AMENDMENT 1 TO RESAR-SP/90 PDA MODULE 5, "REACTOR SYSTEM"

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INSTRUCTION SHEET

Insert all pages behind QUESTIONS/ANSWERS tab.

490.1 The WAPWR fuel design has a new feature for those rods containing
4.2 integral fuel burnable absorber. Will the absorbing material melt during any operational transients before the fuel melting limit is exceeded?

RESPONSE:

The melting temperature of [ ], the absorbing material, exceeds +a,c
that of UO_2, namely [ ] versus a maximum of 2800°C for +a,b,c
UO_2. In addition the absorbing material is a [
] so that its temperature will always +a,c
be below the temperature of the coolest portion of the fuel. Hence, there are no transients, operational or accidental, where the temperature of the absorbing material approaches the melting point.

490.2 What is the limit and method used for creep collapse analysis for
4.2 WAPWR fuel rods? Since this is a new design, please provide pertinent information on the fuel densification limit and the initial fuel pressure of the fuel rods to assure no creep collapse occurs.

RESPONSE:

Even though the WAPWR is a new design, the current fuel rod analysis methodology described in WCAPs 8218, 8720 and 8377 continues to be applicable. With the exception of thicker clad, the WAPWR fuel rod is similar to that of 17x17 OFA or Vantage 5. Therefore, the densification and collapse modeling for WAPWR fuel remains the same as that given in these WCAPs. The clad flattening time for WAPWR is ≥45,000 EFPH for initial backfill pressure of [ ] psia or greater. +a,c

490.3 Provide analyses of combined seismic-and-LOCA loads on WAPWR fuel
4.2 assemblies to demonstrate the conformance to Appendix A of SRP 4.2.

RESPONSE:

The WAPWR fuel assembly seismic capability has been analyzed for proposed high seismic sites covering a wide spectrum of foundation characteristics in Japan. This seismic analysis was based on the S2 earthquake which is equivalent to the Safe-Shutdown-Earthquake. The seismic response spectra used are conservative compared to site seismic characteristics for all U.S. nuclear plants.

The results of the seismic analysis show that the WAPWR fuel assembly structural integrity is maintained. Since the fuel assembly components are deformed elastically, a coolable geometry and control rod insertion capability are assured.

As for time fuel assembly response to LOCA loads, asymmetric blowdown loads resulting from large double-ended breaks in the main loop piping are not considered as part of the design bases for WAPWR. Analyses of the potential for pipe fracture from ductile rupture and unstable flaw extension, materials tests to define tensile and toughness properties, and predictions of leak rates from postulated flaws will be prepared and subtitled as part of the RESAR-SP/90 FDA document. These analyses will be in accordance with the technical bases presented in the USNRC General Letter 84-04, "Safety Evaluation W Topical Reports Dealing with Elimination of Postulated Pipe Breaks in PWR Primary Main Loops," dated Feb. 1, 1984. As a result, the induced core plate motions will be small and the effect on the overall fuel assembly will be negligible. For a discussion of the pipe breaks considered as part of the WAPWR design bases, see Section 3.6 of RESAR-SP/90 PDA Module 7, "Structural/Equipment Design".

490.4 Describe plans for on-line fuel system monitoring and postirradiation
4.2 surveillance.

RESPONSE:

Methods and instrumentation for on-line fuel monitoring (e.g., coolant activity monitoring, etc.) are discussed in RESAR-SP/90 PDA Module 13, "Auxiliary Systems".

A routine fuel inspection program will be implemented on the irradiated and discharged initial WAPWR fuel during plant refueling outages. The program will involve visual examinations on a representative sample of assemblies from the first WAPWR fueled core at each refueling until this fuel is discharged. Visual observations will include, but not be limited to, crud buildup, rod bowing, grid strap conditions and inspections for potential missing components. Additional fuel inspections would be performed depending on the results of operational monitoring, including coolant activity, and the visual fuel inspections.

491.1 4.3 Past agreements with Westinghouse, going back as far as Robinson and Indian Point 2 reviews, relating to X-Y plane xenon stability, have been that specific tests would be performed to demonstrate stability for reactor classes with significant, relevant new characteristics such as core diameter or power density. This is the primary bases on which assurances of stability have been accepted. Please indicate if such tests will be carried out for WAPWR.

