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|  | EUROPEAN COMMISSION  DIRECTORATE-GENERAL ‘RESEARCH’ | INTERNATIONAL  SCIENCE AND  TECHNOLOGY  CENTER |  |

**CONTACT EXPERT GROUP on CORIUM MANAGEMENT**

**(CEG-CM)**

**MINUTES OF THE 4th MEETING**

**NITI, Research Institute of Technology, Sosnovy Bor**

**Meeting Location: St. Petersburg, House of Scientists, Conference Hall**

**September 18-19, 2003**

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| Dissemination level: RE  PU: public  RE: restricted to EC and a group specified by the CEG-CM members  CO: confidential, only for EC and CEG-CM members |

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Revised minutes, November 21, 2003 CEG-CM / M-04

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| Subject: Fourth Meeting of the ISTC  ‘Contact Expert Group on Corium Management’ (CEG-CM)  Place: House of Scientists, Conference Hall, St. Petersburg, Russian Federation  Date: September 18-19, 2003  Participants: 28 participants of 17 organisations from 4 countries:  Mr. B.Adroguer IRSN, Cadarache  Mr. H.J.Allelein GRS, Cologne  Mr. G.Azarian Framatome ANP, Paris  Mr. D.Bottomley JRC / ITU, Karlsruhe  Mr. G.Cognet CEA/DEN/DSNI, Saclay  Mr. M.Fischer Framatome ANP, Erlangen  Mr. P.Hofmann Consultant, Karlsruhe (secretary)  Mr. J.Stuckert FZK, Karlsruhe  Mr. W.Tromm FZK, Karlsruhe  Mr. H.Unger RUB, Bochum  Mr. A.Zurita DG-Research / J.4, Brussels (chairman)  Mr. S.Bechta RIT / NITI, Sosnovy Bor  Mr. V.Bezlepkin SPAEP, St. Petersburg  Mr. A.Boldyrev IBRAE, Moscow  Mr. S.Bogatov RRC-KI, Moscow  Mr. S.Butorin RMINSC / Minatom, Moscow  Mr. V.Chudanov IBRAE, Moscow  Mr. N.Gorin VNIIEF / Minatom, Snezhinsk  Mr. A.Grebennikov RFNC-VNIIEF, Sarov  Mr. V.Khabensky RIT / NITI, Sosnovy Bor  Mr. V.Kumayev IPPE, Obninsk  Mr. E. Kruschinov RIT / NITI, Sosnovy Bor  Mr. Y.Leontiev SPAEP, St. Petersburg  Mr. A.Palagin IBRAE, Moscow  Mr. A.Lukianov IPPE, Obninsk  Mrs. V.Rudneva ISTC, Moscow  Mr. L.Tocheny ISTC, Moscow (co-chairman)  Mr. M.Veshchunov IBRAE, Moscow  Distribution list: Mr. A.Mitsos DG-Research  Mr. L.Bellemin DG-Research / 05  Mr. P.Fernández Ruiz DG-Research / J  Mr. M.Poireau DG-Research / J.1  Mr. J.Poussielgue DG-Research / J.1  Mr. H.Forsström DG-Research / J.4  Mr. D.Taylor DG-TREN / H.2  Mr. R.Schenkel JRC  Mr. P.Frigola JRC/ 05  Intranet of Unit J.4  Mr. D.Gambier ISTC, Moscow  Mr. L.Tocheny ISTC, Moscow  EU members  Contact person: Mr. A.Zurita Tel.: +32-2-29.58365 – MO75, 5/30 |

Agenda of the meeting see annex 1, list of participants see annex 2.

The 4th CEG-CM Meeting in St-Petersburg has been fit well with the two-days Steering Committee Meeting on the ISTC projects #833.2 (METCOR) and #1950.2 (CORPHAD) where progress reports on the project status have been presented and were discussed in detail.

**Restricted session**

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

The meeting was divided into open and restricted sessions. A.Zurita opened the restricted session and welcomed the EU participants of the 4th meeting of the International Science and Technology Centre (ISTC) – Contact Expert Group on Corium Management (CEG-CM).

17 Russian scientists attended the meeting. Nine of them gave presentations on the status of ongoing ISTC projects, project proposals or ideas, which can be considered as candidates for future project proposals, or other type of research works related to the technical scope of the CEG-CM group.

**Topic #2:** Adoption of the agenda

After some discussion the attached agenda (see annex 1) was accepted.

**Topic #3:** Approval of the minutes of the 3rd CEG-CM meeting in Moscow

On the basis of the draft minutes the secretary considered the various comments received in the reviewed minutes, dated May 2003, which were finally approved without changes at the meeting in St. Petersburg.

**Topic #4:** Specific action list

Remarks to the action list of the last meeting:

Action 2/3: The group decided to invite organisations of the new member countries of the EU, after its forthcoming enlargement foreseen in May 2004, to the meetings.

Actions 2/5+2/6: The possible USB collaboration in the ISTC project #833.2 and that of ANL in the project #1950.2 was again discussed. L.Tocheny discussed these points with D. Gambier, the new executive director of ISTC. Also in the case of EC-funded projects, potential third party collaborators should request such collaboration for possible approval by the financing party (with specific conditions, if any). In all cases the financing body has the property rights.

Concerning the project #833.2 an interest of some partners of the group exist in a collaboration Nevertheless, any decision should be made unanimously.

If ISTC receives a request of an organisation to act as collaborator it will be transferred to the chairman A.Zurita for discussion with EC authorities (D.Gambier) for further decision. Arguments of recipients have to be taken into account.

