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SUBJECT: Forwards rept "Qualification of Supply Sys Use of RODEX2 " Code," for Gap conductance calculation in topical rept WPPSS-FTS-131, "Applications Topical Rept for BWR Design & Analysis.Rept provides justification for use of code.

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM
P.O. Box 968 • Richland, Washington 99352-0968

December 27, 1996
GO2-96-252

Docket No. 50-397

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Gentlemen:

Subject: **WNP-2, OPERATING LICENSE NPF-21**
QUALIFICATION OF SUPPLY SYSTEM USE OF RODEX2 CODE FOR THE GAP CONDUCTANCE CALCULATION IN TOPICAL REPORT WPPSS-FTS-131, "APPLICATIONS TOPICAL REPORT FOR BWR DESIGN AND ANALYSIS"

References:
1) Letter GO2-93-021, dated January 27, 1993, from G. C. Sorensen to NRC, "Nuclear Plant No. 2, Operating License NPF-21, Notification of Request for NRC Review of Topical Report WPPSS-FTS-131, Rev. 1, 'Applications Topical Report for BWR Design and Analysis'"

2) Letter dated June 4, 1996, TG Colburn (NRC) to JV Parrish (SS), "Issuance of Amendment for the Washington Public Power Supply System Nuclear Project No. 2 (TAC No. M95247)"

In response to discussions with the staff, the attached report provides justification for Supply System use of the NRC approved RODEX2 computer code. This code was developed by Siemens Power Corporation (SPC) for calculation of gap conductances in reactor fuel for applications to BWR transient analysis as described in Revision 1 of the "Applications Topical Report for BWR Design and Analysis, WPPSS-FTS-131A" issued to section 6.9.3.2 of the WNP-2 Technical Specifications by Reference 2. No specific action by the staff is requested by this letter.

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Should you have any questions or desire additional information regarding this matter, please call me or Ms. L. C. Fernandez at (509) 377-4147.

Respectfully,

P. R. Bemis
Vice President, Nuclear Operations
Mail Drop PE23

Attachment

cc: JE Dyer - NRC RIV
KE Perkins, Jr., - NRC RIV, Walnut Creek Field Office
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DL Williams - BPA / 399
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Purpose

The purpose of this report is to document the Supply System's qualification to use SPC's RODEX2[1] code to calculate gap conductances. This qualification will satisfy the requirement of using RODEX2 for gap conductance calculations in the Supply System reload methodology documented in the report WPPSS-FTS-131A[2], as issued by the NRC to section 6.9.3.2 of the WNP-2 Technical Specification.

Verification and Validation on Installation of RODEX2 at Supply System

The RODEX2 code developed by SPC and approved by the NRC[3] has been installed on the Supply System IBM workstation RISC6000. The Supply System performed installation verification and validation of the code according to the Supply System Engineering Directorate Manual EDP 2.16 "Production Computer Program and Data Base Control," which conforms to FSAR Chapter 17 Quality Assurance requirements. Three sample problems provided by SPC[4] for the purpose of validating the code installation were run on the Supply System computer. These sample problems, designated as Cases 1, 2, and 3, had 160, 166, and 365 time steps respectively. The Supply System results were identical to the SPC results for all analytical steps. Attached Tables 1, 2, and 3 provide a comparison of the Supply System and SPC results for the final time step. Only the final step is shown in the tables because the effect of any differences between the analytical results at intermediate time steps would proliferate, thereby affecting the results for the final time step.

It should be noted that the first three rows in Tables 1, 2, and 3 are computer input, and the remaining rows are from the computer output. As can be seen, the Supply System outputs are identical to the SPC outputs. This demonstrates that the RODEX2 code as installed on the Supply System IBM workstation RISC6000 provides identical results as the same code installed on SPC computers.

Methodology for Generating Core Average and Hot Channel Gap Conductances

The methodology used for the calculation of core average and hot channel gap conductances is the same as that of SPC except the codes used for burnup histories as explained below. The Supply System uses SIMULATE-E, which is part of the physics codes as approved by the NRC for WNP-2 reload analysis[5] to compute burnup histories for each batch and for the hot bundles. SPC uses MICROBURN-B.

The main input to RODEX2 includes mechanical design parameters, such as pellet and clad materials and dimensions, and burnup histories, which include LHGR histories, axial power profiles, coolant enthalpy, coolant flow rates and reactor pressure.

The axial and radial fuel rod powers used as input to the RODEX2 code are determined from core follow and predicted control rod step-through SIMULATE-E calculations. These SIMULATE-E calculations are used as input to determine both the core average gap conductance and hot channel gap conductance for each fuel design.

