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|  | EUROPEAN COMMISSIONDIRECTORATE-GENERAL ‘RESEARCH’ | INTERNATIONALSCIENCE ANDTECHNOLOGYCENTRE |  |

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## NON PROLIFERATION THROUGH SCIENCE AND CO-OPERATION

**CONTACT EXPERT GROUP**

**on**

**SEVERE ACCIDENT MANAGEMENT**

**(CEG-SAM)**

**MINUTES OF THE 14th MEETING**

**Kiev, Ukraine**

**Science & Technology Center in Ukraine (STCU)**

**September 9-11, 2008**

Meeting Location: Conference room of the

“Institute for Safety Problems of NPP’s” of the National Academy of Science of Ukraine

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| Dissemination level: REPU: publicRE: restricted to EC and a group specified by the CEG-SAM membersCO: confidential, only for EC and CEG-SAM members |

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Final minutes, March 10, 2009 CEG-SAM / M-14

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| Subject: 14th Meeting of the ISTC “Contact Expert Group on Severe Accident Management” (CEG-SAM)Place: Conference room of the ISP NPP of the Nat. Acad. of Science of UkraineDate: September 9-11, 2008Participants: 29 participants of 23 organizations from 9 countries: Mr. D.Bottomley EC, DG JRC / ITU, Karlsruhe Mr. B.Clement IRSN, Cadarache Mr. G.Ducros CEA, Cadarache Mr. S.Güntay PSI, Villigen Mr. L.E.Herranz CIEMAT, Madrid Mr. P.Hofmann Consultant, Karlsruhe (**secretary**) Mr. M.Hugon EC, DG-RTD / J.4, Brussels (**chairman**) Mr. Z.Hozer AEKI, Budapest Mr. Ch.Journeau CEA/DTN, Cadarache Mr. A.Kotchurko FZK, Karlsruhe Mr. M.Krause AECL, Chalk River, Canada Mr. J.S.Lamy EdF, Clamart Mr. A.Miassoedov FZK, Karlsruhe Mr. A.Palagin FZK, Karlsruhe Mr. G.Pretzsch GRS, Berlin Mr. V.Stepanenko STCU, Kiev Mr. J.Stuckert FZK, Karlsruhe Mr. W.Tromm FZK, Karlsruhe Mr. P.Volkholz Areva NP, Erlangen Mr. M.Zayet STCU, Kiev Mr. S.Bechta RIT-NITI, Sosnovy Bor Mr. A.Kisselev IBRAE, DNS, Moscow Mr. O.Klyuchnykov ISP NPP, Kiev Mr. B.Konorev I&C SCC, Kharkiv Mr. V.Krasnov ISP NPP, Kiev Mr. V.Loktionov MPEI, Moscow Mr. V.Nalivaev NPO LUCH, Podolsk Mr. A.Nevsky ISP NPP, Kiev Mr. A.Odintson ISP NPP, Kiev Mr. V.Pahetnov OKP “Gidropress”, Podolsk Mr. M.Veshchunov IBRAE, Moscow Mr. E.Visotsky ISP NPP, Kiev Ms. V.Zasukha FSUE-NITI, Sosnovy Bor Mr. V.Zhdanov IAE NNC, Kurchatov-City, RKDistribution list: Ms. Z.Stancic DG-RTD(Shortened version Ms. M.Minch DG-RTD / Dof the minutes) Mr R.Burmanjer DG-RTD / D.3 Mr. J.Sanders DG-RTD / D.3 Mr. O.Quintana Trias DG-RTD / J Mr. A.Perez Sainz DG-RTD / J.1 Mr. S.Webster DG-RTD / J.2 Mr. M.Deffrennes DG-RTD / J.2 Mr. P.Manolatos DG-RTD / J.2 Mr. G.Van Goethem DG-RTD / J.2 Mr. R.Schenkel DG-JRC Mr. P.Frigola DG-JRC / 2 Mr. G.Sadler DG-JRC / 2 Intranet of Unit J.2 Mr. L.Tocheny ISTC, Moscow Mr. S.Vorobiev ISTC, Moscow Mr. W.Gudowski ISTC, Moscow Mr. A.Gozal ISTC, Moscow EU CEG-SAM membersContact person: Mr. M. Hugon Tel.: +32 2 296 5719 – DG-RTD / J.2 |

Revised final agenda of the meeting see Annex 1, list of participants see Annex 2.

The Science & Technology Center in the Ukraine (STCU) organized together with the “Institute for Safety Problems of NPP’s” (ISP NPP) of the National Academy of Science of Ukraine the 14th CEG-SAM meeting in Kiev, Ukraine, on September 9-11, 2008. The meeting location was the conference room of the ISP NPP in Kiev.

The CEG-SAM meeting is divided into restricted and extended sessions. The restricted sessions are to discuss internal matters and the status of current ISTC/STCU projects. The extended sessions are dedicated to presentations of the progress of on-going ISTC/STCU projects and of new or revised ISTC/STCU proposals by scientists from the Russian Federation, the Republic of Kazakhstan and/or the Ukraine.

The chairmen M.Hugon (EC) and V.Stepanenko (STCU) welcomed the CEG-SAM members

**Restricted session**

**Topic #1:** Welcome and opening remarks

The chairman M.Hugon opened the first part of the restricted session and welcomed the EU participants of the 14th meeting of the Contact Expert Group on Severe Accident Management (CEG-SAM) of the International Science and Technology Centre (ISTC) and of the Science & Technology Centre in the Ukraine (STCU).

He used the opportunity to express his thanks to V.Stepanenko (STCU) and V.Krasnov (ISP NPP) who kindly offered to organize and host the 14th CEG-SAM meeting in Kiev, Ukraine. He regretted that the co-chairman L.Tocheny (ISTC) was not able to attend the meeting due to other obligations.

**Topic #2:** Adoption of the agenda of the 14th CEG-SAM meeting

The order of presentations was slightly modified and the planned presentation of V.Baty (ISP NPP) on the STCU project proposal #3511 on “Development of the setting and measurement methods of angular gamma-radiation distributions under hard radiation conditions” was deleted. With these changes, the appended agenda (see Annex 1) was accepted.

**Topic #3:** Approval of the minutes of the 13th CEG-SAM meeting in Budapest, Hungary, March 5-7, 2008.

The secretary took into account the comments received on the draft minutes by the participants in the revised minutes dated June 23, 2008. The revised minutes were then approved by the CEG-SAM members without any additional changes at the meeting in Kiev, September 9, 2008.

**Topic #4:** Discussion of the “Specific action list” of the 13th CEG-SAM meeting in Budapest

**Action 13/1:** L.Tocheny (ISTC) will contact all managers of on-going ISTC projects to inform them that they should provide information (name and e-mail address) to A. Miassoedov (FZK) and K.Trambauer (GRS) to be included in the CEG-SAM website users list. After that they will have full access permissions to their project web-pages and will be exclusively responsible for updating the project documentation/deliverables and the upload of presentations from project progress meetings. *Pending action*.

**Action 13/2:** L.Tocheny (ISTC) will initiate working meeting (or/and phone/e-mail conferences) of the # 3635 Project Manager (PM) and the project EU collaborators (CEA-Saclay, JRC-ITU, FZK, FZR, RIT). The goals are: to get information on current status and further perspective of the project implementation and to agree possible actions and corrections (if any) of the project Work Plan accordingly to available budget. The CEG SAM members will be informed on the results of the meeting. *The meeting took place in Moscow, July 2008 (see topic #20).*

L.Tocheny (ISTC) will ask the US and Japanese foreign collaborators to contribute to the funding of ISTC project # 3635, which is underfunded due to increase of costs in the Russian Federation. The manager of this project is looking for additional financial means in Russia. *Pending action*.

**Action 13/3:** S.Güntay (PSI) will define together with the other foreign collaborators of the ISTC project #3690 a test scenario for the planned test PARAMETER-SF4 by August 2008 at the latest. *Action not yet completed*.