Action 3/1: The procedure to apply as collaborator was implemented, i.e. formal letter to the ISTC secretariat in Moscow with copies to Messrs. Zurita, Tocheny and Hofmann.

Action 3/2: The extension of the technical scope of the CEG-CM will be discussed under topic #6.

Action 3/3: Thanks were expressed to L.Tocheny, S.Bechta and V.Khabensky for the excellent logistic organisation of the meeting.

All actions were fulfilled.

**Topic #5:** Report by the secretariat

L.Tocheny expressed the usefulness of the CEG-CM group and its importance for decisions of the governing board. The project #1648.2 was approved as worth funding by the ISTC Governing Board.

Several letters of interest were received by the ISTC secretariat to act as collaborators. The summary of the status for the three on-going projects recommended by the CEG-CM is the following:

#0833.2: confirmed collaborators: FZK, Fortum, JRC-ITU, CEA and FANP

new collaborators: IRSN and FZR

#1648.2 confirmed collaborators: FZK and IRSN (EDF to be clarified)

new collaborators: CEA and JRC-ITU

#1950.2 confirmed collaborators: FZK, IRSN, JRC-ITU, CEA and FANP

no new collaborators

This situation should be confirmed by ISTC Secretariat (action 4/1).

The list of considered ISTC projects was distributed –together with the minutes- to the group members.

Requirements should be established to submit ISTC project proposals to CEG-CM. The group can also give recommendation on proposals to the possible recipient and/or financial party even if the proposal is not yet registered. The proposals of topic #15, 16, 17, 18 and19 have been already registered by ISTC, that of #20 will be registered very soon and those of topic #21 and 22 are new proposals.

A.Zurita informed that he has invited Prof. M.Kröning, the former executive director of ISTC, to give an introductory lecture on “ISTC objectives and achievements” at the FISA-2003 conference in Luxembourg, 10-13 November 2003. This will be an important contribution to acquaint the EC forum with ISTC tasks. The invitation was accepted.

**Topic #6:** Discussion on the enlargement of the technical scope of the ISTC CEG-CM

The research on corium-related issues is a narrow field. In line with the discussion initiated at the last meeting (action 3/2), A.Zurita raised therefore the question to enlarge the technical scope of the group for new topics as for example LOCA, RIA, AMM and/or fission product release phenomena. The group should decide on the enlargement and the group members should also consult their organisations. A positive decision would mean that in future meetings, experts on these topics should be invited or their opinion should be obtained by group members and presented at the meetings.

In the subsequent discussion the following suggestions were made on possible topics to be considered in future: (i) fission product release and transport (in- and ex-vessel), (ii) accident management items to corium-related phenomena (accident management aspects should cover all phases of the accident in order to find out, discuss and propose early and late phase mitigation possibilities), (iii) source terms, heat production and reactivity control and management questions for different time scales (especially with respect to recriticality scenarios), (iiii) measures to keep the corium and its entire array in a safe, well controlled “stillstand-phase” with minimised emission of radioactivity for a very long time. Research areas as presented under topic #21 and #22 should be excluded. The group should also not consider containment-related phenomena (except fission product behaviour).

The general conclusion of the discussion was that an enlargement of the technical scope of the group is needed. However, the development of the technical scope should be in a certain way generous, but it should remain reasonable and clear limits have to be identified in order to avoid a too large group and plenty of CEG meetings. Two meetings per year seem reasonable to fulfil the tasks. The enlargement should be done in a gradual stepwise manner and will require flexibility in the group to be able to get the most expert opinions on certain aspects outside the existing members’ activities. In such cases the members could seek out the opinions of colleagues with expertise in such fields or invite them to the meeting.

The guidelines of the group will be updated and the draft will be distributed for further discussion within the various organisations (action 4/2). Any feedback should be given to the secretariat of the group. The revised guidelines will then be discussed and agreed at the next meeting. The list will be updated and enlarged (action 4/3).

L.Tocheny informed the group that D.Gambier accepts in principle the enlargement of the technical scope of the CEG-CM to some additional aspects of severe accident phenomena.

L.Tocheny was asked to provide as soon as possible a list of topics on severe accident related phenomena to be considered in future meetings. For topics within the limits of the new scope of the group it is absolutely necessary to receive the ISTC project proposals some weeks before the meeting either to invite experts or obtain their opinion in time. In this connection, it was stressed by the group the convenience to establish some rules by ISTC for the submission of preliminary project proposals.

**Topic #7:** Preliminary discussion/checking of individual ISTC proposals/projects

Comments on proposal topic #15 (KIAE, IBREA): The proposal consists of eight tasks focused on processing of numerous measurements on Chernobyl corium, creation of a proper material database, and development and verification of corium models and codes. The current scope of the proposal is too wide. The opinion of the group has been that there are already a sufficient number of models available to describe the high temperature material and fission product behaviour. The modelling work should be therefore more focussed on topics were the EC database can be completed or improved, and the group should define these deliverables. However, one has to keep in mind that many of the models to be developed will consider “Chernobyl” typical boundary conditions, which have to be modified for EC application. In general, more precise objectives are needed on a reduced scope of activities.

Comments on proposal topic #17 (ICES, VNIITF): This is not yet a ready proposal. Only one-page information was available. The transient behaviour (RIA) of fuel rod segments for breeder, WWER and RMBK reactors were studied under extreme test conditions up to melting and in one case up to partly evaporation of the fuel. The experiments should be described, systemized and analysed by different Russian codes. The data may be useful for comparison with CABRI data. A proposal should be still developed with clear descriptions and references in order to be considered with respect to the enlargement of the scope of the group.

