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SPECIALIST MEETING ON  
**CORE DEBRIS/CONCRETE INTERACTIONS**  
(1-3 April 1992)

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**SUMMARY AND RECOMMENDATIONS**

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Organised by  
**OECD Nuclear Energy Agency**  
in collaboration with  
**Kernforschungszentrum Karlsruhe**





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**SUMMARY AND RECOMMENDATIONS**

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### SUMMARY

The Second CSNI Specialist Meeting on Core Debris-Concrete Interactions was held in Karlsruhe, Germany, on April 1 to 3, 1992. It was hosted by the Kernforschungszentrum Karlsruhe (KfK) and organized in collaboration by OECD-NEA and KfK. About sixty experts attended the meeting, from 13 countries including Russia and the Czech & Slovak Federal Republic and of 2 international organisations. Thirty-seven papers were presented in five sessions on the different aspects of core concrete interaction including melt coolability aspects. The final session summarized the results and discussed the current status of knowledge and the direction of future work.

The first CSNI Specialist Meeting on Core Debris-Concrete Interactions had been held at Palo Alto, California in September 1986. Since this meeting, major experimental programs and substantial modelling work had been undertaken worldwide. The scope of the second meeting was to review the experimental and theoretical work and the predictive capabilities for severe accident evaluation. In addition to the scope of the previous meeting the issues of melt spreading and coolability were addressed as options to mitigate or end a severe accident.

The contributed papers were presented in the following sessions:

- I. Experiments on molten core-concrete interactions under predominantly dry conditions
- II. Modelling and codes of molten core-concrete interactions under predominantly dry conditions
- III. Experiments on melt spreading and coolability
- IV. Modelling and codes on melt spreading and coolability
- V. Code comparisons and plant applications.

### CONCLUSIONS AND RECOMMENDATIONS

The following general conclusions and recommendations were formulated after a careful evaluation of the presentations and discussions:

1. A significant integral effects data base on dry molten core debris-concrete interaction now exists which consists of independent experiments in several different facilities, so that no additional large scale experiments under dry conditions are necessary. The data base is adequate for thermal hydraulics, chemical reactions, and aerosol and fission product release during dry MCCI.
2. The present results of the codes in modeling the experiments are promising. To make optimal use of the existing experimental data base it is recommended that a matrix of selected and consistent experiments is set up covering the different aspects of MCC. This matrix would be used to provide final validation for the codes.
3. Considerable progress has been made in the physico-chemical modelling of MCCI melts. This needs to be completed and supported by additional physical property measurements, in particular viscosities and liquidus/solidus temperatures. These should be incorporated into the MCCI codes.
4. A considerable data base has been collected on the release of fission products during MCCI which shows that the releases are significantly less than previously estimated. The modelling of chemical thermodynamics of the multicomponent melt helps develop the understanding of the reasons for fission products retention in the melt, and should be completed for the releases of the important fission products.
5. Significant experimental and theoretical efforts are underway to determine the coolability of molten corium in the containment. Presently, the coolability of the melt by a water overlayer has not been demonstrated, thus the work should be continued. Relevant physical property data should also be measured as needed for modelling and validation. Melt spreading in containments was deemed to be important for analytical and further confirmatory experimental investigations since it affects coolability and containment integrity in some designs.
6. Investigation of physical phenomena related to core catcher design should be continued by the countries interested in such designs.
7. In order to test the codes for application to prototypical accident scenarios and to compare the predictions of different codes, a set of benchmark calculations should be performed. This should include short term and long term applications as well as different reactor cavities and concrete types.

## SESSION SUMMARIES

The following is a summary of the five sessions:

### Session I. Experiments on Molten Core-Concrete Interactions under Predominantly Dry Conditions

The session consisted of six contributions which described the results recently gained in the SURC test series (Sandia), in the BETA V5 series (KfK) and the ACE Program Phase C (EPRI) which is concerned with fission product release from molten corium concrete interactions (MCCI). Out of these six, one UK paper dealt specifically with the initial interaction between a fuel melt and concrete, i.e. the behaviour of the melt during the initial jet impingement phase of a MCCI.