**Action 13/4:** Ch.Journeau (CEA) will send to A.Kondrashenko (VNIIEF) his presentation concerning the composition of the concrete that should be examined in the frame of the ISTC project #3831 (MCCI, first phase). *Action successfully completed. A meeting on this subject took place in Moscow on July 2008, where A.Kondrashenko presented a draft for the planned the small-scale experiments.*

**Action 13/5:** M.Hugon (EC) should inform J.Sanders that the CEG-SAM members have a strong interest in the ISTC project #3609 (EXPULS). In order to consider this project by the ISTC GB once more its status should be changed from [3] (accepted without funding) to[2] (submitted to parties for board decision). *The project #3609 EXPULS was withdrawn by the project manager.*

**Action 13/6:** The recommendations of Advice A-17 on ISTC project #3609 (EXPULS) should be taken into account by its manager, Dr. Migrov. *Action completed*.

**Action 13/7:** A.Miassoedov (FZK), D.Bottomley (JRC-ITU) and Ch.Journeau (CEA) will prepare a joint advice for the planned ISTC project THOMAS. *Action successfully completed*.

**Action 13/8:** B.Clement (IRSN) and D. Bottomley (JRC-ITU) will prepare an advice for the ISTC project VERONIKA. *Action successfully completed*.

**Action 13/9:** M.Hugon (EC) will investigate the possibility for the EC to authorize one of the JRC's institutes to become recipient of the results of ISTC project # 3592 (METCOR-P) to overcome the problem of export license control. *The problem is not the task of the CEG-SAM. However D.Bottomley brought the committee up-to-date, following ROSATOM's insistence to NITI & ISTC about this export control. D.Bottomley had spoken to Mr. Fanghänel, Director of ITU. Mr. Fanghänel had signed a letter where it was stated that ITU would be prepared to act as a recipient for these reports and this had just been sent to ISTC with a copy to the project manager, NITI. However, M. Hugon stressed that the idea of having the JRC as a recipient of the results of ISTC projects is not supported by the EC Secretariat of ISTC in Brussels.*

**Topic #5**: Future of the CEG-SAM

(See Topic #10)

**Topic #6**: Reports by the secretariats

V.Stepanenko (STCU) welcomed the CEG-SAM members and gave a general outline on the course of the meeting and the planned technical excursion to Chernobyl. No additional comments by M.Hugon (see topic #5).

**Topic #7**: Preliminary discussion of updated and/or new ISTC/STCU project proposals

The new and updated ISTC/STCU project proposals will be presented under topics #27 to #31. No status on the ISTC project proposal VERONIKA will be presented.

Since there was only limited time to discuss the proposals in detail the discussion was shifted to topic #34.

# Extended session

**Topic #8**: Welcome of the Russian, Kazakh and Ukrainian colleagues; approval of the shortened minutes of the 13th CEG-SAM meeting in Budapest; adoption of the agenda of the 14th CEG-SAM meeting in Kiev

M.Hugon opened the extended session of the meeting and welcomed the Russian, Kazakh and Ukrainian participants and expressed his thanks to V.Stepanenko (STCU) and his colleagues from the “Institute for Safety Problems of NPP’s” (ISP NPP) of the National Academy of Science of Ukraine who kindly offered to organize and host the 14th CEG-SAM meeting in Kiev. M.Hugon mentioned that the co-chairman L.Tocheny (ISTC) was not able to attend the meeting in Kiev due to other obligations.

The shortened minutes of the 13th CEG-SAM meeting were distributed to the Russian, Kazakh and Ukrainian participants in June 2008. The obtained comments were then considered in the revised shortened minutes. This version of the minutes was accepted without any additional changes.

The order of presentations was slightly modified and the planned presentation of V.Baty (ISP NPP) on the STCU project proposal #3511 on “Development of the setting and measurement methods of angular gamma-radiation distributions under hard radiation conditions” was deleted. With these changes, the appended agenda (see Annex 1) was then accepted.

**Topic #9**: Status of the official ISTC CEG-SAM webpage

The ISTC CEG-SAM webpage is hosted by GRS (Garching, Germany) and is now fully operational (http://cegsam.grs.de). In the new structure of the webpage all documents (project proposals, advices, work plans, progress reports) are collected under the ISTC project number. There will be a unique user name and password for each user and different read/write permissions for the different users. Russian and Kazakh project managers should provide information (name and e-mail address) to A. Miassoedov/K.Trambauer to be included in the users list. After that they will have full access permissions for their project web-pages. They will be exclusively responsible for updating the project documentation/deliverables and the upload of presentations from project progress meetings.

The CEG-SAM members will have full access to minutes (restricted and open sessions) and all stored documents. There will be special access rights for non-European members for the project in which they participate. It will be restricted to two names per institute per project.

L.Tocheny should inform the ISTC project managers on their responsibilities described above (action #14/1) and inform A.Miassoedov (web master) about their names.

**Topic #10**: Future of the CEG-SAM

M.Hugon gave a presentation on the status of the ISTC project contact expert group CEG-SAM. The objective is to provide a mean of contact between various experts involved in project conception, recommendations and implementation and subsequent optimization of project results, to foster exchange of information between various ISTC/STCU projects, and to promote the possibilities of future or joint research through the ISTC/STCU. Results of SARNET activities are periodically presented to CEG-SAM members. In addition, a list of ISTC/STCU projects recommended by the CEG-SAM was presented and updated.

The CEG-SAM is successful since its launch in April 2002 and there exists an excellent interaction with SARNET. Altogether 14 ISTC projects proposals were selected for funding and 7 ISTC projects are in the meantime completed. In addition several STCU project proposals are under discussion but none of them has been funded up to today.

The current ISTC and STCU project proposals of potential interest for the CEG-SAM are: 1) ISTC #3609 EXPULS (in the meantime withdrawn); 2) ISTC #3702 CHESS-2; 3) STCU #4207 Chernobyl shelter; 4) ISTC-VERONIKA, still not yet registered; 5) STCU #4758 Hidden nuclear hazardous clusters of fuel in the Chernobyl NPP Unit 4; 6) STCU #4726 Safety-critical software; and 7) STCU #4452 Robot-technical complex.

M.Hugon stressed once more that future ISTC/STCU project proposals should be in line with the SARNET priorities. The future trend for both ISTC and STCU funding from EC will be in 2008 about 15 M€ and in 2009 about 8 M€, while it was in 2007 about 25 M€. The next SCTU GB meeting will be on November 20 and the ISTC GB meeting on December 11, 2008.

M.Hugon reported then on the results of the 2nd call of the EURATOM FP7 and gave information on the 3rd call on Nuclear Fission for 2009 (budget 48.9 M€). A direct participation of third country partners in Euratom projects with sharing of the costs is considered. A co-operation with Russia on nuclear fission and radiation protection is planned. The future principle of co-operation will change from “assistance” to a “collaboration” approach, for example, in the field of containment thermo-hydraulics of current and future LWRs for severe accident management. Both parties, Euratom and Russian partners, will develop jointly separate Euratom and Russian proposals, as well as a co-ordination mechanism. The European projects will be funded jointly by Euratom and the Member States and the Russian projects by ROSATOM. The overall financial contribution of Euratom for these projects in the 3rd call will be about 3-5 M€. The funding level of the Russian projects by ROSATOM is not yet known.

Finally, M.Hugon then delineated the future of the CEG-SAM: 1) to continue its previous tasks with ISTC/STCU projects and interaction with SARNET/SARNET-2; 2) to include in CEG-SAM coordinated projects financed by Euratom and ROSATOM following the 3rd FP call on “Fission” in 2009; 3) **to enlarge the scope of the “CEG-SAM” to a “CEG on Safety & Accident Management”** to include also developments of numerical codes and experiments on safety (neutronics + thermal hydraulics) as part of the Euratom-ROSATOM Working Group; and 4) to investigate the possibility of establishing a structured dialogue between Euratom and the Ukraine.

