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LECOTELO – INSTALLATION USED FOR CORROSION/EROSION TESTING OF STRUCTURAL MATERIALS IN MOLTEN LEAD

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Generation IV nuclear reactors aim at efficient use of fuel, decreasing waste, reducing the proliferation and operational risks. Member of FALCON Corporation, ICN Pitesti together with ENEA and ANSALDO aims at achieving the Generation IV reactor, ALFRED, and preparing specialists in fast reactors (LFR) is one of the priorities of the institute. Thus, in Pitesti ICN was carried out and improves LECOTELO installation, which is intended for the study corrosion / erosion of metals in the environment of lead liquid. This paper summarizes the LECOTELO project, the problems appeared in the realization and putting it into operation and the results of the first tests.

Keywords: LECOTELO, corrosion loop, HLM

1. Introduction

Heavy metal liquids (HLM) such as Pb, Na or the eutectic alloy Pb-Bi (LBE) have been proposed and analyzed as coolants for fast reactors since the 1950s.

Since 2000, ten countries have joined together to form the Generation IV International Forum to support the realization of a new generation of reactors that meets the new requirements of global economic growth [1]. An agreement was signed in 2013 between ANSALDO Nuclear, ENEA and ICN Pitesti to form the FOLCON consortium (Fostering Alfred construction), aiming to achieve a pan-European infrastructure for lead technology. Its main component, the reactor demonstrator ALFRED, will be built in Romania. As a result, the LECOTELO installation is being built at ICN Pitesti - the first installation of the Institute used for the Study of corrosion / erosion of metals in a molted lead environment – the present paper describes its construction and putting it into operation.

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2. LECOTELO installation [3]

LECOTELO (Lead COrosion test loop) is an experimental installation which circulates molten lead, used to carry out tests to study the corrosion of various structural metal materials in a molten lead environment and the behaviour of the plant components in terms of the specific requirements of the installation.

The LECOTELO plant (Fig. 3.1) is made of austenitic steel 316 L and has the following main components: a centrifugal pump, vessels for melting and storage, central vessel for positioning test samples, equipment for monitoring the movement of lead through the testing loop and temperature control systems.

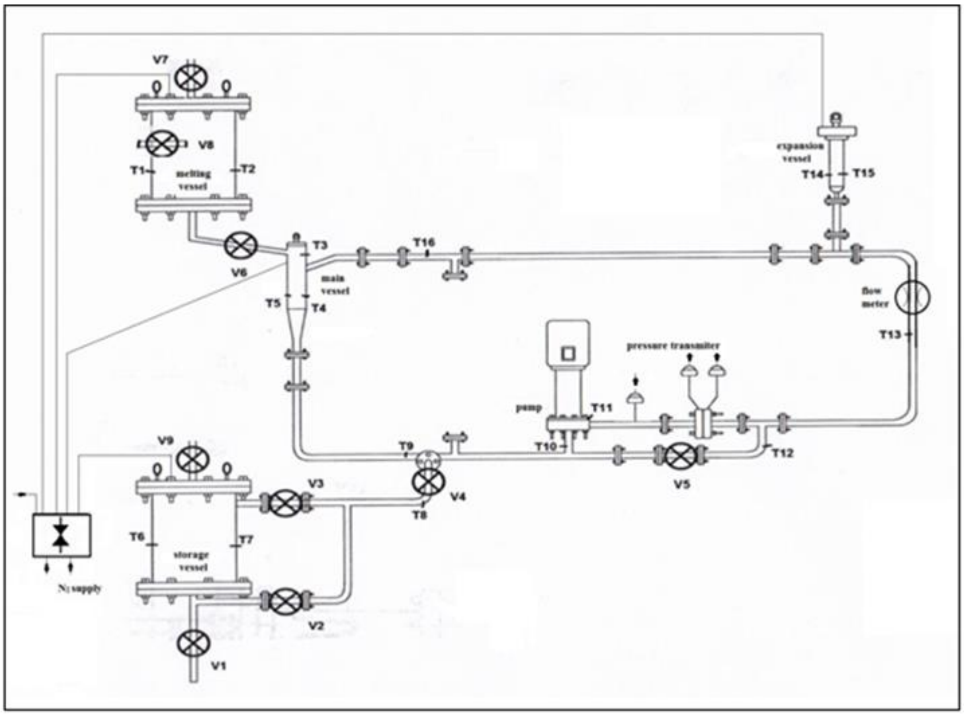

Fig. 3.1 - LECOTELO loop

The technical characteristics of the installation are as follows:

- Dimensions (L x ℓ H [mm]):	5040 x 1650 x 4250;
- Molten Metal circulated:	lead;
- Molten metal temperature:	~ 350 ± 2ºC;
- The volume of molten lead in the installation:	~ 12 liters;
- lead working pressure:	~ 3 bar;
- Pressure of the nitrogen cushion:	~ 1 bar;
- Voltage of the installation:	380Vc.a;
- Power supply to the pump:	380Vc.a.

