VELLA

{Virtual European Lead LAboratory}

VELLA NEWSLETTER	Year 1, issue 1

CALENDAR OF THE EVENTS

April 22-26th, 2007, **ICONE 15**, Nagoya congress centre, Nagoya, Japan
http://www.icone15.org/

May 6-9th, 2007, **Fifth International Workshop on the Utilisation and Reliability of High Power Proton Accelerators (HPPA5),** Mol, Belgium
http://www.nea.fr/html/science/hpa5/index.html

May 13-18th, 2007, **ICAPP 2007**, Nice Acropolis, France
http://www3.inspi.ufl.edu/icapp07/index.html

May 21-23rd, 2007, **IV Workshop on materials for HLM cooled reactors and related technologies**, Roma, Italy
http://web.brasimone.enea.it/

June4-6th, 2007, **workshop on "Structural Materials for Innovative NuclearSystems" (SMINS)**,Karlsruhe, Germany
http://www.nea.fr/html/science/struct_mater

September 16-19th, 2007, **ENC 2007**, Brussels, Belgium
http://www.euronuclear.org/events/enc / enc2007/index.htm

September 24th -October 6th, 2007, **MATGEN-IV**, Cargese, Corsica, France
http://www-matgen4.cea.fr

IN THIS ISSUE

VELLA: towards a common European research area on HLM technologies

G. Benamati[1], H.A.Abderrahim[2]

[1] C.R. ENEA Brasimone, 40032 Camugnano (Bo), Italy, gianluca.benamati@brasimone.enea.it

[2] SCK-CEN, Boeretang 200, BE-2400 Mol, Belgium, Haitabde@sckcen.be

The VELLA (Virtual European Lead LAboratory) initiative is an Euratom FP6 project which has the ambitious intent to create a virtual laboratory for lead technologies. More in detail, the final goal of the project is to create a common research area among the European Union and its associate countries (such as Switzerland) (EU) in the field of lead technologies for nuclear applications.
Due to its attractive properties, in fact, a wide use of pure lead, as well as its alloys (such as lead-bismuth, lead-lithium), is foreseen in several nuclear-related fields: it is studied as coolant for critical and sub-critical nuclear reactors, as spallation target for neutron generation and for tritium production in fusion systems.
Given this foreseen future extensive use of lead in nuclear systems, a deep understanding of its physical properties and engineering applications is not only desirable, but absolutely necessary. As a consequence, given the quite limited nowadays experience , large efforts both at national level as well as within the EU are dedicated to the heavy liquid metal (HLM) technologies.
In particular, the European Union is promoting several large R&D programmes, among which we can mention EUROTRANS- DEMETRA (*EUROpean research programme for the TRANSmutation of high level nuclear waste in Accelerator Driven Systems-DEvelopment and assessment of structural materials and heavy liquid MEtal technologies for TRAnsmutation systems*), ELSY (*European Lead-Cooled System*) and VELLA, which major objective is to integrate the existing European infrastructures, developing synergies and complementarities among the laboratories and the research groups.

As already hinted, the driving idea of VELLA is to homogenize the European research area in the field of lead technologies for nuclear applications in order to produce a common platform of work which continues also after the end of the initiative.

Above all, VELLA has the ambitious intent to both create a network of all the principal laboratories and to strongly connect the different groups of experts, in order to have a common definition of the good operational practices and to promote the exchange of the scientific results by means of appropriate and innovative tools and procedures, creating a common platform
It also has the significant objectives to promote the access to the main existing facilities in the EU to different specialist groups, support the technological development and the qualification activities and create a homogenous European “scientific community”, organized to support all the required technological challenges and the necessary research requirements.

In this framework, detailing the abovementioned goals, VELLA is articulated in *Networking Activities* (NA), *Transnational Accesses* activities (TA) and *Joint Research Activities* (JRA).
The scope of the NA is to create a virtual community of researchers, to define common standards and protocols for the use of the facilities and to interact with the programmes and the institutions operating in this field. The objectives of the TA are to promote the access of researchers, universities and firms to the existing infrastructures and knowledge, in order to increase the competitiveness of the European industry, to train the researchers in using the EU infrastructures during the three years duration of the project and to help the human mobility between and towards the laboratories. The JRA have the goals to create a base of knowledge on lead technologies, develop and operate HLM components and instrumentations, study the HLM thermal hydraulics.

