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ORNL
FOREIGN TRIP REPORT
ORNL/FTR-3780

DATE: October 16, 1990

SUBJECT: Report of Foreign Travel of L. J. Ott, Engineering Analysis Section, Engineering Technology Division

TO: Alvin W. Trivelpiece

FROM: L. J. Ott

PURPOSE: To participate in the 1990 CORA Workshop at Kernforschungszentrum Karlsruhe (KfK) GmbH, Karlsruhe, FRG, on October 1-4, and to participate in detailed discussions on October 5 with the KfK CORA staff on future CORA Boiling Water Reactor (BWR) experiments.

SITES VISITED:

10/1-4/90	CORA Workshop	KfK, Karlsruhe, FRG	Conference Participants
10/5/90	CORA Staff	KfK, Karlsruhe, FRG	S. Hagen

ABSTRACT: The traveler attended the 1990 CORA Workshop at KfK, FRG. Participation included the presentation of a paper on work performed by the Boiling Water Reactor Core Melt Progression Phenomena Program at Oak Ridge National Laboratory (ORNL) on posttest analyses of CORA BWR experiments.

The Statement of Work (November 1989) for the BWR Core Melt Progression Phenomena Program provides for pretest and posttest analyses of the BWR CORA experiments performed at KfK. Additionally, it is intended that ORNL personnel participate in the planning process for future CORA BWR experiments. For these purposes, meetings were held with KfK staff to discuss such topics as (1) experimental test schedule, (2) BWR test conduct, (3) perceived BWR experimental needs, and (4) KfK operational staff needs with respect to ORNL support.

1. INTRODUCTION

The Boiling Water Reactor Severe Accident Technology Program at Oak Ridge National Laboratory (ORNL) has developed a set of models specific to boiling water reactor (BWR) response under severe accident conditions. These models have been applied successfully to both pretest and posttest analyses of the DF-4 experiment performed within the ACR Reactor at Sandia National Laboratories, resulting in excellent agreement between model prediction and experiment. These BWR-specific models have also been applied to pretest analyses of the forthcoming FLHT-6 experiment to be performed in the NRU Reactor at Chalk River, Canada.

The CORA operational staff (Drs. Hagen and Hofmann) have requested the USNRC, under the auspices of the Severe Fuel Damage Partners Program, that the ORNL BWR-specific models be applied in support of BWR experiments being performed in that facility. Accordingly, the Statement of Work (November 1989) for the BWR Core Melt Progression Phenomena Program at Oak Ridge provides for application of the ORNL BWR models to the BWR experiments performed at CORA. In addition, ORNL personnel are expected to participate in the planning process for future CORA experiments investigating the phenomena associated with BWR core heatup and relocation.

In accordance with Task 2 of the Form 189 for FIN L1366 dated November 20, 1989, the ORNL program is to analyze the results of the CORA BWR experiments via the ORNL BWR-specific models and interpret the phenomenological implications of the results. Additionally, the program is to perform pretest analysis of CORA BWR experiments for experimental planning purposes.

One purpose of this trip was to participate in the CORA Workshop by presenting the results of posttest analyses of the CORA-16 BWR experiment. Secondly, the support effort requested by the CORA operational staff cannot be adequately performed without an intimate knowledge of the facilities and the experimental conduct. Personal contact with the operational staff (during the Workshop and on October 5) and the in-depth knowledge instrumental to continued BWR Core Melt Progression Phenomena Program support of CORA were achieved during this trip.

2. INTERNATIONAL CORA WORKSHOP (OCTOBER 1-4)

The CORA Workshop was conducted in conference facilities at the Kernforschungszentrum Karlsruhe GmbH (KfK), Karlsruhe, FRG, and was chaired by Dr. P. Hofmann of KfK. Appendix A provides a list of Workshop attendees and Appendix B gives the complete agenda for the Workshop. Papers from the Workshop are available upon request. The traveler presented the paper:

"Post-Test Analyses of the CORA-16 Experiment"

Dr. B. Kuczera (KfK) opened the Workshop on Monday, October 1, with a welcome to the attendees. He noted that the research and development funding at KfK for nuclear fission indicates a decreasing trend from ~70% of the laboratory budget in 1983 to a projected ~30% in 1993. Those areas that are increasing in budget share include basic research, materials research and environmental issues. With respect to German safety studies, Dr. Kuczera made the following comments:

1. Energetic steam explosions that lead to RPV rupture have been excluded as a risk relevant accident path.
2. RPV failure at high-pressure is controllable for pressures <30 bar but could cause containment failure for pressures >80 bar (further research is necessary).
3. Conventional techniques are applicable for MCCI and basemat penetration.
4. The hydrogen deflagration/detonation problem has not been resolved.

