UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

December 11, 2008

MEMORANDUM TO: ACRS MEMBERS

FROM: David Bessette **/RA/**
Advisory Committee on Reactor Safeguards

SUBJECT: CERTIFICATION OF THE MINUTES OF THE THERMAL HYDRAULIC SUBCOMMITTEE MEETING, GENERIC SAFETY ISSUE 191, EVALUATION OF LONG TERM COOLING CONSIDERING PARTICULATE,FIBROUS, AND CHEMICAL DEBRIS IN THE RECIRCULATING FLUID, MARCH 19, 2008

The minutes of the subject meeting have been certified as the official record of the proceedings for that meeting. A copy of the certified minutes is attached.

Attachment: As stated

cc via e-mail: ACRS Staff Engineers
S. Duraiswamy
J. Flack
V. Murphy

UNITED STATES
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February 5, 2009

MEMORANDUM TO: David Bessette, Senior Staff Engineer, ACRS

FROM: Sanjoy Banerjee, Chairman

SUBJECT: CERTIFICATION OF THE MINUTES OF THE THERMAL HYDRAULIC SUBCOMMITTEE MEETING, GENERIC SAFETY ISSUE 191, EVALUATION OF LONG TERM COOLING CONSIDERING PARTICULATE,FIBROUS, AND CHEMICAL DEBRIS IN THE RECIRCULATING FLUID, MARCH 19, 2008

I hearby certify, to the best of my knowledge and belief, that the minutes of the subject meeting on March 19, 2008, are an accurate record of the proceedings for that meeting.

______**/RA/**_____________
Sanjoy Banerjee, Chairman
Thermal Hydraulic Phenomena

______2/5/2009___
Date

Certified by: Sanjoy Banerjee Issued: 12/11/2008
Certified by: 2/5/2009

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE ON THERMAL HYDRAULIC PHENOMENA
MARCH 19, 2008
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Thermal Hydraulic Phenomena Subcommittee met with representatives of the NRC Staff, Westinghouse, and the PWR Owners Group. The purpose was to review the PWR Owners Group report, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid," WCAP-16793-NP, and the staff's draft safety evaluation. During the meeting, the Subcommittee heard presentations by and held discussions with Westinghouse, the PWR Owners Group, its consultants, and the NRC Staff. David Bessette was the Designated Federal Official. The meeting was convened by the Chairman at 8:30 am and adjourned at 6:00 pm.

ATTENDEES

ACRS Members/Staff

Sanjoy Banerjee, Chairman
Said Abdel-Khalik, Member
Dennis Bley, Member
Michael Corradini, Member
Otto Maynard, Member
Tom Kress, Consultant
Graham Wallis, Consultant
David Bessette, Designated Federal Official

Staff

James Beall
Ellery Coffman
Ralph Landry
Robert Litman, Staff Consultant
Paul Klein
William Ruland
Mike Scott

Industry

Tim Andreychek, Westinghouse/PWROG
Matt Brands, AREVA, PWROG
William (Art) Byers, Westinghouse
Mo Dingler, Westinghouse/PWROG
David Fink, Westinghouse
Brett Kellerman, Westinghouse/PWROG
Kevin Menames, Westinghouse/PWROG
Paul Pyle, Westinghouse/PWROG
William Rinkacs, Westinghouse/PWROG
Gordon Wissinger, AREVA/PWROG

AGENDA

1.	Introductory Remarks by the Chairman	Sanjoy Banerjee
2.	Update on GSI-191 Status and Future Activities	Mike Scott, NRR

3. PWR Owners Group Presentation WCAP-16793-NP — Mo Dingel, Westinghouse W; Tim Andreychek, W

4. NRC Staff Presentation on Draft SE for WCAP-16793-NP — Ralph Landry; Paul Klein

5. Subcommittee Discussion

1. CHAIRMAN'S INTRODUCTORY REMARKS

The Chairman opened the meeting, stating that its purpose was to review the PWR Owners Group report, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid," WCAP-16793-NP, and the staff's draft safety evaluation.

2. Status Summary - Mike Scott, NRC Staff

Mr. Scott presented an overview of status and activities underway to resolve GSI-191. Generic Letter 2004-02 is the staff's regulatory vehicle to resolve GSI 191. GL 2004-02 requested that licensees determine their plant specific debris generation and transport and make any changes to plant design necessary to ensure long term cooling in the recirculation mode. The plants were asked to respond by the end of 2007, but most requested and received extensions to that date. All actions will not be completed until 2009. In the meantime, in view of low probability of the accident scenarios and the installation of the new screens, the staff considers the schedule for GSI 191 resolution to be satisfactory.