B. Turland reported on a scoping experiment on the interaction between a superheated uranium dioxide jet and cold concrete. The test has been carried out at the Winfrith Technology Centre using its Molten Fuel Test Facilities. 24 kg of a molten fuel simulant represented by a mixture of 81% uranium dioxide and 19% molybdenum at a temperature of 3600 K poured under gravity onto the cylindrical target of basaltic concrete. With the high superheat a vigorous interaction took place. The impingement of the molten jet caused a depression in the centre of the concrete target which was about 60 mm in diameter and 33 mm deep. In the neighbourhood of the jet impact enhanced erosion was observed which corresponds to a local heat flux of the order of 10 MW per m<sup>2</sup>. The vigorous interactions on initial contact have been reasonably replicated by an interim version of CORCON Mod. 3.

In the discussion it was concluded that although the high superheat may not be representative for accident scenarios, melt splashout may be an important issue in this context.

E.R. Copus from Sandia presented the highlights of the SURC test series related to sustained uranium dioxide/concrete interactions. The purpose of these integral tests was to study the protracted interaction of an oxidic melt pool on various basemat materials, when liquid water is not present. The 200 kg melt mixture was composed of 63% UO<sub>2</sub>, 27% ZrO<sub>2</sub> and 10% Zr; the 40 cm diameter concrete basemat was formed from limestone concrete in SURC-1 and basaltic or siliceous concrete in SURC-2, respectively. In SURC-1 the interaction was sustained for over 130 minutes and in SURC-2 for over 180 minutes, i.e. over 3 hours. The major conclusions from the experiments are that the interaction temperatures remain well (about 300 K) above the concrete melting point and that the Zr chemistry drastically affects the ablation rate and the gas composition of both types of concrete. As a baseline response 5-15 cm/hr has been derived for one-dimensional (downward) concrete erosion in the absence of Zr metal which can accelerate to 15-30 cm/hr when Zr metal is included.

In the discussion two aspects were mentioned: The high level of the interaction temperatures has to be considered in context with the oxidic melt, because the heat transfer from the oxidic melt in comparison to a metallic melt is lower. VANESA seems to generally overpredict the fission product release from MCCI in a conservative sense.

The presentation of H. Alsmeyer specifically focused on the influence of Zirconium metal oxidation on melt/concrete interaction phenomena. He reported on the corresponding BETA test series V5 recently performed at KfK. In these experiments the initial melt mixture was composed of 300 kg (mostly) iron, 80 kg Zr and an oxidic portion of 50 kg. A cylindrical melt crucible fabricated from siliceous concrete provided information on the two-dimensional erosion process. The decay heat generation was simulated by induction heating which was varied in the three tests from 670 W/kg metal to 3300 W/kg metal. It turned out that the exothermic Zr oxidation in the melt mixture dominates the interactions in the very first minutes. This is combined with a fast cavity erosion and a high gas and aerosol release. However, the exothermic Zr oxidation has no significant influence on the melt temperature behaviour in the BETA tests. The fast decrease from 2100 K to some 1750 K indicates an effective heat transfer to the concrete structure.

In the discussion it was confirmed that the comparison of different thermocouples (KfK/ANL/Sandia) revealed a good agreement in the temperature measurements ( $\Delta T=30$  K). Due to the high heat transfer from the metallic melt the interaction temperature in the BETA test series is in the metal freezing range. Due to the two-dimensional erosion process in BETA the Zr oxidation (consumption) is faster than that observed in the SURC tests.

There were three papers related to the ACE-Program. The first presentation given by B.R. Sehgal described the Program Phase C which concentrates on fission product release from molten corium concrete interactions (MCCI). In the corresponding L-series seven experiments have been carried out with four different concrete types. The corium mixture was derived from both PWR and BWR conditions.

The second paper presented by D. Thompson provided an overview of thermal hydraulic results from the ACE MCCI tests, which comprise melt temperatures, ablation rates and off-gas compositions. In general, the thermal-hydraulic data obtained may serve as excellent benchmarks for computer models used for MCCI analysis.

In the third part, J.K. Fink focussed on the aerosols released during these experiments. The release fractions were determined for corium, the fission products and the various control materials. Without repeating all the detailed information described in the paper it might be mentioned that the release fractions of the fission products were significantly below those predicted by the present VANESA code.

In conclusion, it is expected that a summary report on the Phase C test program will be issued by September 1992.

In the discussion it was stated, that the phenomenological similarities between the Phase C tests and the SURC tests confirm the common understanding of the main MCCI phenomena. The experimental information provided by the Phase C Program extends the data base for prototypical melts.