**Topic #11**: Overview of SARNET; “Achievements and research topics proposed in

SARNET-2”

B. Clément (IRSN) presented the SARNET (**S**evere **A**ccident **R**esearch **NET**work of excellence) update. Up to now the interaction between CEG-SAM and EC-SARNET works well and the EC-SARNET recommendations were considered in the final work programmes of the various ISTC project proposals. The results of ISTC projects are used by foreign collaborators in the framework of SARNET.

The interaction between EC-SARNET and CEG-SAM brings mutual benefits and further assures a critical mass of expertise for ISTC proposals addressing specific issues in the SAM area. The objective of the interaction is the resolution of still-pending questions that are important for reactor safety, and the knowledge transfer for safety application.

The main objectives of SARNET are to tackle the fragmentation that exists between the different R&D organisations, notably in defining common research programmes, to harmonize the methodologies applied for assessing risk and improve Level-2 Probabilistic Safety Assessment (PSA), to disseminate the knowledge to newcomers to the European Union more efficiently and to bring together top scientists in SA research to constitute world leadership in advanced computer tools for SA risk assessment.

B. Clement described the on-going work on Severe Accident Research Priorities within SARNET. Six issues remain open with high priority, four issues with medium priority, and five issues remain open with low priority and could be closed after finalizing the related research activities.

The 6 issues with **high priority** are: 1) research on core coolability during reflood and debris cooling in lower head. 2) research on ex-vessel melt pool configuration during MCCI and ex-vessel corium coolability by top flooding. 3) research on melt relocation into water and ex-vessel FCI. 4) research on hydrogen mixing and combustion in containment. 5) research on oxidising impact on source term. 6) research on iodine chemistry in RCS and in containment.

The 4 issues remaining with **medium priority** are:Research activities on hydrogen generation during reflood, on corium coolability, on the integrity of RPV by external vessel cooling and on direct containment heating.

The 5 issues with **low priority** are: Research on corium coolability in external core catcher, on corium release following vessel rupture, on dynamic and static behaviour of containment, on aerosol behaviour impact on source term and on the impact of core reflooding on source term.

Research issues that could be closed are on the integrity of reactor coolant system heat distribution, on ex-vessel core catcher and on steam explosion.

B.Clement described briefly the achievements obtained in the research areas as corium formation and behaviour, containment behaviour, and source term. Remaining research topics within SARNET-2 will be experimental programmes on in-vessel degraded core coolability and ex-vessel corium coolability as well as corium interaction with concrete and threat to the containment due to steam explosion and hydrogen combustion and studies on the potential radioactive release of iodine and ruthenium to the environment.

**Topic #12**: Iodine chemistry and aerosol studies in SARNET; Approach and major insights

L.E.Herranz (CIEMAT) described the current status in this research area. The 5th FWP EURSAFE project highlighted iodine chemistry in the containment as one of the issues which required further research to reduce source term uncertainties associated to iodine. Likewise, despite the vast investigation carried out on nuclear aerosols, some remaining issues were highlighted as deserving further investigation: retention in complex structures, such as steam generator by-pass SGTR sequences or cracks in concrete walls of an over-pressurised containment, and primary circuit deposit remobilization, either as vapours (re-vaporisation) or aerosols (re-suspension), noting their potential to increase the source term (except for SGTR studies) and the absence of proper models (if any) in source term evaluation codes. Consistently, the 6th FWP SARNET project launched a set of studies aimed to enhance understanding and predictability of all the phenomena mentioned.

More specifically, SARNET has striven for: fostering common interpretation of integral and separate-effect tests data; producing new models and/or improvements, if needed and compiling the existing knowledge and know-how on this matter. Primary deposit re-vaporisation has been experimentally proven on samples from the PHEBUS-FP project. Data review has pinpointed variables affecting the process, particularly temperature. Available models have been satisfactorily used to interpret separate-effect tests, but integral experiments, where re-vaporisation is likely combined with other processes, still pose a difficult challenge. Further experimental data as well as modelling efforts seem to be necessary to get a full understanding. Re-suspension, sometimes referred to as mechanical remobilization, has been recently addressed in SARNET and although a set of models were already available in the literature, further work is needed to extend current capabilities to multi-layer deposits and to produce simplified, but sufficiently accurate, models. A major remaining uncertainty is the particle-to-particle/wall adhesion and its dependence on micro-scale roughness. Data from the previous EU STORM project have been retrieved and further experiments designed for code validation are being used to benchmark the models.

**Topic #13**: Corium and Debris Coolability within SARNET-2

W.Tromm (FZK) described the planned work packages on corium and debris coolability within SARNET-2. The major motivation is to reduce or to solve the remaining uncertainties on the possibility of cooling structures and materials during severe accidents, either in the core or the vessel bottom head or in the reactor cavity, so as to limit the progression of the accident. This could be achieved either by ensuring corium retention within the vessel or at least a slow corium progression and small flow rates of corium release into the cavity. These issues are to be covered within the scope of accident management for current reactors, and also within the scope of the design and safety evaluation of future reactors. Increased understanding was reached with the help of computer codes such as MAAP, MELCOR, SCDAP/RELAP, ICARE/CATHARE, ATHLET-CD and ASTEC being under European development. Nevertheless, as the required status of validation and partial modelling of these codes are not yet fully achieved and as a convincing PSA depends on the quality of prediction of the analytical tools used, current PSA level 2 studies still show very large uncertainties in the results of the reflooding phase.

The different actions of the “Corium and debris coolability” project should improve our understanding of the phenomena associated with reflooding and allow the integration of validated models applicable to reactor conditions in the severe accident codes, in particular the ASTEC integral code, with the final aim of reducing the uncertainties on the evaluation of in- or ex-vessel coolability, during the different phases of the severe accident. Three key situations and processes are considered for corium coolability and retention.

1) Reflooding and coolability of a degraded core: The focus will be on the phase after cooling boil-off during the accident. Heating and melting of core materials may produce a severely damaged, partly molten core with relocated material and broken parts. If a core is quenched at this stage by water injection, an increased fragmentation of material and the additional formation of molten material can be expected resulting in the formation of a debris bed.

2) Re-melting of debris, melt pool formation and coolability: if the core cooling measures fail a melt pool will form within the core and molten material might flow down into remaining water in the lower head. The TMI accident indicated that even though coolability of the core is not attained, a coolable configuration may result from break-up of the melt in the water of the lower head. If cooling in the core and in the lower head is not possible, the development of a melt pool in the lower head has to be analysed and whether a melt pool can be kept in-vessel due to external vessel cooling or the timing and modes of vessel failure have to be considered. The modes of vessel failure concern location and size of the failure. Due to the similarity of the processes under ex-vessel conditions, the related coolability questions are to be investigated in conjunction with the ex-vessel case.

3) Ex-vessel debris formation and coolability: A porous debris bed can be formed in a water pool of the reactor cavity due to the fragmentation of the molten corium jet ejected from the lower head of the vessel. The water pool is available through cavity flooding or water accumulation in the sump of a PWR due to LOCA conditions or containment spray. This is a similar process to the in-vessel situation, when molten material relocates from the core into a water filled lower head.

4) Bringing research results into reactor application: A general view on coolability shall be reached based on available modelling and derivation of conclusions for adequate modelling in ASTEC. This requires further studies and evaluations focusing on the major accident situations described above. The emphasis will be on validation with experimental results, code to code comparisons and joint reactor applications.

**Topic #14:** A review presentation on “Chernobyl shelter-status-myths and reality”

The director of ISP NPP O.Klyuchnykov presented an overview on the accident of the Chernobyl NPP Unit 4 in 1986 and its current state of the destroyed reactor and the object “Shelter”. The accident constantly attracts the attention of the society and remains a source of various versions and hypotheses. The accident was the severest one in the entire history of nuclear power industry (level 7 accidents by INES rating). The reactor core and all safety barriers and systems were completely destroyed and the majority of the core-bearing structures were damaged. The destroyed reactor immediately started releasing radiation to the environment and the adjoining territory was contaminated by active core fragments consisting of pieces of fuel rods, graphite, and contaminated structural elements.

