SMUD
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February 8, 1983

DIRECTOR OF NUCLEAR REACTOR REGULATION
ATTENTION JOHN F STOLZ CHIEF
OPERATING REACTORS BRANCH 4
U S NUCLEAR REGULATORY COMMISSION
WASHINGTON DC 20555

DOCKET 50-312
RANCHO SECO NUCLEAR GENERATING STATION
UNIT NO 1
FLUX REDUCTION TO DELAY REACHING PTS SCREENING CRITERIA

During the January 14, 1983 meeting with the NRC staff in Bethesda on Flux Reduction Programs, we committed to document the information presented in the meeting in order to provide additional clarification and to provide a schedule for submittal of additional information not available currently. The enclosure to this letter is intended to comply with our commitment.

Your January 18, 1983 minutes of the January 14, 1983 meeting contained two incorrect statements. First, the next Rancho Seco fuel cycle is cycle 7 rather than cycle 8 as reported in your minutes. Second, your minutes stated that "Rancho Seco is committed to an in-in-out core in cycle 8". The correct statement is that SMUD is willing to commit to further study the feasibility of implementing an in-in-out fuel management pattern for Rancho Seco and reporting the results to NRC. Preliminary studies indicate that implementation is feasible, but it may be impractical to implement earlier than cycle 8. However, additional study is needed to determine when and if implementation is practical at all. The enclosed information should more clearly identify what steps we believe will be needed before a decision to implement an in-in-out shuffle scheme can be made.

The enclosure primarily addresses fluence reduction options which have been implemented or are being considered for the Rancho Seco reactor vessel. However, we feel it is important to stress that the NRC should not be prescriptive in the methodology used to assess RT_{NDT} shift. The current revision of Regulatory Guide 1.99 states:

> "When credible surveillance data from the reactor in question become available, they may be used to represent the adjusted reference temperature...".

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We feel that the RT_{NDT} correlation specified in SECY 82-465 should be considered no more sacred than the correlation in the Regulatory Guide. Consequently, a licensee should be allowed the flexibility to use a shift correlation for his vessel materials if he can demonstrate credibility. The B&W Owners intend to complete the development of a B&W specific correlation in the very near future which is based on the significant amount of available data for the B&W weld metals. We feel that this correlation will be particularly useful to SMUD due to the large amount of data available on our critical weld metal.

John J. Mattimoe

John J. Mattimoe
General Manager

Enclosure

ENCLOSURE

Fluence Reduction Options and Alternatives
to Fluence Reduction to Delay Reaching
PTS Screening Criteria

A. Current Status of Rancho Seco

1. Accumulated Fluence on vessel inner surface at peak location:

As of 12/31/81 : 0.218×10^{19} nvt (at 3.73 EFPY)
As of 02/18/83*: 0.248×10^{19} nvt (at 4.29 EFPY)

*Estimated End of cycle 5

2. RT_{NDT} of Limiting Weld (longitudinal)

As of 12/31/81: ~ 206°F
As of 02/18/83: ~ 216°F

3. Estimated Rate of Fluence Accumulation at Peak Location

Based on current fuel management
(low leakage or in-out-in shuffle scheme)

$= 0.016 \times 10^{19}$ nvt/EFPY

4. Date when RT_{NDT} Screening Limit Will be Exceeded

Based on current fuel management, the 270°F limit for the limiting weld will be exceeded after an additional 11.3 EFPY. If an optimistic 80 percent capacity factor is assumed, this would occur in 1997. Using a more realistic 60 percent capacity factor this would not occur until 2002.

B. Flux Reduction Options Considered

1. Historical Fluence Reduction at Rancho Seco

The table below shows the historical progression of fluence estimation for the Rancho Seco vessel up to and including the refueling to begin in February, 1983.

