Background

In recent years the interest of the nuclear research sector towards liquid lead alloys arose due to their selection as working fluids for advanced nuclear applications such as GEN IV, ADS and fusion. An important example is the development of the accelerator driven system MYRRHA (or XT-ADS) at SCK•CEN.

Although the risk of embrittlement of materials exposed to liquid metals has been recognized for many years, its prediction remains problematic due to the limited knowledge of the mechanisms involved in the phenomenon. Generally, when solid metals are exposed to liquid metals and stress is applied, they may undergo premature brittle failure known as liquid metal embrittlement (LME). It is characterized by a premature brittle failure of an otherwise ductile material when placed in contact with specific liquid metal for the material under stress. LME is of prime interest because of the risk of damage wherever the handling of liquid metals is required.

The ferritic-martensitic steel T91 and the austenitic stainless steel 316L have been selected as main candidate structural materials for the XT-ADS whereas the focus in the fusion community is mainly on the reduced activation steels such as EUROFER97. Recently, several European groups, within the FP5-MEGAPIE-TEST project, the FP6-project EUROTRANS and within fusion have launched studies to assess the compatibility of the selected steels with liquid lead alloys. However, the availability of mechanical testing facilities for irradiated materials in liquid lead alloy environment remains limited.

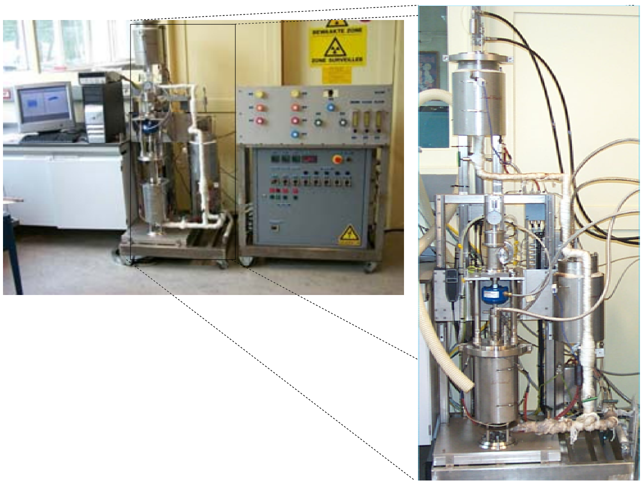
Objectives

SCK•CEN has committed itself to build out the necessary facilities to enable the mechanical testing of these candidate structural steels in liquid lead alloy environment. Requirements of these test facilities are well controlled chemistry conditions and temperature control of the liquid metal environment. As the interest of the study of the compatibility of structural materials with liquid lead alloys has its origin in different research programs, the testing installation should be able to change the liquid lead environment and allow for various types of mechanical tests.

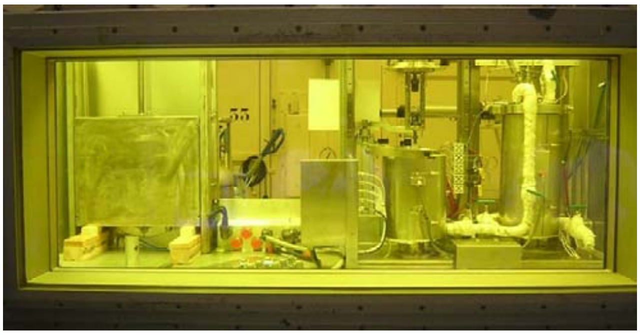
Principal results

In 2004 the first testing facility dedicated to performing tensile tests in liquid lead bismuth was built. This facility named LIquid Metal Embrittlement Testing Station 1 (Limets1) is shown in the picture below. Limets 1 allowed to perform tensile tests of non-active materials under well controlled conditions. This testing facility has proven to be a very useful tool in the research of the compatibility of structural materials T91 and 316L in liquid lead bismuth [1].