In the technical design, the vessels used for melting /storage (Fig. 3.2) were provided with four 1000W resistors on the inside and 3000W resistant mattresses on the outside, resulting in a total power of 7000 W / vessel. Since the supplier of the electrical resistors necessary to equip the plant was changed, the resistors purchased had another configuration. In these conditions, the project was modified so that the vessel is equipped with nine 400W electrical resistant cartridges on the insider and four 1500 W resistors on the outside, resulting in a total of 9600 W, enough electrical power to melt the lead in the vessel and keep the vessel temperature to its working amount. The upper melting vessel was dropped, using only the lower vessel for melting and storage.

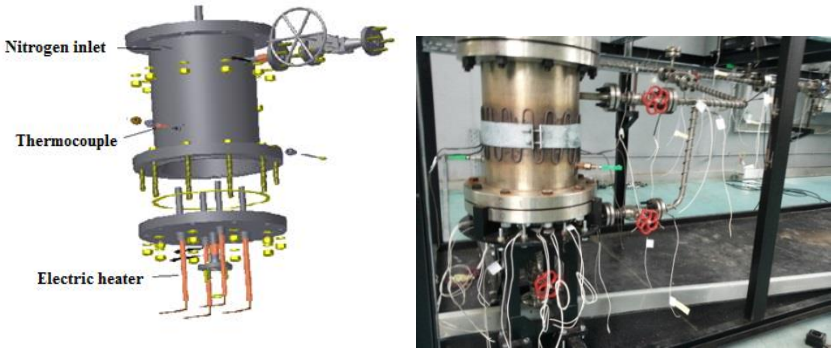

Fig. 3.2 - Melting/storage vessel

The transfer of lead between the vessel and the plant is done by gravity drop or by using the pressure of a gas (nitrogen) which, when in the vessel, pushes the lead into the plant that was a vacuum beforehand.

The main vessel (fig. 3.3) represents a subassembly in which test samples subject to corrosion tests are located. The samples are mounted in a holder which is fixed on a central rod, the whole assembly being introduced into the vessel through the top.

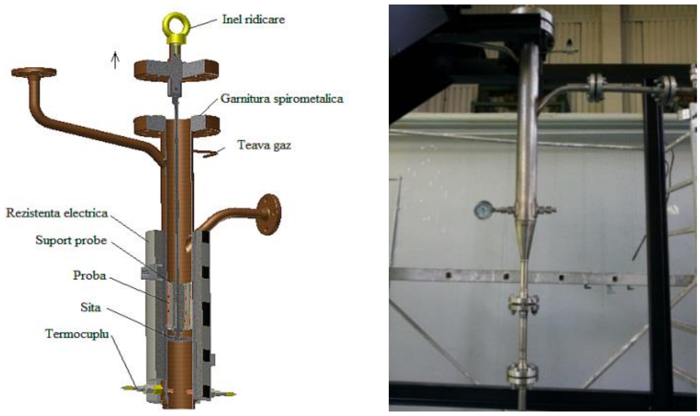

Fig. 3.3 – Vasul principal Main Vessel

The dimensions of samples placed in the holder (Fig. 4) are 30x20x2 mm. They are introduced using a forceps and blocked into position by the little space between the outer diameter of the sample holder and the inner diameter of the central vessel.

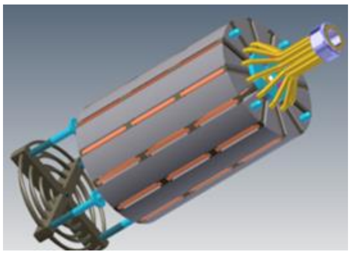

Fig. 3.4 – Suportul de probe / Sample holder

As a comparison, in the CORIDA installation from KIT - Germany, the samples used for experiments are cylindrical (Ø8 x 35 mm) and are fixed into position (16 pieces) by threading them onto the rod that is inserted into the test section [1]. In similar HLM research facilities, positive displacement, magnetic or electromagnetic pumps are used to move molten metal. Thus, at SCK-CEN – Mol, installations such as Liliputter, MEXICO or CRAFT are equipped with screw pumps (Fig. 3.5) or permanent magnets pump (Fig. 3.6) [2].