The core average gap conductance is determined by RODEX2 using as input the SIMULATE-E core follow and predicted control rod step-through calculations as follows. First, the average gap conductance is determined for each batch in the core for the initial conditions of the transient. This is done by using SIMULATE-E to calculate the batch average axial power history, the batch average radial power history and the batch average flow history from the time when the batch was first inserted into WNP-2 until the exposure where the transient is initiated. These average batch histories are input to RODEX2 to calculate an average gap conductance for each batch.

Following SPC's methodology, the core average gap conductance is then determined from the batch average gap conductances by power and assembly weighing each batch according to the following formulation:

$$CAGC = \frac{\sum_i (BAGC_i \times N_i \times BARP_i)}{\sum_i (N_i \times BARP_i)}$$

where CAGC = Core Average Gap Conductance,
BAGC = Batch Average Gap Conductance,
N = Number of Assemblies and
BARP = Batch Average Radial Power.

The hot channel gap conductance for each fuel design (8x8, 9x9-9X, etc.) is determined by RODEX2 using as input the SIMULATE-E core follow and predicted control rod step-through calculations as follows. For each fuel design at the point of initial conditions for the transient, the assembly with the minimum critical power ratio is selected as the hot channel. Then for each selected assembly, the axial power history, radial power history and flow history are calculated using SIMULATE-E from the time it is first inserted into the WNP-2 core until the exposure where the transient is initiated. These histories are input to RODEX2 to calculate the hot channel gap conductance for each fuel design. Once the RODEX2 calculation has determined the historical effects on the gap conductance, the gap conductance in the hot channel is determined at varying power conditions. The resulting gap conductances are used in subsequent analysis as described in the Applications Topical Report WPPSS-FTS-131A[2]. This approach is consistent with SPC's application of RODEX2.

<u>Supply System Results and Comparison with SPC</u>

Tables 4 through 7 provide gap conductance calculations and comparisons with SPC results for Cycles 8, 10 and 11. Table 4 gives the core average results. Tables 5 through 7 give the hot channel results. The data in Table 5 through 7 are also plotted as Figures 1 through 6. The gap conductances for Cycle 9 are not compared because the Supply System did not perform the Cycle 9 calculation. The differences in calculated gap conductances are attributed mainly to differences in burnup histories introduced by the different depletion codes (SIMULATE-E versus MICROBURN-B) and differences in the core follow and rodded depletions used in these codes. It should be noted that in the gap conductance calculations, the burnup histories for earlier cycles

(Cycle 7 and earlier for the Cycle 8 analysis, Cycle 6 and earlier for the Cycle 10 and 11 analyses) were based on Haling depletion. The larger differences seen in the 8x8 hot channel gap conductance for Cycle 8 are primarily attributed to the use of a Haling depletion in SIMULATE-E for Cycle 7. These Haling depletions were part of the Supply System approach for determining gap conductances prior to adopting the SPC methodology. However, rodded step-throughs were used for later cycles to be consistent with SPC methodology.

The hot channel gap conductance comparisons are based on analyzing the assemblies that were selected by SPC using MICROBURN-B. The results show excellent agreement.

The differences in gap conductance are summarized below (note: the positive values are non-conservative for core-wide and conservative for hot channel. The impact of the differences for core-wide is much less than the impact for hot channel.)

Percent Difference in Gap Conductance

		Hot Channel*	
Cycle	Core-Wide	8X8	9X9
8	4.9%	-3.5%	2.9%
10	0.2%	-1.9%	0%
11	1.7%	1.4%	0.5%

*Typically, the LHGR for 8X8 hot channel for the Δ CPR calculation is ~11 kW/ft, and for 9X9 it is ~7 kW/ft. The differences listed in the above table are based on these LHGRs.

In summary, the Supply System calculated gap conductances for both core average and hot channel compare very closely with SPC's results. The small differences are mainly caused by the different depletion codes used by the Supply System and SPC to generate inputs to RODEX2. It is further concluded that the impact of the differences in gap conductance on thermal limits are within the overall accuracy of the calculations.

TABLE 1
CASE 1 OUTPUT - SUPPLY SYSTEM VERSUS SIEMENS POWER CORPORATION

	Supply System*	Siemens Power Corp.*
Time Step No.	160	160
Time (hours)	17915.2	17915.2
LHGR (kw/ft)	11.7	11.7
Fill Pres. (psia)	1491.	1491.
Therm. Gap (mil)	0.135	0.135
Gap Coef. (Btu/hr/ft^2/F)	7429.	7429.
Tclad (F)	777.352	777.352
T-Max (F)	2663.7	2663.7
T-Avg (F)	1644.9	1644.9
T-Sur (F)	845.0	845.0
Release Frac (%)	5.51	5.51
Burnup (GWD/MTU)	49.687	49.687
Contact Pressure (psi)	6142.7	6142.7

* Results are for axial node 7 of a 13-node rod.

