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Minutes of the first RP general meetings

Author: **Marc Schyns (SCK•CEN)**

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Džubinský Mykola	EC	Mykola.DZUBINSKY@ec.europa.eu
Alemberti Alessandro	ANSALDO	Alessandro.alemberti@ann.ansaldo.it
Gerra Guido	ANSALDO	Guido.Gerra@ann.ansaldo.it
Mansani Luigi	ANSALDO	Luigi.mansani@ann.ansaldo.it
Alvarez Francisco	CIEMAT	Francisco.alvarez@ciemat.es
Martín-Fuertes Francisco	CIEMAT	Francisco.martin-fuertes@ciemat.es
Ekberg Christian	CHALMERS	che@chalmers.se
Retegan Teodora	CHALMERS	tretegan@chalmers.se
Skarnemark Gunnar	CHALMERS	gunnar.skarnemark@chalmers.se
Moreau Vincent	CRS4	moreau@crs4.it
Profir Manuela	CRS4	manuela@crs4.it
Bandini Giacomino	ENEA	Giacomino.bandini@enea.it
Delnevo Alessandro	ENEA	Alessandro.delnevo@enea.it
Di Piazza Ivan	ENEA	Ivan.DiPiazza@enea.it
Sarotto Massimo	ENEA	massimo.sarotto@enea.it
Tarantino Mariano	ENEA	Mariano.tarantino@enea.it
Luther Wolfgang	GRS	Wolfgang.luther@grs.de
Pasichnyk Ihor	GRS	Ihor.Pasichnyk@grs.de
Pautz Andreas	GRS	Andreas.pautz@grs.de
Perin Yann	GRS	Yann.perin@grs.de
Velkov Kiril	GRS	kiril.velkov@grs.de
Ferrari Anna	HZDR	a.ferrari@hzdr.de
Konheiser Joerg	HZDR	stefan.mueller@hzdr.de
Mueller Stefan	HZDR	J.Konheiser@hzdr.de
Barbos Dumitru	INR	dumitru.barbos@nuclear.ro
Mladin Mirea	INR	mirea.mladin@nuclear.ro
Roth Csaba	INR	csaba.roth@nuclear.ro
Bubelis Evaldas	KIT	evaldas.bubelis@kit.edu
Bruzzese Christian	KIT	Christian.bruzzese@kit.edu
Chen Xue-Nong	KIT	Xue-nong.chen@kit.edu
Class Andreas	KIT	Andreas.class@kit.edu
Jaeger Wadim	KIT	Wadim.jaeger@kit.edu
Litfin Karsten	KIT	karsten.litfin@kit.edu
Pacio Julio	KIT	andrei.rineiski@kit.edu
Rineiski Andrei	KIT	julio.pacio@kit.edu
Wetzel Thomas	KIT	thomas.wetzel@kit.edu
Karbojian Aram	KTH	aram@safety.sci.kth.se
Konovalenko Alexander	KTH	kono@kth.se
Kudinov Pavel	KTH	pkudinov@kth.se
Sevostian Bechta	KTH	bechta@safety.sci.kth.se
Wallenius Janne	KTH	Janwal@kth.se
Vurim Alexandr	NNC	vurim@nnc.kz
Doolaard Heleen	NRG	doolaard@nrg.eu
Roelofs Ferry	NRG	roelofs@nrg.eu
Arien Baudouin	SCK•CEN	barien@SCKCEN.BE
Belloni Francesco	SCK•CEN	fbelloni@SCKCEN.BE
Bisogni Dario	SCK•CEN	dbisogni@SCKCEN.BE
Boer Brian	SCK•CEN	bboer@SCKCEN.BE
Cardinaels Thomas	SCK•CEN	tcardina@SCKCEN.BE
Castelliti Diego	SCK•CEN	dcastell@SCKCEN.BE
Keijers Steven	SCK•CEN	skeijers@SCKCEN.be
Kennedy Graham	SCK•CEN	gkennedy@SCKCEN.BE
Schuurmans Paul	SCK•CEN	pschuurm@SCKCEN.BE
Schyns Marc	SCK•CEN	mschyns@SCKCEN.BE
Van den Eynde Gert	SCK•CEN	gvdeynde@SCKCEN.BE
Van Tichelen Katrien	SCK•CEN	kvtichel@SCKCEN.BE
Verwerft Marc	SCK•CEN	mverwerf@SCKCEN.BE

Methodology, Analysis and eXperiments for the "Safety In MYRRHA Assessment"

EC project officer: Mykola DŽUBINSKÝ

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Summary: These minutes report the progress of the technical work done from the start of the project in November 2012 up to April 2014, thus covering the first reporting period.