## Conclusions of Session I

From both, paper presentations and discussions, it is concluded that the dominating mechanisms and phenomena of MCCI under dry conditions are sufficiently well understood. This comprises the containment load phenomena (concrete erosion, gas production) as well as fission product release into the containment.

In this respect, the (exothermic/endothemic) Zr and Si chemistry which now is represented in the MCCI code versions plays an important role. On the other hand, foaming phenomena observed in some test cases are considered to influence the long-term MCCI consequences only to a limited extent. In case of fission product release it became obvious from comparison with experimental observations (ACE-Phase C) that the models (e.g. VANESA) tend to overpredict the release.

There is a broad experimental database for MCCI under dry conditions available from several test series which have been carried out with various concrete types. These data may stimulate further code improvements.

## Session II. Modelling and Codes of Molten Core-Concrete Interactions under Predominantly Dry Conditions

### Codes and Thermal Hydraulics

The session on integral codes contained four presentations on the status and validation of the 3 most widely used MCCI codes (CORCON, DECOMP and WECHSL). In addition there were two papers describing analysis of the ACE-L6 test, which has been the subject of a blind post-test code comparison exercise, and a paper considering the uncertainties in heat transfer correlations arising from uncertainties in thermal-physical properties.

New versions have recently been completed of the 3 most widely used MCCI codes. WECHSL-Mod3 has been used in France and Germany for more than 1 year, and an extensive validation programme has been undertaken. This was described by C. Renault (CEA). The validation matrix contains tests from the BETA, SURC and ACE programmes. Only comparisons of calculated against experimental vertical ablation were presented. Apart from the later stages of the BETA V3.2 test (limestone concrete) and the ACE-L6 and L2 tests there was good agreement overall; the tests noted above showed differences between predictions and experimental data of up to a factor of 2. In the case of the ACE tests this may be due to the omission of the endothermic reduction of  $\text{SiO}_2$  to  $\text{SiO}$  by Zr; in the case of BETA V3.2 this may be due to the different degradation process for the limestone concrete.

The WECHSL-Mod3 code has also been assessed using the data from BETA V5.1. This was presented by J. Foit. The WECHSL-Mod3 code does include the reduction of  $\text{SiO}_2$  by Zr to Si. The experimental data for the BETA V5.1 (a metallic melt with Zr) confirm the modelling in the code for temperatures below 2100 K. Even during the exothermic oxidation of the Zr, both the code and the experiment showed a rapid decrease in temperature, indicating good heat transfer from a metal layer. Some differences between calculation and experiment were noted, particularly the overprediction of  $\text{H}_2$  and  $\text{CO}$ ; indicating that the oxidation of Si was being overestimated by the code.

The CORCON-Mod3 code incorporates many model changes and new options. These include slag film models for heat transfer to concrete, condensed phase reactions, the ability to calculate, or force, layer mixing, the inclusion of VANESA (with feedback for aerosol generation), and improved coolant heat transfer models. The code has not been generally released yet, or a full validation programme undertaken. However, D. Bradley's paper presented a comparison with three experiments (SURC-4, SURC-1 and ACE-L6). Good agreement on ablation, and, in general, on melt temperature was obtained for the SURC tests, but the temperature and ablation rate were underpredicted for the ACE-L6 test. The code also predicted radionuclide releases to within an order of magnitude, except for Mo and Ru which were underpredicted by several orders of magnitude.

M. Plys (FAI) described the version of DECOMP incorporated into MAAP-4. The code contains simplified models, which may be calibrated using detailed first principle methods. No validation material was presented. Plys observed that in his opinion "physical chemistry of the melt is more important than thermal-hydraulics."

As noted above the ACE-L6 test has proved difficult to match accurately with code calculations. J. Sugimoto (JAERI) presented calculations for this test with a version of CORCON Mod 2.04 in which Greene's correlation for convective heat transfer was replaced by that of Kutateladze. This provided a good match to the overall ablation in the test, although the respective times for insert and basemat ablation differed from the test data. A calculation for the aerosol release with VANESA 1.01 indicated that there was a need to obtain a better estimate of the oxygen potential by allowing for condensed phase reactions.

M. Corradini presented an energy balance of the ACE-L6 test. On the basis of Si detected in the aerosol system, it was assumed that during the ablation of the insert SiO<sub>2</sub> reacted endothermically with Zr producing SiO gas; during the basemat ablation it was assumed that half of the remaining Zr was oxidised by SiO<sub>2</sub> endothermically. These assumptions gave a good energy balance for both parts of the test.