Fusion Reactor Tritium Breeding Blankets: Mock-ups testing in ITER and importance of PbLi as candidate T-breeder material

L. Giancarli
CEA-Saclay, DEN/CPT, 91191 Gif-sur-Yvette, France, luciano.giancarli@cea.fr

Breeding blankets represent one of the major technological breakthroughs required from passing from ITER to the next step, usually called DEMO, a demonstration reactor able to furnish electricity power to the grid. In fact, a DEMO breeding blanket and associated systems have to ensure Tritium breeding self-sufficiency, to show good power conversion efficiency and to withstand high neutron fluence. For this reason, among the technical objectives of ITER it is specifically stated that “ITER should test tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency and to the extraction of high grade heat and electricity production”.

In order to comply with this mission, a working group, called ITER Test Blanket Working Group (TBWG), has been officially established by the ITER and charged to define and coordinate an appropriate breeding blanket testing program in ITER. The TBWG is formed by representatives from ITER Team and from each of the ITER Parties participating to the corresponding ITER phase.

The TBWG assessment has indicated that breeding blankets and their integrated first wall for DEMO reactors have several feasibility issues which require large R&D efforts. The capability of reaching Tritium breeding self-sufficiency has yet to be demonstrated. ITER may be the only opportunity for testing breeding blankets mock-ups (TBMs) in a real fusion environment before the construction of a DEMO reactor, ensuring relevant magnetic field, surface heat flux, and disruption-induced loads in the initial H-H phase and additional relevant neutron flux and Tritium control/management capabilities in the following D-T phase. Major testing objectives will be: i) validation of structural integrity theoretical predictions under combined and relevant thermal, mechanical and electromagnetic loads, ii) validation of Tritium breeding predictions, iii) validation of Tritium recovery process efficiency and T-inventories in blanket materials, iv) validation of thermal predictions for strongly heterogeneous breeding blanket concepts with volumetric heat sources, and v) demonstration of the integral performance of the blankets systems.

Various blanket designs using specific materials combinations are proposed by the different ITER parties. Resulting from a selection based on many years of studies and R&D, four major blanket families are proposed for testing, namely: 1) He-cooled ceramic/Be blankets using Ferritic/ Martensitic Steel (FMS) structures, pebble-beds of Li-based ceramics and pebble-beds or porous Be, 2) He-cooled or Dual-coolant (He) Lithium-Lead blankets with FMS structures, 3) Water-cooled pebble-beds ceramic/Be blankets with FMS structures, 4) Self-cooled or He-cooled Molten Lithium blankets.

Breeding blankets using Lithium-Lead (LL) and FMS structures are proposed by several Parties. EU has selected the Helium-Cooled (HCLL) version, while US, China and India have selected the Dual-Coolant (DCLL) version, with He cooled FW and structures while PbLi is the coolant for the breeder zone. Also Japan and RF have expressed interest on this family of blankets.

In particular, all proposed PbLi-based TBM designs consist of a single martensitic steel box reinforced by He-cooled steel stiffeners, and use He at 8 MPa with Tin=300 and Tout up to 500°C. The eutectic Pb-15.8Li is the selected PbLi compound (melting point 235°C). The EU design uses only He as coolant while the DCLL design uses both He and PbLi coolant at Tin of 460°C and Tout up to 700°C. In the DCLL concept, PbLi and steel walls are separated by SiC/SiC flow channel inserts in order to provide the required thermal and electrical insulation. PbLi circuit components are located in the ITER port cell, the recovered Tritium is sent to the ITER Tritium system.