The plants responded to the generic letter by installing new sump screens that are 20 to 100 times larger in area than the originals. Several plants have sent submittals indicating they are in compliance with long term cooling requirements. NRR believes the risk of sump screen blockage has been reduced considerably, but that significant uncertainties still exist with respect to debris generation, transport, settling, and screen deposition.

Installation of the new screens has preceded testing in most cases which creates some risk, however, the Commission and industry believed it was important not to delay installation of the new screens. If further changes were found to be necessary, it would be in the area of reducing fibrous insulation or changing the buffer.

Testing of the new screens has uncovered new information rather than being just proof testing. An important factor in the results is the way in which debris is introduced into the flow, such as order of addition. It has taken industry some time to perform the tests and to resolve staff comments. Prof. Wallis indicated some of the testing should, therefore, be termed research.

The staff was not ready to talk about details of test conduct at this meeting because information is still arriving and is being evaluated. The staff has performed nine audits thus far on how licensees have conducted test programs and made changes to the plant design including removal of fibrous insulation as well as changing the screens. In general, the licensees were following staff guidance. One area that was generally lacking was guidance for considering chemical and downstream effects. Licensees were waiting on WCAP-16530 and WCAP-16793. Several additional audits will be performed in 2008.

The staff is making some attempt to bin the plants based on sump screen vendor because of similarities in screen design but there are differences in design by the same vendor based on containment configurations.

Testing shows that particulates pass through the sump screen when they are introduced before fibers. When the order is reversed, the fibers tend to catch on the screen and in turn filter the particulates.

Prof. Wallis questioned the basis for the bypass of 1 ft^3 of debris per 1000 ft^2 of screen area. (The 1 ft^3 of debris refers to as-manufactured fiberglass density of ~38 kg/m^3, 2.4 lb/ft^3, as compared to the density of ordinary glass ~2500 kg/m^3). Mr. Klein indicated that the number came from a wide range of testing of screens. The data are from four or five different sump screen vendors. The uncertainty in the number was said to be ±10%. Supporting data were not presented.

It was noted that information exists from testing in Germany and Japan, as well as from other facilities located in foreign countries. It was also noted that German plants do not add a buffer to the sump water. About ½ dozen US plants have changed the species of buffer used.

At the last subcommittee meeting in May 2007, industry discussed three approaches to dealing with uncertainties in addressing the problem: 1) removing fibrous insulation; 2) test results to demonstrate a smaller zone of influence; and 3) calculations of settling.

BWRs are being re-evaluated by RES to see whether lessons learned from GSI-191 have any regulatory impact or not.

3. PWR Owners Group Presentation WCAP-16793 - Mo Dingler, Tim Andreychek, Westinghouse

Mr. Dingler began the presentation by discussing bypass testing sponsored by the PWR Owners Group. Tests were run with: particulate only; fiber only; and mixtures of the two. The findings were that only small amounts of very small length fibers passed through the screens. The distribution of fiber lengths used in the tests was determined from jet impingement experiments, with some of the data being from the 1970s. Prof. Wallis raised a question about whether aged insulation is more brittle than new material. Mr. Dingler noted that the insulation is encapsulated in the plant.

Mr. Andreychek's presentation addressed chemical and downstream effects based on the topical report WCAP-16793. Westinghouse is preparing a revision to this report based on requests for additional information (RAIs) from the staff and its responses to those RAIs.

PWR fuel assemblies have inlets designed to prevent foreign material from entering the core. The hole diameter of the inlet assemblies is ½ to 2/3 the screen mesh size. WCAP-16793 considered collection of debris at the core inlet, in spacer grids, and on cladding surfaces. A peak cladding temperatures of 800F was adopted as the success criteria since it corresponded to the experimental data base from autoclave experiments run for 30 days. The acceptance criterion for cladding surface deposits is 50 mils to avoid bridging 110 mil subchannels.

Early on following shutdown, approximately 250 gpm of makeup is required to replace losses from boiling. By 30 hours this number is reduced to ~150 gpm as decay heat decreases. Chairman Banerjee inquired about how much resistance would be necessary to restrict flow to the core or past spacer grids until the makeup rate was equal to the boiling rate. This calculation has not been performed.