Title: Minutes of the first RP general meetings

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DATE	*Author* Marc Schyns SCK•CEN	*Task leader* Name/Company Signature	*WP leader* Name/Company Signature	*Coordinator* Marc Schyns SCK•CEN

Contents

The progress of the work of the different technical work packages of MAXSIMA was discussed during the joint MAXSIMA – SEARCH review meeting, held at the university Ghent in Belgium on 29-30 April 2014.

I. WP 2 Safety analysis in support of MYRRHA

Diego Castelliti (SCK•CEN) reporting

A WP2 meeting has been organized besides the general joint SEARCH-MAXSIMA review meeting at SCK•CEN headquarters in Brussels on Wednesday, 28th April 2014 to allow extended discussions on WP2 topics. It is envisaged to hold similar meetings in parallel with all the future MAXSIMA review meetings.

The minutes of the meeting (reported by D. Castelliti, SCK•CEN) can be found on the MAXSIMA website in the folder documents/WP2 meetings. During the SEARCH-MAXSIMA meeting the following main outcomes of the meeting have been presented:

The progress of Task 2.1 status has been presented by Massimo Sarotto (ENEA). The maximum critical and sub-critical core configurations have been studied and characterized in several operating conditions (different temperatures and burn-up levels) and a complete set of reactivity coefficients for both operating modes has been derived and it will be ready to be used by other Tasks. Several potential reactivity insertion accidents can now be evaluated by transient analysis.

A notable difference has been found between the coolant reactivity feedback coefficient for MYRRHA design revision 1.4 (based on a core designed during the CDT project) and the new ones. These differences can be explained by the fact that in the current evaluation there is no distinction between fissile height and total height. The final official data set will be, however, more comprehensive, allowing for a detailed representation of core reactivity feedbacks. For SIMMER evaluations to be performed in Task 2.3, the most promising choice seems to involve the consideration of the correct temperature in each core position, and then applying the proper reactivity feedback. The full set of data will be made available in Deliverable 2.1, which is foreseen to be issued as a first draft at the end of July 2014. By combining these data with MYRRHA design version 1.6, it will be possible to release the Phase 2 Technical Database.

The progress of Task 2.2 was presented by Diego Castelliti. The Phase 1 is considered to be concluded with the Uncertainty + Sensitivity (U + S) analysis applied on the "test case" transients events (ULOF and PLOF), which has been performed by the four participants involved (SCK•CEN, ENEA, KIT and GRS) during the previous six months. It is foreseen to begin with Phase 2 of Task 2.2 activities in September, once the MYRRHA Design Version 1.6 Technical Description will be available.

For what concerns the Task 2.2 technical activities, SCK•CEN finalized the deterministic transient analysis comparison for ULOF and PLOF between the three participants primarily involved in this specific activity (SCK•CEN, ENEA and KIT). In general, the ULOF and PLOF deterministic analysis has shown a good agreement, with some differences mainly located in:

- Natural circulation mass flow rate and, as a consequence, in the hot channel temperatures (LBE and clad)
- Primary Pump (PP) characteristics and coast-down curve causing different reverse mass flow rate during the first phases of the transients
- Heat Transfer Coefficient (HTC) in core and Primary Heat Exchanger (PHX)

All the differences have been well explained and justified during the discussion. The preliminary deterministic phase could be thus considered as finished.

U+S analyses have been carried out by KIT, ENEA and SCK•CEN by coupling with the help of GRS the SUSA code and TRACE, RELAP 5 and RELAP 3 D respectively. The quantitative results comparison, obtained through Pearson correlation coefficients, shows an overall good agreement between the findings of the three participants.