After the explosion of the reactor different fuel-containing materials (FCM) are formed and distributed in manifold manner in the destroyed reactor building that is now covered by a huge “Shelter” (sarcophagus). It is estimated that the “Shelter” still contains 95% of the fuel, which had been in the reactor before the accident (about 200 t). Post–accident examinations revealed the FCM at many locations as fuel assemblies with fresh fuel in the central hall and spent fuel in the exposition pool, active core fragments in the form of fuel pellets, fuel elements and debris, black and brown lava-like fuel-containing materials (LFCM), fuel dust and hidden nuclearly hazardous clusters (in room 305/2). Potential dust generation from irradiated fuel and LFCM compounds currently represent the main hazards.

In the more than 20 years since the accident no more than 60% of the object “Shelter” rooms have been surveyed. The residual premises cannot be entered because of either high radiation fields or impenetrable obstructions. Thus, a significant portion of the object “Shelter” has not been surveyed. The resultant lack of knowledge of large portions of the “Shelter” contributes to some of the most serious risks today.

The results of scientific researches of the last years testify a need to perform all the tasks for both “Shelter” object stabilization and for the extension of research activities in the areas of nuclear and radiation safety (e.g. leaching of rainwater through leaks in the roofs is leading to an increase in the Pu concentration of the water in the shelter basements). The construction of a new protective envelope above the object “Shelter” (SIP: Shelter Implementation Plan; NSC: New Safe Confinement) is one of the most critical conditions for the “Shelter” conversion into an environmentally safe system. Estimated costs: about 1.2 G€ over ~10 years construction time.

**Topic #15:** Safety analyses of nuclear installations at the Chernobyl site

G.Pretzsch (GRS-Berlin) presented the GRS activities in this research field. Since 1992 GRS is providing support and assistance to the State Nuclear Regulatory Commission of Ukraine (SNRCU) in the frame of bilateral, multilateral and EU projects. Among them are important projects towards solving the problems at the Chernobyl site.

Besides safety analyses of the four nuclear installations (Units 1, 2 and 3 and SFSF-1, Spent Fuel Storage Facility, of CNPP) also comprehensive analyses of the safety status of the Chernobyl object “Shelter” have been performed along with scientific Institutes of Ukraine and Russia. Special interest has been devoted to the risk of accidental radioactive releases and subsequent radiological impact, of re-criticality and of groundwater contamination. One of the main targets of the French-German Initiative for Chernobyl was to establish a comprehensive data base of safety-relevant parameters with a GIS navigator. Moreover, GRS is involved in several projects concerning safety issues of spent fuel storage, as e.g. ISF-2 (Interim Storage Facility), and waste treatment facilities.

**On-going project presentations**

**Topic #16:** Status of the ISTC project #3690 on the “Fuel assemblies behaviour under severe accident top quenching conditions in the PARAMETER-SF test series (PARAMETER-SF3 and PARAMETER-SF4 experiments)

V.Nalivaev (FSUE SRI SIA “LUCH”) presented the current status of the project PARAMETER that includes the conduct of VVER-1000 bundle experiments with UO2 pellets and Zr+1%Nb cladding under severe reactor accident conditions (18 heated rods and 1 unheated rod). For the test PARAMETER-SF3 the following test conditions are planned. Coolant flow rates: argon 2g/s and steam 3.5g/s. The pre-oxidation of the bundle will be carried out at about 1470K for 3000s. Then the bundle will be heated up with 0.5 K/s to 1870K and then flooded with water from the top (40 g/s). The test parameters for the bundle experiments (heat-up rate, steam flow rate, extent of pre-oxidation of the cladding, maximum cladding temperature before quenching, flooding rates) are fixed on the basis of SVECHA code predictions by IBRAE.

In addition, a short description of the planned test scenario for the PARAMETER-SF4 experiment was given. The objective of the experiment is to study the behaviour of a VVER-1000 fuel assembly under severe accident conditions with bottom quenching of the assembly that will be heated up to about 18000С in an air environment (similar to the FZK experiment QUENCH-10). Details were discussed at the Project Progress Meeting in Moscow, Russia, July 14-17, 2008 (see CEG-SAM web-page: http://cegsam.grs.de).

**Topic #17:** Results of post-test examinations of SF2 fuel bundle and numerical simulations of the experiments PARAMETER-SF3 and -SF4

A.Kiselev (IBRAE RAS) presented the status of the PARAMETER-SF2 destructive post-test investigations. Five bundle cross sections were examined in detail. UO2 fuel relocation was not observed. A pronounced Zr+1%Nb cladding oxidation took place at the bundle elevations between 1000 and 1300mm. Beside the formation of a compact ZrO2 layer on the outer cladding surfaces, a localized spalling of thin ZrO2 multi layers took place. Quantitative data on the oxide layer thicknesses were given. The crack surfaces in the metallic part of the cladding (through wall cracks) were not oxidized. The pickup of hydrogen by the shroud was measured at different elevations. The maximum hydrogen concentration was about 23 at% at the 900mm elevation.

In addition a comparative analysis of the results of the PARAMETER-SF2 post-test and the PARAMETER-SF3 pre-test calculations were performed using different code systems as SOCRAT, ICARE, RELAP, PARAM-TG and ATHLET. The results were presented.

The results of PARAMETER-SF2 post- and pre-test calculations have been compared with the obtained experimental data. The comparison reveals that the applied experimental electric power at the pre-oxidation and the transient phase was higher than the calculated ones. Post-test calculations were performed on the basis of the exact PARAMETER-SF2 experimental data on power history, mass flow rates, and inlet temperature (except RELAP code). In the course of the PARAMETER-SF2 post-test calculations the heat loss in the external resistances (leads and electrodes) and the radial heat loss through the shroud, which were not exactly known, were improved. The heat loss in the external resistance is assessed to be 1.5 kW at the pre-oxidation and the transient phases. Scattering in calculated Joule heating power doesn’t exceed 0.5 kW. Radial heat loss through the shroud is assessed to be 1 kW.

All codes well reproduce temperature evolution of the bundle heated part besides the “hump” in experimental temperature at 12000 s. The calculated maximal temperatures before flooding onset correspond to measured experimental ones (1770 K). The RELAP code demonstrates a too fast runaway during the transient phase, and an early electric power switch-off is needed to fit the observed experimental maximum temperature.

At the flooding stage all codes predict practically no hydrogen release. Some hydrogen increase observed in the SOV-3 system may be the result of the time delay connected with hydrogen transport from source to the hydrogen measurement device. The best coincidence between experimental hydrogen mass and calculated mass is achieved in calculations by the ICARE code for the entire experiment. 28 g of hydrogen mass was measured at the end of the experiment; the ICARE code determined 25.5 g. The ATHLET and SOCRAT codes show a lower hydrogen release. One of the possible ways to improve the calculated results is to clarify the causes of the “hump”.

Input data decks for PARAMETER-SF3 pre-test calculations were derived from the PARAMETER-SF2 post-test calculation and were adjusted to the special proposed initial and boundary conditions of the PARAMETER-SF3 test. The analyses of heat balance and temperature distributions over the heated zone calculated by different codes were presented.

**Topic #18:** PARAMETER SF-4: a proposed strategy for experiment definition

### S.Güntay (PSI) described the key test objectives and proposed test parameters of the planned experiment PARAMETER SF-4.

### The test objectives are: 1) Achieve air oxidation sufficient to lead to a significant period of oxygen starvation. 2) Achieve successful reflood without significant excursion and without melting/degradation. 3) Complete ZrO2/ZrN formation would be interesting but is less important than achieving oxygen starvation. 4) UO2 oxidation is also interesting but probably not feasible in conjunction with other objectives and facility constraints.