Westinghouse did perform a calculation that showed that one unblocked fuel assembly, or its equivalent, out of ~200 is sufficient to keep the core covered. Prof. Wallis noted that predictions of possible resistance and tolerable resistance are not found in WCAP-16793. Dr Landry stated that tests were run with a large accumulation of debris using a prototypic core inlet plate that produced a pressure drop of less than 1/3 psi. It was noted that the sump screen area is about 100 times larger than the core inlet flow area.

Chairman Banerjee inquired about chemical gels that might accumulate at the core entrance and cause large flow resistance. Mr. Andreychek indicated that such gels, if they formed, would be captured by the sump screens. According to Mr. Klein, Westinghouse assumed that anything that got past the screens was transported to the core. The solubility of aluminum hydroxide was noted to be a function of temperature. Testing by at least one licensee supports the assumption that precipitates will be transported to the core.

Tests run at Argonne National Laboratory showed very high flow resistance developing at the core inlet. The tests were run at room temperature and, therefore, did not properly treat solubility of aluminum hydroxide early in an accident where sump temperatures are high. However, as long term cooling proceeds, sump temperatures will drop and precipitation may be expected to increase. Also, between the sump and the core, the flow passes through a heat exchanger.

Dr. Kress inquired whether the analyses indicated any difficulties with either boron dilution or concentration and precipitation. Dr. Landry replied that it was being addressed on a plant specific basis.

Mr. Andreychek indicated that the lengths of fibers that passed through the screen were determined to be in the range of <750 μm (0.03 in) to 2000 μm (0.08 in). Professors Abdel-Khalik and Wallis indicated that the value of 1 ft^3 ±10% per 1000 ft^2 of fiber bypass seemed surprising given the uncertainties in the inlet flow conditions and whether the tests were really prototypic. What may be conservative for screen blockage may be nonconservative for bypass. Experiments indicate that most of the total debris that gets through the screen is bypassed early and that bypass drops off as debris accumulates on the screen.

An experimental facility was shown that employed a single prototypic bundle inlet nozzle, a ~1/3 height fuel bundle array, and a lower plenum representation. Tests run in this facility indicated settling in the lower plenum and some accumulation on the inlet nozzle and lowest spacer grid.

One-dimensional radial heat transfer calculations were performed for fuel rods to investigate the effects of postulated debris deposits on cladding temperature. A 1979 test report prepared by NUKON was referenced. These NUKON tests included heating a rod up to 2200F and quenching it in fibrous slurry. Other NUKIN testing included two-hour tests with nucleate boiling and film boiling. In these tests, the fibers did not adhere to the cladding.

In WCAP-16793, it is assumed that particulates or solutes that get through the screen are transported to the core. In the core, wherever boiling is occurring the transported material is assumed to deposit on the cladding according to concentration of the material in the water. A conduction study was performed to evaluate the effect of the cladding deposits on heat transfer. The pre-existing layers of ZrO_2 and crud were also included. Prof. Wallis indicated that the discussion in WCAP-16793 of this work was very unclear.

A spreadsheet code called LOCADM was developed to calculate chemical deposition on cladding (method from WCAP-16530-NP-A). The conduction calculations were done with ANSYS. Surface heat transfer was calculated using coefficients from COBRA/TRAC. The conductivity of ZrO_2, (2.79 W/m-C), was determined from Halden data ["Westinghouse Improved Performance Analysis and Design Model (PAD 4.0)," WCAP-15063-P-A pp 53-56, ML003735390; and EPRI TR-107718-P1 and P2]. This data had an uncertainty range of approximately ±1 W/m-C. The value used for conductivity of crud was 0.5 W/m-C. The value used conductivity of post-LOCA scale deposits was 0.2 W/m-C and was varied from 0.17 to 1.5 W/m-C, from literature survey of boiler scale deposits. The conductivity of precipitates was varied by about a factor of 10 from 1.6 to 0.17 W/m-C. A study was also done on reduction in flow at spacer grids but no results presented. A maximum clad temperature of less than 800F was adopted as the acceptance criterion.

Paint and coatings from containment were considered as sources of zinc, epoxies, etc. to the sump water.

Boric acid was said not to precipitate according to current accepted licensing calculations.

Westinghouse 2-loop upper plenum injection plants issues are much the same as for cold leg injection.

Profs. Wallis and Banerjee noted that many of the slides included qualitative statements rather than quantitative results. Mr. Scott noted that the staff's safety evaluation took note of many conservative assumptions in the Westinghouse evaluation in concluding the overall approach to be conservative.