Comments on proposal topic #18 (IPPE): In the last meeting the group requested some more information on this rather old (about 7 years) proposal. The planned work should complement past work and ongoing work as planned in project #1648. It is important to know –beside the initial conditions as the burnup of the fuel- the experimental conditions, what type of fission products (chemical state) will be measured, what are the environmental conditions and the fuel temperatures. What will be the objective for the use of the data? More precise objectives are needed.

Comments on proposal topic #19 (IPPE): The need of additional models has to be shown in a preliminary step for any further decision.

Comments on proposal topic #20 (IBRAE): This is a well-defined project proposal whose work plan is related to ongoing EC research activities. Links from the SVETCHA code to codes on late phase degradation (e.g. CONV) should be established. LIVE tests expected to be analysed have to be indicated.

# Extended session

**Topic #8:** Welcome of the Russian colleagues; discussion of the agenda

A.Zurita opened the extended session of the meeting and welcomed the Russian participants and expressed on behalf of the CEG-CM their thanks to NITI (S.Bechta and V.Khabensky) and ISTC (L.Tocheny) for preparing and hosting the 4th CEG-CM meeting, which was excellently organised.

L.Tocheny explained the Russian participants the task, scope and objectives of the group. A.Zurita added that not only new ISTC project proposals are considered and evaluated by the CEG-CM group but also the on-going research work of approved projects as #1950.2 (CORPHAD), #833.2 (METCOR) and #1648 (QUENCH). He also emphasised the potential possibilities of establishing joint industrial applications of R&D results, as well as future joint research in the frame of the ISTC Agreement.

The agenda of the extended session was briefly discussed and agreed by the Russian scientists.

**Topic #9:** Welcome and review of research activities at the Research and Design Institute ATOMENERGOPROECT, St. Petersburg

The St. Petersburg Research and Design Institute ATOMENERGOPROECT (SPAEP) have a long history that was briefly described by V.Bezlepkin. It was founded in 1929 as design-survey institute for thermal power plants. The work on NPPs started in 1954. SPAEP is the designer of many Russian NPPs; some of them were exported to Finland, Slovakia, Czech Republic and China.

The medium sized reactors of the type VVER-640 with double steel and concrete containment included passive safety features (for example, passive heat removal systems for the containment and steam generator) and were developed in compliance with Western routine for justification and licensing and were subject of multiple international reviews.

The larger NPPs of the type VVER-1000 with a leak-tight containment and external events protection (aircraft crash, seismic load) were based on the defence-in-depth principle with multiple barriers to prevent the release of radioactive fission products. VVER-1000 type reactors were sold to China and have been offered to Finland. The containment is designed to handle severe accidents to localise and cool down a core melt, to prevent core-concrete interactions, to limit hydrogen combustion loads and to limit releases to the environment.

V.Bezlepkin also described briefly the various code systems used for severe accident analysis (RATEG, SVECHA, GEFEST, DINCOR and others); about 40 people work in these research tasks mainly involved in coordination, supervision and reporting.

**Topic #10:** Research activities on severe accidents within the EURATOM 6th Framework Program

A.Zurita described the scope and objectives of past and future EURATOM Framework Programmes. The first EURATOM reinforced concerted action on reactor safety was carried out between 1990 and 1994. Different EURATOM Framework Programmes followed it: the 4th FP from 1994 until 1998, the 5th FP from 1998 until 2002 and the 6th FP started in 2002 and will last until 2006.

The 6th FP covers fusion energy research, management of radioactive waste, and radiation protection as thematic priorities. Furthermore, within the area of ‘Nuclear Technologies and Safety’, also research activities on innovative concepts, safety of existing installations and education and training are foreseen. Within the 6th FP a wider range of joint activities is planned by the formation of networks of excellence (NoE) and integrated projects. The objectives are to facilitate needed rationalisation and consolidation in European research activities, as well as to maintain critical mass and competence by more effective use of diminishing resources. The NoE proposal SARNET for sustainable integration of European research on SA phenomenology will be launched in 2004. Strong links are recommended with the various ongoing ISTC projects financed by the EC.

The various projects within the 6th FP and their specific tasks and objectives were described in detail. Additional information were given on the conduct of EUROCOURSES on reactor safety, on the international PHEBUS FP Programme, performed by IRSN and also co-sponsored by the EC, to evaluate the source term, on the ISTC Contact Expert Group on Corium Management (CEG-CM) and on the FISA-2003 Conference, which will take place in Luxembourg, 10-12 November 2003. At the FISA meeting the results of the 5th FP on the operational safety of existing NPPs, plant life extension, severe accident management measures and evolutionary safety concepts will be presented. Furthermore, four specific post-FISA workshops (13 Nov.) will take place (brochures with the complete programme were distributed).

**Topic #11**: Development of models and calculation tools for justification of radiation safety under NPP severe accident conditions

Y.Leontiev presented features of proposed research programmes oriented on PWR/VVER severe accident management strategy: core melt retention, ensuring containment performance and limiting of fission product releases. Currently exists only a very initial stage of ISTC/SPAEP co-operation; therefore, a detailed workout is needed. There exist altogether 8 extensive projects related to in-vessel core behaviour, hydrogen management, source term assessment, aerosol behaviour and external impact. The modelling work is conducted by IBRAE, VNIIEF, RRC”KI”, NITI and some other Russian organisations using own or foreign code systems. The 8 projects [(1): Modelling of VVER degraded core quenching..., (2): Investigation of surface condensation effects…, (3): VVER neutronics/FP inventory calculation, (4): FP fuel release during in-vessel stage of SA, (5): FP release from core melt into the containment of NPP…, (6): Aerosol behaviour during SA, (7): Investigation of iodine species behaviour during SA, (8): Environmental impact assessment for SA] are described in detail in the handout (can be obtained by the secretary).