Most of Monday's presentations (by KfK personnel) were on the CORA experiments conducted since the 1989 Workshop (i.e., CORA-7, -9, -18). CORA-7 was a large (52 rods with 5 absorber rods) bundle PWR experiment conducted at ~1.2 bar overpressure. CORA-9 was a small (23 rods with 2 absorber rods) bundle PWR experiment conducted at ~10 bar pressure (absolute). CORA-18 was a large bundle (48 rods) BWR experiment conducted at ~1.2 bar overpressure. Dr. Hagen made the following observations about these tests:

1. In general, the large bundle tests show the same damage behavior as in the smaller bundle tests.
2. Temperature escalation starts at ~1200°C and continues even after shutoff of the electric power as long as metallic Zircaloy and steam are available.
3. For the high-pressure experiment (CORA-9), the same power input as in a similar low-pressure test resulted in a slower structural temperature increase; also, compared to the low-pressure test, there was less recognizable melt movement but the overall damage in the bundle was similar to that in the low-pressure tests.
4. Collapse of the Zircaloy cladding in the high-pressure test did not occur over the full length of the fuel pellets but only locally.
5. In CORA-18, initiation of liquefaction was due to the interaction of the B_4C and stainless steel in the absorber blade. There was destruction of the channel wall in the neighborhood of the absorber blade <u>and</u> in the half of the bundle away from the blade.

During Monday afternoon's presentations, Dr. Schumacher (KfK) discussed the analysis of CORA test gaseous effluents and presented the results of his analyses (i.e., hydrogen generation rates, etc.) for CORA-7, -9 and -18. In Mr. Minato's presentation on Zircaloy oxidation in CORA-2 and CORA-5, several innovative diagrams (developed by Dr. Hering of IKE) were shown which illustrated core isotherms correlated with time, steam flow, hydrogen generation, power and observed core degradation phenomena (i.e., droplet and rivulet flow and melt refreezing). This was an interesting demonstration of a technique that can be employed to illustrate on <u>one</u> page the experiment progression and highlights.

The final presentation on Monday (by Dr. Hofmann) dealt with the results of separate-effects tests and the influence of Zircaloy oxidation on chemical interactions with other bundle components. One conclusion from this research is that ZrO_2 layers on Zircaloy structures delay the beginning of chemical interactions and shift the liquefaction of the components to higher temperatures. Consequently, future CORA tests may include pre-oxidation as a test condition parameter. This would more accurately reflect the state of the Zircaloy structures within operating reactors.

Tuesday's presentations discussed code analyses (SCDAP/RELAP5, ATHLET-SA, KESS-III and CORA/BWR) of the CORA experiments. There have been code and model improvements in ATHLET-SA and KESS-III, and the agreement of the calculated results from these codes with the experimental observations is better (relative to results presented in 1989) but, in general, is still poor. Dr. Haste (UKAEA) showed great skill in successfully applying SCDAP/RELAP5 to the CORA-7 pretest predictions. He presented results from cladding ballooning studies (for CORA-2, -5, -7, -12 and -15) using SCDAP/RELAP5 and Winrith's CANSWEL-2 code. The scope of Dr. Haste's work is focused on SCDAP/RELAP5 validation studies (required for UK safety analysis), and only the CORA PWR tests are being reviewed (the UK has no BWRs). He did note the late prediction (via SCDAP/RELAP5) for the oxidation excursion in CORA-12 and the underpredicted heat losses at the bottom of the bundles. These are areas for further study (by UKAEA).

The experiment-specific analytical modeling at ORNL for CORA-16 yielded the following points of interest and discussion by the attendees:

1. The gaseous coolant (at 1.2 bar overpressure) should be treated as a transparent, noninteracting medium but, at 10 bar pressure, it behaves as a gray interacting (i.e., absorbing, transmitting) medium.
2. The spacers appear to cause higher local rod temperatures.
3. The predicted and observed cladding thermal response are in excellent agreement until application of the available Zircaloy oxidation kinetics models causes the low-temperature (900-1200°C) oxidation to be underpredicted.

