WPSAE-CPR(18) 21071

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Preprint of Paper to be submitted for publication in Proceeding of
30th Symposium on Fusion Technology (SOFT)

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Testing of some potential techniques for the DEMO radioactive waste management

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Selection of technologies that are suitable for detritiation and recycling of DEMO waste materials has been made. To study treatment of waste technological process at DEMO facility where it has to be accounted groups of specific materials as composites, metals, oxides and others. From them the DEMO facility will be constructed and which are considered for further modification of this unit. Nevertheless, the new design changes of DEMO had significant impact on waste and recycling. For example, there would be very different requirements for the different breeding blanket options. The tests provided information about the potential MSO and IMCC devices for the part of DEMO plant connected to the Waste Management. The Molten Salt Oxidation (MSO) and the Induction Melting in Cold Crucible (IMCC) facilities has to be flexible for specifying kinds and quantities. The IMCC technology was tested for suitable materials that require temperatures up to 1000°C above melting point for the desired changes. The MSO technology can apply to different characteristic materials, typically from a liquid or suspension to small solids. For both technologies, groups of characteristic materials were selected, some of the representatives were tested and evaluated from the safety and environmental point of view as well.

Keywords: Waste management, Detritiation, Recycling, High temperatures, Molten Salt Oxidation, Cold Crucible

1. Introduction

The production of waste from operation and decommissioning of future fusion power plant models will depend on the plant model design and the operation conditions. Nevertheless, when applied to existing clearance limits in different countries, most of the waste has to be disposed of in a repository [1].

The selection of potential DEMO waste reduction technologies was created in the Safety and Environment Group (WP SAE). Criteria for the selection of technologies for detritiation and recycling of waste have been identified [2]. Appropriate techniques have been listed. Other important parameters for selection, in particular important material properties and general evaluation criteria, are summarized and published [3]. MSO and IMCC technologies have been selected for a shorter choice of potentially suitable technologies.

2. Materials for the Waste Management of the part of DEMO plant

The number of materials from which the fusion power plant will be built can only be estimated, considering how complicated and complex the whole system of basic facilities is represented by the complex around the very principle of the nuclear fusion and its center - the tokamak. In addition, they are measuring, tracking and monitoring systems, both from the local point of view and the whole, in order to ensure the safety and functionality of the device.

DEMO in Europe is considered to be the nearest-term reactor design to follow ITER and capable of producing electricity, operating with a closed fuel-cycle and to be a facilitating machine between ITER and a commercial reactor. One from European DEMO goals is to minimize activation waste and no long-term storage. The most recent changes to the DEMO design and concept are in the article [4].

Within the location of ITER in Cadarache is estimated 32 000 tons of wastes [5]. The wastes produced during operation (7%) and decommissioning (93%) are then distributed in 58% of very low activity wastes, 32% of low and medium activity with short half-life wastes and 10% of medium activity and long half-life wastes. The weight of the DEMO device will be larger but the proportional quantities of DEMO wastes are likely to be similar.

From the point of view of WP SAE, all construction materials will not become the monitored waste. The intended and actual life of the individual materials during the normal operation of the equipment is important.

The main groups of materials used can be simply divided into multiple steels and alloys, cermets, various groups of composites and coatings and so on. Most of the industrially used chemical elements, but parts of precisely defined ratios, are applied. It is necessary to perform tests with materials that have an important and often problematic property, although the particular material tested is unlikely to be used in the EU DEMO.

The wear-out can be more complicated and produced in different ways by neutrons, alpha, beta and gamma radiation. Similarly, we can say that ongoing processes are related to tritium and the products that are generated by irradiation of plant materials.

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3. MSO technology

The Molten Salt Oxidation technology is suitable for processes when combustible materials are present. Perspectively, for example, the processing of rinse and cleaning processes, the concentration of trapped dust and the elimination of organic-based filters and ion-exchangers are considered.

Similar conditions for the operation of MSO as our technology but with other molten salts and other ion exchangers have been described in the paper [6]. The study attempts to identify the proper conditions of the prototype two stage MSO reactor system, where each reactor performs different functions. Basic scheme of the two-stage MSO is shown in Fig. 1.

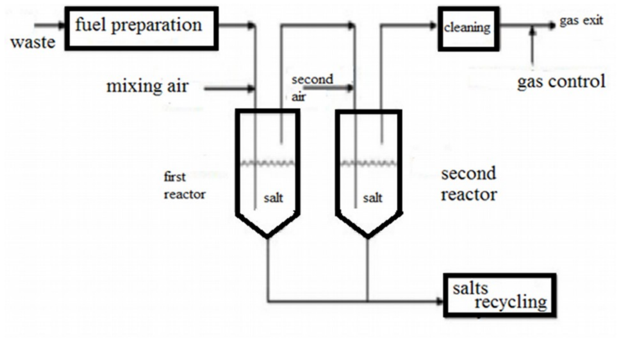

Fig. 1. Basic scheme of the MSO device.