Date	Core Cycle	Peak Flux at Vessel Wall	Σ EFPY	Σ nvt	Estimated EOL nvt***
1973	FSAR	2.4×10^{10}	-	-	2.4×10^{19}
1979	1,2,3*	1.94×10^{10}	2.82	0.17×10^{19}	1.96×10^{19}
1982	4**	1.71×10^{10}	3.45	0.21×10^{19}	1.75×10^{19}
1983	5	1.54×10^{10}	4.29	0.25×10^{19}	1.62×10^{19}
1984(est)	6	1.41×10^{10}	5.24	0.29×10^{19}	1.48×10^{19}

* original out-in-in fuel management.
** transition to low leakage in-out-in fuel management
*** assuming 32 EFPY at End of Life

It is estimated that a continuation of the current low leakage (in-out-in) fuel management would result in a fast flux at the peak location on the vessel inner wall of approximately 1.47×10^{10} nv. This corresponds to roughly 0.046×10^{19} nvt per EFPY. Based on an optimistic 80 percent capacity factor until the expiration of the Rancho Seco Operating License in 2008, the accumulated fluence at the peak location would be approximately 1.24×10^{19} nvt. Since the fluence to reach the screening criterion of 270°F calculated by the method specified in SECY 82-465 is 0.77×10^{19} nvt, a flux reduction factor of 1.98 would be needed during the remaining lifetime to avoid exceeding the screening criterion. If a more realistic capacity factor of 60 percent is assumed (actual performance to date is ~ 52 percent) the estimated fluence accumulated at the time of expiration of license is 1.00×10^{19} nvt. The flux reduction factor required to avoid reaching the screening criterion for this case is approximately 1.49.

Figure B-1 is enclosed to provide an example of the difference between the loading schemes for the original out-in-in and the low leakage (in-out-in) fuel management patterns. Rancho Seco cycle 3 was chosen as an example of near equilibrium conditions for the out-in-in design. Rancho Seco cycle 6 is an example of near equilibrium for an in-out-in design. Figure B-2 shows the corresponding power distribution for the two patterns.

3. Fluence Reduction Studies Undertaken to Date

The primary cause of the degradation of ability of vessel weld material to withstand PTS is embrittlement due to cumulative exposure to neutrons with energies greater than 1.0 MeV. The magnitude of the neutron flux impinging on the reactor vessel is proportional to the flux leaking from the core. Calculational experience has shown that > 90 percent of the fast flux that reaches the vessel is due to fissions in the peripheral assemblies. Consequently, the magnitude of the flux at the vessel depends on the power (number of fissions) of the core peripheral assemblies and the path length of the exiting neutrons. Figures B-3 and B-4 illustrate the circumferential distribution of the > 1.0 MeV flux at the inside surface of the pressure vessel for an 18-month, LBP fuel cycle. As can be seen the maximum flux at the vessel surface occurs at 10 to 14 degrees off a major axis, while the minimum occurs at 30 to 35 degrees. The variation in flux magnitude is attributed, in part, to the variation in peripheral assembly relative power, though more importantly, it depends on the integrated path length from the core to the vessel. The longer the path, the greater the probability of scattering, thus reducing neutron energy below that of concern with regard to material degradation.

Almost a year ago a scoping study was initiated by the BaW Owners to evaluate the feasibility of a very low leakage fuel management scheme which has been referred to recently as an in-in-out shuffle pattern. Recently this scoping study was completed and the preliminary results are summarized in the subsequent paragraphs. It should be noted that this contains additional information not available to us at the time of the January 14 meeting with the NRC staff.

Figure B-5 shows pictorially the general pattern difference for the original out-in-in, the current low leakage (or LBP) in-out-in and very low leakage (VLL) in-in-out schemes. Industry experience to date is limited to the out-in-in and the in-out-in fuel shuffle patterns. The in-in-out or VLL shuffle scheme is an extension of the in-out-in or LBP (Lumped Burnable Poison) scheme and like the LBP scheme uses burnable poison to offset power peaking. Since the predominant fuel management plan in use by the BaW Owners is an 18 month LBP fuel cycle, this study compared the VLL scheme to a typical 18 month, 64 feed LBP scheme for evaluation of potential benefits. Figure B-6 shows a comparison of the relative power distribution for the reference LBP in-out-in scheme and the VLL in-in-out scheme evaluated.

