ATTACHMENT 26

Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3

Technical Specifications (TS) Change 478

Addition of Analytical Methodologies to Technical Specification 5.6.5.b for Browns Ferry 1, 2, & 3, and Revision of Technical Specification 2.1.1.2 for Browns Ferry Unit 2, in Support of ATRIUM-10 XM Fuel Use at Browns Ferry

Browns Ferry Unit 2 Cycle 19 MCPR Safety Limit Analysis with SAFLIM3D Methodology (Non-Proprietary)

Attached is the non proprietary version of the SLMCPR report for Unit 2 cycle 19. This report supports the change to Technical Specification 2.1.1.2 for Unit 2.

AREVA

AREVA NP Inc.

Engineering Information Record

Document No.: 51 - 9191259 - 001

Browns Ferry Unit 2 Cycle 19 MCPR Safety Limit Analysis With SAFLIM3D Methodology

Browns Ferry Unit 2 Cycle 19 MCPR Safety Limit Analysis With SAFLIM3D Methodology

Safety related? ☒ YES ☐ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☐ YES ☒ NO

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, A/A-CRF, A/A-CRI	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
S.A. Tylinski, Engineer Thermal-Hydraulics Richland	SA Tylinski	P	10/30/12	All
D. D. Crockett, Engineer Thermal-Hydraulics Richland		R	10/30/12	All
D.W. Pruitt, Manager Thermal-Hydraulics Richland		A/A-CRI	10/30/12	All
A.B. Meginnis, Manager Product Licensing		A	10/30/12	All

Note: P/LP designates Preparer (P), Lead Preparer (LP)
R/LR designates Reviewer (R), Lead Reviewer (LR)
A/A-CRF designates Approver (A), Approver of Customer Requested Format (A-CRF)
A/A-CRI designates Approver (A), Approver - Confirming Reviewer Independence (A-CRI)

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000		Initial issue. **This is the nonproprietary version of 51-9191258-000.**
001	All	This document is revised to keep the revision number the same as the proprietary version. No other changes have been made to this document

Table of Contents

Tables

Figures

1.0 PURPOSE

Reference 1 presents an AREVA methodology for determining the safety limit minimum critical power ratio (SLMCPR) that was recently approved by the NRC. The methodology is an update or extension of the previously approved methodology presented in Reference 2. The SLMCPR methodology was updated to incorporate full implementation of the ACE critical power correlation (References 3, 4, and 5), a realistic fuel channel bow model (Reference 6), and expanded coupling with the MICROBURN-B2 core simulator (Reference 7). More detailed descriptions of these improvements are discussed in Reference 1. The purpose of this report is to provide SLMCPR results for Browns Ferry Unit 2 Cycle 19 using the Reference 1 methodology to support a change in the list of approved methodologies in the Technical Specifications and also a change in the Technical Specification SLMCPR values for two-loop operation (TLO) and single-loop operation (SLO).

2.0 METHODOLOGY

The analysis presented in this document used the methodology presented in Reference 1. The SLMCPR is defined as the minimum value of the critical power ratio which ensures that at least 99.9% of the fuel rods in the core are expected to avoid boiling transition during normal operation or an anticipated operational occurrence (AOO). The SLMCPR is determined using a statistical analysis that employs a Monte Carlo process that perturbs key input parameters used in the calculation of MCPR. The set of uncertainties used in the statistical analysis include both fuel-related and plant-related uncertainties.

The SLMCPR analysis is performed with a power distribution that conservatively represents expected reactor operating states that could both exist at the operating limit MCPR (OLMCPR) and produce a MCPR equal to the SLMCPR during an AOO. [

]

In the AREVA methodology, the effects of channel bow on the critical power performance are accounted for in the SLMCPR analysis. Reference 1 discusses the application of a realistic channel bow model.

