



NEW STORAGE LATENT AND SENSIBLE  
CONCEPT FOR HIGH EFFICIENT CSP PLANTS



Schweizerische Eidgenos-  
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## **Deliverable D4.2 - Compatibility of metallic materials with PCMs and sensible-heat Ca ternary salts (Part I and II)**

### **ABSTRACT**

This Deliverable D4.2 titled “Compatibility of metallic materials with PCMs and sensible-heat Ca ternary salts” is framed within the Task 4.2 “Interaction of latent PCMs with metallic components” and Task 4.3 “Interaction of MS with metallic components of CSP plants”, from WP4 “Advanced materials combination and stability”.

The first part of this report (Task 4.3) concluded in August 2018 shows the developments obtained for three high thermal performance steels considered as structural materials that could be used in the NewSOL project.

The document is divided in two main sections:

1. Stability of metallic components in contact to Ca-ternary molten salts at high temperature. The corrosion process was fully characterized by LNEG.
2. Evaluation of the chemical properties of the molten salt samples before and after corrosion at high temperature. These measurements were performed by DLR and discussed with LNEG and University of Évora.

The second part, dedicated to the corrosion studies involving the phase change materials (PCMs) encapsulated, was afterwards presented because the experimental design of encapsulated PCM was discussed and better defined in the Steering Committee meeting in Trondheim (July 2018). The corrosion studies with these materials began after the conclusion of D3.6.

The NewSOL project in task 4.3 within WP4 aims to study and understand the interaction of the three types of stainless steels chosen in WP2 with Ca-ternary mixture (WP3). The development of this work plan allowed defining the best combination of construction material of metallic materials – MS that will be used in the pipe circuit in the prototypes within WP6.

Evaluation of the long-term performance in terms of the chemical stability of the defined materials at close realistic experimental conditions was developed. The corrosion resistance of selected combination of metallic materials and Ca-ternary mixture was performed under static and mechanically stirred conditions to simulate, for instance, the piping flow settings. Long-term corrosion



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rate was estimated based on gravimetric data obtained at high temperature and sufficient long periods of time. To deeply understand the compatibility and chemical stability of the materials a combination of several analytical techniques was used in order to assess the compositional and structural features of the oxidation layers formed at the surface of metallic substrates. Furthermore, changes in chemical composition of MS was assessed after the metallic corrosion tests.

Three structural materials, SS316L, SS321H and SS430, were tested for compatibility with Yara MOST under close operational conditions to be used under TES system in NewSOL project and the main conclusions obtained are as follows.

*Under static conditions:*

- a) The visual thickness of the corrosion scales increases over time, which is accordance to the gravimetric results, suggesting a proper protection of the scale.
- b) The outer layer of the corrosion scale is mainly composed by Mg, Ca and O, possible in the form of oxides or carbonates compounds, even their concentration in the salts is very low.
- c) After corrosion process, the corrosion products are mainly composed by crystalline multiple iron oxide compounds ( $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_3\text{O}_4$ ).
- d) Based in all experimental results, the materials tested demonstrated acceptable corrosion rates but, apparently greater activity of SS430 is observed comparatively to the austenitic steels.

Between the two austenitic steels, 316L reveals the lower corrosion rate.

*Under dynamic conditions:*

At approximately 1 m/s, the corrosion behaviour of SS321H is similar at longer times to the one verified at static conditions. More velocities should be tested to get more information of the high temperature corrosion of metallic materials under flow conditions.

The second part of this Deliverable (Task 4.2) concluded in November 2019 shows the results of the metallic materials behaviour in contact with PCMs selected and supplied by UEvora, described in Deliverable 3.6. The design of the capsules and the encapsulation of PCM were carried out by UEvora.

This document (Part II of the D4.2) is divided in three main sections:

1. Corrosion evaluation of flat metallic materials.
2. Corrosion evaluation of cylindrical capsules (PCM encapsulation materials). The corrosion process was fully characterized by LNEG.
3. Evaluation of the chemical properties of the PCMs before thermal cycles. These measurements were performed by DLR.

SS321H was tested as flat samples and as encapsulation material for PCMs in contact with Ca ternary molten salt in thermal cycling conditions, from 200°C-500°C, during 3000 hours (125 cycles).

The main conclusions are the following:

- 1) Daily thermal cycles from 200°C to 500°C during 3000h leads to lower thickness of oxide layers and lower corrosion rate than isothermal conditions (500°C);



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- 2) The corrosion rate of SS321H is 3.49  $\mu\text{m}/\text{year}$  at thermal cycling conditions and 6.11 $\mu\text{m}/\text{year}$  at isothermal conditions;
- 3) The corrosion products at cycling and isothermal conditions are similar, mainly composed by crystalline multiple iron oxide compounds ( $\text{Fe}_2\text{O}_3$  and  $\text{Fe}_3\text{O}_4$ ). The presence of MgO after 1440 h of exposure and  $\text{FeCr}_2\text{O}_4$  spinel after 3000h of exposure seem to be present.
- 4) No significant corrosion scales were observed on the inner surface of closed cylindrical capsules in contact with both PCMs with daily thermal cycled conditions from 200°C to 500°C during 3000h.
- 5) Molten salt chemistry was observed to be stable in terms of nitrate-nitrite and oxide ion chemistry, thus presenting no concern for long term cycling experiments in the future. Carbonate formation was observed and although it presents no concern in terms of corrosion, the origin of  $\text{CO}_2$  would have to be elucidated when envisaging the use of encapsulated PCMs on a larger scale facility.