These are very interesting potential activities in the enlarged technical scope of the CEG to encompass also ‘Source Term’ issues. The presented technical information should be distributed to the CEG members to transfer that information to the specialists of their organisations for checking and evaluation in order to obtain some feedback, e.g.: supporting letters, potential interest to act as collaborator and exchange of technical information

**Technical tour; visit of the Leningrad NPP**

The CEG-CM group members had the unique opportunity to visit one of the four NPPs of the type RMBK-1000 (reactor hall, control room, turbine-machine hall), which are located in Sosnovy Bor, a city of about 50000 inhabitants (approximately 100km away from St. Petersburg). The NPP reactors were put into operation in 1973, 1975, 1979 and 1981 and are still producing electricity. Starting in 1998 through 2006 extensive work on technical upgrade, safety enhancement and life extension activities have been and will be performed on the NPP. After the termination of planned upgrades by 2006 it is then currently planned to continue the operation of the power units up to the year 2021.

Refuelling of the reactor core and the continuous change of fuel elements from one to other core position (2 per day) occurs during operation of the NPPs. The spent fuel elements will be cut and then stored at place; no reprocessing was done or is planned. Altogether about 5.500 people work for all activities (maintenance, engineering, etc…) of the four nuclear power plants. A NPP operator shift consists of about 70 people.

**Topic #12:** Status of the project #1950.2 (CORPHAD)

S. Bechta presented the status of the project CORPHAD phase 2 “Phase diagrams for multi-component systems containing corium and its interaction products with NPP materials”. The project started at July 2003 and will last until June 2006. The objective of the project is the experimental study of phase diagrams of specific corium/NPP material mixtures. The obtained results will be used for the optimisation of the thermodynamic database, for thermodynamic code validation and modelling of the corium behaviour. Based on the results obtained so far the eutectic temperature and chemical composition for the system FeO-ZrO2 could be specified and the solubility limits for FeO in cubic and tetragonal ZrO2 were determined. For the phase diagrams FeO-UO2, Fe2O3-SiO2, Fe3O4-SiO2 and U-Zr-O first experimental points were generated. Also for this project the yearly progress reports should be sent to the CEG-CM group members.

**Topic #13:** Status of the project # 833.2 (METCOR)

S. Bechta presented the status of the project METCOR phase 2 “Investigation of corium melt interaction with NPP reactor vessel steel”. The project will last from January 2003 until December 2005. Up to now 5 experiments have been performed with different corium compositions under various experimental boundary conditions. Two tests were described in detail: MC5 and MC6.

The test apparatus and the test conduct were described for the reference test MC5 with fully oxidised corium C-100 (UO2/ZrO2) in argon. The steel surface temperature was varied between 1075 and 1435°C, the corium temperature was about 2600°C, the exposure time went up to 10h. After the test, chemical analyses of the corium and steel specimen were performed to determine corrosion mechanisms. There was no liquid phase formation between the steel and the oxidic melt but a corrosion layer was found. On the basis of these results a qualitative ablation model was developed.

First results were presented of the test MC6 with sub-oxidised corium C-30 (UO2/ZrO2/Zr) in argon at steel temperatures around 1400°C. A new phenomenon has been observed, the formation of a metallic (U, Zr, Fe, O) melt at temperatures considerably lower than the steel ablation temperature. The results are consistent with the metal-melt reactions and inversions seen in the MASCA project.

The results obtained up to now show a strong influence of the oxygen potential of the melt on the extent of steel corrosion. The lowest corrosion rates occur for C-100. For the CEG-CM group members it is important to receive the yearly progress reports of the project.

**Topic #14:** Status on the project #1648 (QUENCH)

M.Veshchunov reported that the project “VVER fuel behaviour under severe accident conditions; Quench stage” has been approved for funding by the Governing Board (March 2003) but it has not yet been started. The objective of the project is to find out possibilities to apply available databases to describe the VVER core behaviour under severe accident conditions focussing on the quench phase. For this reason it is necessary to carry out a limited number of experiments with VVER typical materials to find out possible differences in VVER and PWR type material properties under severe accident conditions. The primary task of the project is therefore to conduct a limited number of experiments to obtain data on the physico-chemical behaviour of VVER reactor core materials at high temperatures in order to develop physical models and codes applicable to VVER reactors. This task is assumed to be solved as complementary to the QUENCH project performed in FZK, Karlsruhe. The same methodical approach will allow a comparison of the behaviour of VVER and PWR materials. Within the frame of the ISTC project #1648 it is therefore planned to carry out several small-scale tests with irradiated short fuel rod segments and one large-scale integral experiment with an unirradiated fuel element bundle simulator both under quench conditions with VVER type materials to obtain the required specific database for the development and verification of quench models in code systems.

Necessary provisions should be incorporated in the Project Agreement (presently under preparation) in order to assure and facilitate future collaborations with the SARNET networks of the Euratom Sixth Framework Programme.J.Stuckert expressed the FZK concern on the delay and the necessity to coordinate in time the ISTC project #1648 and the QUENCH project. He asked ISTC and the recipients to start the project as soon as possible.