Xue-Nong Chen (KIT) presented the status of the Task 2.3 activities. A complete SIMMER-III model of the maximum critical core in EoC state has been realized by KIT and successfully run in steady state and also in ULOF transient case. A preliminary core characterization comparison with results found at SCK•CEN through MCNPx code has also been attempted. However, due to some partially inconsistent assumptions on the mass flow rates and temperatures distributions in the core, the results are not directly comparable with Task 2.1 and Task 2.2 outcomes. Similarly to system code models in Task 2.2, the SIMMER III model will be updated basing on the Phase 2 Technical Description, the data coming from D 2.1 for what concerns the neutronic data and D 2.3 for transient definitions. Two different cases of full core blockage scenarios (unprotected and protected) have been studied by SCK•CEN through a dedicated SIMMER-III model. As a preliminary conclusion, the antireactivity provided by the core during an unprotected full core blockage is enough to avoid a CDA, and this case envelopes the protected blockage.

II. WP 3 Core component safety

Karsten Litfin (KIT) reporting

A general presentation of WP3 status was given by Karsten Litfin (KIT). Deliverables D3.1 (Blockage experiments design and instrumentation report) and D3.5 (Report on the design of the test section) have been delivered, D3.2 (Concept for a blockage experiment in natural convection) is delayed.

Task 3.1: Thermal hydraulic fuel assembly blockage experiments (Julio Pacio, KIT).
This task is combined with SEARCH WP2. The Experimental work on the blockage experiments are a delayed by approx. 2 months.

Task 3.2: Safety rod system tests in Heavy Liquid Metal (Graham Kennedy, SCK•CEN)
The COMPLOT mechanical works are completed, and electrical cabling is in progress. Facility commissioning is to proceed with a short delay in M22. The control rod test section design is completed, and the selection procedure of the manufacturer is on-going. The experiments are foreseen to start in M27.

Task 3.3: Fuel Blockage Simulation (Heleen Doolaard, NRG)
This task is combined with SEARCH WP2 and has been presented there. Due to new insights during the work performed by now, a sensitivity analysis of the blockage in the 19-pin experimental mock-up seems more important than the modelling of an internal blockage of the 127-pin fuel assembly. Therefore a change of the DoW, MS14 and MS15 is proposed.

Task 3.4: CFD simulation of safety / control rods system (Manuela Profir, CRS4)
The CFD model of the COMPLOT test section which hosts the Safety Rod and the Control Rod has been constructed an stationary simulations started. The first half of the mechanical movement of the control rod has been reproduced by automatic volume mesh adaption and re-meshing. The remaining part of the movement requires a the methodology of overset meshes and is being tested on a simplified Control rod with promising results.

III. WP 4 Steam Generator and cooling safety

Mariano Tarantino (ENEA) reporting

Task 4.1: aims to characterize the SGTR event in a relevant configuration for MYRRHA reactor. The mock-up of a portion of the MYRRHA-PHX will be implemented in CIRCE facility, set at ENEA Brasimone RC. Four tests, consisting of four water tubes rupture in MYRRHA-PHX conditions, will be performed one at a time. The experimental activity aims mainly to evaluate the pressure wave propagation, cover gas pressurization, possible rupture propagation to the surrounding tubes, steam dragged in the LBE flow, plug formation, oxygen concentration variation and performance of the safety-guard devices adopted to mitigate the effects of the SGTR event. The definitive test section design, called MAXSIMA-TS, and the main objectives, pursued by the overall experimental campaign, have been presented during the 3rd MAXSIMA review meeting. The design of the test section has been carried out conserving or scaling down MYRRHA parameters. A 3D CAD model has been developed and presented. The three rupture positions scheduled to be investigated as shown during the 1st and 2nd MAXSIMA review meeting (at CRS4 and VKI, respectively) are reduced to only two rupture positions (bottom and middle), each one of which is therefore performed twice to provide data about experimental repeatability. MAXSIMA-TS has been described in depth, highlighting for each component (tube bundles, spacer grids, LBE inlet windows, LBE outlet opening, centrifugal and jet pumps, filtering section, distributor and CIRCE cover vessel) the rationales at the basis of the performed dimensional choices. The instrumentation foreseen to be implemented has been presented. Five fast pressure transducers, twelve bubble tubes and their position have been highlighted. Almost 200 thermocouples will be implemented in the MAXSIMA-TS, about 50 TCs will be set in each tube bundle. They are positioned at various levels, each one of which hosts six TCs. The levels are planned to be spaced 300 mm. The location of 30 strain gauges scheduled to be set on the test section has been presented. Nine tensile tests in heated conditions, performed on nine tubes 16x1 mm AISI 316L (MYRRHA-PHX tubes) having a length of almost 135 mm, have been presented. Three tests were performed at 200, 300 and 400°C: The specimen drawing, the tensile and heating machine, the tube notch defined to obtain the rupture in a defined position and the nine strength-elongation trends have been presented. Moreover, the deliverables change proposed and approved has been shown. It consists in the deliverable D4.1 and D4.2 merging, to provide a more fruitful document containing the preliminary pre-tests and the test section design description. Such a merged deliverable, having the title “Large Scale Test Section Design and Preliminary Pre-test Analysis”, has been submitted twice as D4.1 and D4.2.