F. Gonzalez surveyed the dependency of heat transfer correlations on uncertainties in material properties, represented by differences between values in different data bases. He demonstrated how regression analysis could be used to determine priorities for material property determinations.

#### **Observations/Recommendations**

There are no agreed criteria for what is an acceptable level of agreement between codes and experimental data. As there is now a broad range of experimental data, the ability to match erosion data to @30 % and melt temperatures to @100 K should be considered reasonable, and seems to be within the reach of the new codes. The ability to predict fission product releases to within an order of magnitude (only necessary for those species with a significant release) also seems to be close to being achievable.

So far the only code for which a systematic attempt at validation has been published is the WECHSL-MOD3 code. It is important that there is an agreed understanding of the data (and the uncertainties in data) for experiments which are used to validate codes. The type of analysis applied to ACE-L6 (and elsewhere to BETA V5.1) is welcomed. To obtain the greatest credibility for code validation it is recommended that

(1) Data that are contradicted by measurements be modified in the database of the codes (e.g. viscosity, solidus).

(2) Validators of the different codes select a common set of experiments and attempt to reach a common understanding of each experiment, including recommending appropriate boundary conditions.

(3) Care should be taken to ensure that the codes are validated for all important phases (including initial and long term behaviour) of the core-concrete interaction.

The data are now available and a good start has been made. The current models are probably already acceptable for most applications; the recommended work would give this judgement a technical underpinning, which is not yet fully developed.

## Materials Properties

M. Mignanelli reported a series of calculations using the SOLGASMIX-REACTOR Code which showed that the predicted releases of some fission products during MCCI are particularly sensitive to the oxygen potential and the configuration of the melt; there were also lesser dependencies on melt temperature and gas production rate. In addition the CSNI code comparison exercise showed that the predicted releases are extremely sensitive to the thermodynamic data and to the models used for the condensed phases; at the time of the CSNI exercise the predicted releases of some species varied by many orders of magnitude between the different submissions.

In order to overcome the discrepancies resulting from the ad hoc development of pseudo-binary ideal models, two programmes have begun to assess the available thermodynamic data and develop models for the melt in a systematic manner.

The programme of D. Powers to develop non-ideal solution models was reported by E. Copus. Powers uses the Kohler equation to combine subregular models for the binary sub-systems to produce a model for the metal phase. His model for the oxide phase is based on an associate model which has proved useful in the description of complex geological melts. These models have recently been included in the VANESA code.

The other programme is being carried out by a collaboration between CEA and AEA and was reported by M. Mignanelli and P.Y. Chevalier. By analysing new systems and using data already available from NPL and Thermodata a complete set of unary and binary data, along with data for important ternary systems, has been compiled for the  $UO_2-ZrO_2-SiO_2-CaO-MgO-Al_2O_3-FeO-BaO-SrO-La_2O_3$  system. The model for the oxide phase indicates that it behaves as a pseudo-binary eutectic rather than the pseudo-binary ideal models previously used. The data have been used in the MITDATA-nuclear and GEMINI codes to predict the solidus and liquidus temperatures for experiments carried out at ANL. The predicted solidus temperatures are in good agreement with the measured values, but there remain unexplained discrepancies in the predicted and measured liquidus temperatures. Both the new model and the experiments indicate that the difference between the solidus and liquidus temperatures is much greater than calculated by CORCON. The new model of the oxide phase also predicts strong interactions between barium, strontium and lanthanum and the zirconia and silica in the melt, which results in activity coefficients which are much less than unity for the fission products. As a result, barium, strontium and lanthanum are retained in the melt and their releases are greatly overpredicted by ideal solution models. Databases are already available for the gaseous and metallic phases. Therefore, to complete the system a model for the interaction between the metal and oxide phases must be developed. This is particularly important as it determines the oxygen potential, to which the predicted releases have been found to be particularly sensitive. To develop such a model will take a few years.

G. Bamford reported that the BUSCA pool scrubbing code has been updated since the previous CSNI MCCI specialists meeting in Palo Alto. Models have been included for: condensation onto aerosol particles; different bubble shapes; bubble breakup; bubble clusters and swarms. However, modelling has not been included for the churn turbulent flow regime, which is the most relevant regime for water pools overlying molten corium.