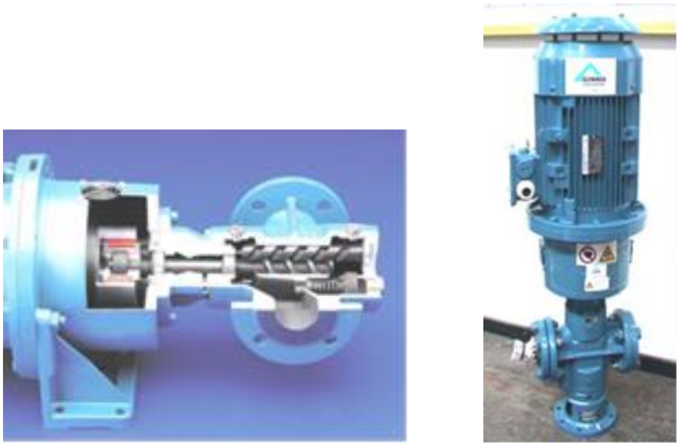

Fig. 3.5 – SCK*CEN Screw pump, Mexico, Liliputter

Fig. 3.6 – Permanent magnets pump

In Germany, at the Karlsruhe Institute of Technology, electromagnetic pumps are used in many installations.

The pump used in the LECOTELO loop was designed so that a speed of up to 2 m / s can be achieved in the main vessel. This decision was made after several CFD simulations using ANSYS software. The pump is an atypical centrifugal pump because the housing is not a spiral, but is concentric with the rotor with a semi- cylindrical channel section. The radial channels of the rotor are shown in Fig. 3.7, and the radial discharge was chosen for the pump exit.

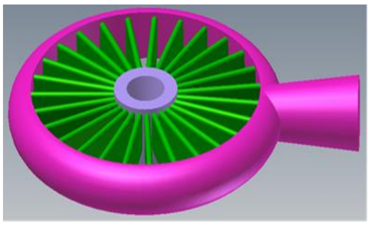

Fig. 3.7 –The volume occupied by the fluid in the pump (rotor channels, casing channel and pump discharge nozzle)

The Pump rotor has a diameter of 150 mm and 27 rectangular radial channels, as shown in Fig. 3.8.

Fig. 3.8 – Rotorul pompei Pump Rotor

An image of the pump - electric motor assembly is shown in Fig. 3.9. The engine has an output of 9.2 kW at 2990 r / min.

The drive shaft of the pump was designed to provide enough space to prevent overheating the engine from the pump and its suction and discharge circuits. The shaft uses a mixed sealing system: graphite bushings / sealing cord.

Fig. 3.9 –LECOTELO loop, pump asambly

The pressure generated by the system is measured by a pressure transducer with capillary tube. The tube is intended to reduce the temperature transmitted to the transducer under the operating temperature (350 – 450^0 C), thus preventing its damage.

LECOTELO's electrical system covers circuits necessary for control, automation and powering the consumers, a terminal box and its associated circuitry for powering the electrical resistances, the motor driving the pump and necessary circuitry for the data acquisition system, all being integrated in a power switchboard.

3. Equipping the installation for performing functional tests [4]

Equipping the components and their installation in the plant was done by joining technical information and conclusions derived from the in houses tests, functional tests with water and functional tests with electric resistances mounted on a section of the sample. Because the installation has several sections with links through flanges which have low heat transfer efficiency, the number of electrical resistances specified in the technical project nearly doubled in order to achieve the necessary operating temperature. Resistances were wrapped around all the circuits; ultimately the installation was fitted with 39 electrical resistances in each section, 4 coil resistances and the cartridge resistances of the melting pot.