3.0 ANALYSIS

The final core design and step-through, developed by AREVA NP to meet the operating requirements specified by TVA, was used in the BFE2-19 MCPR safety limit analysis. The BFE2-19 design supports licensed rated power of 3,458 MWt and operation to licensing end of cycle (EOC) cycle exposure of approximately 16,941 MWd/MTU. The design includes extensions for final feedwater temperature reduction (FFTR) and coastdown. Figure 1 presents the core loading, the cycle the fuel was originally loaded, and the number of assemblies. The BFE2-19 core is made up of ATRIUM™ 10XM* and ATRIUM-10 fuel. Analyses were performed [

] for the Browns Ferry power/flow map for MELLLA operation as shown in Figure 2. The radial power distribution [ ] is presented in Figures 3 and 4.

The ACE/ATRIUM 10XM critical power correlation (References 3, 4, and 5) is used for the ATRIUM 10XM fuel while the SPCB critical power correlation (Reference 8) is used for the ATRIUM-10. The fuel- and plant-related uncertainties used in the BFE2-19 SLMCPR analysis are presented in Table 1. The radial and nodal power uncertainties used in the analysis include the effects of up to 40% of the TIP channels out-of-service, up to 50% of the LPRMs out-of-service, and a 2500 effective full power hour (EFPH) LPRM calibration interval.

[

]

The BFE2-19 SLMCPR analysis supports a TLO SLMCPR of 1.04 and an SLO SLMCPR of 1.05. Table 2 presents a summary of the analysis results including the SLMCPR and the percentage of rods

* ATRIUM is a trademark of AREVA NP.

expected to experience boiling transition. The percentages of the total number of fuel rods predicted to experience boiling transition in the overall Monte Carlo statistical evaluation associated with each nuclear fuel type are presented in Table 3. The results are for the [

]. The BFE2-19 fuel design is presented in Figures 5 through 7.

4.0 DISCUSSION OF RESULTS

Compared to the current TLO and SLO SLMCPR limits using the Reference 2 methodology, results show a significant decrease in both the TLO and SLO SLMCPR limits with the Reference 1 methodology. The SLMCPR differences are primarily a result of the following differences in the methodologies:

- Implementation of the realistic channel bow model
- Explicit use of the [ ] as a result of the expanded coupling with MICROBURN-B2

The improved SLMCPR results with the Reference 1 methodology are consistent with the results presented in Tables 4-1 and 4-3 of Reference 1.

5.0 REFERENCES

1. ANP-10307PA Revision 0, *AREVA MCPR Safety Limit Methodology for Boiling Water Reactors*, AREVA NP, June 2011.
2. ANF-524(P)(A) Revision 2 and Supplements 1 and 2, *ANF Critical Power Methodology for Boiling Water Reactors*, Advanced Nuclear Fuels Corporation, November 1990.
3. ANP-10298PA Revision 0, *ACE/ATRIUM 10XM Critical Power Correlation*, AREVA NP, March 2010.
4. ANP-3140(P) Revision 0, "Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation," AREVA NP, August 2012.
5. ANP-10298PA Revision 0 Supplement 1P Revision 0, Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, December 2011.
6. BAW-10247PA Revision 0, *Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors*, AREVA NP, February 2008.

7. EMF-2158(P)(A) Revision 0, *Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4 / MICROBURN-B2*, Siemens Power Corporation, October 1999.

8. EMF-2209(P)(A) Revision 3, *SPCB Critical Power Correlation*, AREVA NP, September 2009.

9. Letter, H. Donald Curet (AREVA) to H.J. Richings (USNRC), "POWERPLEX® Core Monitoring: Failed or Bypassed Instrumentation and Extended Calibration," HDC:96:012, May 6, 1996. (38-9043714-000).