### Session III. Experiments on Melt Spreading and Coolability

This session dealt with a topic which was not a part of the previous CSNI specialist meeting on core debris concrete interaction. The session primarily addressed the phase of severe accident in which interaction of the corium melt with water takes place during the MCCI. The issue is whether water will be able to cool the corium melt so as to halt the MCCI and stabilize and stop the accident. The session also dealt with the spreading of the melt in the PWR containment cavity or BWR drywell and considered either dry or wet conditions.

The first paper by H. Alsmeyer et al. described a test performed in the BETA facility in which the primarily metallic melt interacted violently with the water present in the annulus of the BETA crucible. The steam explosion produced ~5 bar pressure. The main conclusions derived from this test were that the water presence outside the crucible cylinder did not retard the MCCI so that failure of the concrete wall did occur. The interaction of the metallic melt with water is not representative of the prototypic conditions. A similar experiment performed a week before the meeting produced the same conclusions, and the energy generated in the steam explosion was larger and partially damaged the BETA facility. The visit to the BETA facility demonstrated the extent of the damage.

Melt spreading experimental research was the focus of the paper by B.R. Sehgal and B. Spencer. They proposed a set of large scale tests using prototypic corium melt material for spreading in containment cavity representations. These tests would use the MACE equipment and the MACE furnace with a receiver vessel having either a simple geometry (channel or a sector) or a faithful replica of an actual containment. They proposed to perform a set of tests with a one-dimensional receiver vessel for purposes of validating the code MELTSPREAD, which models the physics of spreading. That code has embodied complex physical phenomena and needs data for validating the models.

B.R. Sehgal described the status of the ACE program phase D i.e., the MACE Program. He argued that the coolability conditions for the melt do not necessarily have to be that the melt is completely quenched. Indeed the minimum coolability condition is that the melt is reduced in temperature to less than the concrete solidus temperature (~ 1500 K) and subsequently heat removal rate by water is equal to the decay heat generation rate in the solidified melt. Sehgal briefly described the main features of MACE test M0 and M1 and in terms of the programme status told about the near term scheduling of the MACE test M1B.

B.R. Sehgal was followed by Spencer who gave more detailed descriptions of the tests M0 and M1 performance and the results obtained in the tests. The test M0 provided important observations and results which were useful in the modelling of the coolability phenomena (currently there is not enough knowledge base on coolability and many scenarios have been proposed for either coolability or lack of coolability). Spencer argued that the melt swells up periodically to contact the crust formed in the MACE test M0 and breaks through and contacts water. This was observed in the MACE test M0 and a debris bed was formed on top of the crust. Spencer described the operation of the test M1 and pointed out that the specified initial conditions of melt-water contact were

not achieved. A sintered thick layer of the initial powder separated the water from the melt; however, it allowed the gas to pass through. The data obtained from the test M1 are not applicable for coolability issue resolution.

The MACE test description was followed by the description of the WETCOR test performed at Sandia Laboratories by E. Copus. The test employed about 35 kg of oxidic high temperature simulant material interacting with concrete and surrounded by a high temperature tungsten cylinder. This test produced a thick crust which precluded the cooling of the melt. A video of the test was also shown. Copus's conclusion was that it probably is not possible to cool or quench a prototypic melt in prototypic accident scenarios.

W. Tromm described a conceptual design of a core catcher which is studied in Germany and later described the experiments currently being carried out at KfK to obtain data on the physical phenomena on which the core catcher concept is based. In particular, the experiments were directed towards the melt fragmentation that may occur when water is introduced in a melt layer from below. The experiments performed at KfK with thermite ( $\text{Al}_2\text{O}_3$ , Fe and CaO) have shown fragmentation of the melt layer when water was introduced before the melt interacting with concrete. The experiment with 38 kg of melt resulted in a quenched bed. The fragmentation pieces were 5 mm or larger size. No steam explosion occurred. Experiments with a plastic melt have also been conducted to obtain visual information on the melt quenching process.

In summary, significant experimental efforts are in place to identify the feasibility of cooling and/or quenching a molten corium mass released from the RPV after a core melt down accident. Generally it is not clear whether the stationary melt can be cooled by a water overlayer. Spreading tests are being proposed to study the melt coolability during its movement in the containment. Also, alternative modes of water addition are being investigated for melt cooling/quenching, in conjunction with a design effort on core catchers.