The VLL fuel shuffle scheme developed in this study achieved a 25 percent reduction in the relative power of the peripheral assemblies. This reduction translates to an estimated 20 to 25 percent decrease in vessel fluence relative to the reference LBP scheme, and nearly a 50 percent reduction relative to a conventional out-in fuel scheme. The VLL scheme vessel fluence was compared to a composite of the fluence from six different operating cycles. The six cycles were selected so that they would be representative of the vessel fluence for typical BaW designed 177-FA core reload cycles. The VLL scheme is estimated to yield a 28 percent reduction in the maximum fluence at the inside surface of the reactor vessel wall at 10 to 14 degrees of a major core axis.

Figure B-7 shows the azimuthal variation in core peripheral assembly relative power density. The decrease in power in assemblies D, E, and F is less than the 25 to 39 percent decrease exhibited by assemblies A, B, and C. Therefore, the reduction in vessel fluence at 20 to 45 degrees off the major axis also would be less than the 28 percent value identified for the vessel peak flux location. The maximum power of a peripheral assembly occurs in location D, which contains a once-burned rather than a twice-burned assembly as in the other locations. However, location D is also further from the vessel wall and therefore, contributes proportionately less to the flux level. Design trade-offs can be made to use a twice-burned assembly in this location should reactor-specific requirements dictate.

The gain in fluence reduction which appears to be possible via the VLL in-in-out shuffle scheme is not without penalty. The increase in power peaking, although compensated partially by burnable poison, is estimated to be between 2 and 3 percent. We expect that, if this is typical of a plant specific design for Rancho Seco, it could be accommodated without derating of the plant. Some restrictions on plant maneuvering are likely, however. In order to confirm the feasibility of this fuel management pattern for Rancho Seco, additional, plant specific, analyses would be required.

Since the critical weld for Rancho Seco is located within the peak fluence region (10-14 degrees), the reduction in fluence is estimated to be 28 percent above that achieved by the currently in-place low leakage pattern. This is a greater fluence reduction than we estimated previously and presented in the January 14 meeting.

If we assume that an in-in-out (VLL) shuffle were implemented at Rancho Seco in cycle 8, the accumulated fluence at the time of expiration of the operating license assuming an optimistic capacity factor (80 percent) and realistic capacity factor (60 percent) is shown below:

Capacity Factor	Peak Flux at Vessel Wall	nvt/EFPY	Esimated nvt at end of License *
80 Percent	1.06×10^{10} nv	.0335	0.95×10^{19}
60 Percent	1.06×10^{10} nv	.0335	0.79×10^{19}

*approximately 23 calendar years after cycle 8 startup.

Our NSS vendor believes the predicted 28 percent flux reduction of the VLL scheme is conservative and that up to 35 percent reduction may be achievable. Consequently, we believe that implementation of the VLL scheme by cycle 8 would reduce the vessell fluence sufficiently to avoid reaching the NRC staff proposed screening criterion for PTS during the term of the operating license. Additional work will be required to assure that the VLL scheme can indeed be implemented at Rancho Seco without impacting upon core design or operating limits.

C. Alternatives to Flux Reduction for Delay of Reaching Screening Criteria

As discussed in the January 11 and 12 meetings between the B&W owners and the NRC staff, the B&W owners have sponsored work which as a result of the Integrated RV Materials Surveillance program and other sources of data on B&W weld metals will define a RT_{NDT} shift correlation relating materials properties and fluence for the B and W materials. We believe this correlation will improve the knowledge of the industry for B&W materials and will be shown to be an improvement upon the Reg Guide 1.99 and SECY 82-465 methodologies for RT_{NDT} shift prediction.

We recognize that time must be allowed for preparation of suitable documentation to support the correlation, and time for NRC staff review. However, preliminary results from this work indicate that the RT_{NDT} shift predicted by the SECY 82-465 methodology and Regulatory Guide 1.99 Revision 1 is significantly larger than surveillance data for the B and W materials indicates. We believe that the NRC staff should remain flexible in the RT_{NDT} shift prediction methodology rather than so prescriptive as to require that a specific formula be used. The use of a material specific correlation is expected to delay reaching the PTS screening criteria for the Rancho Seco Vessel by several years.