**Topic #15:** Development of analytical model for the processes that took place with nuclear fuel of Unit 4 of the Chernobyl NPP during the active phase of the accident

S. Bogatov presented the paper. In the Chernobyl accident, a power burst occurred in an explosion blowing the top of the pressure vessel off and wrecking the reactor hall. The resulting air ingress ignited the graphite blocks. Later a sarcophagus was constructed around it. During the accident a large amount of radioactive species as well as damaged and intact fragments of the core were released from the reactor.

One of the objectives of the work is to explain the current physical and chemical state of the various reactor materials as well as the special locations of fuel-containing materials (FCM) and radioactive substances inside the damaged unit and to evaluate the deterioration of building structures along the way of molten FCM penetration. Another objective is to make predictions for long-term corium behaviour in corium catchers being developed for several PWRs as EPR and VVER-1000.

The main core materials before the accident: were 2000t graphite, about 175t of Zr-Nb alloys and about 1400t of various types of steels. After the accident different types of “hot” fuel particles of various sizes could be detected inside the shelter. Fuel particles and dust was distributed everywhere and also airborne in the rooms. Core fragments formed by the explosion were found in the central hall and adjacent rooms. “Lava”-like fuel containing melt formed (elephant foot) and interacted with bottom reactor lid and concrete forming black, brown, “pumice” like ceramic and slag or slag-like granulated material. In addition, a solidified, once molten metallic material, which contained no fuel, was found. The assessed temperature of the molten ceramic material was between 1600 and 1700°C.

The modelling work will be conducted by IBRAE. The code RASPLAV was developed to simulate MCCI phenomena, and the code SPREAD to simulate the spreading behaviour of the melt. The main task will be the assessment of adequacy of existing and –if necessary- the development of new models describing the corium behaviour and comparison with the available post-accident results. The modelling work should be focussed on topics were the EC database can be completed or improved, and these deliverables should be clarified. However, one has to keep in mind that many of the models to be developed will consider “Chernobyl” typical boundary conditions, which have to be modified for EC application.

The “Chernobyl lessons” have been very expensive for the world society, for this reason it is important to understand the physico-chemical phenomena that occurred during and after the accident. They are of great importance both for general safety issues and for specific issues to be solved in the future during removal of FCM from the sarcophagus and its final disposal.

During the discussion, it was stressed that graphite burning should have had significant power in the corium. It was also stated that no new code development is planned; only assessment of existing codes is expected. Regarding the corium formation and spreading, a very large uncertainty is recognised on the timing of corium progression. Several CEG partners underlined the need to identify clearly what is available before defining corium behaviour calculations. Finally, it was requested to revise the project taking into account recommendations of CEG members.

**Topic #16:** ISTC project proposals #1445 and #1448

The project proposal #1445 “Development of a test problem set for verification of 3D program systems for computing coupled problems at heavy reactivity accidents” and #1448 “3D simulation of coupled NPP safety problems on parallel computers taking into account neutron transport processes in group transport approximation”, were considered to be outside the current scope of the group and it can therefore give no technical advice on this research area.

A.Grebennikov presented a brief overview on both proposals. First of all the code system TENAR was described. TENAR is used as a multidimensional linked program for reactor dynamics and safety computations as operational and transient conditions as well as design accidents (LOCA). The code system consists of different individual codes as RATEG (thermo-hydraulic), CAFR (fuel element thermo-mechanics and thermo-chemistry), KORAT-3D (neutron processes), CONCORD (processing of library cell neutron constants) and DANCO (mechanical behaviour of NPP structures).

The objective of the proposal #1445 is the development of a computer code system for the accident analysis with regard to neutron kinetics, thermo hydraulics and mechanical load. Therefore, the main task is the provision of a test problem set for 3D codes designed for simulation of coupled reactor dynamics and safety problems and improvement and refinement of the models and numerical methods for computing 3D coupled reactor dynamics and safety problems with the codes TENAR and DANCO and finally 3D computations with the improved code versions.

The main objective of the proposal #1448 is the development of a 3D-program package for computing dynamic problems and analysing safety for reactors as VVER, PWR and RBMK type based on neutron nuclear simulation in the multi-group transport approximation.

The group should now have enough information to transfer them to the EU specialists of their organisations to obtain some feedback. The group recommended once more to combine the two proposals and to show in the revised proposal what the added value to the state-of the-art will be. In addition the assessed costs should be indicated. The envisaged manpower of the proposals seems to be too high.

Up to now no foreign collaborator announced his interest in these proposals. IRSN underlined that the difficulty of the coupling task between complex codes does not seem to be compatible with the duration and the size of an ISTC project. In addition the topic of neutron kinetics remain outside of the current technical scope of the group. This kind of project needs to be clearly documented before the meeting to obtain an evaluation by specialists. However, some interest exists in these topics by the Forschungszentrum Rossenendorf to act possibly as “moderator” (action 4/4).

**Topic #17:** Description and analysis of experiments done at the reactor IGR regarding studies of behaviour of fuel during reactivity accidents

This is not a proposal. N.Gorin (VNIITF) described the uranium-graphite pulse reactor (IGR), part of the conducted experiments and plans to build a new multi-purpose pulse reactor (MIGR). Right now there was no proposal presented, but it will eventually be prepared in the future. The planned new MIGR reactor should also be a graphite reactor and could form the basis for the planned ISTC proposal.