#### Session IV. Modelling and Codes on Melt Spreading and Coolability

The need for more detailed or mechanistic modelling of melt spreading and coolability stems from consideration of a number of factors.

One postulate for ex-vessel debris-water interactions for the case in which water is added as an overlying pool has been the assumption of uniform spreading and fragmentation of the debris (or significant water ingress) such that the effective surface area for heat transfer and thus heat removal is enhanced. This postulated behaviour allowed for the development of simple surrogate models for heat transfer which predicted rapid melt quenching and coolability.

However, the integral tests performed to date, SWISS, WETCOR, BETA, and MACE have not provided confirmation of the fundamental behaviour implicit in the simplified modelling approach. All of the tests performed to date have indicated a propensity for the melt to form an impervious crust at the melt/water interface. Thus, it is seen that analysis of the tests as well as reactor analysis should include modelling to account for crust formation including those mechanisms serving to inhibit crust development (i.e. gas sparging) as well as the mechanisms which act to cause failure of a crust after one has formed (thermal stresses, gas pressure from concrete decomposition).

For reactor designs which allow for greater spreading of molten debris, thus enhancing prospects of cooling and avoiding structural damage, validated models are needed to ensure analyses of greater spreading are realistic. Earlier models have focused on the hydrodynamic aspects of melt spreading and have not rigorously treated the influence of heat transfer on the melt spreading behaviour, i.e., melt immobilization and material flowing over previously frozen material.

In the event that corium water heat transfer in the static post spread configuration is insufficient to quench core debris it may be beneficial to more accurately model heat transfer in the transient and spreading mode of the process.

Modelling approaches have been described which focus on the initial formation of the crust (ANL) by evaluating the effects of the superficial gas velocity as well as an approach which incorporates into the CORCON-UW code (University of Wisconsin) more detailed modelling of the stresses created in a floating or bonded crust which would cause eventual crust failure. Incorporation of crust formation criteria into the CORQUENCH code and analysis of the MACE scoping tests by M. Farmer (ANL) showed good agreement with observed behaviour and measured heat fluxes. It is important to note that while small scale experiments have produced continuous crusts spanning the vessel cross section (20-50 cm) scaling studies and stress analysis performed by R. Engelstad (U. of Wisconsin) predict that at a lateral dimension greater than 2 m thermal and bending stresses would cause crust failure. However, there is a dearth of material property data relevant to thermo-physical properties (including fracture strength) of crustal material. This is an area which should be pursued.

An alternative approach to modelling of heat transfer to overlying water in the presence of a crust was presented by J.M. Seiler of CEA/CENG in which the focus of analysis was the entrainment of molten material by sparged gas through defects in the crust. This analysis indicated corium entrainment characterized as an entrainment coefficient of .007 cm<sup>3</sup> of debris per liter of sparged gas would be sufficient to quench a debris bed 30 cm deep.

All of the models for predicting crust behaviour including that for mass entrainment appear to be based on a solid crust or in the case of the CEA/IPSN model a crust which is solid except for large discrete openings which would allow entrainment of molten debris. All of the integral tests involving oxidic melts (WETCOR, MACE) have produced crusts which are porous to gas flow but non porous to water ingression or melt entrainment. The models should be examined for the applicability to porous crusts and should receive further validation against experimental data.

In order to improve the prospects for ex-vessel coolability for new reactors various design features have been considered. One such design which is intended to avoid both molten core-concrete interactions and steam explosions has been proposed by A. Turricchia of ENEL-DCO. The basic feature is a three dimensional lattice of staggered graphite beams located beneath the reactor pressure vessel. The heat capacity and thermal conductivity of the graphite provides for the initial cooling of the debris; surface area enlargement for heat transfer is accomplished by the staggered arrangement of the beams which lessens the need for altering the lateral dimensions of the reactor cavity. Long term cooling of the corium would require flooding of the reactor cavity. While preliminary estimates of the graphite temperatures achieved upon initial contact with the corium indicate temperatures below those associated with chemical reactions or graphite burning, additional analysis is warranted to confirm this view. It was also suggested that additional analysis is needed to ensure the integrity of the design for moderate and high pressure melt ejection events.