#### The proposed test parameters are: In principle as agreed at the Podolsk meeting in July 2008. 1) Pre-oxidation in air at a temperature of 1200°C, to achieve oxide layer thicknesses up to 300-400 micro m at the hottest bundle location. 2) Power reduction to decrease the maximum bundle temperature to about 900°C with an airflow of 0.8-0.9 g/s (similar to QUENCH-10). 3) Power increase to reach a reflood temperature of about 1750°C to initiate bottom reflood at the same rate as in PARAMETER SF-3 with about 40g/s water.

**Topic #19:** Overview of the SARNET-2 MCCI proposal and link with ISTC projects

Ch.Journeau (CEA) reminded the proposal of a follow-up of the SARNET Network of Excellence in the 7th FP. The proposal has been favourably evaluated by EC independent experts.

In the case of a severe accident with vessel melt-through, the containment is the ultimate barrier between the corium and the environment. Two accident management strategies exist depending on countries and reactor designs: either the pit is dry at the vessel melt-through and Molten Core Concrete Interaction (MCCI) will occur, or the pit is flooded prior to the corium ejection and a debris bed will be formed. Both configurations have been studied for quite a long time, mainly in idealized one-dimensional (1D) configurations and it was commonly expected, when SARNET was proposed, that they were reasonably close to conclusion. However, recent results indicated that multidimensional configurations of MCCI and debris bed (and inhomogenity of the bed formation) have specific behaviours that totally affect the validity of 1D-models and require a new research program.

Further research on MCCI is aimed at providing new data and understanding of corium-concrete interaction, by using innovative approaches to address more prototypical phenomena with the view to closing the issue in 2013 or, at least that significant progress toward this issue's closure will be reached. It has been designed to ensure complementarities with the ongoing MCCI projects of the OECD-NEA and ISTC/STCU.

It is planned to study the effect of the concrete nature on 2D ablation profiles (limestone-rich concretes are ablated isotropically while silica-rich concretes interacting with oxidic corium are more ablated on the sides than downwards); the role of the metallic layer on the MCCI; theefficiency of water cooling to terminate the concrete ablation and, finally to transfer the R&D results to the reactor scale.

The proposed research will re-group experiments both with simulant and prototypic materials (mainly at CEA, FZK and VTT) to determine which phenomena are causing the observed effect of concrete composition on the ablation shape and to assess their influence at reactor scale. The use of simulant material enables precise measurements while prototypic materials allow taking better into account the various phenomena occurring in the reactor case. In particular, it is planned to use specially designed artificial concretes to assess which property of the siliceous and limestone concretes control the observed differences in ablation behaviours. Finally, data must be acquired (at ITU and UJV) on the phase diagrams between the corium and concrete.

**Topic #20**: Report on the ISTC #3831 (MCCI) project progress meeting in Moscow, July 2008

Unfortunately, nobody from VNIIEF could attend the meeting. A.Miassoedov (FZK) gave a short presentation on the progress meeting on “Development and experiments at large-scale installation for heating and retention of corium” in Moscow in July 2008. The task of the project is to develop a technology of producing concrete crucibles and corium, to conduct experiments, to develop a measuring system for corium temperature and concrete heat flow diagnosis, and to establish a middle-scale installation (100-120kg) and to carry out experiments on corium/concrete interaction at 2500-2700°C. A concrete and corium composition (VB-U6) was recommended for the middle-scale experiment. The corium mass will be 31kg. The scope of activities for the middle-scale and large-scale experiments was presented and discussed. A list of questions from the French collaborators to VNIIEF was presented at the meeting. It has been decided that Ch. Journeau (in conjunction with David Bottomley) will e-mail them (in conjunction with a reminder of the questions raised by other collaborators at the July meeting) to VNIIEF partners (action 14/2).

**Topic #21:** Numerical simulations in containment safety analysis

A.Kotchourko (FZK) described the current work that is devoted to problems connected with application of CFD (Computer Fluid Dynamics) tools for NPP safety analysis for the scenarios with possible damage resulting from combustion and explosion of large amounts of hydrogen expected in most SA scenarios.

In order to reproduce mechanistically the whole sequence of events in the course of SA scenario, a possibility for modelling each event in the sequence is required. Such event sequence includes a number of individual phenomena; e.g., a typical scenario with hydrogen combustion can include the following chain: formation of a source of hydrogen, mixing with air and formation of flammable mixture (a cloud or a confined volume filled with mixture), ignition of such mixture, combustion, flame acceleration (FA), fast deflagration, deflagration-to-detonation transition (DDT), and detonation. Some of those phenomena are very well understood (and very well numerically modelled, e.g., shock wave propagation), some of them could be described numerically with acceptable accuracy and reliability (e.g., detonation propagation) and some are still far from clear understanding and therefore from accurate numerical description (e.g., DDT). Clearly, that due to the possible lack of knowledge and to a limited power of modern computers the completely mechanistic and fully 'resolved' numerical approach will definitely fail. Thus, an answer to a question whether it is possible to make simulations aimed at producing reasonable and reliable results, has to be addressed in the course of safety analysis.

A commonly accepted technique in industry for evaluation of damage potential is probabilistic risk analysis. Such analysis makes predictions on the basis of probability of a certain event taking into account the severity of its consequences. Nowadays for the consideration of event evolution and evaluations of the consequences, CFD tools are widely used, since they can provide detailed information on process evolution and expected damage. However, it appears that this way of CFD simulation is often not completely validated or even inadequate. Obviously, a corresponding methodology which is able to obtain reliable results in CFD analysis is required.

**Topic #22**: Progress report on the ISTC project # K-1265 “Study of the processes of corium-melt retention in the reactor pressure vessel” (INVECOR)

V.Zhdanov (IAE NNC RK) described the objective of the in-vessel corium retention experiments (INVECOR), i.e. the improvement of the safety assessment of LWR corium in-vessel retention (IVR) and the modelling of the thermal and physico-chemical processes of the prototypical corium pool and its retention in the water-cooled RPV lower head.

Within the past 9 quarters of activities for the project INVECOR the following results have been obtained: 1) The technology of graphite protection of the experimental facility to avoid chemical interactions with corium components at high temperatures has been fulfilled. The reliability of the protection has been checked up to the melting point of prototypic corium in a small-scale facility and in large-scale experiments by heating of 12kg of prototypic corium with the application of coaxial plasmatrons. The design of a crucible for melting of 60kg of prototypic corium has been modified to obtain a uniform coating on its internal surface. 2) The design of coaxial plasmatrons used for decay heat imitation in molten corium pool has been improved. As a result of numerous experiments the power of individual plasmatrons has been increased up to 18.5kW for up to 2.5 hours. 3) The design of the device for decay heat imitation in the molten corium pool has been further developed using 5 coaxial plasmatrons with total power over 90kW. 4) The experimental test section representing a RPV model of semi-elliptic shape with an internal diameter of 400mm and a wall thickness of 50mm has been developed and fabricated. The experimental section was manufactured from carbon steel. For the heat maintenance in an interaction zone "corium/steel" the external surface of experimental section is covered by a thermal insulating package. Experimental tests have shown, that the application of the thermal insulation allows increasing the temperature in the interaction zone "corium/steel" up to more than 1000°C. 5) Seven large-scale experiments with heating of 12kg prototypic corium components using individual plasmatrons (TOP experiments) have been executed. The experimental cell for the TOP tests contained a thermal insulation on the external surface. The duration of experiments varied from 1 to 2.5h at plasmatrons power from 17 to 19 kW. Tests have shown that the plasmatrons power can be considerably increased in case of using graphite from type R4340 SGL Carbon Group. 6) Post-test examinations have been executed to determine the degree and character of corium heating, the phase composition of the solidified melt, the state of the coating on the graphite which was in contact with corium melt during the tests. 7) Pre- and post-test calculations have been executed. 8) The equipment and materials necessary for manufacturing the furnace and electrode nozzles have been bought. It should be mentioned that the manufacturing of the electro-melting furnace is only possible using graphite of SGL Carbon Group. In connection with a delay of the export license for delivery of necessary materials from Germany to Kazakhstan the work will be suspended into the 10th quarter.