RESPONSE:

On the first plant built and ready for testing (i.e., prototype/ first-of-a-kind) Westinghouse will propose tests to determine the stability of the plant with respect to axial and radial xenon transients. These proposed tests will be documented in RESAR-SP/90 PDA Module 14, "Initial Test Program".

491.2 4.3 Discuss the effects of low radial leakage core-reflector design on excore detection, particularly the SRM and axial distribution measurements with the four segment power monitors. Also, we have not as yet seen an uncertainty analysis topical report for the four segment excore system. Is this report to be submitted? Will it address low leakage configuration?

RESPONSE:

Assuming adequate signal strength, the ability to measure axial power distribution is expected to be as good or better than the current detector design, regardless of the type of the core-reflector design employed. With regard to the SRM, it is concluded that the count rate remains the same order of magnitude as that of current PWRs. Should the count rate prove to be lower than expected, this can be remedied by installing another available detector of higher sensitivity.

With regard to uncertainty analyses, this subject was addressed in WCAP-10665(P)/10666(NP) sent to the NRC in September 1984. The topical report does not address a low leakage configuration.

491.3 There have recently been some problems with current Westinghouse
15.4.1 reactors about Technical Specifications and the control rod withdrawal at zero power event in modes 3, 4, or 5 because of differences between Technical Specification allowed equipment operability and the analysis which assumes two pumps in operation. How will this problem be handled in WAPWR?

RESPONSE:

The current Westinghouse position on this question, explained in E. P. Rahe, Jr's letter to Mr. D. Eisenhut, "Number of Operating Reactor Coolant Pumps in Mode 3," NS-EPR-2935, July 9, 1984, applies to WAPWR. If this position is changed in the future, the revised position will also be applied to WAPWR.

492.1 4.4 You state on page 4.4-8 of WAPWR-RS "It was concluded from preliminary evaluation of the data that the CHF characteristics of WAPWR fuel assembly design are not significantly different from those of the current 17x17 design, and can be described by the WRB-2 CHF correlation."

Provide the data from your CHF tests which model the WAPWR fuel assembly and give your analytic justification for the use of the 1.17 design criterion.

RESPONSE:

The WAPWR fuel assemblies use eight type "R" grids with mixing vanes of the same design as the W 17x17 mixing vane. DNB testing of the WAPWR typical and thimble cell geometries has been performed to characterize the DNB performance of a WAPWR fuel assembly. Evaluations of the data have been performed using the WRB-2 CHF correlation, Reference 1, which was developed to predict the DNB performance of W fuel designs which employ grids with the 17x17 type of mixing vane design. The results of these evaluations indicate that the WRB-2 correlation predicts the data well. Use of a 1.165 design limit DNBR with the WRB-2 correlation is justified for the WAPWR fuel assembly.

A description of the WAPWR DNB test program and the data evaluations follows.

WAPWR DNB TEST PROGRAM

Test Geometries

The WAPWR DNB test program was conducted at the Columbia University Heat Transfer Laboratory. Two 6x6 rod bundles were tested -- one with all rods heated (typical cell) and one with the center four rods replaced by an unheated thimble tube (thimble cell). Both rod bundles were full length and both used a cosine axial power distribution. Figures 1 and 2 show the typical and thimble cell bundle cross sections. The axial locations of the grids and the thermocouples used to detect DNB are shown in Figure 3, and Figure 4 shows the axial power profile.

The WAPWR DNB test bundles were tested over a wide range of fluid conditions:

Inlet pressure: 1500 - 2450 psia
Inlet mass velocity: 1.0 - 3.6 x 10^6 lbm/hr-ft^2
Inlet temperature: 400 - 620°F

Test Procedure

The general procedures followed in conducting the WAPWR DNB test program were the same as those described in Reference 2.

DATA EVALUATIONS

The local fluid conditions for each test run were calculated using the THINC subchannel code. The measured critical heat flux for each data point was compared to the critical heat flux predicted by the WRB-2 CHF correlation. Tables 1 and 2 show the local conditions at the point of minimum DNBR for each run in the WAPWR typical and thimble cell data sets. Also shown for each run is the measured-to-predicted critical heat flux ratio at that location, as calculated by the WRB-2 correlation.