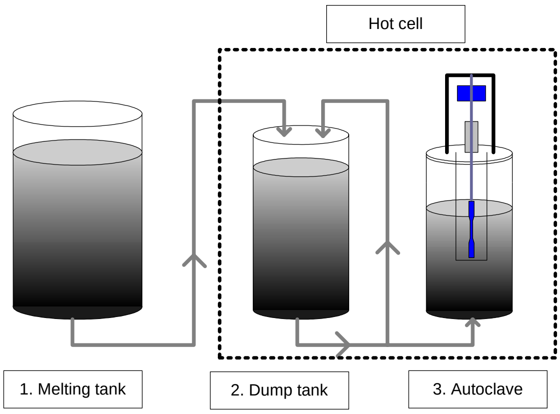
The need to investigate irradiated materials in liquid metal environment under well controlled conditions such as achieved in Limets 1 lead to the construction of Limets 2 in a hot-cell at LHMA.



The Limets 2 LME test set-up which is shown in the picture on the next page, has been constructed and received the necessary licenses to start active tests in liquid lead lithium at the end of 2006. Actual testing on active materials is expected to start beginning of 2007. Tensile tests can be performed with a loading unit allowing strain rates in the range of 10^{-3} to 10^{-7} s^{-1} with a maximum load of 20 kN.



The set-up consists of three vessels as shown in the schematic below. A typical test is then performed as follows. The first vessel (melting tank) is filled with solid particles of lead. Then the melting tank is heated to melt the lead. Melting can be performed under argon atmosphere. Then the melted lead is transported to the second vessel (dump tank) leaving the oxides formed during melting in the first vessel. A small over pressure is used to move the liquid metal from the melting tank (1) to the dump tank (2). From the dump tank, the lead melt can be transported to the autoclave (3) in the same way. A tensile specimen will be positioned in the tensile rig. This rig is present in the autoclave (3). Then the autoclave is filled with the melted lead and a slow strain rate tensile test can be carried out. When this tensile test is finished, the lead melt is brought back to the dump tank. A new test campaign can be started using the lead melt in the dump tank.



Future developments

In 2007 mechanical tests of irradiated EUROFER97 will be performed in liquid lead lithium environment for the fusion programme. When these tests are finished, the LIMETS2 will be modified to be used for tests in liquid lead-bismuth. This modification is necessary to allow testing of samples that have been irradiated in liquid lead bismuth in the BR2 reactor in the so-called Twin Astir experiment. This experiment, being the first of its kind, is a parameterisation study of the most important factors influencing material degradation in ADS environment. In order to allow mechanical testing of these materials in the Limets 2 set-up a modification is needed. This modification involves: replacement of the lead lithium with lead bismuth, adding a dismantling installation for the Twin Astir capsules and extending the license to allow testing in liquid lead bismuth environment.

Main contact person

Joris Van den Bosch, joris.van.den.bosch@sckcen.be

Main reference

[1] J. Van den Bosch, D. Sapundjiev, A. Almazouzi, *Effects of temperature and strain rate on the mechanical properties of T91 material tested in liquid lead bismuth*, J. Nucl. Mat., 356 (2006) 237-246.

[2] R.W. Bosch, S. Van Dyck, A. Almazouzi, *Investigation of the susceptibility of EUROFER97 in lead-lithium to Liquid Metal Embrittlement (LME)*, to be published in Fusion Engineering and Design.

[3] R.W. Bosch, A. Almazouzi, D. Sapundjiev, H. Dekien, *Development of a hot-cell test set-up for liquid metal embrittlement (LME) studies in lead-lithium and lead-bismuth*, In: Proceedings of EUROCORR 2005, Lisbon, Portugal, pp. 1-8.

[4] J. Van den Bosch, R.W. Bosch, A. Almazouzi, *Liquid Metal Embrittlement of ferritic-martensitic steel in liquid lead alloys*, to be published in Journal of Nuclear Materials.