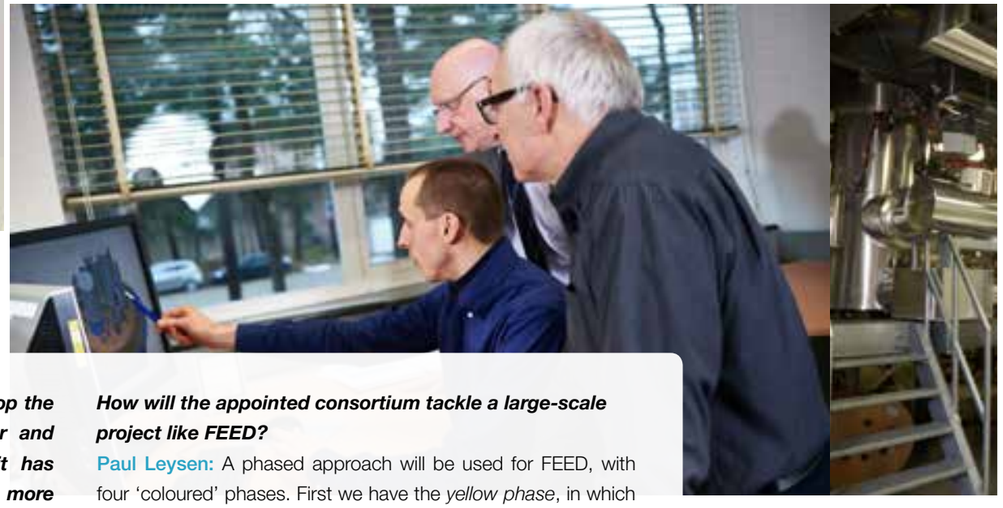
Paul Leysen
'FEED runs in four phases until mid-2016.'



Obviously SCK•CEN will develop the primary system – the reactor and related systems – because it has the know-how to do it. The more conventional aspects of the structure have been outsourced to an external consulting firm. Who was given the contract?

Paul Leysen: In 2011 we started the tendering process for this large contract. We followed the steps required by law, and in October 2013 we signed a contract with the selected consortium. This consortium is composed of Areva TA, Ansaldo Nucleare, and Empresarios Agrupados, with the Belgian company Grontmij as subcontractor of AREVA TA. Their job is to implement the design, what we call FEED, which stands for Front End Engineering Design. This will take approximately two and a half years, which is until mid-2016.

What are the objectives of FEED?

Paul Leysen: The consortium must work out the design project in such a way that we get an answer to three questions. *One:* what will the investment cost? The answer will be a budget estimate with a margin of around 25 percent. *Two:* can this innovative project be licensed from a nuclear point of view? FANC will have to answer that question. And *three:* how will the project continue? The answer to that question is a construction planning model in which the project is divided into twenty or so lots for detailed engineering and construction.

How will the appointed consortium tackle a large-scale project like FEED?

Paul Leysen: A phased approach will be used for FEED, with four 'coloured' phases. First we have the *yellow phase*, in which the primary nuclear process (reactor, cooling, essential buildings, enclosure and nuclear protection) is described in sufficient detail to provide answers to the focus points raised by FANC. This is followed by the *green phase*, in which the major cost items of the project are identified and budgeted. The third step is the *blue phase*: all the necessary elements are worked out in detail to enable FANC to draw up an entirely positive pre-licensing document. Finally, in the *red phase* everything is worked out in such a way that the cost estimate, construction planning, lot definition and specifications can be drawn up.

So FEED is now in the yellow phase?

Paul Leysen: Yes, that's right. The external consortium is busy collecting all the data that will form the basis for the design work. We will round off the yellow phase within a year, towards the end of 2014. This phase ends with a multidisciplinary overall engineering review, in which we bring together the design work of the various disciplines into one large whole that will form the basis for the green phase.