The average measured-to-predicted critical heat flux ratios for the WAPWR typical and thimble cell data sets are 0.9870 and 0.9899, respectively. It is apparent that the WRB-2 CHF correlation accurately predicts the DNB performance of the WAPWR fuel design.

CRITERION FOR DESIGN

The WAPWR DNB data sets have been incorporated into the database of the WRB-2 correlation. Table 3 shows the results of applying the WRB-2 CHF correlation to each of the data sets in the revised database.

For the design of Westinghouse reactor cores, the chosen criterion is that CHF will not occur at a 95 percent probability with a 95 percent confidence level. In order to meet this criterion, a limiting value of DNBR is determined by the method of Owen, Reference 3. Owen has prepared tables which give values of k_p such that at least a proportion P of the population is greater than $(\frac{M}{P})_{AVG} - k_p s$ with confidence ν where $(\frac{M}{P})_{AVG}$ and s are the sample mean and standard deviation, respectively. When this method was carried out using all 887 data points, the results indicated that a reactor core designed using the WRB-2 correlation could operate with a minimum DNBR of 1.165 and satisfy the design criterion.

REFERENCES

1. Davidson, S. L. (Ed.), "Reference Core Report -- Vantage 5 Fuel Assembly," WCAP-10444, December 1983.

2. Hill, K. W., Motley, F. E., Cadek, F. F., Wenzel, A. H., "Effect of 17x17 Fuel Assembly Geometry on DNB, WCAP-8296-P-A (Westinghouse Proprietary) and WCAP-8297-A (Non-proprietary), February 1975.

3. Owen, D. B., "Factors for One-Sided Tolerance Limits and for Variable sampling plans," SCR-607, March 1963.

TABLE 1

TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
TYPICAL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	ELEVATION FROM INLET (INCHES) MEAS.
						+(b,c)			+(b,c)
W2508							.9585		
W2510							.8166		
W2511							.9449		
W2512							1.1081		
W2513							1.1132		
W2514							1.0386		
W2515							.8985		
W2516							1.0047		
W2517							.8732		
W2518							1.0460		
W2519							1.0167		
W2520							1.1394		
W2521							1.1078		
W2522							1.0599		
W2523							.9875		
W2524							1.0781		
W2525							1.0752		
W2526							1.0543		
W2527							.8868		
W2528							.8604		
W2529							.9140		
W2530							.9110		
W2531							.9258		
W2532							.9922		
W2533							1.0310		
W2534							1.0295		
W2535							.9699		
W2536							.9715		
W2537							.9099		
W2538							.9753		

L =12.8 FT
DE = .4518 IN
16 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.5 IN SPACING
INNER ROD/OUTER ROD POWER = 1.1628

TABLE 1 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
TYPICAL CELL

+(b,c) +(b,c)

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	MEAS.
W2540							.9628		
W2541							.9885		
W2542							.9142		
W2543							.8970		
W2544							1.0387		
W2545							1.0330		
W2546							.9807		
W2547							1.0139		
W2548							.9183		
W2549							1.0179		
W2550							.9629		
W2551							1.0205		
W2552							1.0388		
W2553							1.0053		
W2554							.9288		
W2555							.9676		
W2556							1.0167		
W2557							.9906		
W2558							.9700		
W2559							1.0127		
W2560							1.0293		
W2561							.8943		
W2562							1.1406		
W2563							.9646		
W2564							.9450		
W2565							.9451		
W2566							1.0073		
W2567							.9951		
W2568							1.0304		
W2569							1.0449		

L =12.8 FT
DE = .4518 IN
16 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.5 IN SPACING
INNER ROD/OUTER ROD POWER = 1.1628

TABLE 1 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
TYPICAL CELL

+(b,c) +(b,c)