A large R&D effort on PbLi-based blankets is on-going worldwide for several decades, since it is recognized the PbLi is one of the most promising T-breeder materials for fusion power. The largest R&D program for this type of blankets is performed in EU. Besides the corresponding design activities, most R&D is devoted to the blanket structural materials (aiming to minimize the corresponding nuclear waste and to improve the operation temperatures) and the establishment of the complete data base for PbLi.

For Eurofer, the EU grade of FMS, most physical properties before irradiation are already well known and have been used in performing the TBM designs. Properties after irradiation are being studied in fission reactor experiments, and the most critical one appears to be the Ductile-to-Brittle Transition Temperature (DBTT) at high doses. Other R&D areas include design code qualification, tritium-related properties (e.g., solubility, permeability) needed for T-control and management, compatibility with breeder materials and coolants, compatibility with coating fabrication process, and modeling of irradiation effects. For Eurofer, little industrial production experience is available. Moreover, component assembly and joining technologies are not yet available. Experimental work on various techniques, such as HIP, laser welds and EB welds, is being performed at the laboratory level, but significant R&D is still required before reaching the industrial scale.

For PbLi, areas of R&D include compatibility with F/M steels and SiC/SiC, tritium solubility, MHD effects, and the tritium extraction process. Efficient purification processes for activated elements and for corrosion products need to be further developed. In a LL TBM, the lithium has to be enriched in the range of 70% up to 90% in 6Li.

In conclusion, it must be said that, after successful ITER operations, breeding blankets development will become one of the most challenging issues that will remain to be addressed for designing and constructing a DEMO reactor. The tests of DEMO-relevant TBMs in ITER will give essential information to accomplish such a development. In this context, it is internationally recognized that Lithium-Lead is one of the most promising breeder materials and, when used also as coolant, is the only one allowing to achieve very high operation temperatures (700°C or above) with consequent potentially high reactor thermal efficiency.

The VELLA Transnational Access activities

C. Fazio,
FZK, Forschungszentrum Karlsruhe GmbH, Hermann-von-Helmholtz-Platz 1,
D 76344 Eggenstein-Leopoldshafen, Germany, concetta.fazio@nuklear.fzk.de

The Transnational Access (TA) objectives are to promote the access of researchers, universities and SMEs to the existing European Heavy Liquid Metal (Pb, Pb-Bi eutectic, etc.) infrastructures and knowledge, in order to increase competitiveness of the European industry, to train researchers and to foster human mobility between and towards the laboratories.
The two components of the VELLA TA are:

- Users interested in technological development and/or basic research are granted for access to the infrastructures
- The mobility of researchers is supported both inside and outside the VELLA Consortium.

Access to the infrastructures

The European HLM platform

The European laboratories, partners of the VELLA consortium, are equipped with laboratory scale and prototypical scale facilities which all together constitute an important technological platform in the field of materials studies, thermal-hydraulics and liquid metal chemistry. An important action of VELLA is to create a network of those laboratories in order to offer to the European Community homogenous tools for the study and development of HLM systems. In particular, the facilities dedicated to the materials studies have been networked in a one virtual laboratory called “MATLAB”. In a similar way all facilities used for the liquid metal chemical studies have been networked in the virtual laboratory “CHEMLAB” and finally the prototypical scale facilities dedicated mainly to thermal-hydraulics studies constitutes the “Large Facilities” component of the infrastructure. Through the VELLA TA there is now the unique opportunity to access these network of European laboratories for researchers and users (e.g. SMEs, Universities, Research groups).

MATLAB

MATLAB (MATerial LABoratory) has been initiated to meet the willing of different laboratories spread through the EU to act as a unique structure, in order to offer the opportunity to perform test campaigns on materials for different HLM components and applications. Within this virtual lab it is possible to perform several types of materials studies in HLM. Indeed, the possible tests include tensile, fatigue, fracture toughness, creep and corrosion investigations on irradiated and not irradiated materials
The MATLAB includes the following facilities.
For tests of not irradiated materials in flowing HLM:

- LECOR & CHOEPE III (ENEA, Italy)
- COLONRI I&II (NRI, Czech Republic)
- LINCE (CIEMAT, Spain)
- CORRIDA (FZK, Germany)
- CICLAD (CEA, France)