Table 1 Fuel- and Plant-Related Uncertainties MCPR Safety Limit Analyses	
Parameter	Standard Deviation
Fuel-Related Uncertainties	
[	
	]
Plant-Related Uncertainties	
Feedwater flow rate	1.8%
Feedwater temperature	0.8%
Core pressure	0.7%
Total core flow rate TLO SLO	 2.5% 6.0%

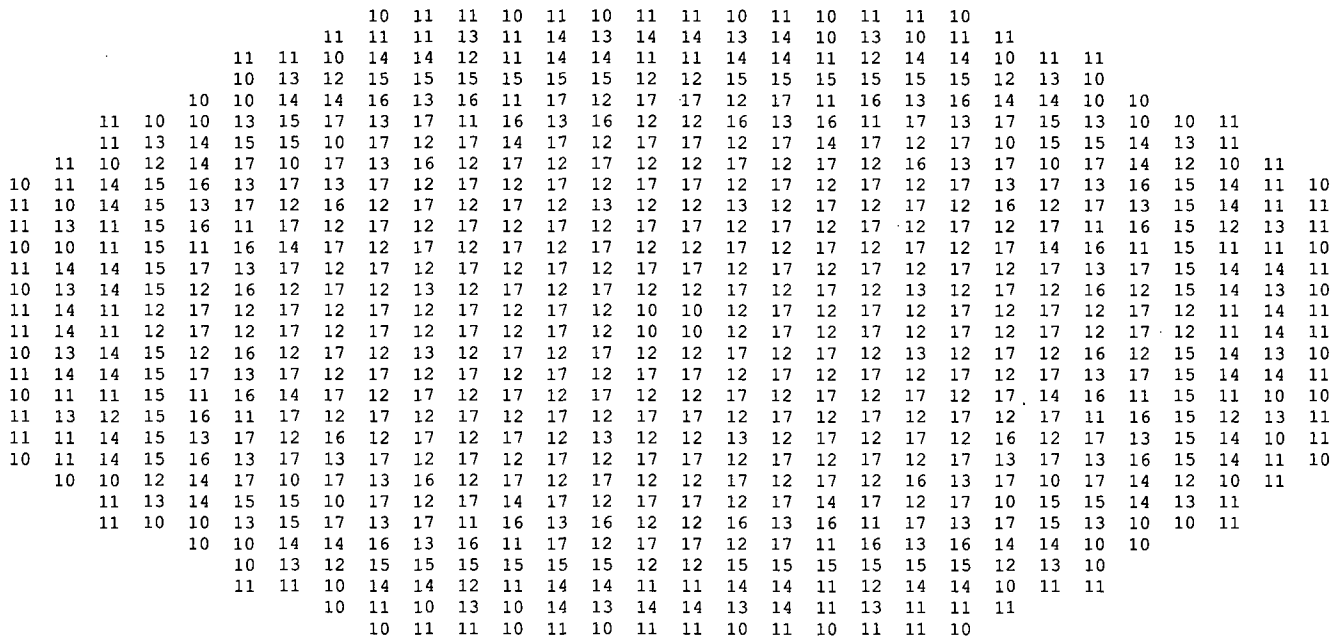
* [ ]

Table 2 Results Summary for MCPR Safety Limit Analysis

SLMCPR	Percentage of Rods in Boiling Transition
TLO – 1.04	0.0834
SLO – 1.05	0.0921

Table 3 Contribution of Total Predicted Rods in BT by Nuclear Fuel Type

Nuclear Fuel Type	Fuel Design	Burnup Status	Contribution of Total Rods Predicted to be in BT (%) TLO [ ]	SLO [ ]
10	ATRIUM-10	Twice burned	[	
11	ATRIUM-10	Twice burned		
12	ATRIUM-10	Once burned		
13	ATRIUM-10	Once burned		
14	ATRIUM-10	Once burned		
15	ATRIUM 10XM	Fresh		
16	ATRIUM 10XM	Fresh		
17	ATRIUM 10XM	Fresh		]