It was noted that the treatment of the gas as a gray interacting medium effectively increases the convective heat transfer, which could partially explain the slow structural heatup in CORA-9 (a 10 bar test). Dr. Haste pointed out that he is chairing a committee (for the OECD) which is preparing a report on the state of the art with respect to Zircaloy oxidation kinetics. He will forward material addressing the low-temperature Zircaloy oxidation problems encountered in the CORA-16 analyses to ORNL.

Tuesday afternoon, the workshop attendees toured the CORA and BETA test facilities. The CORA-13 test bundle has been installed, and this PWR experiment with quench initiation at high temperature will be attempted in late October. CORA-13 will be used for an OECD International Standard Problem. The CORA facility is impressive, and the tour conducted by S. Hagen and L. Sepold was very informative. The BETA facility (used to study molten corium/concrete interaction) has been restarted after a lapse of 4-5 years. The current BETA test program is focusing on typical BWR corium mixtures (i.e., high metals content, high Zircaloy content, and presence of boron compounds). This BWR data base will be used to upgrade the German WECHSL code. It would be prudent to analyze these new experiments with the USNRC-developed CORCON-Mod3 code to determine if any code changes or model modifications are needed.

The final day of the Workshop agenda was devoted to organizations other than KfK (i.e., JAERI, AECL, CEA, SNL, and Siemens/KWU). Initial presentations provided a review of severe accident research in JAERI and the development by JAERI of an interesting (although limited) colorimetric technique to evaluate temperature in an inpile fuel rod melting test. H. Rosinger, AECL, presented a good overview of the Canadian CHAN thermochemical experiments at Whiteshell; and C. Gonnier, CEA/Cadarache reviewed the French PHEBUS facility, severe fuel damage program, and the inpile experimental results. There was general agreement that Gauntt's proposed ex-reactor metallic melt relocation and blockage experiments at SNL will address an existing melt progression uncertainty and are a logical extension of current in-core melt progression experiments.

H. Plank (Siemens/KWU) made an interesting argument for the reduction of heatup rates in future CORA tests based on accident probabilities in German LWRs. Historically, the CORA structural heatup rate has been ~1 K/s, which reflects the most probable German severe accident core heatup rates. However, backfits to German BWRs will make the long term sequences (4-10 h or >10 h) more likely and these sequences exhibit heatup rates of ~1/3 K/s. There was some concern that this low rate could lead to complete oxidation of the Zircaloy with little or no metallic melting and relocation. (This has been predicted in previous studies for U.S. BWRs for long-term accident sequences with a small injection rate.) Low heatup rates will be considered as a future CORA test parameter as will bundle preoxidation. G. Schanz (KfK) presented the results of a study that focused on the temperature and duration for Zircaloy preoxidation with a recommendation of a 2 h pretest at 800°C maximum temperature.

The Workshop ended with an impromptu gathering of SCDAP/RELAP5 users (requested by Siemens/KWU). Apparently, per H. Plank, problems (i.e., errors) have been encountered when the code was applied to a BWR accident scenario (boildown sequence at high pressure with SRV actuations). Also, there were drastic differences in the computed results in a code comparison with MAAP and SCIMA (a Siemens code). There was no resolution of these problems, but the code developer did review some major areas of code improvements that have been proposed to the NRC for 1991.

3. MEETING WITH CORA ANALYSTS, NRC AND KfK PERSONNEL

The topics of discussion on Friday ranged from the CORA facility schedule to the information requirements of the analysts and the support needed by the CORA operational staff (in the form of pretest analyses).

The CORA experiment schedule for the remainder of 1990 and for 1991 is shown in Table 1. CORA-13 is tentatively set for late October and has been accepted by the OECD as an international standard problem. The current CORA facility operating license ends in 1991, and the facility will be shutdown in mid-1991 in preparation for moving the facility from the old FR2 reactor hall to a new building. The estimated period for the relocation is 1-1½ years.

Dr. Hagen provided videos and color photographs of the bundle end-states for CORA-7, -9 and -18 to the analysts.

Discussions primarily included basic engineering needs such as (1) type and location of instrumentation, (2) manner of bundle power control, (3) characterization of the shroud insulation, and (4) flow instrumentation for the test section inlet and outlet gas streams. Major facility changes (such as new gas flow instrumentation) will probably be done during the CORA relocation. Licensing requirements make changes in the current facility difficult. Modifications to the power profile for future CORA tests were suggested as necessary to allow some calibration (analytical models) prior to the test transient phase. This calibration phase could also be used to preoxidize the bundle. Hagen noted that the operational staff would have to rely on pretest analyses to develop the desired calibration power profile.

