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ENEA experience in LBE technology

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Abstract

Since 1999, several facilities have been operated with flowing LBE in the frame of ADS R&D activities at CR ENEA Brasimone. The experimental activities have gone through thermal-hydraulics, heat exchange, science of materials, qualification of components and operational procedures. Thanks to the performed work, a large amount of observations were made, and experience was gained. This paper is focused on the survey of these experiences gained, in order to point out advantages and disadvantages of the LBE technologies. In particular, experience on plant components, measurement instrumentations and operational procedures will be pointed out.

1. Introduction

Presently proposed accelerator-driven systems (ADS) are subcritical nuclear reactors in which the fission reaction chain is maintained in steady conditions by the injection of neutrons generated in a target material through the spallation reaction by a high energy proton beam produced in an external accelerator. The neutronic characteristics of the reactor are conceived as to efficiently incinerate long-lived fission products by transmutation, in order to reduce the need for very long term geological disposal of nuclear wastes produced in the nuclear reactor fuel cycle [1–3].

From the beginning of the most important research programs on these systems, the lead–bismuth eutectic (LBE) alloy was proposed as one of the most promising target materials as well as coolant for the reactor. Then, since 1999, several small devices as well as large loops and facilities have been operated at the CR ENEA Brasimone, to perform experimental activities aimed to investigate thermal-hydraulics, heat exchange, science of materials, qualification of components and operational procedures topics related to the use of LBE.

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2. Experimental facilities

2.1. The LECOR loop

The LECOR loop (lead corrosion) is a non-isothermal, eight shaped forced lead–bismuth loop, which consists of a surge tank, a mechanical pump, a heat exchanger, a heater, three test sections, an air cooler and a storage tank with 600 l liquid lead–bismuth eutectic (LBE). An oxygen sensor was installed close to the test sections to monitor the oxygen activity in LBE during the operation of the loop. The detail description of the LECOR loop is given in Ref. [12].

2.2. The CHEOPE III loop

The CHEOPE loop (chemistry and operations) is installed in the ENEA Brasimone Centre to evaluate the operation conditions for liquid metal. The CHEOPE III is one part of a multipurpose facility, which was used to perform the corrosion test in a controlled oxygen environment (with high oxygen activity comparing to that in the LECOR loop). The structure of this loop is similar to the LECOR loop. It consists of a storage tank filled with 400 l of LBE, a test section and an oxygen sensor.

In Table 1 the technical parameters of both loops are summarized.

2.3. The CIRCE facility

CIRCE (circulation experiment) [4–6] is a large-scale test facility designed for studying key operating principles of the 80 MW experimental accelerator-driven system (XADS). It basically consists of a reduced diameter (1:5 the XADS vessel diameter), full-height, cylindrical vessel (Main Vessel S100) filled with about 70 of tons molten LBE with argon cover gas and recirculation system, LBE heating and cooling systems, and auxiliary equipment for eutectic circulation [4,5]. Dedicated test section can be housed in the main vessel. The facility is completed by a LBE storage tank, by a small LBE transfer tank and by a data acquisition system. The facility is designed to perform large-scale experiments to investigate the thermal-hydraulic, chemical and mechanical issues related to the development of the LBE-cooled XADS in a pool configuration. The main parameters of CIRCE are given in Table 2.

Table 1
LECOR and CHEOPE main working parameters

Parameters	LECOR loop	CHEOPE III loop
Temperature in the test section (°C)	400	400
Temperature in the cold part (°C)	300	300
Test time (h)	1500, 4500	1500, 3000, 4500
Velocity in the test section (m/s)	1	1
Oxygen concentration (wt%)	10^{-10}–10^{-8}	10^{-6}–10^{-5}

Table 2
CIRCE main vessel parameters

Outside diameter	1200 mm
Wall thickness	15 mm
Height	8500 mm
LBE inventory	70 tons
Operating temperature range	200–550 °C

3. Plant components

3.1. Standard component available on market

The experimental facilities have been built mounting the standard components available in the specialized scientific and industrial markets in order to reduce the costs of the research activities and the time for the implementation of the facilities; in this way was possible to improve the reliability and the repeatability of the tests.

For example, the measuring instrumentation includes calibrated K-type thermocouples, electromagnetic and vortex flow meters and differential pressure transducers, which are commonly utilized in standard industrial applications; the data acquisition system that consists of a personal computer, a data acquisition board and several conditioning modules, is the same kind of the other ones installed in several facilities.

3.2. Mechanical pumps

The pumping system, at the first moment, had some problems related to the pump chosen. It was a Novatome (Fr) electro magnetic pump. The deposition of LBE oxides over the internal surface of the pipe compromised the functioning of the pump, downgrading its already low efficiency (∼5%).

In order to solve this problem, two mechanical pumps (see Table 3) were installed on the LECOR