Surface appearance of copper-based materials at unsheltered marine conditions

Dr. Gunilla Herting, PhD (herting@kth.se)
Prof. Inger Odnevall Wallinder, PhD (ingero@kth.se)
Exposure sites in Brest, France

<table>
<thead>
<tr>
<th>Exposure site</th>
<th>Distance from sea shore</th>
<th>Corrosivity category</th>
<th>Measured first year corrosion rate (g/m²/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Base Navale</td>
<td>&lt;5 m</td>
<td>C₅ (very high)</td>
<td>24</td>
</tr>
<tr>
<td>2 St Anne</td>
<td>25 m</td>
<td>C₄ (high)</td>
<td>16</td>
</tr>
<tr>
<td>3 St Pierre</td>
<td>1.5 km</td>
<td>C₃ (moderate)</td>
<td>12</td>
</tr>
<tr>
<td>4 Langonnet</td>
<td>40 km</td>
<td>C₃ (moderate)</td>
<td>9</td>
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</tbody>
</table>

Corrosivity categories according to the ISO 9223 and ISO 9225 standards on Corrosion of metals and alloys
## Cu sheet (45° South)

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
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</thead>
<tbody>
<tr>
<td>6 months</td>
<td></td>
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<tr>
<td>1 year</td>
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<table>
<thead>
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<th>Site 1</th>
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<tbody>
<tr>
<td>Year 1</td>
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<tr>
<td>Year 5</td>
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</table>
Cu sheet (45° South)

Site 1

Site 2

Site 3

Site 4

Year 1

Year 5
### Cu sheet (45° South)

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<tr>
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Cu sheet (90° South)

Site 1 | Site 2
---|---
6 months
1 year
3 years
4 years
5 years

Site 1 | Site 2 | Site 3 | Site 4
---|---|---|---
Year 1
Year 5
Cu sheet  
(90° South)
Cu sheet
(90° South)

Site 1  Site 2  Site 3  Site 4

6 months

1 year

3 years

4 years

5 years

unexposed
BRASS – CuZn15
(45° South)

unexposed

Site 1  Site 2

6 months

1 year

3 years

4 years

5 years

Site 1  Site 2  Site 3  Site 4

Year 1

Year 5
BRASS – CuZn15
(45° South)

Site 1

Site 2

Site 3

Site 4

unexposed

6 months

1 year

3 years

4 years

5 years

Site 1

Site 2

Site 3

Site 4

Year 1

Year 5
<table>
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<tr>
<th>Site</th>
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BRASS – CuZn15 (90° South)

Site 1

Site 2

Site 3

Site 4

Year 1

Year 5

unexposed
BRASS – CuZn15
(90° south)

unexposed

Site 2

Site 4

6 months

1 year

3 years

4 years

5 years

Site 1

Site 2

Site 3

Site 4

Year 1

Year 5
### BRASS – CuZn15

(90° South)

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<td><img src="image5" alt="Image" /></td>
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BRONZE, CuSn4
(45° South)

Site 1

Site 2

Site 1

Site 2

Site 3

Site 4

Site 1

Site 2

Site 3

Site 4

unexposed

6 months

1 year

3 years

4 years

5 years

Site 1

Site 2

Site 3

Site 4

Year 1

Year 5
BRONZE, CuSn4
(45° South)

Site 1

Site 2 Site 4

Site 2 Site 3 Site 4

Site 1 Site 2 Site 3 Site 4

Year 1

Year 5

unexposed

6 months

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BRONZE, CuSn4
(45° South)

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BRONZE, CuSn4
(90° South)

unexposed

Site 1 | Site 2
---|---
6 months | 

Site 1 | Site 2
---|---
1 year | 

Site 1 | Site 2
---|---
3 years | 

Site 1 | Site 2
---|---
4 years | 

Site 1 | Site 2
---|---
5 years | 

Site 1 | Site 2 | Site 3 | Site 4
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Year 1 | | | 

Site 1 | Site 2 | Site 3 | Site 4
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Year 5 | | | 
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(90° South)

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GOLD COLOURED ALLOY
(45° South)

unexposed

Site 1  Site 2
6 months

Site 1  Site 2
1 year

Site 1  Site 2
3 years

Site 1  Site 2
4 years

Site 1  Site 2
5 years

Site 1  Site 2  Site 3  Site 4
Year 1

Site 1  Site 2  Site 3  Site 4
Year 5
GOLD COLOURED ALLOY
(45° South)

Site 1

Site 2

Site 3

Site 4

6 months

1 year

3 years

4 years

5 years

Year 1

Year 5

unexposed
GOLD COLOURED ALLOY
(45° South)

Site 1  Site 2  Site 3  Site 4

unexposed

6 months

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5 years
# GOLD COLOURED ALLOY

*(90° South)*

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GOLD COLOURED ALLOY
(90° South)

Site 1
Year 1
Year 5

Site 2
Site 3
Site 4

6 months
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**GOLD COLOURED ALLOY**
(90° South)

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unexposed
Quantifying surface appearance

Spectrophotometry
The surface appearance can be quantified scientifically using for example spectrophotometry. This is a useful tool that enables comparison between different surfaces as the appearance is very different depending on e.g. light and weather conditions in addition to patina characteristics. Spectrophotometry measures the reflected and/or scattered light from a well-defined white light source illuminated on a surface at a given angle. Absorption of light gives a measure of the surface brightness.

Key references


Additional publications and reports available via: https://www.kth.se/profile/ingero/

The results presented are a result of a long-term research collaboration on atmospheric corrosion of copper and copper based alloys between KTH Royal Institute of Technology and ECI/ICA.

Camera settings: Canon G16; ISO 400; f/2.8; 1/200; measured by Polaris flash meter.