Nuclear Fuel Type	Fuel Description	Cycle Loaded	Number of Assemblies
10	ATRIUM-10	17	74
11	ATRIUM-10	17	103
12	ATRIUM-10	18	175
13	ATRIUM-10	18	68
14	ATRIUM-10	18	72
15	ATRIUM 10XM	19	60
16	ATRIUM 10XM	19	40
17	ATRIUM 10XM	19	172

Figure 1 Browns Ferry Unit 2 Cycle 19 Core Loading Map

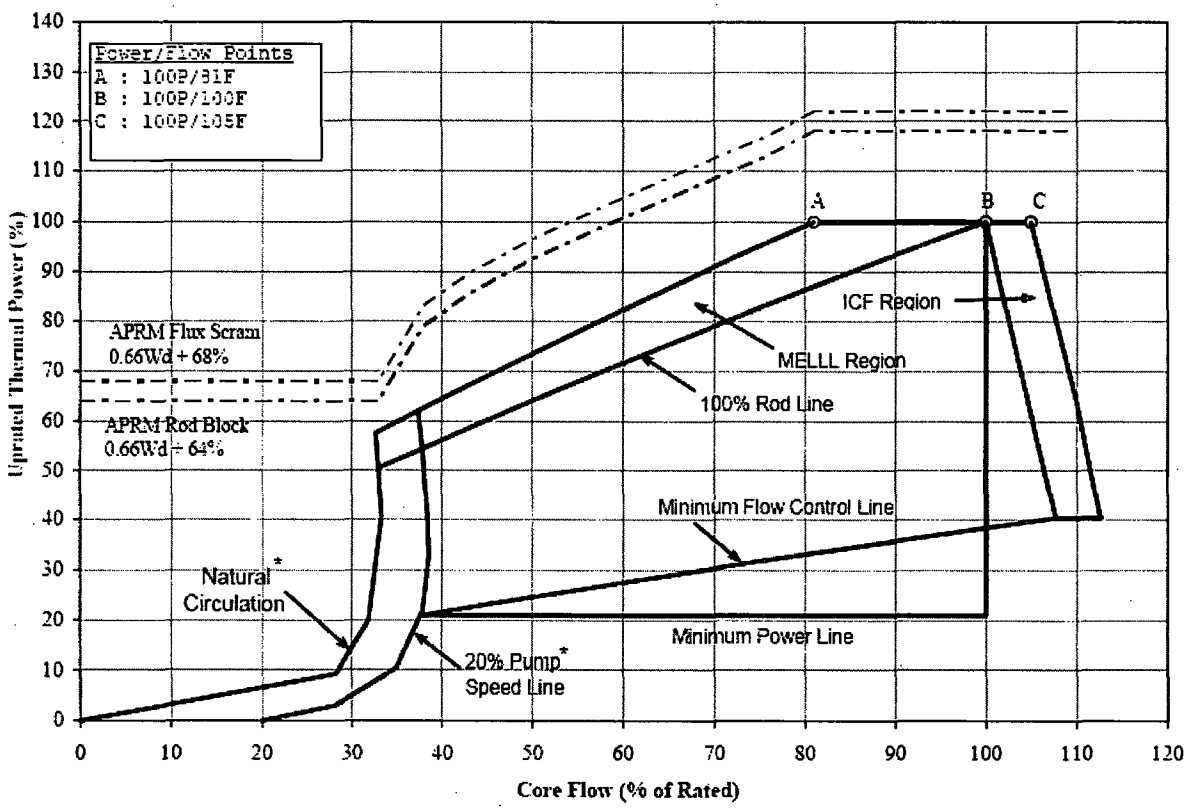


Figure 2 Browns Ferry Power / Flow Map

								0.194	0.250	0.284	0.291	0.313	0.308	0.312
							0.278	0.388	0.521	0.614	0.577	0.666	0.659	0.664
						0.201	0.335	0.478	0.749	0.856	0.852	0.754	0.898	0.906	0.763
						0.330	0.620	0.819	1.075	1.169	1.202	1.222	1.238	1.233	1.048
					0.337	0.515	0.855	0.998	1.215	1.113	1.302	1.036	1.335	1.169	1.340
			0.201	0.328	0.515	0.827	1.131	1.235	1.137	1.340	1.066	1.371	1.189	1.392	1.221
			0.326	0.617	0.854	1.130	1.253	1.042	1.361	1.201	1.404	1.222	1.390	1.201	1.388
		0.270	0.464	0.812	0.994	1.231	1.041	1.360	1.210	1.429	1.234	1.388	1.151	1.310	1.158
	0.184	0.370	0.735	1.063	1.207	1.133	1.356	1.208	1.429	1.255	1.438	1.186	1.003	0.859	1.257
	0.233	0.431	0.838	1.154	1.106	1.332	1.196	1.421	1.249	1.447	1.259	1.358	0.880	0.846	1.089
	0.268	0.589	0.827	1.187	1.290	1.061	1.394	1.224	1.421	1.238	1.431	1.217	1.335	1.134	1.343
	0.278	0.539	0.741	1.207	1.028	1.360	1.215	1.376	1.162	1.346	1.215	1.426	1.226	1.416	1.232
	0.307	0.656	0.889	1.225	1.320	1.181	1.380	1.154	1.000	0.879	1.342	1.240	1.448	1.251	1.440