A schedule for submittal of the documentation of the proposed B&W materials shift correlation is currently being developed, but submittal is anticipated within approximately six weeks.

4. Fluence Reduction Studies to be Undertaken

We are currently evaluating possible refinements and additional steps necessary to implement the VLL scheme. Although it appears that the VLL shuffle described in B.3 above would provide adequate flux reduction to satisfy the PTS screening criterion, we recognize that limiting the vessel fluence to the extent practical is a desirable goal. We consider that achievement of capacity factors significantly greater than 60 percent is optimistic, but we do not want to intentionally limit the lifetime of the reactor vessel and 2008 is too far into the future to predict that relicensing for additional use of Rancho Seco will or will not be desirable. Consequently, it is our intention to evaluate selective placement of highly burned or very low enrichment fuel assemblies in selected locations near the critical welds with the goal of reducing fluence at critical locations to the maximum extent practical.

We are presently considering funding an analysis to determine the relative importance of each of the fuel assemblies on the periphery of the core which significantly impact the neutron flux at the critical weld(s). This would subsequently be used to determine a target power distribution for the critical fuel assemblies which would be needed to achieve a desired flux reduction, which in turn would be used to select a loading pattern and for evaluation of peaking, operating limits and margin, etc. Portions of this analysis could easily be made generic, thus other B&W owners may elect to support the work. We expect that a defined scope can be agreed upon and work initiated within approximately two months. The "generic" portion of the work is then expected to require approximatey 6 months to complete. Since this schedule would support plant specific design work beginning by November, 1983 and the next refueling outage (to load cycle 7) is not anticipated before the fall of 1984, the time required should not preclude implementation of an optimized very low leakage cycle or transition cycle as early as cycle 7. The results of the analysi should at least be adequate to determine the feasibility of further flux reduction and support further information submittal to NRC.

FIGURE B-1

Out-In-In Shuffle Pattern

BOC Enrichment and Burnup Distribution — Rancho Seco, Cycle 3

	8	9	10	11	12	13	14	15
J	2.67 25,846	3.00 29,355	3.00 22,876	3.00 23,216	**3.04 0**	3.00 23,136	3.19 9,610	**3.04 0**
K		**3.04 0**	3.00 20,668	3.19 12,359	3.00 23,952	3.19 10,403	3.00 26,107	**3.04 0**
L			3.19 8,055	3.19 9,422	3.19 13,417	3.00 22,266	**3.04 0**	**3.04 0**
M				2.67 25,846	3.19 7,953	3.00 18,794	**3.04 0**	
N					3.00 20,834	3.19 7,394	**3.04 0**	
O						**3.04 0**		
P								
R								

XXX   Initial enrichment, wt % ^{235}U
XXXXX   BOC Burnup, MWd/mtU

Low Leakage (in-out-in) Pattern

Enrichment and BOC Burnup Distribution, Rancho Seco Cycle 6

	8	9	10	11	12	13	14	15
H	2.01 18,058	3.21 17,643	3.04 25,000	**3.14 0**	3.21 21,945	**3.14 0**	3.21 22,151	3.21 14,619
K		3.21 19,278	**3.43 0**	2.01 16,698	**3.14 0**	3.21 17,447	**3.43 0**	3.14 12,417
L			3.21 19,271	**3.43 0**	3.04 21,233	**3.14 0**	3.21 14,940	3.14 12,947
M				2.01 16,280	**3.43 0**	3.21 17,714	3.14 12,132	
N					3.04 18,648	**3.43 0**	3.14 12,701	
O						3.21 14,616		
P								
R								

X.XX   Initial Enrichment, wt % ^{235}U
XX,XXX   BOC Burnup, MWd/mtU

(Bold outlined box) Location of Fresh Fuel

FIGURE B-2

Out-In-In Shuffle Pattern

BOC 3 (4 EFPD) Two-Dimensional Radial Power Distribution
Full Power, Equilibrium Xenon, Normal Rod Positions
(Group 8 Inserted) – Rancho Seco