**Topic #23**: Progress report on the ISTC project #3592 (METCOR-P) "Corium Melt Interaction with Reactor Vessel Steel”

S.Bechta (RIT-NITI) described the objectives of METCOR-P project: Qualification and quantification of physico-chemical phenomena of corium melt interactions with reactor vessel steel with particular interest to interaction characteristics at vertically positioned interfaces, peculiarities of interaction with European vessel steel, and corium melt oxidation transients.

Test МСР-3 has been conduced to identify qualitative and quantitative phenomena taking place during the oxidation of molten corium by steam during its interaction with a cooled steel specimen. The first phase of the test repeated МС6 conditions. At the second stage the melt was oxidized by steam. At the third stage the interaction zone, which was formed during the first phase, was oxidized. Preliminary results of the completed test and incomplete post-test analysis are as follows: Before oxidation, in the conditions close to the MC6 С-30 corium - steel interaction, in the USS sighting spot the MCP-3 interaction zone was deeper by approx. 1.4mm, and the incubation period was shorter by approx. 6000s. The rates of oxidation and hydrogen generation measured during the pool oxidation were close to MA-9 test (MASCA programme). The oxidation was controlled by the steam supply to the molten pool surface. The most conservative regime was realized in the test, i.e. the interaction zone was oxidized by the previously oxidized molten corium. A partial melting of the steel surface took place in the end of oxidation regime. This was caused by the uncontrollable increase of heat transfer from the melt (setup-specific factor) and/or additional heat generated by chemical reactions. The respective heat fluxes have been evaluated as 0.61 and 0.15MW/m2.

Using the METCOR correlations on VVER steel corrosion rate at the interaction with sub-oxidized and fully oxidized melts an evaluation has been made of corrosion impact on the in-vessel retention of the stratified and homogeneous pools in the VVER-1000 lower head. The ANSYS code (FZ Dresden-Rossendorf) was used in the calculations. For calculating the vessel temperature conditions a temperature for the external water-cooled vessel surface and heat flux distribution on the internal surface were set. The heat flux was calculated using half-empirical models of free-convective heat exchange. The final vessel configuration was determined with and without corrosion influence. It has been shown that corrosion significantly reduces the vessel wall thickness, in particular, for the homogeneous molten pool. The calculation of stress-and-strain vessel condition has proved that corrosion does not produce a significant influence on the in-vessel pressure resulting in the vessel failure; this is explained by the external cool layer of steel, which takes the main impact.

S.Bechta also mentioned some organizational problems such as restrictions imposed by the ROSATOM Export Control measures, e.g., an export license is necessary. A partner should be found and the results confidentiality should be confirmed. JRC-ITU is ready to be a partner and has already sent a letter to that effect. An agreement on the conditions of providing project deliverables to the ISTC is currently being negotiated between ROSATOM and ISTC.

**Topic #24**: Progress report on the ISTC project #3813 “Phase relations in corium systems” (PRECOS)”

S.Bechta (RIT-NITI) described the objectives of the project **PRECOS. The** subject of the project is the experimental investigation of phase diagrams of oxidic and metal-oxidic corium systems that form as the result of core meltdown and interactions of melt with construction and structural materials of the reactor core, concrete shaft, and core catcher.

The following systems will be studied in PRECOS: 1) Binary and ternary oxidic systems (CaO-UO2, CaO-FeO, SiO2-UO2, UO2-FeO-SiO2, UO2-FeO-CaO, ZrO2-FeO-SiO2, and ZrO2-FeO-CaO) that contain components of concretes and sacrificial materials, i.e., of importance for modeling the interaction of corium with materials of the concrete shaft and core catcher. The SiO2–containing systems should be specially mentioned, as their high viscosity and low conductivity make their experimental investigation problematic. 2) Metal-oxidic systems U-Zr-Fe-O with different concentrations of components, especially in the miscibility gap. 3) Multi-component mixtures representing prototypic ex-vessel corium.

First results of experiments in the SiO2-UO2 system (GPRS 1-3), to define the monotectic temperature and the shape of the miscibility gap, were presented.

**Topic #25:** Status of the ISTC project #3635 “Scale experimental investigation of the thermal and structural integrity of the VVER pressure vessel Lower Head in severe accidents”

V.Loktionov (MPEI) presented the progress of the ISTC project. The objective is the experimental and numerical study of the behaviour of VVER-440 LH reactor vessel scale models during transient thermal and overpressure loading corresponding to realistic SA scenarios. The expected results will be experimental data on the creep behaviour, heat-up and failure of the VVER-440 vessel scale models. The data will be used for verification of thermo-mechanical codes that are used in safety assessment in SA management strategy for NPPs.

The status of the different tasks was presented in detail as the designing and construction of the test facility, the manufacturing of the VVER LH reactor vessel scale models, the conduct of the scale experiments with VVER vessel models at high temperatures as well as separate-effects tests on the creep behaviour of the VVER vessel steel and numerical pre- and post-test analyses of the scale experiments.

Savings on the costs of the vessels will be achieved by the use of a cheaper steel (22K) for the head and upper sections of the vessel, leaving just the central section in the prototypical 15Kh2MFA steel. Funding is assured for 1 vessel, but they are still looking for funding of 2 further vessels.

**Topic #26:** Thermo-hydraulics of U-Zr-O molten pool under oxidising conditions in multi-scale approach (crucible- bundle -reactor scales); ISTC project #3876 (THOMAS)

M.Veshchunov (IBRAE RAS) described the objectives and work plan of the approved project THOMAS. Non-destructive and destructive post-test examinations of bundles in various tests showed the formation of molten pools of different scales at various stages of core degradation. Small local pools were observed at different elevations in bundles in the early stage of core degradation in CORA and QUENCH tests. Results of the PHEBUS -FP tests confirmed that a significant part of the fuel bundle was liquefied and that the amount of fuel damage was close to TMI-2 with an extended molten pool located in a central zone of the bundle underneath a cavity. In the late stage of a severe accident, the formed melt can relocate into the lower head of the reactor pressure vessel and form a large molten pool interacting with cooled walls.

Oxidation kinetics of Zr-containing melts can be significantly higher in comparison with that of solid materials, therefore, it strongly determines high heat generation and hydrogen source term during severe accidents, as unambiguously shown, i.e., in the QUENCH tests. On the other hand, the oxidation kinetics strongly depends on thermal hydraulic behaviour of oxidised melt. Therefore, investigation of in-vessel molten pool behaviour under oxidation conditions is still an important issue with respect to core degradation and reactor pressure vessel coolability and failure analysis.

The newly-approved project THOMAS aims at the tight coupling of the two advanced tools developed within the previous Project #2936: the SVECHA physico-chemical (molten pool oxidation) model and the thermo-hydraulic code CONV. This will allow a realistic mechanistic description of a (U-Zr-O) molten pool behaviour in oxidising conditions and will extend the thermal hydraulic consideration of oxidised melt from small-scale (crucible tests) up to a large-scale (reactor pressure vessel), including an intermediate scale corresponding to molten pools in the bundle tests. Moreover, improved interpretation of PHEBUS-FP test observations of corium melt oxidation, as well as transposition of thermal hydraulic consideration from the experiments (i.e. MASCA, RASPLAV) to reactor case, are foreseen.

The developed and verified models will be further used for benchmarking and improvement of simplified models of various system codes such as ICARE/CATHARE, ASTEC or the Russian SA code SOCRAT.

There will be no export control difficulties within this project proposal since ROSATOM does not give its agreement but the Russian Academy of Sciences (to which IBRAE belongs) instead. The developed code system will be available to CEG-SAM members on a bilateral basis. The formal commencement of the project is September 2008.