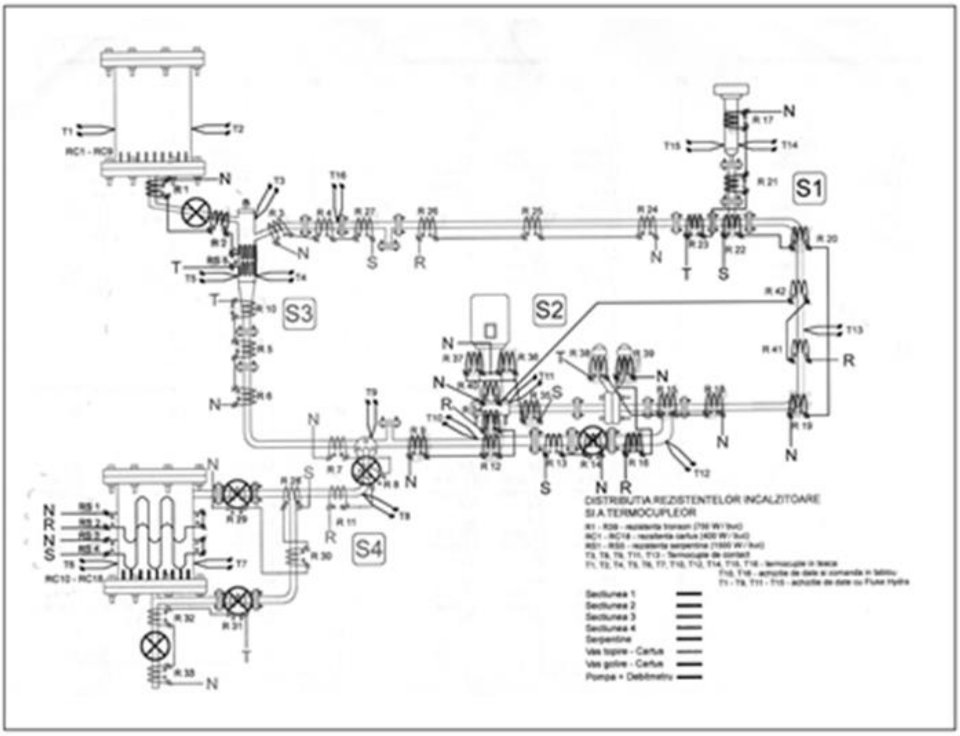

Fig. 3.1 – The location of the electrical resistors

Supplying the electrical resistance lead to a modification in the electrical power supply circuit; this resulted in changes in the supply and control panel, but not in a reconfiguration of the electrical panel. After the setting the electrical connections used to power the heating systems and the measurement and control system, the installation was ready for coupling the Hydra data acquisition system and starting testing (Fig. 3.2).

Fig. 3.2 - Fully equipped installation, ready to be connected to Hydra

4. Tests [3,4]

Before pre-operational tests, a series of in house tests were conducted to determine the functional characteristics of the installation
Diagrams of the pressure drop of the main vessel or of the flow meter with respect to the speed of the pump are shown in Fig. (4.1, 4.2)

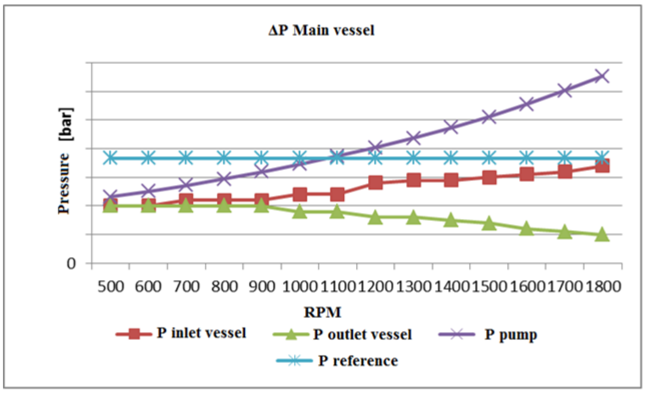

Fig. 4.1 – Δ P main vessel

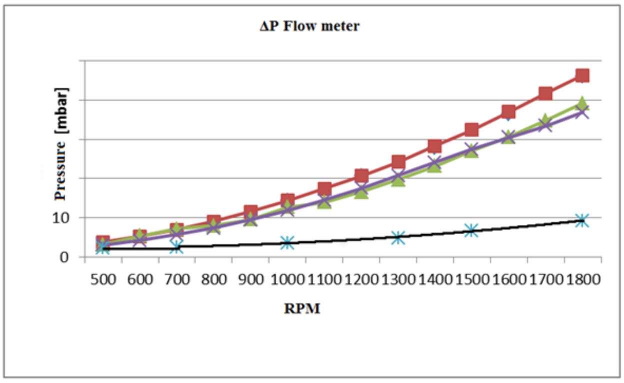

Fig. 4.2 – Δ P flow meter

The most important functional tests are the pre-operational tests that determine the characteristic operating curves of the pump. These tests were scheduled to be held in two stages. The first phase involved calibration of the monitoring and data acquisition system, functional tests of the heating system on each section, melting lead in the emptying vessel and cleaning the vessel of impurities.