	0.306	0.653	0.897	1.219	1.155	1.375	1.201	1.303	0.858	0.847	1.147	1.422	1.250	1.420	1.217
	0.311	0.659	0.757	1.035	1.312	1.189	1.371	1.148	1.250	1.078	1.342	1.232	1.426	1.198	1.018
	0.311	0.659	0.758	1.035	1.312	1.189	1.370	1.147	1.248	1.077	1.341	1.231	1.426	1.197	1.017
	0.308	0.656	0.900	1.221	1.156	1.375	1.200	1.300	0.854	0.843	1.145	1.420	1.250	1.419	1.218
	0.312	0.663	0.894	1.230	1.323	1.182	1.379	1.151	0.995	0.874	1.338	1.239	1.447	1.252	1.440
	0.288	0.575	0.751	1.216	1.031	1.361	1.214	1.374	1.160	1.342	1.214	1.424	1.227	1.415	1.236
	0.284	0.613	0.851	1.197	1.294	1.061	1.392	1.221	1.417	1.236	1.428	1.217	1.335	1.136	1.344
	0.252	0.520	0.854	1.164	1.108	1.333	1.194	1.418	1.246	1.444	1.257	1.357	0.883	0.850	1.093
	0.196	0.386	0.746	1.070	1.209	1.133	1.354	1.205	1.426	1.252	1.434	1.186	1.005	0.863	1.258
		0.268	0.469	0.815	0.994	1.230	1.039	1.356	1.207	1.424	1.231	1.385	1.152	1.310	1.158
			0.328	0.617	0.852	1.127	1.249	1.041	1.356	1.197	1.399	1.220	1.387	1.201	1.386
			0.201	0.328	0.514	0.825	1.127	1.229	1.133	1.333	1.063	1.365	1.186	1.388	1.220
					0.336	0.513	0.853	0.993	1.206	1.106	1.292	1.030	1.329	1.166	1.338
						0.328	0.617	0.813	1.063	1.155	1.188	1.211	1.231	1.229	1.047
						0.200	0.331	0.471	0.735	0.839	0.836	0.743	0.892	0.903	0.764
								0.263	0.369	0.433	0.591	0.543	0.659	0.656	0.663
									0.180	0.231	0.268	0.282	0.307	0.307	0.312