For screening tests and mechanical test in stagnant HLM:

- LIMETS I&II (SCK.CEN, Belgium) (mechanical tests on irradiated materials)
- COSTA 1-6 (FZK, Germany)
- COLIMESTRA (CEA, France)

CHEMLAB

CHEMLAB (CHEMistry LABoratory) is a virtual laboratory for the study of chemical and physical properties of the HLM. The aim is to develop appropriate chemistry control methods and techniques (e.g. oxygen control and monitoring, aerosols and slags in the liquid and gas phase) for the different applications.
The facilities of CHEMLAB are:

· ELEFANT (FZD, Germany)
· STELLA (CEA, France)
· OCEAN & THESYS (FZK, Germany)
· CHEOPE II (ENEA, Italy)

Large facilities

The large facilities made available for the VELLA transnational access are:

· "CIRCE" (ENEA, Italy), which is a pool type facility for the study of thermal – hydraulics issues
· "TALL" (KTH, Sweden) was originally designed to investigate the thermal-hydraulic phenomena for normal and transient conditions of the accelerator driven system.
· "KALLA" (FZK, Germany) modular facility having relevant dimension for basic thermal-hydraulic studies and components test

More details on the facilities are given in the VELLA web page: www.3i-vella.eu

This VELLA infrastructure concept makes these virtual laboratories easily accessible by researchers and they are enough flexible to give integrated answer to complex questions (i.e. materials selection for HLM components, qualification of instruments and technologies). Moreover, the idea of networking, sharing of know-how and human mobility is an important contribution to the European Research Area.

Human Mobility

The VELLA TA has foreseen also grants to support the mobility of

· Researchers, PhD students, Master Students etc. belonging to the VELLA associations and working on joint research activities.
· Researchers, PhD students, Master Students etc. coming from European countries or institutes outside the VELLA consortium and participating to a transitional access.

Rules to Apply to the VELLA TA and calls

The rules and procedures to apply to the two VELLA TA components (Access to infrastructure and Human Mobility) are given in the VELLA web page: www.3i-vella.eu.

The first call of TA has been opened on February 12th and the deadline is March 20th. The next call will be opened in July 2007 and have its deadline at the end of September 2007.

The potential of LFR for a safe, economic and sustainable nuclear energy generation

L. Cinotti,
Del Fungo Giera Energia S.p.A., Italy
luciano.cinotti@delfungogieraenergia.com

In the nineties, Russia has partially disclosed its lead-bismuth technology developed for cooling submarine-propulsion reactors and made it available for the use as civilian nuclear technology of the future. Moreover, the Russian Research and Development Institute of Power Engineering (NIKIET) with the BREST fast reactor concept and associated fuel cycle has indicated an innovative approach to nuclear waste management in a closed fuel cycle.

To day, the interest in nuclear waste management has become larger and larger and consequently has renewed the interest towards fast reactors.

As regards to lead technology, alternate phases of increasing and decreasing interest have characterized the international scenario.

In a first phase the potential of molten lead as the reactor coolant has been emphasized, especially for expectation of plant simplification and increased safety, thanks to peculiar characteristics. In fact:

Lead does not react with water making possible the elimination of the Intermediate Cooling System with reduction of capital cost, construction time and O&M costs.

Lead does not burn in air resulting in less stringent requirements of leak tightness and in the simplification of the fuel handling system.

Lead has a very low vapour pressure (boiling point 1745 °C) making primary system pressurization almost impossible. The high lead boiling point and the negative total core void coefficient exclude also the risk of large reactivity increase.

Lead is a weak moderating medium and has low absorption cross-section .This allows the designer to arrange in the Reactor Vessel a large, fast-to-thermal continuous neutron flux region, useable to fission minor actinides and to transmute selected long-lived fission fragments, particularly where the neutron energy corresponds to the resonance absorption of the waste nuclides, thus maximising the incineration yield, and to use fuel subassemblies with fuel rods spaced larger apart, similar to the subassemblies of a LWR, with associated lower core pressure loss and lower output power of the Primary Pumps, in spite of the high density of lead. The result is a reactor configuration with high natural circulation capability.