**New or updated project proposals**

**Veronika**

This project was quickly mentioned by J.Stuckert and M.Veshchunov. RIAR has carried out all the necessary actions for submission to ISTC and given it to MINATOM (now ROSATOM - their controlling ministry) for checking and submission to ISTC. Much delay has been due to the re-organisation of RIAR but also due to considerable changes at ROSATOM. Export control regulations will cause additional problems for this project.

## Topic #27: Status of the STCU project proposal #4207 “Status of the STCU project proposal #4207 “Problem of uranium and transuranium elements accumulation in “Shelter” object aqueous clusters as nuclear and radiation hazard factor”

A. Odintsov (ISP NPP) presented the current status of the project proposal STCU #4207. The Chernobyl shelter of the RBMK-1000 Chernobyl NPP unit 4 is a source of radioactive particles that formed during the accident (now present inside the construction in the form of dust) and in the subsequent period due to physical-chemical destruction of the fuel containing material (FCM). In view of the planned transformation of the “Shelter” into an ecologically safe system, the presence of the fuel dust in the shelter (about 30000kg) will become a serious problem. In spite of the numerous data on the characteristics, composition and localization of the fuel dust in the shelter, the mechanisms of its formation and, especially, the prognosis of its further physical/chemical transformation are still not clear.

One other serious problem as nuclear and radiation hazard factor is the uranium and trans-uranium elements accumulation in the “Shelter” object's aqueous clusters. The purpose of these activities is to obtain new experimental data on leaching processes of uranium, Pu238, Pu239+240, Am241 and Cm244 by water flows in some rooms of the Chernobyl NPP unit 4 and to estimate the radionuclide and fissionable elements accumulation velocity in bottom sediments in the lower parts of unit 4. The main sources of water penetration into the “Shelter” object per year are: 1) atmospheric precipitation (about 1500m3); 2) condensed moisture (about 1600m3); and 3) water from the dust suppression system (150-200m3). A part of the accumulated water will evaporate in the autumn/winter period (about 2000m3) and/or spill-over outside the “Shelter” object (about 1000m3). In the bottom most rooms of the unit 4 are located constantly between 380 and 400m3 of water.

Results on the seasonal and annual changes of the uranium, plutonium, americium, and curium as well as of a few fission product concentrations in the water-containing clusters were presented and discussed. At some locations within the “Shelter” object sediments and dried colloid forms containing uranium, trans-uranium elements and fission products have been generated. According to estimates, the bottom sediment in room 001/3 can exceed 90m3. The concentration of fissionable isotopes as U235 and Pu239 in the sediment amounts to 860 and 430g, respectively, which has to be considered in assessing the ”Shelter” object nuclear safety. Am241 is also accumulating in this sediment. Further, fission product Sr-90 has been observed to concentrate in the finest particles sizes (<1µm). The transformation (dissolution) of different types of “Shelter” object fuel-containing masses occurs with various rates. In 100 years approximately 4% of the fuel is transformed in soluble and/or colloid forms.

The problems described above show the importance of additional research work in this area. Unfortunately, until now the problems concerning funding of the STCU project #4207 is not yet solved, which delays the acquisition of needed materials and equipment. Nevertheless, limited further work will be carried out in this important field.

The main objective of the project is to use these data from the previous tasks to create a model predicting the long-term (50-100 years) behaviour of the radioactive dust in the shelter. The model will describe both transformation of the existing fuel dust and the processes of the dust formation from the main types of FCM under the current and future shelter conditions.

**Topic #28**: Status of the STCU project proposal #4758 “Estimated experimental researches to characterize hidden nuclear hazardous clusters of fuel containing materials in the destroyed Chernobyl NPP Unit 4”

E.Visotsky (ISP NPP) presented the status of the STCU project. Two fuel-containing material aggregations of about 50t were analyzed on basis of dynamic temperature and neutron gradient measurements. The material aggregations are located in the concrete of reactor foundation plate in cavities that have formed by the molten fuel-containing material during or immediately after the reactor accident. Currently these material aggregations are covered by water that penetrated to the foundation plate from atmospheric precipitation (rain) and condensate water. From the location of the material aggregation periodically a flow of heated water has been observed. Periodic temperature fluctuations have been noted in the eroded concrete foundation plate.

In the room 305/2 a neutron incident (re-criticality) occurred in July 1990 that was observed by neutron measurements in the neighbouring room. The introduction of neutron absorber gadolinium resulted in the blocking of the neutron sensor and stopped further measurements. In addition, water was supplied to places of material accumulations in order to decrease their temperature below 100°C. It is assumed that self-quenching occurred as result of immersion of the fuel-containing material in water; this is the typical behaviour of a neutron-multiplying medium with reduced-enriched uranium.

A hypothesis on the structure of the corium pool (showing an underlying metal layer and two oxidic layers, a UO2 rich at the middle and a SiO2-rich at the top) has been presented. Since only samples from the corium surface have been collected and analyzed, this could explain why neutron measurements can reach higher values than with calculations assuming a homogeneous corium composition.

The aggregation of fuel-containing material is nuclearly dangerous because it is immersed permanently in water and any change of the local physical and/or chemical conditions may result in the initiation of a nuclear incident. For this reason, a more detailed examination of the neutron/physical and physical/chemical characteristics of buried fuel-containing material aggregations as well as the development of methods for their safe containment under sub-critical conditions are the prior problems in transforming the object “Shelter” into an ecologically safe system.

Ch.Journeau indicated that knowledge of the composition of the buried layers of fuel-containing material could also have interest for the modeling of Western reactor MCCI.

**Topic #29**: Status of the STCU project proposal #4726 “Safety-critical software independent verification and latent faults assessment based on diverse measurement of invariants”

B.Konorev (I&C SCC) presented the project proposal. The project purpose is the development of methodologies and tool environment, providing trustworthiness of critical software qualification. The aim of the project is the development of the advanced information technology of proven independent verification and prediction of software latent faults for critical systems related to NPP safety. The main tasks are the prediction of software latent faults, the estimation of the test coverage completeness and cost-effective management.

**Topic #30:** Status of the STCU project proposal #4452 “Robot-technical complex for ChNPP on the base of robots of Ukraine and USA”

A.Nevsky (ISP NPP) presented the project proposal. The long-term problem with the Chernobyl NPP Unit 4 “Shelter” object is the conversion of Unit 4 into an ecologically safe system. In conformity with Ukrainian strategy of «Shelter» object conversion and the international plan (SIP) «Shelter implementation plan», a huge scope of diverse work is being carried out. Some of this work must be conducted under conditions of high levels of ionizing radiation which are dangerous for human beings. Currently, the world has no technical approach suitable for the safe conduct of much of the work under the existing conditions in «Shelter» object. Therefore, the problem requires the development and use of un-manned technological processes capable of operation in a nuclear and high-radiation environment and creation of the technical capabilities for their realization, with minimum personnel exposure to the radioactive contamination of the surrounding area.

The main purpose of the project is to develop safe, robot-technological processes for nuclear and radiation work aimed at the conversion of the Chernobyl "Shelter" object and the decommissioning of the Unit4 by creating a new robotic technical complex. The essence of the project includes the completion and upgrade of the earlier robotic systems, by addressing the issues revealed during preliminary testing of the robot technical system "Pioneer" designed in the USA, as well as the robots developed in Ukraine, and their unification into a single complex possessing new technical capabilities, to realize the following activities and objectives: 1) support the work to recharge the fuel located in the ChNPP Unit3 interim repository; 2) radiation and technological monitoring and characterization of stored spent nuclear fuel; 3) Characterization of fuel-containing masses (FCM) in the "Shelter" object and creation of a database to plan future work (including FCM sampling, 3-D mapping, measuring of parameters of ionizing radiation, mechanical and thermo-physical characteristics); 4) development of the technological processes and conduct of a demonstration experiment of the extraction and containerization of accessible FCM clusters in the "Shelter" object; and 5) the development of capabilities to respond to urgent emergency and recovery works in case of accidents at nuclear power plants and other radiation and nuclear facilities in Ukraine.