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	MEAS.
W2570							.9920		
W2571							.8845		
W2572							.9085		
W2573							.8884		
W2574							.9751		
W2575							1.0034		
W2576							.9419		
W2577							1.1063		
W2578							1.1187		
W2579							.9843		
W2580							.9089		
W2581							1.0363		
W2582							1.0829		
W2583							1.1358		
W2584							.9071		
W2585							1.0565		
W2586							.9138		
W2587							.9941		
W2588							.8323		
W2589							.9812		
W2590							.9875		
W2592							1.0092		
W2593							1.0416		
W2594							.9851		
W2595							.8445		
W2597							.9019		
W2598							1.0016		
W2600							1.0518		
W2601							1.0272		
W2602							1.0343		

L =12.8 FT
DE = .4518 IN
16 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.5 IN SPACING
INNER ROD/OUTER ROD POWER = 1.1628

TABLE 1 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION TYPICAL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	ELEVATION FROM INLET (INCHES) MEAS.
							+(b,c)		+(b,c)
W2603							.8908		
W2604							.8825		
W2607							.3567		
W2608							.9863		
W2609							.9490		
W2611							.9101		
W2612							.9613		
W2613							1.0802		

L =12.8 FT
DE = .4518 IN
16 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.5 IN SPACING
INNER ROD/OUTER ROD POWER = 1.1628

TABLE 2. TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION COLD WALL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT)		(MEAS/ PRED)	ELEVATION FROM INLET (INCHES)	
					MEAS.	PRED.		PRED.	MEAS.
W2615							.9987		
W2616							.8449		
W2617							1.0115		
W2618							.9313		
W2619							1.0357		
W2620							1.0669		
W2621							1.0093		
W2622							1.0309		
W2623							1.0358		
W2624							1.1320		
W2625							1.1114		
W2626							1.0691		
W2627							1.0799		
W2628							.9679		
W2629							1.0594		
W2630							.9832		
W2631							1.0834		
W2632							.9746		
W2633							1.0665		
W2634							1.0040		
W2635							1.0288		
W2636							1.0693		
W2637							1.0172		
W2638							.9677		
W2639							.8322		
W2640							.9139		
W2642							1.0248		
W2643							.9815		
W2644							.9433		
W2646							.9279		

+(b,c)

+(b,c)

L =12.8 FT
DE = .4566 IN (LG THM)
.3315 IN (SM THM)
12 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.8 IN SPACING

INNER ROD/OUTER ROD POWER = 1.1628

TABLE 2 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
COLD WALL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (X)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	MEAS.
W2647							+(b,c)		+(b,c)
W2648							.9662		
W2649							1.0588		
W2650							.9646		
W2651							1.0112		
W2652							.9749		
W2653							.9701		
W2654							1.1315		
W2655							.9789		
W2656							.9286		
W2657							.9922		
W2658							1.0549		
W2659							.9861		
W2660							1.0712		
W2661							1.0217		
W2662							.9914		
W2663							1.0330		
W2664							1.0333		
W2665							.9746		
W2666							1.0740		
W2667							1.0835		
W2668							1.0327		
W2669							.9565		
W2670							1.0682		
W2671							.9940		
W2672							1.0343		
W2673							.7825		
W2674							.7985		
W2675							1.0775		
W2676							.9818		
							.9973		

L =12.8 FT
DE = .4568 IN (LG THM)
.3315 IN (SM THM)
12 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.5 IN SPACING

INNER ROD/OUTER ROD POWER = 1.1628

TABLE 2 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
COLD WALL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) PRED.	(MEAS/ PRED) +(b,c)	ELEVATION FROM INLET (INCHES) PRED.	ELEVATION FROM INLET (INCHES) MEAS. +(b,c)
W2677							1.0027		
W2678							.9881		
W2679							1.0094		
W2680							.9313		
W2681							1.0691		
W2682							.9753		
W2683							1.0091		
W2684							.7731		
W2685							.9166		
W2686							.9036		
W2687							1.0084		
W2688							.9869		
W2689							.9724		
W2690							.8670		
W2691							1.0124		
W2692							.8547		
W2693							.9480		
W2694							1.0365		
W2695							.9006		
W2696							.9595		
W2698							.8398		
W2699							1.0445		
W2701							.9788		
W2702							.8937		
W2703							.8881		
W2705							1.0096		
W2706							.9880		
W2707							.9904		
W2709							1.0334		
W2710							1.0134		