This first phase, during which several International Organizations have proposed reactors with lead as the coolant, has been followed by a second phase of reduced interest and reflection on the lead technology and, in general, of expectation without important programmes of development.

The reason thereof is perhaps that the advantage of the elimination of the Intermediate Cooling System seems neutralised by the larger size and mass of the Primary System as a consequence of the lower coolant velocity chosen for reducing pressure loss and erosion, and of the lower heat transfer coefficients of lead with respect to sodium. Furthermore, it has been also said that the large density of lead is of particular concern in case of earthquake conditions and could allegedly oblige to limit LFR to the medium-size reactor category. The still open issue of the corrosion resistance at the higher temperatures of the known structural steels in the unusual molten lead environment, coupled to the limited commitment of R&D resources, has contributed to temporarily worsen the perspective of development of the LFR.

By chance, however, development of sub-critical, accelerator driven reactors has been meanwhile pursued forward in Europe and also elsewhere, particularly in the field of pool-type reactor design and of lead-alloy technology, that is closely related to the pure lead technology. Thus, design capabilities have improved and the continuity of lead technology development ensured.

A major step in favour of LFR did occur, when EURATOM has decided to fund ELSY (acronym of European Lead cooled SYstem, a Specific Targeted Research Project. Since September 2006, namely, seventeen European, two Korean and one USA Organisations are pursuing forward the development of ELSY, a lead-cooled, critical reactor of 600 MWe power.

Already after a few months of activity, very preliminary results indicate that potential comes true in the frame of the LFR technology, even if it remains for the most part unexplored.

The effect of the high density of lead, for instance, on the mass of the Primary System can be mitigated by more compact solutions and improvement of the design of the Reactor Vessel support system, with the use of seismic isolators for a seismic-resistant design. The potential of the feasibility of LFR larger than medium-size seems open again.

It is recognised that the high density of lead has advantages in term of safety, because it reduces the risk of re-criticality in the assumed event of core melt, owing to the fact that the oxide fuel would float and spread apart on the free surface of lead. The density of lead, if exploited purposely, can even be used to simplify the Primary System design. For instance, the free level difference of hot and cold collectors at normal operating condition, only 1-2 m, is sufficient to feed the core, eliminating the complicated, pressurized core feed system (Liposo and Sommier, in French) typical of the pool-type, sodium-cooled reactors.
Simplification of the Internals will make possible removable in-vessel components, a provision for investment protection.
To limit corrosion by lead it is possible to increase the primary flow rate while simultaneously reducing the temperature difference between core inlet and outlet.
A possible thermal cycle of 400°C/480°C in lead namely, not degraded by heat transfer via the Intermediate Cooling System, offers reduced risk of steel creep and milder thermal transients, while providing thermal efficiency above 40%.
Simplicity is expected to reduce both capital cost and construction time, limited also by the compactness of the reactor building of reduced foot print and height. The reduced foot print would be the consequence of the elimination of the Intermediate Cooling System, the reduced elevation the result of the design approach of reduced-height components and of the innovative Decay Heat Removal systems.
Basing on these promising first results, it is deemed that ELSY can confirm the ambitious objectives of the Designers and will open a third phase in the lead technology development, the phase of the maturity, during which the characteristics of the coolant will be exploited at maximum, the effects of the drawbacks minimized, the research pursued forward in a systematic way to establish LFR as the innovative reactor appealing to Utilities for up-to-dated electric energy generation.

MEGAPIE: A Successful Story

MEGAPIE is an international pioneering experiment at the Paul Scherrer Institute (PSI) in Villigen Switzerland, the goal of which is to produce neutrons from a liquid metal target. In a world first, a high power neutron beam was produced from one megawatt of input. Energetic neutrons are used in many research fields and could theoretically be used to break down nuclear waste. The first phase of the experiment was recently completed and to the great satisfaction of the international scientific community, the results exceeded expectations.