## Session V. Code Comparisons and Plant Applications

M. Firnhaber reported the results of International Standard Problem ISP 30 on BETA Test V5.1. The presentation first recalled the objectives of the test, which involved both thermal hydraulic behaviour with high Zr content and Zr chemistry in the condensed phase, and two-dimensional erosion and aerosol release. Accordingly, two types of variables were considered: thermal-hydraulics and aerosol release.

Different results were obtained with the codes WECHSL and CORCON; WECHSL was observed to predict more accurately than CORCON the initial decrease of the temperature, while, for erosion, the axial velocity was initially too high for WECHSL and too low for CORCON; the prediction of the total eroded mass was rather good.

The gas production was underestimated, because the release from the upper part of the concrete device had not been taken into account.

For Zr chemistry, calculations performed with condensed phase chemistry models exhibit rapid elimination of metallic zirconium.

The conclusions have stressed the following points:

- importance of condensed phase chemistry modelling;
- slow temperature evolutions in CORCON;
- interest in an experimental validation matrix for future work.

Results of aerosol code comparisons with releases from ACE MCCI Tests were reported by J. Fink. The calculations presented were performed for the ACE L6 test, with 30% Zircaloy oxidation and a siliceous concrete. Different participants to the code comparison exercise have used the codes SOLGASMIX, CORCON, and VANESA.

Very large differences in aerosol release predictions were observed; differences between the codes and the experiment can be tentatively attributed to:

- the differences in oxygen potential modelling;
- the absence of modelling of chemical reaction between condensed phases;
- zirconium chemistry;
- no modelling of metal vaporization;
- influence of the different databases used.

It has to be noted that, for some fission products, the released quantity is less than the detection limit.

As a conclusion, the author recommended to continue the work on thermodynamic databases - including experiments if necessary - and to increase the efforts for condensed phase chemistry modeling.

The calculations presented by F. M@uller analysed a VVER 1000 reactor with a 2.50 m thick basemat consisting of serpentine concrete. The effects of instrumentation tubes in the walls of the reactor pit and a connecting door to

the other parts of the containment were considered. Results suggest that these instrumentation tubes could constitute a potential cause of early containment failure in the case of core-concrete interaction, as they are located relatively close to the inner part of the reactor pit walls.

In the subsequent discussion, it was pointed out that a satisfactory simulation of MgO chemistry to describe the serpentine concrete behaviour may be obtained by considering it as CaO in the WECHSL calculation.

Also, the possibility for corium cooling subsequent to spreading was suggested as a possibility for further studies.

Application of the WECHSL code to PWR and BWR calculations were reported by J. Foit. Two basic cases were considered in this study:

- PWR like configuration with siliceous concrete and water ingress ion after 0.9 m erosion;
- BWR like configuration with limestone concrete of higher decomposition temperature and a very small reactor cavity
- These calculations also differed by the thickness of the basemat and the residual power being considered.

For the PWR case, a penetration of 6 m was predicted to occur in about five days. Sump water ingress ion hardly changed this time. For the BWR case, time was shorter due to the absence of lower crust formation.

These figures were given for further comparison with other codes (for example CORCON).

Appendix

## Members of the Programme Committee and/or Session Chairmen

Dr. Hans Alsmeyer (KfK, Germany) - Chairman  
Dr. Bernhard Kuczera (KfK, Germany)  
Mrs. Catherine Lecomte (CEA/IPSN, France)  
Dr. B. Raj Sehgal (EPRI, USA)  
Dr. Paul N. Smith (AEA Technology/WTC, UK)  
Mr. Charles Tinkler (USNRC)  
Dr. Brian D. Turland (AEA Technology/SRD, UK)

Mr. Jacques Royen [OECD (NEA)] - Secretary

AnnexO E C D

The Convention establishing the Organisation for Economic Co-operation and Development (OECD) was signed on 14th December 1960.

Pursuant to article 1 of the Convention, the OECD shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and this to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The current Signatories of the Convention are Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

N E A

The OECD Nuclear Energy Agency (NEA) now groups all the European Member countries of OECD and Australia, Canada, Japan and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objectives of NEA are to promote co-operation between its Member governments on the safety and regulatory aspects of nuclear development, and on assessing the future role of nuclear energy as a contributor to economic progress.

NEA works in close collaboration with the International Atomic Energy Agency, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

C S N I

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and coordinate the activities of the OECD Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries.

CSNI is sponsoring several Senior Groups of Experts and Principal Working Groups (PWG's). PWG4 is dealing with the confinement of accidental radioactive releases.