Mr. Andreychek continued with a description of two COBRA/TRAC calculations. One calculation assumed 99.4% blockage, which corresponds to blockage of 216/217 fuel assemblies. In the second calculation, all central fuel assemblies were blocked (K ramped up from 1.5 to 1×10^9). The peripheral assemblies were unblocked. If only one fuel assembly is open to flow, the inlet flow velocity to that assembly is ~4 ft/s, which is about 1/3 the normal pumped, full power flow velocity. While there is a flow path between the core barrel and the core baffle, with holes in the baffle wall leading to the core, this flow path is not credited in the analyses.

Prof. Wallis and Chairman Banerjee indicated that Westinghouse did not provide evidence with which to evaluate the applicability of COBRA/TRAC for this type of analysis. Mr. Dingler acknowledged this was so, and stated the staff performed independent calculations in lieu of this applicability determination.

The Chairman inquired why no calculations were performed assuming a uniform mat with a loss coefficient of, perhaps 10^4 to10^5.

Once water enters the core from below, COBRA/TRAC calculates good lateral flow across the core from gravity force.

Within the core region, conduction heat transfer calculations were performed for a subchannel within a spacer grid. The ΔT between the coolant and the cladding hot spot was calculated to be ~150F. The calculation was done assuming a 50 mil deposit of post-LOCA scale. Mr. Klein indicated that the LOCADM spread sheet that was used to calculate scale deposits on cladding was based on local boiling rates. It predicted ~10 mils deposit on the worst case rod. Prof. Wallis noted that there were a few cases of inverse solubility such as calcium. In response to a question by the Chairman, Mr. Andreychek indicated that boiling in the core stops when injection is switched from the cold leg to the hot leg, which would take place ~4 to 9 hours into the accident.

There followed a discussion of what would happen for various configurations of debris collection at the core inlet, within the core, and at the core exit. Mr. Dingler and Mr. Andreychek indicated that experiments did not produce compressed mats at the core entrance that might lead to a substantial flow resistance. Mr. Scott added that the experiments indicated substantial settling in the lower plenum with most of remaining debris forming a rather loose permeable layer at the core entrance.

Mr. Steve Smith from the staff returned to the question of the experimental evidence for the amount of sump screen bypass. Based on four tests, a conservative estimate for the bypass was 1.3 ft^3 per 1000 ft^2 of screen area (other tests have been performed but the data have not been archived). The bypass rate decreased substantially with time as fibers built up on the screen. The approach velocity to the screens was ~0.1 inch/s.

Mr. Scott indicated that licensees must show that debris settles upstream of the screens in order to take credit for it. Otherwise, debris is assumed to stay in suspension until reaching the screen. In the four tests discussed there was not substantial settling. The Chairman noted that bypass should be dependent on formation of a mat on the sump screen and that under prototypic conditions this may form more non-uniformly than in the experiments. A non-uniform mat may be expected result in more bypass than a uniform mat.

The question of fiber size distribution was revisited. Mr. Dingler noted that the method used at Wolf Creek was to lay individual fibers under a microscope next to a ruler in order to measure their length.

4. NRC Staff Presentation on Draft SE - Ralph Landry, Paul Klein

Dr. Landry began by introducing Paul Klein of the staff, who was responsible for review of chemical effects, along with Robert Litman, a consultant. Dr Landry discussed the buildup of scale on cladding surfaces, as calculated using LOCADM. Licensees are likely to credit treatment of chemical and downstream effects described in WCAP-16793 as conservative, but they are expected to verify that this is indeed so. Prof. Wallis inquired as to how the staff would respond if different licensees submitted much different estimates for the same process, such as bypass. Mr. Klein replied that the staff attempts to reconcile the reasons for the differences. There are one or two principal reviewers for the submittals so differences between licensees will most probably be caught and resolved.

Concerning the effects of blockage at the core inlet on core temperatures, the staff performed audit analyses using RELAP5 and TRACE. Calculations of core flow distributions were performed with FLUENT. The TRACE calculation assumed inlet flow blockage of 95%. This calculation showed an increase of maximum clad temperature of 10F over no blockage. There was little difference in void fraction between blocked and unblocked core entrance cases. The blockage assumption was that 95% of the core entrance was completely blocked while the remaining 5% was unblocked.