0.311	0.306	0.307	0.281	0.268	0.231	0.181								
0.663	0.656	0.658	0.542	0.591	0.432	0.369	0.270							
0.763	0.902	0.892	0.743	0.836	0.838	0.735	0.471	0.332	0.200					
1.048	1.230	1.231	1.211	1.188	1.155	1.062	0.812	0.616	0.328					
1.339	1.166	1.330	1.032	1.293	1.106	1.206	0.993	0.852	0.513	0.336				
1.221	1.390	1.186	1.365	1.063	1.334	1.132	1.229	1.126	0.824	0.514	0.328	0.201		
1.388	1.201	1.388	1.220	1.399	1.196	1.355	1.040	1.248	1.126	0.851	0.616	0.327		
1.158	1.311	1.152	1.385	1.230	1.423	1.206	1.355	1.038	1.228	0.993	0.813	0.469	0.276	
1.258	0.862	1.004	1.185	1.434	1.251	1.424	1.204	1.352	1.131	1.207	1.068	0.745	0.386	0.196
1.090	0.849	0.882	1.357	1.256	1.443	1.244	1.416	1.192	1.330	1.106	1.162	0.852	0.519	0.252
1.343	1.134	1.334	1.216	1.427	1.234	1.416	1.219	1.389	1.059	1.291	1.194	0.849	0.611	0.283
1.232	1.415	1.225	1.423	1.212	1.341	1.158	1.371	1.211	1.357	1.029	1.212	0.749	0.574	0.287
1.440	1.251	1.446	1.237	1.337	0.873	0.993	1.148	1.376	1.179	1.319	1.226	0.892	0.661	0.311
1.218	1.419	1.248	1.419	1.143	0.842	0.852	1.297	1.197	1.371	1.153	1.218	0.897	0.654	0.307
1.017	1.197	1.424	1.230	1.339	1.075	1.245	1.145	1.367	1.186	1.309	1.033	0.756	0.658	0.311
1.019	1.197	1.424	1.230	1.340	1.076	1.247	1.145	1.367	1.186	1.308	1.032	0.756	0.658	0.310
1.218	1.419	1.249	1.419	1.145	0.846	0.856	1.299	1.198	1.371	1.152	1.216	0.895	0.652	0.306
1.440	1.251	1.445	1.239	1.339	0.877	0.998	1.151	1.376	1.178	1.317	1.222	0.888	0.656	0.306
1.235	1.414	1.225	1.423	1.213	1.343	1.161	1.373	1.212	1.356	1.026	1.205	0.741	0.540	0.278
1.343	1.134	1.332	1.216	1.428	1.236	1.417	1.220	1.390	1.058	1.287	1.185	0.835	0.590	0.268
1.092	0.846	0.879	1.355	1.257	1.444	1.246	1.417	1.193	1.329	1.104	1.152	0.838	0.432	0.234
1.257	0.860	1.001	1.185	1.434	1.252	1.426	1.205	1.353	1.131	1.204	1.061	0.734	0.369	0.184
1.158	1.309	1.151	1.385	1.232	1.425	1.208	1.357	1.040	1.229	0.993	0.811	0.464	0.267	
1.386	1.201	1.388	1.221	1.401	1.199	1.358	1.043	1.250	1.127	0.853	0.616	0.326		
1.221	1.389	1.188	1.368	1.067	1.338	1.136	1.233	1.129	0.826	0.515	0.329	0.201		
1.339	1.168	1.333	1.037	1.300	1.112	1.213	0.997	0.856	0.515	0.337				
1.048	1.232	1.237	1.220	1.200	1.167	1.074	0.819	0.620	0.330					
0.764	0.906	0.898	0.753	0.852	0.857	0.750	0.478	0.334	0.201					
0.664	0.660	0.666	0.577	0.614	0.522	0.388	0.276							
0.312	0.309	0.313	0.292	0.284	0.251	0.194								

Figure 3 Radial Power Distribution Map for Browns Ferry Unit 2 Cycle 19 SLMCPR [ ]