4. CONCLUDING REMARKS

The diversity of CORA Workshop attendees increased this year to include French and Canadian representatives. Although the focus was on CORA experiments and analyses, the increased international flavor was technically refreshing and informative. For instance, the overviews by Drs. Rosinger, Gonnier and Gauntt on the CHAN, PHEBUS and SNL experimental programs keep the technical community abreast of the international severe fuel damage programs' results and objectives. Such diversity also helps to illustrate the knowledge gaps and phenomenological uncertainties and what is being done internationally to reduce the uncertainties. For instance, major uncertainties, such as the metallic relocation and material interactions in the BWR core plate region and the effect of oxidized surfaces on material interaction and relocation, will be addressed by future experiments at SNL and KfK.

The restart of the BETA facility with emphasis on typical BWR corium/concrete interaction should lead to a major improvement in the MCCI data base. It would be prudent to analyze these experiments with CORCON-Mod3.

The CORA operational staff was very receptive to the analyst's requests and suggestions, especially with regard to improved characterization of the CORA experimental boundary conditions. Nevertheless, some of the requests, such as flow instrumentation at the inlet and outlet of the test section, may be delayed until the reconstruction of the facility in its new building.

Table 1. CORA Test Matrix

Test No.	Max. Cladding Temperatures	Absorber Material	Other Test Conditions	Date of Test
2	≈2000°C		UO_2 refer, Inconel spacer	Aug. 6, 1987
3	≈2400°C		UO_2 refer, high temperature	Dec. 3, 1987
5	≈2000°C	Ag, In, Cd	PWR absorber	Feb. 26, 1988
12	≈2000°C	Ag, In, Cd	quenching	June 9, 1988
16	≈2000°C	B_4C	BWR absorber	Nov. 24, 1988
15	≈2000°C	Ag, In, Cd	rods with internal pressure	March 2, 1989
17	≈2000°C	B_4C	quenching	June 29, 1989
9	≈2000°C	Ag, In, Cd	10 bar system pressure	Nov. 9, 1989
7	<2000°C	Ag, In, Cd	57-rod bundle, slow cooling	Feb. 22, 1990
18	<2000°C	B_4C	59-rod bundle, slow cooling	June 21, 1990
13	≈2200°C	Ag, In, Cd	OECD/ISP; quench initiation at higher temperature	planned for 1990
29*	≈2000°C	Ag, In, Cd	preoxidized, quenching	planned for 1991
31*	≈2000°C	B_4C	slow initial heatup (≈0.3 K/s), quenching	planned for 1991
30*	≈2000°C	Ag, In, Cd	slow initial heatup (≈0.3 K/s), quenching	
28*	≈2000°C	B_4C	preoxidized, quenching	
10	≈2400°C	Ag, In, Cd	very high temperature, lower part of bundle in H_2O	
27	≈2400°C	B_4C	very high temperature lower part of bundle in H_2O	
25	≈2000°C	B_4C	10 bar system pressure	
26	≈2000°C	B_4C	fast heatup, quenching	
24	≈2000°C	B_4C	steam rich conditions, quenching	
32*	≈2000°C	Ag, In, Cd	quenching from the top	

Initial heatup rate: ≈1.0 K/s; steam flow rate, PWR: 6 g/s, BWR: 2 g/s; quench rate (from the bottom) ≈ 1 cm/s.

*Further proposed experiments (May 1990).

