	5 wt%
pH	Neutral (6.5 – 7.2)	Neutral (6.5 – 7.2)
Time, salt spray	0.5 hours → 12/d → 21 days	2 hours → 1/d → 7 days
Temperature, salt spray	95F	95F
High humidity level	98%	93%
Time, high humidity	1.5 hours → 12/d → 21 days	22 hours → 1/d → 7 days
Temperature, high humidity	95ºF	95ºF
Cycle time	2-hours	24-hours
Cycles per day	12	1
Total number of cycles	252	7
Total time (days)	21	7

d. Tube Materials
316, 6MO, 2507

e. Number of test pieces
min 2 for each tube material to be tested

f. Analysis
Any evidence of corrosion should be inspected using an optical digital microscope with the following resolution:
Resolution and analysis direction x, y: max 10 µm (horizontal)
Resolution and analysis direction z: max 1 µm (vertical, depth)

g. Inspection process
Final inspection following completion of the weeks combined tests. It is not permitted to disassemble any sample for inspection or cleaning purposes before the conclusion of the complete test

h. Acceptance criteria

i. This test is seen as one of the most aggressive accelerated test programs that can be performed.

j. The objective of this test is to observe any signs of crevice corrosion for higher grade tube materials. Any evidence of crevice corrosion is not permissible. No crevice corrosion should be recorded on materials 2507 and 6MO.

k. In this test program tube material 316 is included in the test only as a base line when comparing performance to higher grade tube materials. As a result for tube material 316 some slight crevice corrosion may be observed due to differing MO content of the tube material that may be utilized when performing this test. Should this be observed a maximum corrosion depth of 0.1 mm and a maximum volume of 0.02 mm^3 would still indicate a highly reliable pipe clamp performance. Excess of these measurements it is highly likely crevice corrosion is directly caused by the clamp design.

9. High Temperature, high humidity

a. Test Description
Tropical environment ocean-facing onshore facility

b. Test Standard
Test panels placed ocean-facing for a period of not less than 4 years

c. Test conditions
Tropical marine environment

d. Tube Material
316

e. Number of test pieces not less than 30 samples

f. Analysis
Any evidence of corrosion should be inspected using an optical digital microscope with the following resolution:
Resolution and analysis direction x, y: max 10 µm (horizontal)
Resolution and analysis direction z: max 1 µm (vertical, depth)

g. Inspection process
Test pieces must remain in position for the complete test period. It is not permitted to disassemble any sample for inspection or cleaning purposes before the conclusion of the complete test

h. Acceptance criteria
No crevice corrosion to be observed using at the analysis as shown in point f.

10. Accelerated corrosion test

a. Test Description
Accelerated corrosion test

b. Test Standard
Test to be carried in accordance with the following table:

Cycle	Days	Duration (hours)	Humidity	Temperature
A	Monday Friday	1	Sea Water	Ambient Temperature
		3	Dry (Relative Humidity <40%)	60° C
		3	Relative Humidity > 95%	35° C
		2,5	Dry (Relative Humidity <40%)	60° C
		2,5	Relative Humidity > 95%	35° C
		1	Salt Spray (1%NaCl pH=4)	35°C
		3	Dry (Relative Humidity <40%)	60° C
		3	Relative Humidity > 95%	35° C
		2,5	Dry	60° C
		2,5	Relative Humidity > 95%	35° C
B	Tuesday Wednesday Thursday	1	Salt Spray (1%NaCl pH=4)	35°C
		3	Dry (Relative Humidity <40%)	60° C
		3	Relative Humidity > 95%	35° C
		2,5	Dry (Relative Humidity <40%)	60° C
		2,5	Relative Humidity > 95%	35° C
		1	Salt Spray (1%NaCl pH=4)	35°C
		3	Dry (Relative Humidity <40%)	60° C
		3	Relative Humidity > 95%	35° C
		2,5	Dry	60° C
		2,5	Relative Humidity > 95%	35° C
D	Saturday Sunday	24	Relative Humidity > 95%	35° C

- **Sequence: A-B-B-B-A-B-B (1 week)**
- **Total duration : 10 weeks**

c. Tube Material
316L

d. Number of test pieces
16

e. Analysis
high resolution photography

f. Inspection process
4 clamps to inspected using high resolution images
Observations should be taken and recorded after 2, 4, 7 and 10 weeks

g. Acceptance criteria
No crevice corrosion to be observed using the analysis as shown in point “e”.

11. General Performance Criteria

a. Tube clamps
Qualified tube clamps should be provided with torque assembly measurements for both single and double clamp designs.

b. Tube clamps should be provided with full material safety data sheets (MSDS)

c. Tube clamps must be supplied with a fire certificate according UL V0

d. Tube clamps must be certified for UV stabilization of not less than 2.000 hours.

e. Metal parts
Evidence must be given that stainless steel 316 support accessories used for the fixing of clamps to structure have been subject to a cleaning process or are manufactured in a clean environment thereby removing foreign particles, i.e. steel from the base material. It is required that evidence be provided at the time of acceptance of improved performance as a direct result of the cleaning process.

12. Extended Life Performance

a. Evidence must be given that the fixing points (clamp bodies to tubes) remain intact and airtight to minimize any risk of crevice corrosion both at assembly stage and following an extended period of functionality (corrosion avoidance, tube clamping) of not less than 15 months

13. Sub Sea Performance

a. Whilst crevice corrosion is not evident in sub-sea applications it is a requirement that the owner operator may wish to surface this equipment on occasions. At that time it is a requirement that the seawater drains from the tube to clamp contact point as quickly as possible.

b. An extended period of the equipment being surfaced may then give risk to the crevice corrosion process occurring and must be avoided. Therefor to ensure the approved solution is suitable for top side and sub-sea applications evidence of suitability and performance shall be judged against the following:

c. Resistance against pressure
200 bar (This corresponds to the pressured of 2.000 m water depth)
400 bar (This corresponds to the pressured of 4.000 m water depth)

d. After a pressure load of the ACT terminals of 200 bar and 400 bar, no visible damage or deformation should be visible to the clamp body or parts directly in contact to the tube.

14. Validity

All statements in this letter shall not be binding, in particular because all Stauff products are subject to an ongoing process of development and improvement.
The report may therefore no longer be valid for future product versions and variants that are developed after this report has been issued.
Please contact Stauff to ensure you have the latest available version of this report. Previous revisions of this document are no longer valid.

The validity of this report is from 19th March 2020 until 19th March 2023

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