Dr. Landry revisited the four Continuum Dynamics Inc (CDI) tests run to study debris behavior in the lower plenum and core. The inlet nozzle for these tests was supplied by Calvert Cliffs. Atypicalities of the test included the short, 1½ foot core length using and unheated a plastic bundle to represent the fuel bundle. The pressure drop across the core entrance was ~1/3 psi.

In response to a question by Prof. Wallis, it was stated that the staff has not yet obtained reports or data on debris deposition experiments performed by AREVA in Germany.

Prof. Wallis noted that tests performed by Argonne National Laboratory (ANL) included chemical effects, which the CDI tests did not. The ANL tests showed a factor of 100 increase in flow resistance. Mr. Klein replied that CDI ran some tests for a licensee that included 100% of the WCAP surrogate chemical and observed a pressure drop of 0.2 psi to 2.6 psi across the core inlet, based on a flow rate for a hot leg break. Mr. Klein indicated that the WCAP-specified amounts of sodium-aluminum-silicate and aluminum-oxyhydroxide are very conservative.

Dr. Landry indicated that the Westinghouse conduction calculations to determine peak cladding temperature treated the thicknesses of the oxide, crud, and scale layers each in a conservative manner. The prior clad oxide layer was assumed to be at the 17% limit; the crud layer was taken to be 100 μm; and the scale layer was 1.27 mm (50 mil), which is 5 times greater that the maximum calculated from LOCADM.

The question of whether the lower plenum participates as a mixing volume with the core with respect to boron was raised. The scenario is that, if the core entrance is so severely blocked as to inhibit gravity driven upflow of water into the core, then it might inhibit downflow as well. Prof. Wallis noted the volume occupied by material transported to the vessel is very small. Dr. Landry indicated that some plants do not take credit for mixing between the core and lower plenum. In response to questions by Subcommittee members, Mr. Andreychek stated that the question of whether such mixing will take place should hinge mainly on the relative density of the water in the core, whose density is increasing due to boron concentration, and the higher density of the colder water (~90F) entering the lower plenum compared to the ~260F water in the boiling region of the core.

Mr. Klein reported on the staff's review of chemical effects. He noted that the staff last briefed the Subcommittee on WCAP-16530 in May 2007. The safety evaluation of this report is now complete. A peer review of this report was performed and Mr. Klein indicated that some of the questions raised in the peer review became RAIs. Based on its review of WCAP-16530, the staff decided to perform confirmatory tests at ANL on head loss and at Southwest Research Laboratory on chemical effects. The staff concluded that the WCAP surrogate was conservative in assuming all dissolved aluminum and silicon combines with phosphates to rapidly precipitate. Passivation of aluminum was not considered. The WCAP surrogate was based on thermodynamic equilibrium. The ANL tests indicated that using the WCAP surrogate could produce quite high flow resistances. The ANL loop had a vertical orientation so settling was precluded and all the precipitates ended up at the strainer surface.

Tests performed by some of the screen vendors for licensees have concluded that the WCAP-specified quantities of precipitates formed are conservative. Even when an effort is made to keep precipitates in suspension, settling occurs. Also, deposition with a horizontal arrangement is nonuniform compared to the vertical ANL test section.

WCAP-16793 uses the assumptions from WCAP-16530 to evaluate downstream chemical effects. In response to a question by Prof. Wallis, Dr Litman indicated that since boiling occurs preferentially in pits and crevices, and cladding surface conditions with crud are porous, scale tends to collect preferentially in these surface imperfections. Once scale is formed on cladding surfaces, the WCAP assumes it stays put and does not re-dissolve. The scale is taken to be a sodium-aluminum-silicate with a conductivity of 0.2 W/m-C (~0.1 BTU/hr-ft-F), which falls in the range of insulating materials.

A discussion followed between the Subcommittee and the presenters regarding conclusions that could be drawn. Prof. Wallis inquired about how the LOCADM evaluation model had been validated and demonstrated to be conservative. The last slide in the presentation gave a comparison of the model with an experiment taken from a paper. The Chairman requested that the staff provide the reference.

An example of a LOCADM calculation was included in WCAP-16793-NP and reviewed by the staff. It was for a large 3188 MWt plant with high fiber (7000 ft^3) and a large quantity of calcium silicate insulation (80 ft^3). The maximum scale deposit calculated over 30 days was 10 mils. The maximum clad surface temperature after the start of recirculation was 324F, well below the 800F acceptance criteria.