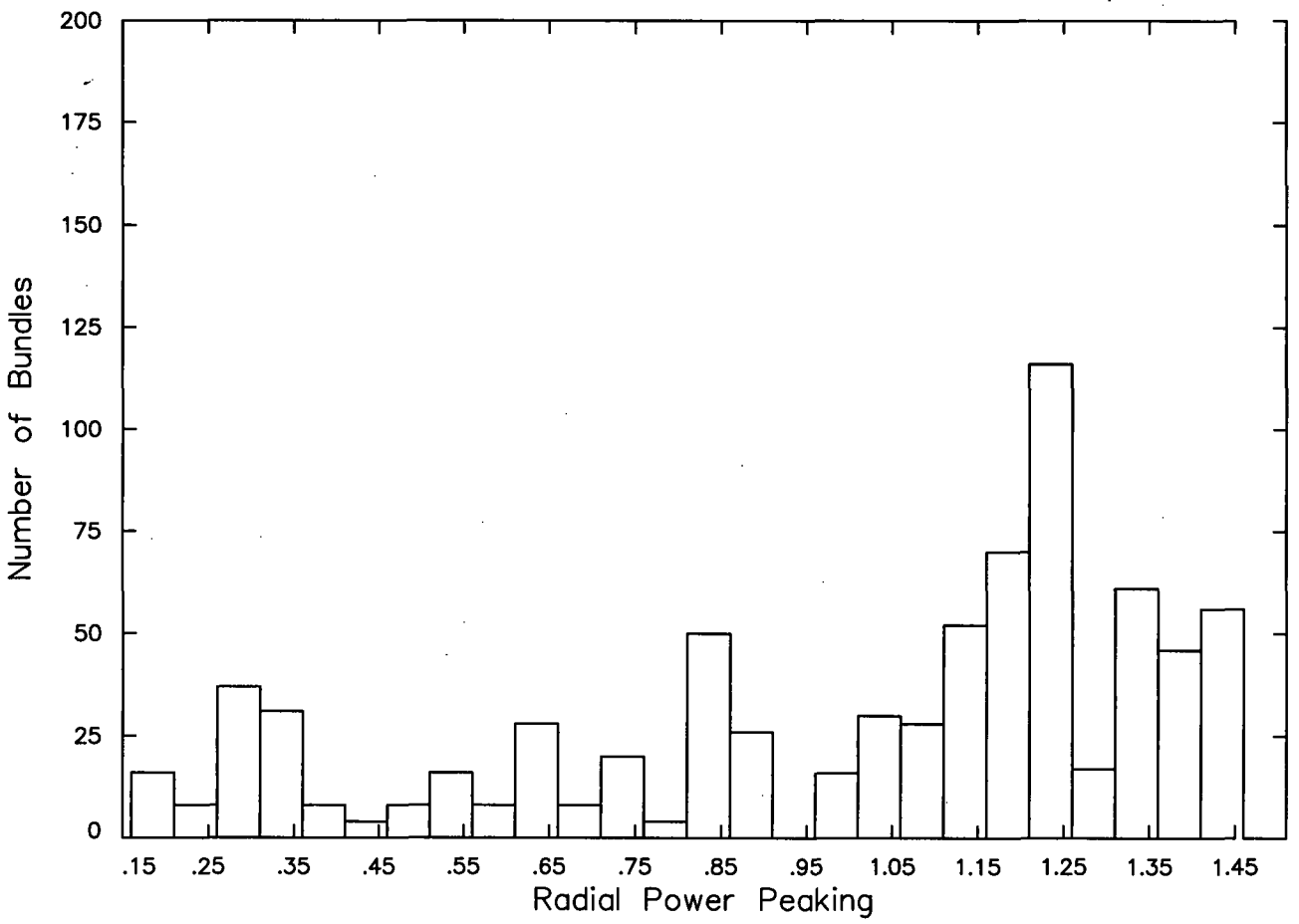


Figure 4 Radial Power Distribution for TLO Limiting Exposure of [ ]