L =12.8 FT
DE = .4568 IN (LG THM)
.3315 IN (SM THM)
12 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.8 IN SPACING

INNER ROD/OUTER ROD POWER = 1.1628

TABLE 2 (cont.) TEST RESULTS -12.8 FOOT .406 INCH OD NONUNIFORM TEST SECTION
COLD WALL CELL

RUN NO.	INLET PRESSURE (PSIA)	INLET TEMP (F)	INLET MASS VELOCITY (X10E6 LBM/HR-SQFT)	LOCAL QUALITY (%)	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) MEAS.	LOCAL HEAT FLUX (X10E6 BTU/HR-SQFT) PRED.	(MEAS/ PRED)	ELEVATION FROM INLET (INCHES) PRED.	ELEVATION FROM INLET (INCHES) MEAS.
						+(b,c)			+(b,c)
W2711							1.0317		
W2713							1.0481		
W2714							.9571		
W2715							.8835		
W2716							.8606		

L =12.8 FT
DE = .4568 IN (LG THM)
.3315 IN (SM THM)
12 RODS 100%
20 RODS 86%

ROD O.D. = .406 IN
MIXING VANE GRIDS 17.8 IN SPACING

INNER ROD/OUTER ROD POWER = 1.1628

TABLE 3

WRB-2 CHF CORRELATION - STATISTICAL RESULTS

Rod O.D. (inch)	L_h (ft.)	g_{sp} (inch)	Heat Flux Profile	Configuration	N	$(\overline{M/P})$	Sample Standard Deviation,S
0.360	14	10	Cosine	TYP-5x5	51	0.9861	0.0758
0.360	14	10	Cosine	TYP-5x5	31	1.0097	0.0680
0.406	12.8	17.5	Cosine	TYP-6x6	98	0.9870	0.0704
0.406	12.8	17.5	Cosine	THM-6x6	95	0.9899	0.0723
0.360	14	20	Cosine	TYP-5x5	63	0.9961	0.0946
0.360	14	20	Cosine	THM-5x5	38	0.9832	0.0599
0.374	8	22	Uniform	TYP-5x5	67	1.0316	0.0897
0.374	14	22	Uniform	TYP-5x5	71	1.0095	0.0664
0.374	14	22	Cosine	TYP-5x5	74	0.9893	0.0822
0.374	14	22	Cosine	THM-5x5	70	0.9884	0.0775
0.374	8	26	Uniform	TYP-5x5	78	1.0198	0.0810
0.374	8	26	Uniform	THM-5x5	68	1.0398	0.1062
0.374	14	26	Uniform	TYP-5x5	73	0.9914	0.0823
				All Data	877	1.0014	0.0825

[ ]$^{+b,c}$

Dimensions in Inches

Ⓐ Rod Relative Power

FIGURE 1: WAPWR TYPICAL CELL BUNDLE CROSS SECTION

$^{+b,c}$

Timble Tube O.D.: 1.024 Inches

Ⓐ Rod Relative Power

FIGURE 2: WAPWR THIMBLE CELL BUNDLE CROSS SECTION

[ ]$^{+b,c}$

FIGURE 3: AXIAL LOCATION OF GRIDS AND THERMCOUPLES IN WAPWR DNB TEST BUNDLES

+b,c

Q''_{LOC}/Q''_{AVG} LOCAL-TO-AVERAGE HEAT FLUX RATIO

Z, Axial Distance From Beginning of Heated Length (Inches)

FIGURE 4 APWR DNB HEATER ROD AXIAL HEAT FLUX DISTRIBUTION

492.2 Provide the documentation required by NUREG-0737 Item II.F.2. The
4.4 response should be given item-by-item showing how your design complies with each requirement. Clearly state where your design deviates from the requirements and why such deviation is acceptable.

RESPONSE:

Inadequate core cooling instrumentation is considered to be part of the reactor coolant system. Therefore, see RESAR-SP/90 PDA Module 4, "Reactor Coolant System"; Subsection 4.4.6.5 for a description of this instrumentation.