	8	9	10	11	12	13	14	15
H	0.72	0.81	0.88	0.96	1.39	0.95	1.04	0.86
K		1.28	1.04	1.19	0.98	1.10	0.84	0.83
L			1.39	1.30	8 1.01	0.92	1.18	0.70
M				0.96	1.19	0.94	0.99	
N					0.97	1.03	0.68	
O						0.76		
P								
R								

X — Inserted Rod Group No.
X.XX — Relative Power Density

Low Leakage (in-out-in) Pattern

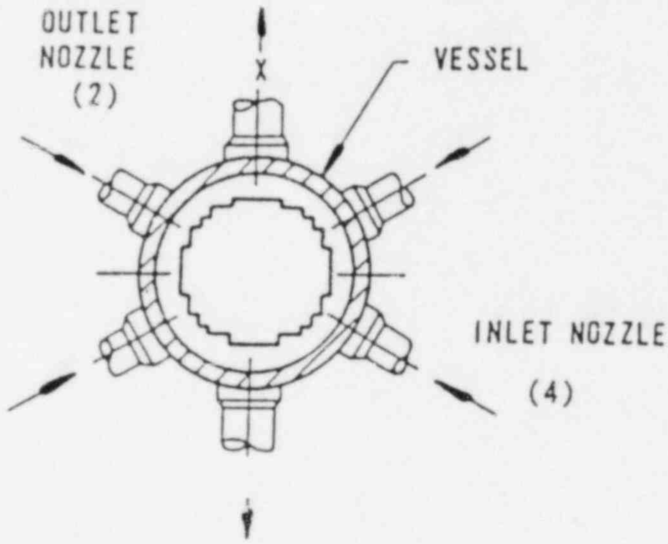
BOC 6 (~ EFPD) Two-Dimensional Relative Power
Distribution – Full Power, Equilibrium Xenon,
Group 8 Inserted

	8	9	10	11	12	13	14	15
H	0.74	1.00	0.95	1.23	1.17	1.27	0.97	0.57
K		1.06	1.27	0.93	1.27	1.23	1.17	0.58
L			1.18	1.31	8 1.08	1.29	0.91	0.43
M				0.95	1.30	1.05	0.70	
N					1.04	1.06	0.48	
O						0.57		
P								
R								