APPENDIX A

PERSONS CONTACTED

Attendees: International CORA Workshop 1990
(October 1-4) KfK Karlsruhe, FRG

R. Wright	USNRC/Washington, DC
C. M. Allison	EG&G/Idaho Falls
R. O. Gauntt	SNL/Albuquerque
L. J. Ott	ORNL/Oak Ridge
T. J. Haste	UKAEA/Winfrith
M. Sobajima	JAERI
R. Nakamura	JAERI
H. Hirschmann	PSI-WurenLingen
H. Rosinger	AECL/Canada/Whiteshell
Adroguer	CEA/France/Cadarache
M. DeCachard	CEA/France/Grenoble
C. Gonnier	CEA/France/Cadarache
A. Meyer-Heine	CEA/France/Cadarache
Porracchia	CEA/France/Cadarache
A. Ball	GRS/Garching
Firmhaber	GRS/Garching
K. Kollath	GRS/Koln
Krause	GRS/Garching
Schubert	GRS/Koln
K. Trambauer	GRS/Garching
J. Eyink	Siemens/KWU/Erlangen
Hellman	Siemens/KWU/Erlangen
H. Plank	Siemens/KWU/Erlangen
M. Bruder	IKE/Stuttgart
W. Hering	IKE/Stuttgart
K. Muller	IKE/Stuttgart
A. Schatz	IKE/Stuttgart
Kronenberg	IKE/TU Dr.
J. Antony	Ruhr-Univ. Bochum
U. Brockmier	Ruhr-Univ. Bochum
A. Schaffrath	Ruhr-Univ. Bochum
H. Unger	Ruhr-Univ. Bochum
H. Benz	KfK/HVT
Grehl	KfK/HVT
Roder	KfK/HVT
Rohling	KfK/HVT
Rolzal	KfK/HVT
Breitung	KfK/INR
Frohlich	KfK/INR
R. Huber	KfK/INR
H. Jacobs	KfK/INR

I. Schub	KfK/INR
G. Schumacher	KfK/INR
S. Hagen	KfK/HIT
H. Malauschek	KfK/HIT
K. Minato	KfK/HIT/JAERI
F. Seibert	KfK/HIT
L. Sepold	KfK/HIT
P. Hofmann	KfK/IMF 1
G. Schanz	KfK/IMF 2
B. Kuczera	KfK/PSF
P. Royl	KfK/IRE

Attendees: Meeting with CORA Analysts and KfK Personnel (October 5)

C. M. Allison	EG&G/Idaho Falls
R. O. Gauntt	SNL/Albuquerque
S. Hagen	KfK/HIT
T. J. Haste	UKAEA/Winfrith
P. Hofmann	KfK/IMF 1
L. J. Ott	ORNL/Oak Ridge
L. Sepold	KfK/HIT
R. Wright	USNRC/Washington, DC

APPENDIX B

AGENDA FOR INTERNATIONAL CORA WORKSHOP 1990
OCTOBER 1-4
KfK KARLSRUHE, FRG

Monday, October 1

9.30 h	Welcome and introduction *B. Kuczera; KfK*
10.00 h	Test results of the experiment CORA-9 with high-system pressure *S. Hagen: KfK*
10.30 h	-----Coffee break-----
11.00 h	Test results of the experiments CORA-7 and CORA-18 with larger PWR and BWR bundles *S. Hagen; KfK*
12.30 h	-----Lunch-----
13.30 h	Gas analysis for CORA-7, -9, and 18 *G. Schumacher; KfK*
14.15 h	Analysis of Zircaloy oxidation and cladding deformation in CORA-2 and CORA-5. *K. Minato; JAERI*
15.00 h	-----Coffee break-----
15:30 h	Results of separate-effects tests; influence of cladding oxidation on chemical interactions with other bundle components *P. Hofmann; KfK*
16.15 h	Individual discussions

Tuesday, October 2

9.00 h	Interpretation of PWR-specific CORA experiments *W. Hering; IKE*
9.45 h	Present state of the KESS-III code and results of calculations of CORA-2 and CORA-5 *K. Muller; IKE*

10.15 h	-----Coffee break-----
10.45 h	Posttest analysis of CORA-2 with ATHLET-SA *K. Trambauer; GRS*
11.30 h	Posttest analysis of CORA experiments with SCDAP/RELAP5 *T. Haste, AEA*
12.15 h	-----Lunch-----
13.15 h	Results of CORA analyses with SCDAP/RELAP5 *C. M. Allison; EG&G*
14.00 h	Posttest analyses of the CORA-16 Experiment *L. J. Ott; ORNL*
14:45 h	-----Coffee break-----
15.00 h	Visit of the CORA and BETA (core melt/concrete interactions) test facilities

Wednesday, October 3

National Holiday due to the German reunification

Thursday, October 4

9.00 h	Progress in some fuel failure researches at JAERI *M. Sobajima; JAERI*
9.30 h	An application of color temperature evaluation method to inpile fuel rod melting tests in NSRR *R. Nakamura; JAERI*
10.00 h	An overview of the Canadian CHAN thermal-chemical experiments *H. E. Rosinger; AECL*
10.30 h	-----Coffee break-----
11.00 h	PHEBUS SFD Program *Ch. Gonnier; CEA*
11.45 h	The SNL ex-reactor metallic melt relocation and blockage experiments *R. O. Gauntt; SNL*
12.30 h	-----Lunch-----

13.30 h	The typical heatup rates for uncovered LWR cores based on risk analysis *H. Plank; Siemens/KWU*
14.00 h	CORA bundle preoxidation, a test parameter under discussion *G. Schanz, KfK*
14.30 h	Discussion on the CORA test matrix for 1991 *P. Hofmann; KfK*
15.15 h	-----Coffee break-----
15.45 h	Concluding discussion

Friday, October 5

Individual discussions on special ad hoc aspects and bilateral matters.