TABLE 2
CASE 2 OUTPUT - SUPPLY SYSTEM VERSUS SIEMENS POWER CORPORATION

	Supply System*	Siemens Power Corp.*
Time Step No.	166	166
Time (hours)	11664.0	11664.0
LHGR (kw/ft)	15.5	15.5
Fill Pres. (psia)	254.	254.
Therm. Gap (mil)	0.373	0.373
Gap Coef. (Btu/hr/ft^2/F)	3392.	3392.
Tclad (F)	717.414	717.414
T-Max (F)	3330.5	3330.5
T-Avg (F)	1962.0	1962.0
T-Sur (F)	879.8	879.8
Release Frac (%)	1.74	1.74
Burnup (GWD/MTU)	21.317	21.317
Contact Pressure (psi)	126.5	126.5

* Results are for axial node 10 of a 24-node rod.

TABLE 3
CASE 3 OUTPUT - SUPPLY SYSTEM VERSUS SIEMENS POWER CORPORATION

	Supply System*	Siemens Power Corp.*
Time Step No.	365	365
Time (hours)	26719.0	26719.0
LHGR (kw/ft)	17.6	17.6
Fill Pres. (psia)	217.	217.
Therm. Gap (mil)	0.386	0.386
Gap Coef. (Btu/hr/ft^2/F)	1758.	1758.
Tclad (F)	730.515	730.515
T-Max (F)	3997.2	3997.2
T-Avg (F)	2355.4	2355.4
T-Sur (F)	1004.3	1004.3
Release Frac (%)	5.95	5.95
Burnup (GWD/MTU)	23.699	23.699
Contact Pressure (psi)	181.9	181.9

* Results are for axial node 13 of a 24-node rod.

TABLE 4
COMPARISON OF CORE-WIDE GAP CONDUCTANCES

Core-Wide H_{gap} at Rated Power (in Btu/hr/ft^2/F):

Cycle Number	H_{gap} Supply System	H_{gap} Siemens Power Corp.	% Diff.
8	627.6*	598^{+}	4.9
10	693.6**	692^{++}	0.2
11	774.5**	761^{+++}	1.7

* Supply System used rodded step-through depletion for Cycle 8, but used Haling depletion in earlier cycles (Supply System Calculation No. NE-02-94-13 "Core Wide Gap Conductance for Cycle 8 Using RODEX2").

** Supply System used rodded step-through depletion for batches beginning in Cycle 7, but used Haling depletion in earlier cycles (Supply System Calculation No. NE-02-95-29, "Revised Gap Conductances for Cycles 10 and 11").

$^{+}$ From Siemens Power Corporation Report EMF-92-039, Revision 1, "WNP-2 Cycle 8 Plant Transient Analysis," June 1992

$^{++}$ From Siemens Power Corporation Report EMF-94-095, "WNP-2 Cycle 10 Plant Transient Analysis," June 1994

$^{+++}$ From Siemens Power Corporation Report EMF-95-006, "WNP-2 Cycle 11 Plant Transient Analysis," March 1995

Table 5
COMPARISON OF HOT CHANNEL GAP CONDUCTANCES FOR CYCLE 8

Hot Channel Gap Conductance for 8x8 Fuel at EOC8

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp.**	% Diff.
1	267	266	0.4
2	295	296	-0.3
3	325	326	-0.3
4	357	359	-0.6
5	393	396	-0.8
6	435	439	-0.9
7	482	489	-1.4
8	538	548	-1.8
9	605	618	-2.3
10	685	704	-2.7
11	783	811	-3.5
12	910	951	-4.3
13	1074	1136	-5.5
14	1292	1388	-6.9
15	1596	1752	-8.9

* From Supply System Calculation No. NE-02-94-21 "Hot Channel Gap Conductance Calculation for Cycle 8 Using RODEX2 Code".

** From SPC Letter SPCWP-94-016 "RODEX2 Data", Feb. 14, 1994.

Hot Channel Gap Conductance for 9x9 Fuel at EOC8

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp.**	% Diff.
1	397	381	4.2
2	429	413	3.9
3	463	447	3.6
4	500	484	3.3
5	542	525	3.2
6	589	573	2.8
7	644	626	2.9
8	706	689	2.5
9	780	762	2.4
10	867	850	2.0
11	972	956	1.7
12	1102	1087	1.4
13	1265	1254	0.9
14	1479	1474	0.3
15	1763	1770	-0.4

* From Supply System Calculation No. NE-02-94-21 "Hot Channel Gap Conductance Calculation for Cycle 8 Using RODEX2 Code".