The pictures show the process of combustion of ion exchangers containing Cs, Sr and Co in MSO technology as representatives of some metal groups. There are used the salt (Na_2CO_3) and the fuel (modified ion exchanger PUROLITE C-100-H) at 930°C. See figures 2-4 for the example of different running of combustion processes.

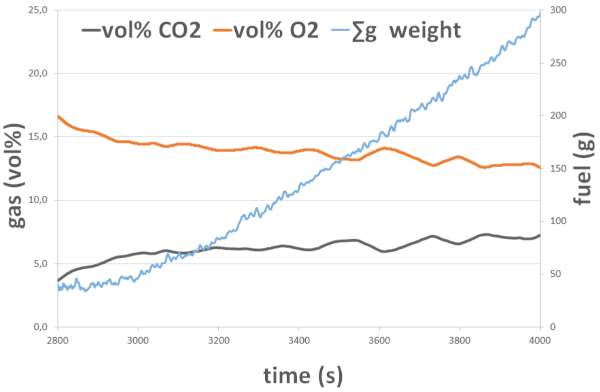

Fig. 2. Steady process of combustion in two-stage MSO technology.

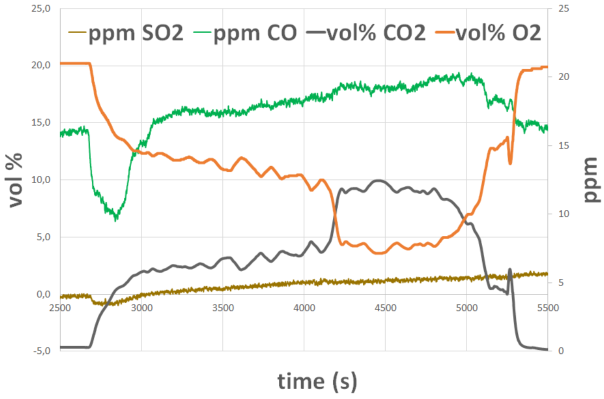

Fig. 3. Unstable process of combustion in two-stage MSO technology.

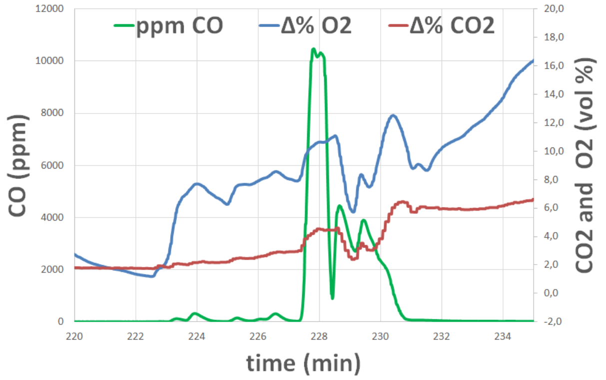

Fig. 4. Composition of outgoing exhaust gases in the combustion process in one-stage MSO technology.

4. IMCC technology

We can use IMCC technology in Fig 5 where we want to achieve high temperatures above 1000 to 3000 degrees C, but it has some limitations.

It is very important to know the chemical composition of the materials being melted. With the same chemical composition, the materials can behave significantly differently, because mineralogical composition is also important.

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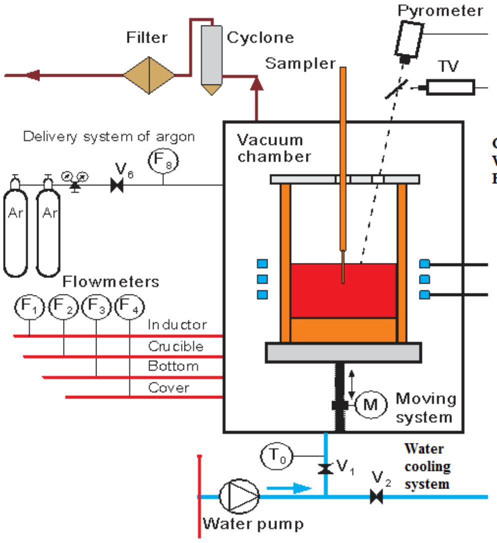

Fig. 5. Basic scheme of the IMCC device.

The classification of materials between conductors and non-conductors can be altered by varying the parameters of a state function, in particular temperature or pressure, achieved.

Creation of Skull layer is important for IMCC technique [7]. The interaction of liquid and solid phases under conditions of a temperature gradient can occur with the participation of chemical reactions and without them. In this case, phase transformations, i.e., melting and solidification, always take place at the interface.

We conceptually tested melting with full use of the scull layer on the interface with water-cooled copper material. The IMCC is ready for use in different atmospheres. Particularly argon and nitrogen were used, but the primary use is for the air atmosphere. Stainless steel and the zirconium metal tests are shown in the figure 6.