MEXICO loop provides essential technology for MYRRHA

SCK•CEN investigates the chemistry of lead-bismuth

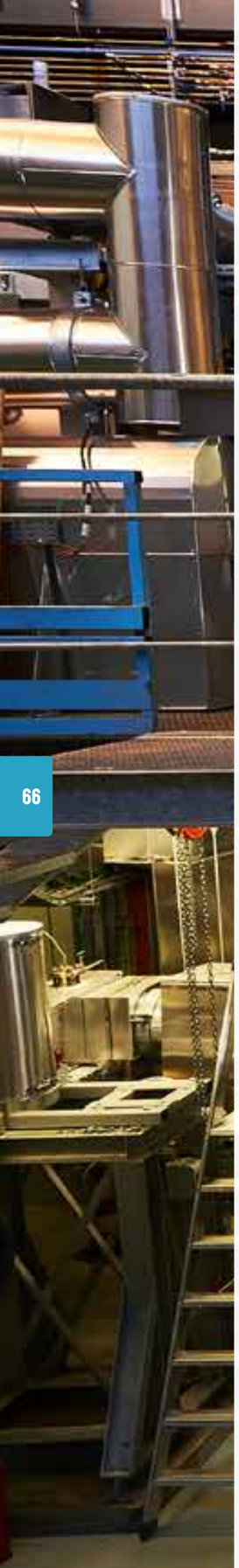
In MYRRHA, Lead-Bismuth Eutectic (LBE) alloy will act as the primary coolant. There are different experimental lead-bismuth loops in the world. Most have been designed to study steel corrosion in LBE or the thermohydraulics of LBE. MEXICO, a test loop developed by SCK•CEN, is unique in that it can be used to study the chemistry of lead-bismuth.

Studies by Russian and European research institutes have already shown that dissolved oxygen plays an important role in the LBE-induced process of steel corrosion. To keep this process under control, the oxygen level in LBE must be sufficiently high. A protective oxide coating will form on the steel structure. But too much oxygen is not good either, as the LBE coolant can begin to form oxides. Oxygen monitoring is therefore an essential technology to keep MYRRHA operating optimally throughout the entire planned lifecycle. It involves monitoring both the oxygen level and the quality of LBE, and minimizing contaminants by filtering.

Oxygen monitoring by MEXICO

SCK•CEN has developed the experimental MEXICO loop (Mass EXchanger In Continuous Operation) for the specific purpose of chemically controlling the LBE coolant technology. The first and foremost aim of MEXICO is to develop an oxygen monitoring system for MYRRHA. The dissolved oxygen in LBE will be consumed by structural steel oxidation processes in the primary system of MYRRHA. To keep the oxygen concentration at the required level, oxygen must be added to LBE in a controlled manner. This can be done by means of diluted oxygen gas, solid oxide, or a method using electrochemical oxygen pumps. All three methods are currently being investigated.

The first option chosen for MYRRHA was an oxygen monitoring system using a solid lead oxide mass exchanger. Engineers are studying the properties of lead oxide mass exchange in LBE in terms of kinetics, chemical stability and controllability.



> *MEXICO is a unique test loop to study the chemistry of lead-bismuth eutectic.*

Numerical modelling of the oxygen mass transfer

In order to predict the oxygen level in MYRRHA's primary system, SCK•CEN has developed a numerical model for oxygen mass transfer in LBE using a commercial CFD code (Computational Fluid Dynamics). The model will be validated on the basis of test results from the MEXICO loop. The validated model will then be ready to use for simulations of MYRRHA and for setting up a monitoring system that regulates the oxygen on the basis of the oxygen concentration. An additional purpose of MEXICO is to test the filtration system for purifying LBE.

Unique test loop

By coupling two heating zones and two heat exchangers, MEXICO has three temperature zones, instead of two as in most LBE test loops. This flexibility allows the researchers to efficiently study the coolant chemistry over a wide temperature range. A total of 23 oxygen sensors were set up in MEXICO at different positions from the highest to the lowest temperature zone. In this way, the variation in oxygen levels can be monitored throughout the loop. The sensors will produce data for validating the numerical model for oxygen mass transfer in LBE. The MEXICO loop also has two filtration systems to separate suspended solid contaminants and dissolved impurities.

SCK•CEN completed the final engineering design at the end of 2012. One year later, the construction work was completely finished. MEXICO is the result of a fruitful partnership between the *Conditioning and Chemistry Programme* unit and the *Design and Engineering Office*. Besides the design and construction work, some important technologies were developed and validated in 2013 for the operation of MEXICO, such as the manufacturing processes for high-quality lead oxide pellets and new sensors for measuring oxygen in a low temperature zone. A major experimental campaign will start in early 2014 that will yield valuable input for MYRRHA.