Dr Landry indicated that Westinghouse will provide the members of the PWR Owners Group with a guidance document on implementing WCAP-16793-NP as well as LOCADM model. Licensees must demonstrate applicability of existing sump screen data or perform their own tests. Core inlet flow blockage must be shown to not affect prior boron mixing analyses.

Prof. Wallis inquired how a licensee could decide what would be acceptable to the staff based on what appears in WCAP-16793-NP. Mr. Scott indicated that a bounding pressure drop from the CDI experiments, based on scaled transport of ~22 ft^3 of fiber and 1389 lb of particulates was equivalent to 10 inches (~1/3 psi) of water (tests did not include chemical effects). Together with the COBRA/TRAC calculation of 99.4% inlet flow blockage, this was an example of providing assurance.

Prof Wallis and the Chairman inquired about providing guidance to the licensees concerning chemical effects which are considered to deposit on the screens but not at the core entrance. Mr. Dingler indicated that tests have shown much less deposition at elevated temperatures than at room temperature. Temperature at the core inlet will become significantly lower than at the screen because the water passes though the RHR heat exchanger on its way to the core. The Chairman noted that the screen and the core inlet function as two screens in series, the first having ~50 times the surface area of the second, so a coupled evaluation model should be carried out.

Drs. Litman and Landry asserted that stored energy in the vessel is not gone for a day, however, no calculations have been done to support this assertion. The Chairman stated that the core inlet temperature has to be known to support the assertion that compounds remain in solution and do not deposit at the core inlet.

The Chairman and Prof. Wallis noted that WCAP-16793 does not provide methods to follow, but sets forth conservative assumptions that when followed should bound the outcome, and if these assumptions are followed, then the outcome meets acceptance criteria. Prof. Wallis gave the example that there is no description of where fibers will end up. There is, however, the calculation that the entrance to the core can be almost completely blocked (99.4%) with no detrimental effect on peak cladding temperature.

The Chairman, referring to slide 43 from the PWR Owners Group presentation, requested an analysis of how much flow resistance at the core entrance would be necessary to reduce inlet flow below boiloff flow until the acceptance criteria of 800F would no longer be met. An answer was not available.

Mr. Scott indicated that, as written on page 8 of the staff's safety evaluation report, the staff does not believe that a uniform bed will form at the core inlet.

Mr. Scott indicated the staff would address the question of whether bed formation at the core inlet affects whether or not the lower plenum functions as a mixing volume for boron.

Mr. Scott indicated that the question of in-vessel fluid temperatures would be investigated. He also indicated that the staff would look into acceptance criteria and methods of analysis for in-vessel chemical effects.

Mr. Dingler indicated that Westinghouse would send design geometry of the lower nozzle and spacer grids to Mr. Scott.

Mr. Scott indicated that there was not much additional testing currently available beyond what was discussed during the meeting but that such testing may be needed. If confirmatory testing were sponsored by NRC, new results would take two or more years. Some information may be sought from licensees.

5. Subcommittee Discussion

Dr. Kress noted that downstream effects depend on bypass and there is no real technical basis for predicting how much bypass will occur. Dr. Kress added that validation of cross flow modeling in COBRA/TRAC should be provided. He concluded that substantial progress has been made in issue resolution with changing insulation and increasing the screen size. Dr. Kress expressed doubt that the debris distribution at the core inlet could ever be determined but the critical flow resistance to limit the inflow rate to the boiling rate should be analyzed.

Mr. Maynard stated that we will never have a definitive set of experiments and some qualitative decision making will have to be accepted. Any test data referenced in WCAP-16973 should be defended in the report as being applicable to the issue for which it is being used. The removal of debris-generating insulation is a move in the right direction.

Prof. Abdel-Khalik expressed reservations of the 1 ft^3 of debris per 1000 ft^2 screen area. The staff gave a number of 1.3 ft^3 which is outside the 10% uncertainty that was stated earlier during the meeting. The actual uncertainty could be an order of magnitude. An evaluation of the scaling and prototypicality of experiments is lacking, including whether important variables have been parametrically studied over the range of conditions expected in the plant. Prof. Abdel-Khalik agreed that the debris distribution at the core inlet is most likely indeterminate, but the flow resistance critical to limiting the inflow to the boiling rate should be analyzed.

The Chairman indicated that any data being generated by licensees to justify the 1 ft^3 of debris per 1000 ft^2 screen area should be obtained since is a very important number for downstream effects. The fact that one could block 99.4% of the inlet flow area and not affect core cooling was encouraging. The critical resistance of a distributed bed should be determined.