** From SPC Letter SPCWP-94-016 "RODEX2 Data", Feb.14, 1994.

TABLE 6
COMPARISON OF HOT CHANNEL GAP CONDUCTANCES FOR CYCLE 10

Hot Channel Gap Conductance for 8x8 Fuel at EOC10

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp.**	% Diff.
1	121	118	2.2
2	153	151	1.5
3	189	187	0.9
4	230	229	0.4
5	280	280	0.0
6	343	345	-0.6
7	426	432	-1.5
8	541	556	-2.7
9	711	740	-3.9
10	955	980	-2.6
11	1203	1227	-1.9
12	1474	1500	-1.7
13	1774	1799	-1.4
14	2094	2097	-0.2
15	2342	2334	0.4

* From Supply System Calculation No. NE-02-95-29 "Revised Gap Conductance for Cycle 10 and 11"

** From SPC letter dated September 26, 1995, "RODEX2 Data", SPCWP:042:95

Hot Channel Gap Conductance for 9x9 Fuel at EOC10

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp.**	% Diff.
1	382	381	0.26
2	415	414	0.24
3	450	449	0.24
4	487	487	0
5	530	529	0.19
6	578	578	0
7	634	634	0
8	699	699	0
9	776	776	0
10	868	868	0
11	980	980	0
12	1119	1120	-0.09
13	1299	1301	-0.15
14	1537	1541	-0.26
15	1861	1868	-0.37

* From Supply System Calculation No. NE-02-94-28 "Gap Conductance for Cycle 10."

** From SPC letter dated September 26, 1995, "RODEX2 Data", SPCWP:042:95

TABLE 7
COMPARISON OF HOT CHANNEL GAP CONDUCTANCES FOR CYCLE 11

Hot Channel Gap Conductance for 8x8 Fuel at EOC11

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp.**	% Diff.
1	107	104	2.9
2	141	138	2.2
3	179	176	1.7
4	224	221	1.4
5	282	278	1.4
6	359	353	1.7
7	466	460	1.3
8	626	617	1.5
9	815	803	1.5
10	1028	1012	1.6
11	1263	1246	1.4
12	1524	1503	1.4
13	1770	1745	1.4
14	1991	1965	1.3
15	2204	2177	1.2

* From Supply System Calculation No. NE-02-94-74 "Gap Conductances for Cycle 11."
** From SPC letter dated September 26, 1995, "RODEX2 Data", SPCWP:042:95

Hot Channel Gap Conductance for 9x9 Fuel at EOC11

LHGR (kW/ft)	H_{gap} Supply System*	H_{gap} Siemens Power Corp. **	% Diff.
1	383	384	-0.26
2	417	418	-0.24
3	452	453	-0.22
4	492	492	0
5	536	536	0
6	587	586	0.17
7	647	644	0.47
8	717	712	0.70
9	800	793	0.88
10	902	891	1.2
11	1028	1013	1.5
12	1192	1170	1.9
13	1410	1377	2.4
14	1711	1660	3.1
15	2154	2072	4.0

* From Supply System Calculation No. NE-02-94-74 "Gap Conductances for Cycle 11."
** From SPC letter dated September 26, 1995, "RODEX2 Data," SPCWP:042:95

REFERENCES

1. K. R. Merckx et al., "RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model," XN-NF-81-58(P)(A), Revision 2 and Supplement 1 and 2, March 1984

2. Letter, G02-93-021, dated January 27,1993, from G. C. Sorensen to NRC, "Nuclear Plant No. 2, Operating License NPF-21, Notification of Request for NRC Review of Topical Report WPPSS-FTS-131A, Rev. 1, 'Applications Topical Report for BWR Design and Analysis'"

3. Letter from C.O. Thomas (NRC) to J.C. Chandler (SPC), "Acceptance for Reference of Licensing Topical Report XN-NF-81-58(P), 'RODEX2 Fuel Rod Thermal Mechanical Response Evaluation Model', Revision 2", Nov. 16, 1983

4. Letter SPCWP-93-0009 from Y. U. Fresk, Siemens, to R.A. Vopalensky, Supply System, "RDX2LSE Computer Code," dated January 25, 1993

5. Letter from James Clifford, NRC, to G. C. Sorensen, Supply System, "Evaluation of Topical Report WPPSS-FTS-127 'Qualification of Core Physics for BWR Design and Analysis' (TAC No. M76783)," dated October 23, 1992