Future work foresees the pre-test execution on the basis of the definitive MAXSIMA-TS design presented at the 3rd review meeting. Presently, the CIRCE cover is under construction and the procurement of the tube bundles, jet pump, filtering section and other components will begin in the coming weeks. The centrifugal pump and the LBE Venturi flow meter are available at Brasimone RC.

Task 4.2: aims to experimentally investigate the SGTR bubble characteristics in a relevant configuration for MYRRHA-PHX, having the objective of developing instrumentation suitable to promptly detect water leakage. The main goals of this task are constituted by the characterization and detection of the release rate by typical cracks, size identification of the steam bubbles and production of high quality experimental data to validate CFD and/or coarse mesh CFD codes. The leakage detection aims to prevent the SGTR phenomenon, making the consequence of a postulated accident acceptable, or even eliminate such an accident. The experimental campaign, scheduled to be performed on the LIFUS5 facility, will be carried out in a dedicated new reaction vessel (S1b), which is larger, higher and having a lower design pressure than theLIFUS5 S1 reaction vessel. This solution has been adopted to achieve a more practical installation of acoustic sensors and prototype mesh sensors and also for keeping the capability to perform large break experiments. The new S1b vessel will be connected to the LIFUS5/Mod2 system by valve V5, previously used for draining water line, and the I&C systems properly adapted. The main critical issues identified to be addressed are constituted by the acoustic detection system, small leakage experiment preparation, injection system (i.e. w and w/o recirculation system), mass flow measurements and bubble characterization. The acoustic emission (AE) sensors installed inside HLM pool are excluded because the temperature range is about 200-600°C. AE sensors (electret microphones, EMs) will be installed outside the S1b vessel and will be connected by acoustic tubes to the inner cover gas volume. Very sensitive EMs have been selected, having high dynamic range (90 dB), wide bandwidth (20-20000 Hz) and low cost. Preliminary experiments using small scale LBE pool, Argon cover gas, water bubbles generator and five cooled EMs with acoustic tubes have been performed. The adopted instrumentation and the acoustic emission spectrum (in Ar) have been presented. The implementation of multi-channel configuration aims at a) correlating crack size, mass flow rate and acoustic emission in MYRRHA operating conditions and b) localizing the bubble emersion position from the pool surface by means of the bubble expansion and explosion in cover gas. The welded/dissolved tungsten wire technology has been presented as the possible way to create cracks of desired shape and dimensions. The injection system constitutes the main open issue, which presents the possibility to realize once through or recirculating (preferable) injection water system. The mass flow rate measurement needs to be improved because the level gauge and the coriolis flow meter, presently implemented on LIFUS5/Mod2 facility, cannot provide a suitable measurement resolution. A current option is based on gravity head water measurement. Bubble characterization is pursued adopting a customized wire mesh sensor immersed in LBE. Such a device is potentially capable to detect vapour bubbling. The technology required to construct the wire mesh, move the signal to the electronic equipment and the electronic signal conditioning and real time data processing constitute the preliminary challenges.

The design of the experiment is going to be finalized, the accumulated delay should not affect the overall time schedule.