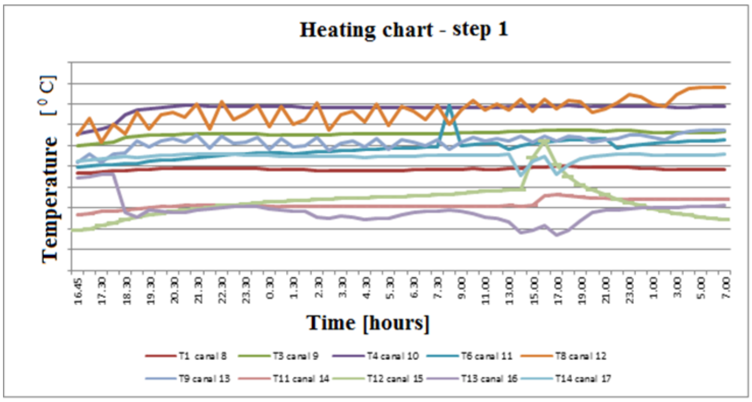

Fig. 4.3 – Heating chart – 1st stage

During the heating process, the increase in temperature was monitored by 8 thermocouples placed on the vessels and circuits of the installation. Additional 4 thermocouples were placed on the backup circuits. Fig. 4.3 shows the temperature variation curves for a period of 40 hours.

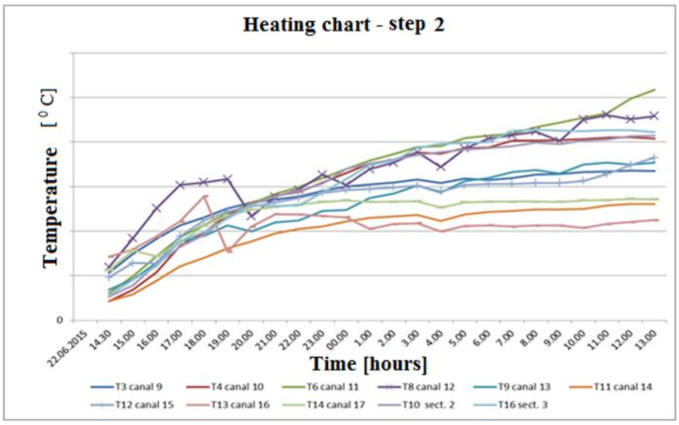

Fig. 4.4 - Heating chart – 2nd stage

Thermocouples distribution was as follows:

T1 - Melting vessel (superior)	T9 - section 4.2
T3 - central vessel (flange)	T11 - pump (cover)
T4 - central vessel	T12 - bypass circuit
T6 - Melting / drain vessel	T13 - flowmeter
T8 – Section 4.1	T14 - Expansion vessel

In the second stage, after bringing the installation to working parameters, tests were scheduled to increase the operating characteristics of the pump. The heating chart is shown in Fig. 4.4. Unfortunately, the pump was blocked at the start of the first functional test because of the shaft sealing system. At the moment, the pump is being repaired and the plant/installation is being prepared for reinstatement.

5. Conclusions

The development of molten metal-cooled reactors has become an increasingly important direction for research and expansion of nuclear research institutes, this being included in the program of research / development of ICN Pitesti. This paper presents a brief description of the Lecotelo installation, the main steps followed to build and prepare the facility for operation, and some of the results obtained following in-house functional tests.

The Lecotelo plant, designed and built within the Institute, aims to achieve the necessary conditions for studying phenomena that occur in molten metal environments. It is designed to study the erosion and corrosion behaviour of various types of structural materials used in the nuclear industry. It also desired to study the operation of various thermal-hydraulic equipment in a molten metal environment, an, last but not least, to allow ICN to familiarize its researchers with facilities of this kind. The program of the Lecotelo project continues with pre-operational testing, using molten lead as a working fluid, in order to determine its capability to perform corrosion tests on metals in different flow regimes.

Acknowledgement

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