A series of experiments was carried out in 1991-92, in which fuel behaviour of different types of reactors in reactivity accidents was studied. The experiments were carried out at the pulse graphite IGR reactor located at Semipalatinsk test site, which is now the Institute of Atomic Energy at the National Nuclear Centre of Kazakhstan Republic. The temperature in the centre of the fuel elements, of their cladding and in the coolant was measured in the experiments together with gas pressure in the fuel element central channel, which allowed determining accurately the cladding decompression time. The pulse width was usually ~0,6-0,7s, its power was chosen regarding the experiment aims.

After all pulse test examinations of the fuel and fuel element claddings were performed in a hot cell. The results of these experiments, which were carried out with participation of NNC RK, VNIITF, FEI, NIKIET and OKBM specialists will certainly be useful for model developments and code verifications.

Most members did not express an interest. JRC-ITU (D.Bottomley) however thought that the nitride fuel data could be useful, as there is some interest in nitrides as advanced fuels.

**Topic #18:** Determination of parameters of fission product release from WWER irradiated fuel under beyond design basis accident conditions

A. Lukianov presented the proposal. It is connected with the ISTC proposal #0243 “Models and codes for accident phenomena in NPPs” which was presented at the last meeting. The opinion of the CEG-CM group has been that the project #0243 is too broad and it would be better to propose a project, which should concentrate on some specific aspects. As a result two new proposals related on fission product release and corium spreading were prepared and are described under topic #18 and #19.

No reliable experimental data on radioactive fission product release from irradiated VVER fuel under typical beyond design basis accidents (BDBA) conditions are available which significantly determine the further behaviour of fission products and aerosols in NPP circuits and the containment. The lack of data on initial conditions makes the development of measures on accident management and radiation safety protection difficult. The main goal of the project is therefore to develop a database on the characteristics of fission products being released from fuel matrix under various conditions on the basis of experimental measurements in “hot” cells. The collected information will be used for verification and up dating of computer codes describing the fission product dynamics at VVER-based NPPs under accident conditions and allows realistic NPP design measures to be made in terms of radiation consequences.

Up to now some experiments have been conducted in the SSC RF IPPE’s hot cells under various heating conditions. The test facility consists of a heating module designed for the temperature range from 150 to 2500 °C, a thermo-stabilised transport section, a filter cascade for fission product separation, a system of gas supply (Ar, He, H2) and their analysis. In the course of these experiments, fuel fragments irradiated to different burn-ups were used in inert and reducing atmosphere. In order to adequately simulate conditions of beyond design basis accidents, it is necessary to perform similar measurements in a steam containing oxidising atmosphere.

The development of fission product release, transport and removal models has been started in the frame of the computer code in lumped parameters describing heat and mass transfer processes in VVER-based NPP circuits and containment. A detailed work plan was presented. The transportation processes are investigated in horizontal lines (horizontal VVER steam generators). The interest for Western countries of such geometry is mainly resuspension.

In the subsequent discussion the group expressed the request for a more detailed proposal to judge the planned experimental and theoretical work. In the more focused proposal it should be shown which models are already available and it should be indicated, which may be improved and which new models will be developed. In addition, the experimental specifications that were or will be used for the modelling work should be given (type of fuel, burn-up, tests with or without cladding, oxidising conditions, heat-up rates, maximum temperature, aerosol measurements in primary circuit). The proposal should be sent to the CEG-CM members (action 4/5) to decide on possible letters of interest.

**Topic #19:** Development of verified models and three-dimensional calculation codes for numerical modelling of spreading and interaction of molten materials in VVER-type reactor under severe accidents

V. Kumayev presented the proposal, which has also to be considered as a part of the initial ISTC project #0243, which was divided in two proposals requested by the group at the last meeting. As special interest was expressed regarding the description of the in-vessel corium melts behaviour and progression in porous media.

Descriptions of specified processes in reactor systems taking into account their real structure, internal and external conditions are necessary for the development of severe accident management and mitigation procedures. For this reason analytical methods and computer codes are needed to consider not only the most important physico-chemical processes, but also the local structures and their effects. Currently the methods and codes are based on simplified models, but are used for complex processes under severe accident conditions.

The model of a multi-component medium can be used as the base for the development of local spatial models. The two-dimensional DINCOR computer code, developed by IPPE, was used for VVER-1000 calculations, corium formation and spreading, melting of the reactor pressure vessel and subsequent release of corium into the melt localisation system (MLS; core catcher). Calculations of melt spreading in the MLS and the interaction with core catcher materials were performed. The further development of advanced models and their introduction in a three-dimensional computer code to remove uncertainties in the accident sequence description is necessary. This will be done by different tasks, which were presented in detail (liquefaction and solidification of materials with inner heat sources, dissolution and chemical interaction of multi-component systems, development of numerical procedures, verification of the code system).

Some EC organisations showed interest in this proposal. B. Adroguer (IRSN, Cadarache) will eventually act as “moderator” (action 4/6). A more detailed proposal on this topic should be prepared for the next meeting.

**Topic #20:** Modelling of the reactor core behaviour under severe accident conditions. Melt formation, relocation and evolution of molten pool.

M. Veshchunov explained some details of the extensive work program. The objective of the proposal is to perform modelling work on the reactor core molten material behaviour at selected stages of a severe accident evolution from the early stage, when the core is mostly intact and Zircaloy cladding melting starts, up to the late stage, when the core is completely degraded and a molten pool is formed in the lower head of the RPV. In the main Russian code systems currently used the models dealing with physico-chemical interactions and melt relocation are oversimplified and are not able to give the adequate description of the corresponding phenomena during core degradation and relocation. The proposed modelling work should significantly improve the modelling of reactor core molten materials behaviour under severe accident conditions.