X — Inserted Rod Group No.
X.XX — Relative Power Density

FIGURE B-3

Rancho Seco Longitudinal Weld Locations to Azimuthal Fluence Profile



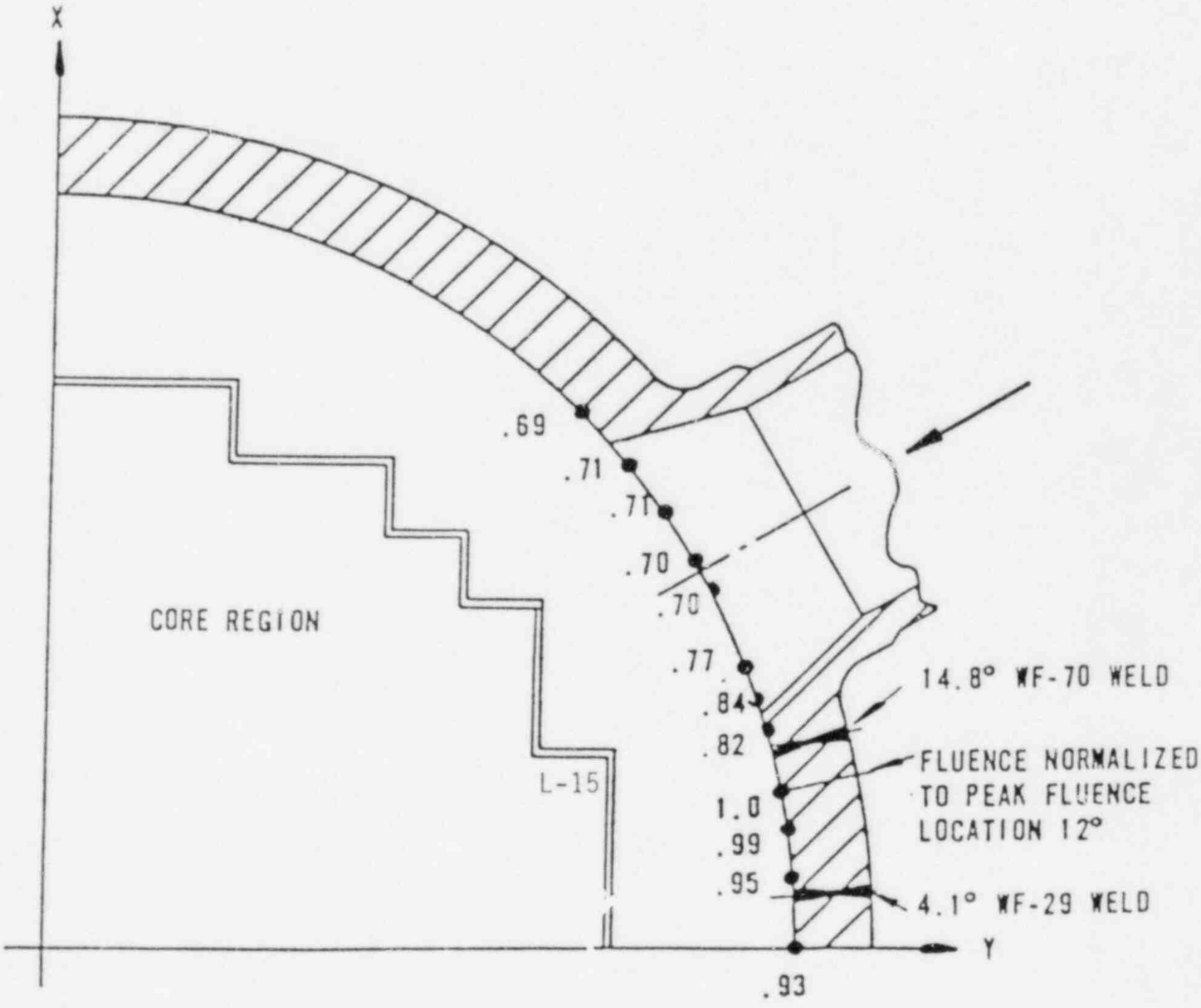
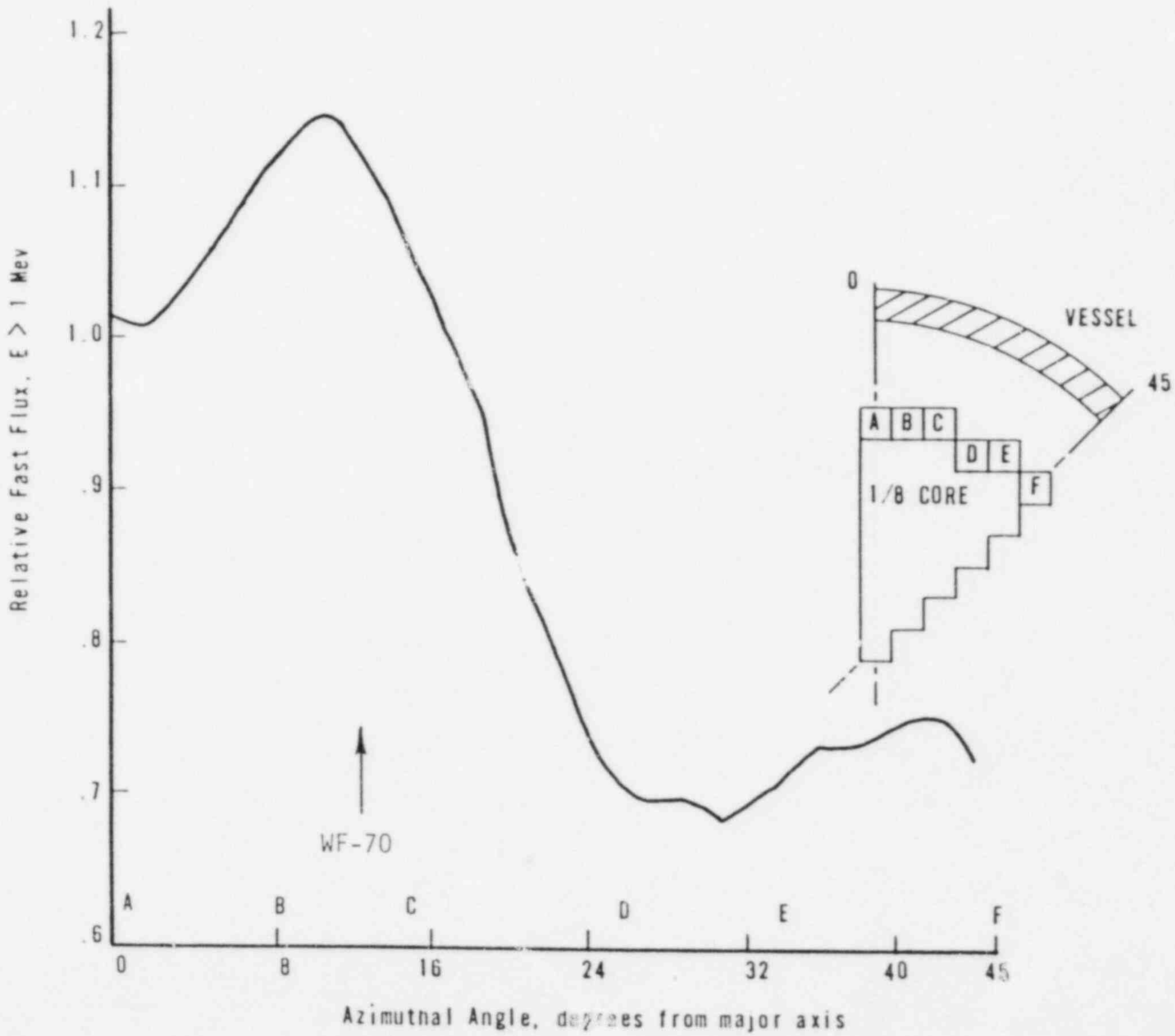