Task 4.3: aims to provide experimental data on drag coefficient of gas bubbles travelling through liquid LBE. Motivations at the basis of the research activity, presented during the previous meetings, have been recalled. The steam dragged to the reactor core and the consequent core voiding is considered a potential problem for reactor control and safety. The uncertainty in the assessment of the bubble transport to the core arises from the lack of experimental data for validating drag models of bubbles flowing in LBE. The experimental campaign will be performed using the TALL loop, modified adding a vertical section injecting bubbles of argon having different sizes in different LBE flow conditions. Tests in laminar and turbulent LBE flow regimes will be carried out, aiming to confirm the minor effect of the flow patterns on the average bubble drag. The LBE temperature will be set coherently to the normal operation conditions of a lead-bismuth cooled reactor. The terminal rise velocity of the bubbles will be measured for validating drag correlations. The bubble generation and measurement device (BGMD), foreseen to be realized by both circular straight capillary and flat micro channel, have been described. Confirmatory tests performed in water and quartz capillary have been presented. The concept design and 3D CAD model of the capillary BGMD, foreseen to be implemented in TALL facility, have been presented. The motion of an horizontal piston will allow an alternated upwards flow of argon and LBE through a quartz capillary. A vertical piston will pressurize the LBE injection chamber. The bubble velocity measurements system (BVMS) will be performed adopting acoustic methods chosen between the UDV and ultrasound transit-time technique, bubble noise detection and resonant acoustic spectroscopy. The functional blocks composing the facility design are constituted by the TALL-3D infrastructure, additional test section, BGMD, BVMS and data acquisition and control system (DACS). The test procedure and test matrix have been presented. Main tests will be done in LBE natural circulation conditions and a series of tests will be performed with different flow regimes. The experiments will be carried out varying the bubble equivalent diameter (0.1-10 mm), LBE temperature (250-400°C), pressure at the bottom of LBE column (2-5 bar), LBE flow rate, velocity and flow conditions.

TALL-3D is currently under commissioning and the procurement process of the equipment will start soon.

IV. WP 5 Fuel Safety

Csaba Roth (ICN) reporting

General presentation of WP5 “Fuel safety” status was given by Csaba Roth (WP leader).

Brian Boer (SCK•CEN) presented the status of WP5.1 (Transient Testing of MYRRHA Fuel). Based on the conceptual design and specifications described in the deliverable D5.2, an experimental rig has been designed and will be manufactured and qualified at INR. The experimental set-up is formed by two major part: the irradiation device itself and the auxiliary equipment dedicated to the assembling and disassembling of the irradiation capsule.

The irradiation device consists of a capsule that can be placed in an external capsule to be inserted in the central loading position of the ACPR-TRIGA core. The internal capsule containing the test segments will be filled with LBE. The external capsule is formed of five beryllium blocks, aimed to work as neutron moderator, fixed between two aluminum alloy plates and the electrical heater.

The functionalities of the auxiliary equipment are test segments insertion/removal, LBE filing/drain as well as capsule closing/opening.

There are two types of instrumentation: the irradiation capsule instrumentation and the experiment instrumentation. The capsule instrumentation include a detector to measure the neutron flux density during the pulse and a thermocouple placed in the LBE to measure its temperature. The experiment instrumentation aims to measure the cladding temperature during the pulse for all three segments. The sensors will be fixed in the central position of the test segments, fastened in a small tube segment itself brazed on the test segment surface. Further investigations are required to confirm the TC fixing solution.

The deliverable D5.4 “Test rig fabrication specifications based on D5.1” has been submitted to EC and uploaded on the MAXSIMA website.

The status of WP5.2 joint to SEARCH WP4 has been presented by Teodora Retegan (Chalmers).

Oven stability tests were made and no problem occurred at higher temperatures (1000^{0}C and higher). Slight instability have been observed at lower temperatures (below 600^{0}C).

Experiments where MOX is in direct contact with LBE and experiments where MOX is in contact with LBE and the cladding material (where one experiment will be carried out at low oxygen concentrations (<10-8 wgt%) and one at saturated oxygen concentration) will be carried out in a range between 1000 and 1700 ^{0}C.

V. WP 7 Education and training

Janne Wallenius (KTH) reporting

Within WP7, an safety simulator for pedagogical purposes is under development at KTH. A graphical interface has been ported to iPhone. The neutronics engine has been tested on Android, ported to C on MacOS. The next step is to port it to iOS. The dynamic engine called BELLA has been benchmarked on ELECTRA with respect to SAS4A code. Simulation of 0.2$ reactivity insertion indicates that physics in the dynamic engine BELLA is appropriate for MAXSIMA purpose.

It has been reminded to send the abstract for the 1st MAXSIMA workshop arranged by KIT on October 7-10, 2014.

The set of lecture notes on safety for HLM system are still not released. Deliverable 7.2 therefore is delayed.