Before the accident at the Chernobyl NPP in 1986, the facilities and capabilities to complete the above-indicated tasks did not exist. That is why, as a result of the implementation of this project, there will be new world-class capabilities and facilities for the management of the consequences of such man-caused catastrophes that do not have analogues at this level of complexity and scale. The expected cost was $240k for the 3 year project.

**Topic #31:** The use of KMS capabilities for PWR containment studies

V.Zasukha (FSUE-NITI) described the KMS large-scale test facility that is designed for 3D experimental modeling of heat- and mass transfer processes, distribution and stratification of steam-gas mixtures, hydrogen (helium), and aerosols inside a PWR containment. The KMS containment shell is a metal cylinder with hemispherical dome. The outer wall of the shell is thermally insulated. The internal metal structures separate the containment space into 11 connected compartments. The total containment volume is 1920 m3. Provision is made for modifying the configuration and varying the number of the compartments. The maximum design pressure is 0.54MPa and the maximum design temperature is 150oC. The KMS containment is equipped with air, steam, and helium injection systems, sprays, and heat removal system. The KMS facility comprises a model of the Passive Containment Cooling System for NPP-2006 Project (LNPP-2, Sosnovy Bor). KMS has about 1000 channels for temperature, pressure, flow rate, level, velocity, and heat flux measurements. Measurement instruments and conditions are experiment-specific and chosen depending on experimental programme and objectives. The gas analysis system of KMS is designed for automatically measuring steam and gas concentrations at 10 points inside containment. An analysis of measured data is carried out by mass spectrometer and gas chromatograph systems. The number of sampling points and their locations can be varied depending on experiment program. KMS has an up-to-date data acquisition and control system (DACS) on the basis of modern computer hard- and software. The DACS records, stores, and displays experiment data on VDU, and executes monitoring and control functions. The DACS has an open modular architecture and can be extended if there is a need to enhance capabilities or apply upgrades.

The objective of the KMS is the verification of containment codes, the testing of spray systems and condensers and the testing of equipment components under realistic emergency conditions inside the containment as well as the testing of the metal shell-strained state under thermal and mechanical loads.

**Topic #32**: Next CEG-SAM meetings in March and September 2009

S.Güntay (PSI) kindly offered to host the 15th CEG-SAM meeting in Villigen, Switzerland, March 10-12, 2009. The 16th CEG-SAM meeting will be kindly organized by M.Veshchunov (IBRAE) in Moscow, September 8-10, 2009. The chairman M.Hugon thanked both organizations for their co-operation and support in advance.

M.Hugon thanked once more V.Stepanenko (STCU) and V.Krasnov (ISP NPP) for the organisation of the 14th CEG-SAM meeting in Kiev. He also expressed his thanks to all speakers and participants for their engagement at the meeting.

**Restricted session** (continued)

**Topic #33:** SARNET and CEG-SAM comments on ISTC & STCU proposals

There was no discussion on specific project proposals.

Concerning the selection of an ISTC/STCU project proposal M.Hugon clarified once more that only officially registered proposals (with a number) can be chosen by the CEG-SAM and proposed for consideration at the GB meetings.

The chairman M.Hugon suggested to look for ISTC projects that may be of interest for the CEG-SAM in other research areas, which are currently outside the scope of the group, as for example in the field of containment studies. In this connection it would be necessary to modify the present CEG-SAM guidelines and complement them regarding new activities. The new name for the group could then be **“Contact Expert Group on Safety and Accident Management”** (still CEG-SAM). The work of the group should be continued in the same manner as before. M.Hugon will supplement the guidelines until the next meeting (action # 14/4).

**Topic #34:** Detailed discussion of presented ISTC & STCU project proposals and preparation of specific CEG-SAM advices

The STCU project proposal #4207 was presented to the STCU GB but it was not financed by the GB, may be because the Russian counterpart project ISTC # 3702 (CHESS-2) was not financed by the ISTC GB. Both proposals address the long-term behaviour of the corium lava after the Chernobyl accident in a complementary way by ISTC and STCU and are of first priority for the Network of excellence SARNET. Since they are of great interest to the CEG-SAM, they should be reconsidered by the GBs for funding.

The STCU project proposal #4758 is not yet approved by the government. The subject of possible re-criticality of fuel-containing material accumulations in the Chernobyl NPP Unit4 is of generic interest to the CEG-SAM. Further research in this area is important and therefore necessary.

The STCU project proposal #4452 is at edge of the CEG-SAM's existing scope, although D.Bottomley pointed out that this project considers similar problems to those of the hot cell remote handling techniques at ITU and of the robotic machines at KTH (the emergency response unit at FZK).

A vote on the ranking of the different STCU project proposals resulted in the following sequence: STCU #4207 (ISTC #3702) > STCU #4758 > STCU #4726 > STCU #4452. The general problem with the STCU project proposals has been that no information of their content was made available to the CEG-SAM before the meeting (at least two weeks in advance). In addition, a part of the distributed information on the proposals at the meeting in Kiev was only available in Russian. Therefore it was not possible to give full consideration to the proposals. The way of processing proposals within the CEG-SAM has been derailed to V.Stepanenko who will diffuse the information to the STCU proposers.

**Topic #35:** Discussion of various actions

See specific action list (Annex #3).

**Topic #36:** Other matters; Final remarks

No specific comments.

The chairman M.Hugon thanked once more STCU and ISP NPP for hosting the meeting and for all their related excellent efforts and he thanked also the participants for their efficient work and contributions and wished them a safe journey back home.

On September 11th, the CEG-SAM members were given a technical visit to the site of Chernobyl. They thank their Ukrainian hosts for the organization of this visit, which was of great interest and emotion for severe accident specialists, and for their hospitality.

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**M. Hugon** (chairman) **P.Hofmann** (secretary)

**Annexes:**

1. Revised final agenda of the 14th CEG-SAM meeting
2. List of participants at the 14th CEG-SAM meeting
3. Specific action list (appended below)

Annex #3:

**Specific Action List**

14th CEG-SAM meeting; Kiev, Ukraine, September 9-11, 2008

**Action 14/1**: L.Tocheny (ISTC) will contact all managers of on-going ISTC projects to inform them that they should provide information (name and e-mail address) to A. Miassoedov (FZK) and K.Trambauer (GRS) to be included in the CEG-SAM website users list. After that they will have full access permissions for their projects web-pages and will be exclusively responsible for updating the project documentation/deliverables and the upload of presentations from project progress meetings.

**Action 14/2**: D.Bottomley (JRC-ITU) and Ch.Journeau (CEA) will write a letter to A.Kondrashenko (VNIIEF) to obtain answers on the questions raised by French collaborators.

**Action 14/3**: M.Hugon (EC) will send a letter to W.Gudowski (ISTC) to get information on the current access regulations for Sarov. The collaborators of the project would like to have a meeting with A.Kondrashenko in Sarov and to use the opportunity to visit the MCCI test facilities.

**Action 14/4**: M.Hugon (EC) will supplement the CEG guidelines concerning the future extended scope of activities of the group to include also developments of numerical codes and experiments on safety (neutronics + thermal hydraulics).

**Action 14/5:** M.Hugon (EC) will write an E-mail to J. Sanders (DG RTD – ISTC Secretariat) to be transmitted by him to the European members of ISTC/SAC and of the similar committee for STCU to ask them to re-consider the funding of ISTC project proposal #3702 (CHESS-2) at the next GB meeting as well as that of STCU project proposal #4207. Both proposals address the long-term behaviour of the corium lava after the Chernobyl accident.

**Action 14/6:** L.Tocheny (ISTC) should check the state of the ISTC project proposal #3702 (CHESS-2).

**Action 14/7:** L.Tocheny (ISTC) should provide invitations and visa support for the foreign participants at the 16th CEG-SAM meeting in Moscow in September 2009 (this request was expressed by IBRAE to CEG-SAM after the meeting).