Due to their unique properties neutrons are indispensable particles for research. Atomic structures and dynamics as well as biological substances can be investigated with these atomic building blocks. In order to obtain neutrons they must be released from the atomic nucleus, as they are at the Spallation Neutron Source (SINQ) at PSI. Here a high energy proton beam is directed at a metal target and the protons knock or ‘spallate’ the neutrons off the metal’s atoms. Up until now the target has been solid, but theoretical calculations predicted that a liquid metal target would produce a higher neutron flow.

Thus the MEGAPIE (Megawatt Pilot Experiment) was set up to demonstrate whether this was so, and the feasibility of running long term a 920 kg liquid lead-bismuth target with the proton beam from the ring cyclotron at PSI, which could provide a power output of one megawatt. Using this, the world’s strongest proton beam, is like heating a tea kettle with the power of 500 electric stoves.

Valuable experience for the treatment of nuclear waste
With their high energy, neutrons can be used for spallating highly radioactive elements such as neptunium, americium and curium, found in long lived waste from nuclear power plants. The transmutation or break-down of this waste into short lived or even stable elements is theoretically possible and MEGAPIE has provided valuable information for developing this technique. However, according to experts, there is still a long way to go on this road.

Yet the prospect of being able to ‘burn’ radioactive waste caused considerable international interest in MEGAPIE. The project costs of 50 Million Euros were shared by many partners, including the EU. Since 2000, an interdisciplinary team has assiduously set up the experiment and conducted countless tests. The 170 strong group consisted of scientists, engineers and technicians from nine research institutes from Europe (CEA, CNRS, ENEA, FZK, PSI, SCK·CEN), Japan (JAEA), Korea (KAERI) and the USA (DOE).

SPOTLIGHT

ENEA, with the support of the European Commission, has launched the
IV workshop on Materials for HLM Cooled Reactors and Related Technologies,
which is planned to be held in Rome, Italy,
on **May, 21 -23rd , 2007**.

The workshop, now in its fourth edition after Karlsruhe 1999, Brasimone 2001, Roma 2003, will be an unique opportunity to share knowledge and insight on the Heavy Liquid Metal technologies for nuclear applications. It will promote the exchange of the scientific results obtained in the different R&D programmes and encourage meaningful interactions and the creation of synergies among the scientists operating in the field.
The Workshop, organized by ENEA, promoted and supported by VELLA Initiative, will be focused on:

system design and component development;
corrosion and structure protection;
mechanical behaviour in HLM;
physical/chemical properties of HLM and impurities control ;
oxygen control;
irradiation in liquid metals;
thermal-hydraulics;
safety and procedures.

The workshop will take place at the headquarters of CNR, Aula Marconi, Piazzale Aldo Moro,7 – Roma, Italy.
More detailed information can be found at:
http://web.brasimone.enea.it/workshop2007/index.htm

PSI was responsible for the installation and assembly of the target and for the operation of the complex system. Extensive safety controls were involved which were overseen by the Swiss Federal Office of Public Health (FOPH).

MEGAPIE leads by a nose

As everywhere in the research world there is stiff competition in the field of liquid metal targets. In the race to prove this technology there are also projects in the USA and Japan. During the operation of the MEGAPIE experiment which ran between August and the end of 2006, results obtained show that there was an 80% higher neutron flux as compared with a solid metal target, greatly exceeding expectations. The examination of the now frozen target will continue for the next couple of years and will deliver invaluable information about the composition and behaviour of materials used in the experiment. This feedback will flow into the design and operation of new spallation neutron sources like SINQ. New accelerator driven systems will also benefit enormously from the experience gained here. For future industrial projects involving the transmutation of nuclear waste, MEGAPIE is a key experiment.

For further information:
Dr. Friedrich Gröschel, Project Manager Megapie, PSI;
Tel: +41 (0)56 310 21 96; friedrich.groeschel@psi.ch

The text of this release, background information and photos are available at:
http://www.psi.ch/medien/medien_news.shtml

contact information: silvia.degrandis@brasimone.enea.it