The proposed work will use previously-obtained theoretical models on UO2 and ZrO2 dissolution and melt relocation, and the numerical codes SVECHA/MELT (initial and intermediate melt behaviour) and CONV (describing 3D turbulent hydrodynamics and heat exchange of the molten pool in the RPV), developed by IBRAE, will be improved. Verification of the new models and updated codes against experimental results obtained in the COLOSS and SARNET projects and preparation of the advanced models for benchmarking system codes such as ICARE/CATHARE, ASTEC and MELCOR. Possible implementation of new models in Western codes is planned.

There was generally a good opinion about this project although clarification on some points is still necessary as for example the rights of collaborators to use the results and the code developed by IBRAE. FZK and ITU will be foreign collaborators. IRSN announced also its participation as collaborator.

**Topic #21:** Development of the International Standard “Analysis of severe accidents initiation capability during airplane crash on a NPP”

S. Butorin presented the topic, which is currently outside the technical scope of the group. A PSA with fault tree for an airplane crash system analysis was shown: the initial event (airplane crash, type of airplane, speed, angle), definition of possible damage types to the construction (points of impact load and its direction on the containment), damage or failure of safety systems, degree of core damage, release of radioactivity (source term), safety assessment and consequence assessment. The considered analysis is very complex as a result of incomplete initial information, such as crash-induced loads, extreme dynamic impacts and scantiness of engineering experience. The obtained methodology can also be applied for other load-induced impacts on the NPP as seismic and explosive impacts, fire, detonation shock waves or secondary missiles.

The presented topic is very interesting but it cannot be considered as an international approach since the assessments were done for a Russian NPP. However, it provides a good basis for plant-specific assessments considering in a first approach worst-case conditions to define maximum consequences to the environment.

Much has been done in this field in Europe but the results of most of the studies are generally confidential.

**Topic #22:** Impact of processes of nuclear reactor structure component degradation after severe accident on neutron, physics and dynamics characteristics of the reactor core, ICNS –International Centre for Nuclear Safety, NIKIET.

This topic was not presented.

**Restricted session**

**Topic #23:** Detailed discussion and preparation of the CEG-CM reports

After the presentation of the various ISTC project proposals by the Russian scientists the restricted session of the meeting continued with detailed discussion on the presented activities to elaborate advice and priorities of the proposals.

In a brief discussion the group expressed the opinion that the enlargement of the technical scope of CEG-CM should be decided at the next meeting since some of the presented proposals are outside of the current scope defined in the guidelines. It was preliminary agreed that the technical scope of the group CEG-CM may be extended to include fission product release, behaviour and transport. For areas as LOCA and RIA assessments, there were different opinions among the members and the discussion will be continued.

It seems that many Russian scientists do not know the CEG role within the ISTC organisation. On the other side the supported ISTC projects should give some fruitful feedback to the EC. It may be helpful for the ISTC if the group recommends some research areas of interest, what type of information we can provide to the Russian scientists and what should be the outcome of an ISTC project.

The running Projects METCOR (#833.2) and CORPHAD (#1950.2) are good examples for a positive feedback to ongoing EC research programs. The feedback of ISTC projects has to be established –beside the official meetings- by semi-annual progress reports. The delivery of progress reports should be fixed in the project agreements. Project meetings took place immediately before the CEG-CM meeting in St.Petersburg. The status of the projects is given in topic #12 and #13. Very valuable results were recently obtained in both projects.

The ISTC project #1648 (QUENCH), recommended by the group at the last meeting, was approved at the last governing board meeting. The work will be started soon. The necessary transport of materials from Russia to Germany (FZK) for the conduct of a VVER-1000 bundle experiment in the QUENCH facility will be difficult and has to be settled in time.

The presented technical information under topic #11 are interesting activities that have a good potential within the new agreed scope on severe accidents of the CEG to encompass also ‘Source Term’ issues. The group has now some information (handout) to transfer them to the specialists of their organisations to obtain some preliminary feedback on the proposal. However, more detailed written information is needed for a final conclusion and recommendation.

The ISTC project proposal “Development of analytical model for the processes that took place with nuclear fuel of Unit 4 of the Chernobyl NPP during the active phase of the accident” described in topic #15 fits well in our approach and will be recommended with ranking of objectives. Organisations that will be interested to act as foreign collaborator should send a letter of interest to ISTC; otherwise the proposal cannot be officially registered. The organisations (GRS, CEA, IRSN and ITU) that will be interested in the proposal will prepare a joint document expressing their interest and scope of expected work (action 4/7). The draft document, which will be prepared by GRS (H.J. Allelein), will then be send to the other CEG-CM member organisations for comments. The final letter of interest should then be send to L.Tocheny who will transfer it to D.Gambier, the executive director of ISTC. Copies should be send to A.Zurita and P.Hofmann.

The group recommended once more combining the two ISTC project proposals #1445 and #1448 into one. In this revised document it should be shown what is the current knowledge in this research area and what will be the added value. Although similar codes are already available, the development of a Russian database is useful. The code development is to be based on existing codes, which are to be improved and to be coupled. The generation of a database for code validation using data from the Chernobyl accident is especially interesting. Up to now no organisations expressed their interest to act as collaborator. FZR will eventually act as “moderator”. FZR is expected to give more information at the next meeting.