APPENDIX C

ACRONYMS

AECL	Atomic Energy Canada Limited
BETA	German facility for molten corium/concrete interaction experiments, not an acronym
CEA	Commissariat a l'Energie Atomique
FLHT	Full Length High Temperature severe damage experiments in the National Research Universal reactor at Chalk River, Ontario, Canada
IKE	Institut Kern Energie, Stuttgart, Federal Republic of Germany
JAERI	Japan Atomic Energy Research Institute
KWU	Kraktwerk Union AG (Federal Republic of Germany)
MCCI	Molten Corium Concrete Interaction
RPV	Reactor Pressure Vessel
SNL	Sandia National Laboratory
UKAEA	United Kingdom Atomic Energy Agency

LITERATURE OBTAINED

1. S. Hagen et al., KfK, "First Results of CORA Tests: 9, High System Pressure; 7, Large PWR Bundle; 18, Large BWR Bundle," Oct. 1990, CORA Workshop.

2. G. Schumacher et al., KfK, "Gas Analysis: CORA 7, 9, 18," Oct. 1, 1990, CORA Workshop.

3. K. Minato et al., KfK/JAERI, "Analysis of Zircaloy Oxidation and Cladding Deformation in CORA-2 and CORA-5," Oct. 1, 1990, CORA Workshop.

4. P. Hofmann et al., KfK, "Results of Separate-Effects Tests: Influence of Cladding Oxidation on Chemical Interactions with Other Bundle Components," Oct. 1, 1990, CORA Workshop.

5. W. Hering et al., IKE, "Interpretation of PWR Specific CORA Experiments," Oct. 2, 1990, CORA Workshop.

6. K. Muller et al., IKE, "Present State of the KESS-III Code System and Results of Calculations of CORA-5 and CORA-2," Oct. 2, 1990, CORA Workshop.

7. K. Trambauer et al., GRS, "Posttest Analysis of CORA-2 with ATHLET-SA," Oct. 2, 1990, CORA Workshop.

8. T. J. Haste et al., UKAEA, "Posttest Analysis of CORA Experiments with SCDAP/RELAP5," Oct. 2, 1990, CORA Workshop.

9. C. M. Allison et al., EG&G, "Results of CORA Analysis Using SCDAP/RELAP5," Oct. 2, 1990, CORA Workshop.

10. L. J. Ott, ORNL, "Posttest Analyses of the CORA-16 Experiment," Oct. 2, 1990, CORA Workshop.

11. M. Sobajima, JAERI, "Progress in Some Fuel Failure Researches at JAERI," Oct. 4, 1990, CORA Workshop.

12. T. Nakamura, JAERI, "An Application of Color Temperature Evaluation Method to Inpile Fuel Rod Melting Tests in NSRR," Oct. 4, 1990, CORA Workshop.

13. C. Gonnier, CEA, "PHEBUS SFD Program," Oct. 4, 1990, CORA Workshop.

14. R. O. Gauntt, SNL, "The SNL Ex-Reactor Metallic Melt Relocation and Blockage Experiments," Oct. 4, 1990, CORA Workshop.

15. H. Plank, KWU, "The Typical Heatup Rates for Uncovered LWR Cores Based on Risk Analyses," Oct. 4, 1990, CORA Workshop.

16. G. Schanz, KfK, "CORA Bundle Preoxidation: A Test Parameter Under Discussion," Oct. 4, 1990, CORA Workshop.

17. S. Hagen et al., KfK, "Quick Look Information on Test CORA-9," Draft report available at CORA Workshop 1990.

18. P. Hofmann et al., KfK, "Chemical Behavior of (Ag, In, Cd) Absorber Rods in Severe LWR Accidents," KfK-4670, CNEA NT-16/89, August 1990.

19. S. Hagen et al., KfK, "Interactions in Zircaloy/UO_2 Fuel Rod Bundles with Inconel Spacers at Temperatures above 1200°C (Posttest Results of Severe Fuel Damage Experiments CORA-2 and CORA-3)," KfK-4378, September 1990.

END

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