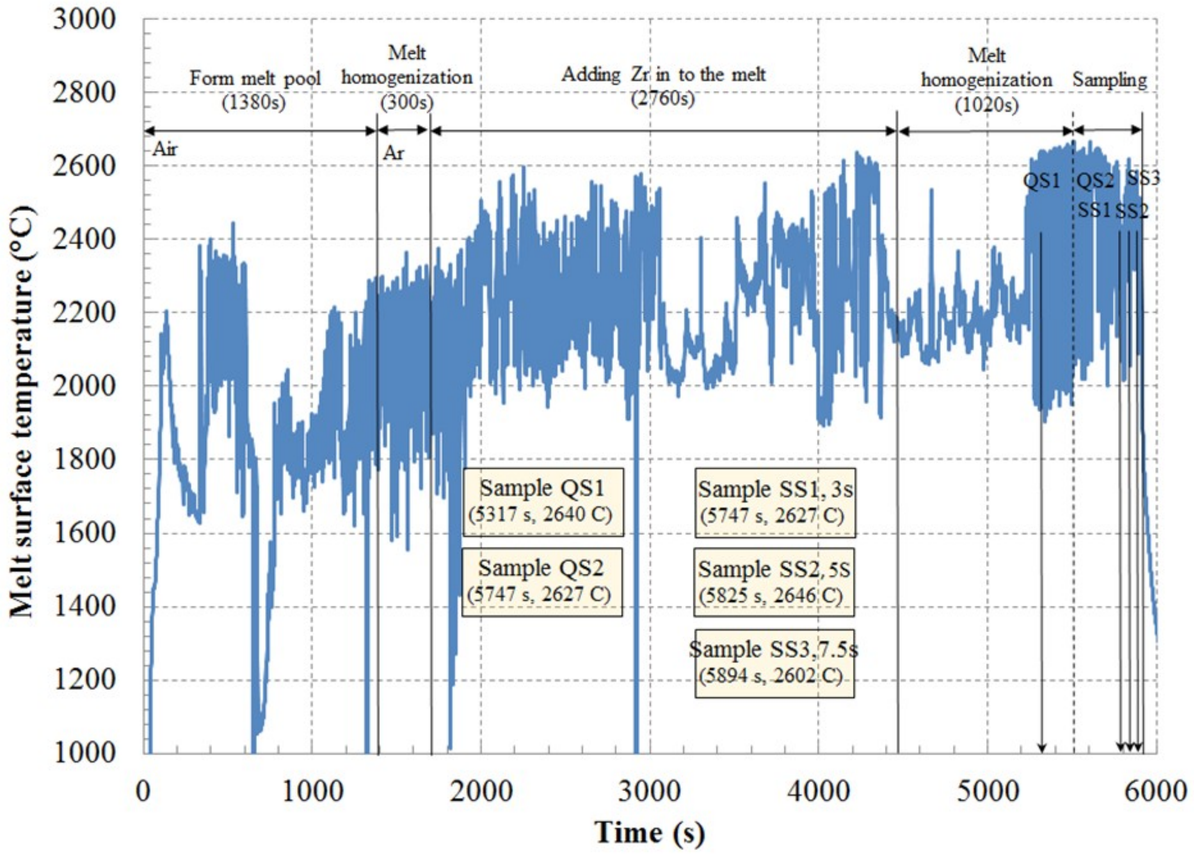

Fig. 6. Tests with the zirconium metal in IMCC, air atmosphere.

We tested various metallic materials (Zr, Al, Fe, stainless steel, Mo) and monitored their behavior at different electromagnetic field characteristics. Non-metallic and non-conductive components of the mixture were various oxides in a defined ratio (e.g. ZrO_2 and Al_2O_3 or UO_2 and ZrO_2)

The mixture usually contained a small amount of HfO_2, the usual accompanying oxide to ZrO_2. Sometimes other oxides (Gd_2O_3, FeO) were added.

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5. Conclusions

We try to set the MSO and IMCC to be flexible. There are a considerable number of potential materials for appropriate processing to minimize activation waste and no long-term storage. In our work we try to clarify the possibilities and define the technical limits for the waste not yet selected. It is common for both technologies to use high temperatures for materials reprocessing. We also predict the types of waste suitable for our technologies that have not yet been specified in official documents. Some types of waste can be assumed if we use analogy with technologies in power generation, especially at nuclear power plants.

Another goal is to look for the conditions for operating our equipment with remote control, to know the limits of the dimensions and performance of the equipment, including the adaptation of the device in the considered part of the EU DEMO technology.

Acknowledgments

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This work has been also supported by a grant no. MSMT-41274/2014-2 from the Ministry of Education, Youth and Sports of the Czech Republic

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