The work presented under topic #17 (IGR reactor) is not a project proposal. It should show what types of experiments were done in the past and which type of experiments could be conducted in the planned MIGR pulse reactor. No money is currently available to build the MIGR reactor.

The tasks described under topic #18 and #19 were requested by the group at the last meeting, that means to divide one large proposal into two smaller ones related to fission product release and corium melt spreading. The topic #18 (fission product release) is of great interest to some members of the group since it will be an important addition to the scarce fission product release data and models. However, more written information is needed for further decision. As soon as they will be available L.Tocheny will distribute them. On the basis of the documents we should then define our specific interest and we should send them available open reports on the subject “fission product release” (for example: OECD State-of-the-art report on fission product release; EC Source Term projects of the FP-4).

In the research area of topic #19 (spreading and interaction of molten materials) the accuracy of the 2D modelling should be verified before going on to 3D modelling. Even limited accuracy in 3D would be useful. FZR and B.Adroguer (IRSN) will eventually act as “moderator” for this topic.

The project proposal discussed under topic #20 is well formulated with clear defined tasks. IRSN pointed out its interest considering both the continuation/consolidation of some modelling activities carried out in the COLOSS project and on the use of similar models in the SVECHA and ICARE codes. In addition, the benchmarking between the detailed CONV code with simplified modules in ICARE code on molten pool behaviour is of particular interest. What should be added in the work plan is the modelling of liquefaction of irradiated oxide fuel. FZK, IRSN and ITU will act as collaborators. The group will give a positive opinion of the project proposal to ISTC.

The research work presented under topic #21 is outside the scope of the group. It was only for information and should not to be considered as a proposal.

L.Tocheny has informed about the decisions of the ISTC Governing Board regarding Topical Programmes and International Science Laboratories. Because those decisions could be of great interest to link future work with European activities, specific information on those new ISTC modalities would be very appreciated by the CEG members (action 4/8).

**Topic #24:** Other issues

A.Zurita asked the members of the group if the extent of minutes, which are very detailed, should be reduced in future or kept at the current size. The decision was to leave them as they are since they provide full information for members who could not attend a meeting.

It is very important, also in view of the further development of the CEG technical scope, to transfer the technical information to appropriate experts within the members’ organisations for further evaluation and potential initiatives. In particular this is the case for the technical topics #11, #16 and #18 (action 4/9).

Up to today the Russian participants did not receive the minutes of the meetings. It was decided that in future they should get the part of the minutes of the extended sessions. For this reason two types of minutes have to be prepared one with and the other one without the comments of the restricted session (action 4/10).

L.Tocheny has touched a problem of improving a scheme of bilateral technical exchange, particular from EU-related programs to proper ISTC project recipients.

L.Tocheny also mentioned that presentations, critics and discussions on on-going projects which took place during the first two days (steering committee meetings on METCOR and CORPHAD) were extremely useful for both sides, the ISTC project recipients and also for the other CEG-CM experts not involved into the specific subject of the projects. It would be very helpful to invite all CEG participants to all non-restricted steering committee sessions. The steering committee meetings should be considered as integral part of the CEG body.

**Topic #25:** Next meeting

The next CEG-CM meeting will take place in Paris in the week of February 9 to 13, 2004. It will be kindly organised and hosted by CEA (G.Cognet) possibly in connection with the METCOR and CORPHAD project meetings (action 4/11). CEA is ready to organize all three meetings in Paris if they will take place in the same week.

A. Zurita (Chairman) P. Hofmann (Secretary)

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**Annexes:**

1. Agenda of the meeting
2. List of participants
3. ISTC CEG-CM related projects (updated 14-02-2003)
4. Summary of ISTC projects discussion at the ISTC 4th CEG-CM meeting
5. Specific action list (see below)

Annex 5: **Specific Action List**

No former actions were pending. Further to the normal CEG-CM operation, the specific actions agreed during the meeting were recalled:

4/1 – Topic #5 The status of collaborators in the three on-going projects #833.2, #1950.2 and #1648.2 should be checked and possibly updated (ISTC secretariat / L.Tocheny).

4/2 – Topic #6: The CEG-CM guidelines have to be updated to consider the planned enlargement of the technical scope of the group (A.Zurita).

4/3 – Topic #6: The list of considered ISTC projects (annex 3) should be updated with respect to the extended technical scope of the group (ISTC secretariat / L.Tocheny).

4/4 – Topic #16: Clarification whether FZR will act as “moderator” in the projects #1445 and #1448 (P.Hofmann).

4/5 – Topic #18: The proposal should be sent to the CEG-CM members (ISTC secretariat / L.Tocheny).

4/6 - Topic #19: Exchange more information between IRSN and IPPE: In a fist stage, IPPE will send the description of the project and more information on existing Russian codes (numerical methods, validation, plant calculations); B.Adroguer.

4/7 – Topic #23: Preparation of a document expressing technical scope of expected work for topic #15 (H.J.Allelein et al.)

4/8 – Topic #23: CEG-CM to be informed on the decisions of the ISTC Governing Board regarding Topical Programmes and International Science Laboratories (ISTC secretariat / L.Tocheny).

4/9 - Topic #24: Technical information of the topics #11, #16 and #18 should be given to appropriate experts to obtain their opinion (All members).

4/10 – Topic #24: Preparation of two types of minutes, one with the comments of the restricted session and the other one without those comments for distribution to Russian participants (P.Hofmann).

4/11 – Topic #25: Also in future two meetings per year should take place, one in Russia and one within the territory of the EC. Exact date and venue of the 5th meeting should be fixed (G.Cognet).