FIGURE B-4

Circumferential Distribution of Fast Flux at Inside Surface of Pressure Vessel for LBP Cycle



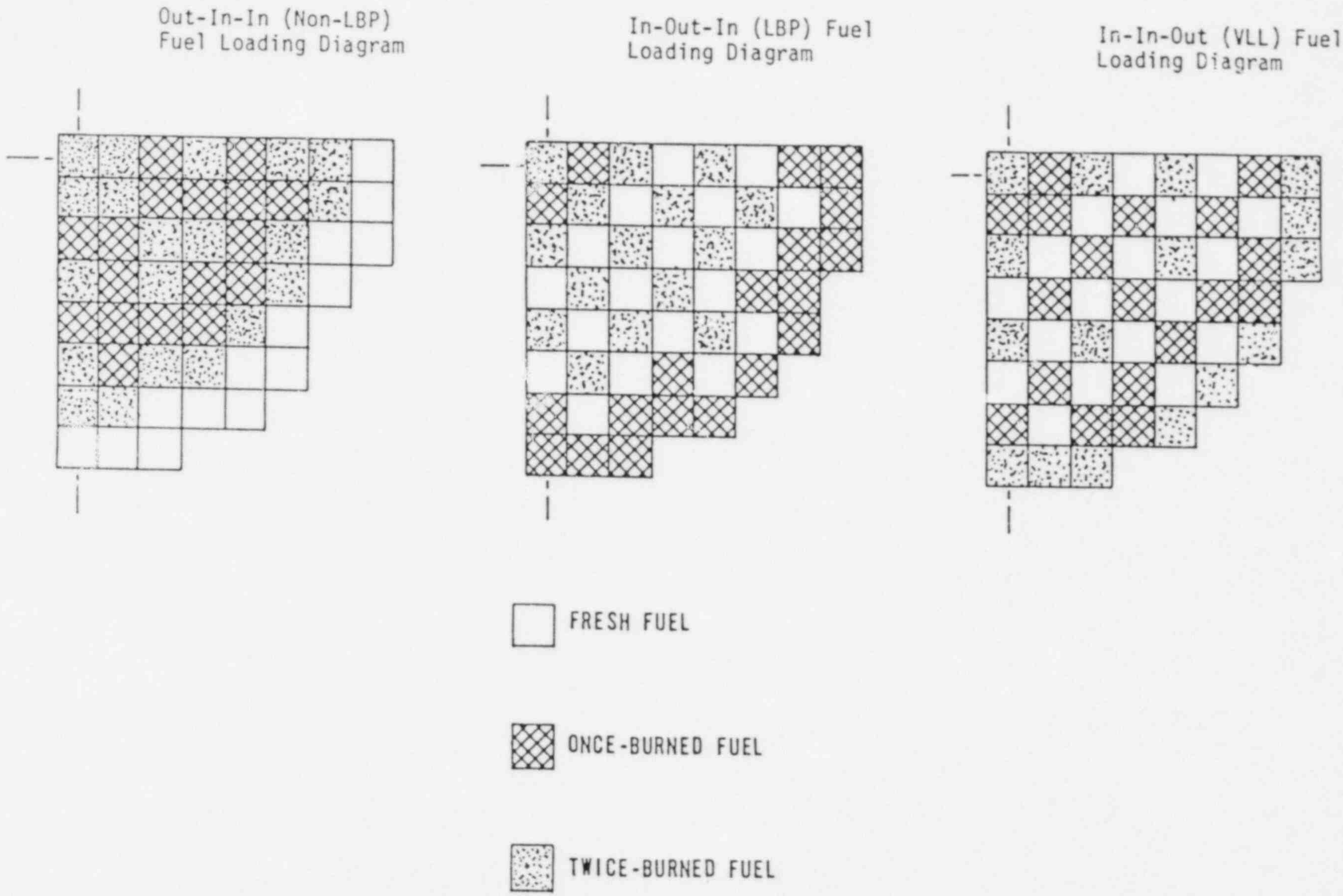


FIGURE B-5

FUEL MANAGEMENT SCHEMES

Fuel Assembly Cycle Average RPD for Equilibrium Cycle

	8	9	10	11	12	13	14	15
H	.839 .938 11.8	1.037 1.160 11.9	1.084 1.104 1.85	1.385 1.395 0.72	1.160 1.128 -2.76	1.353 1.314 -2.88	1.009 .947 -6.14	.548 .375 -31.6
K	1.038 1.161 11.9	1.027 1.205 17.3	1.345 1.398 3.94	1.151 1.288 11.9	1.354 1.359 0.37	1.129 1.204 6.64	1.116 1.112 -0.36	.556 .351 -36.9
L	1.086 1.104 1.66	1.346 1.399 3.94	1.152 1.321 14.7	1.353 1.390 2.73	1.028 1.008 -1.95	1.244 1.226 -1.45	0.907 0.772 -14.9	.411 .248 -39.7
M	1.386 1.396 0.72	1.152 1.288 11.8	1.353 1.389 2.66	1.134 1.273 12.3	1.262 1.342 6.34	0.998 1.073 7.52	634 .577 -8.99	
N	1.160 1.128 -2.76	1.354 1.359 0.37	1.029 1.007 -2.14	1.262 1.337 5.94	0.987 1.153 16.8	0.930 0.944 1.51	.412 .338 -18.0	
O	1.353 1.314 -2.88	1.130 1.204 6.55	1.244 1.225 -1.53	0.998 1.071 7.31	0.929 0.941 1.29	0.499 .397 -20.4		
P	1.009 .948 -6.05	1.117 1.112 -0.45	0.907 0.772 -14.9	0.633 0.576 -9.00	0.412 0.337 -18.2			
R	0.548 0.375 -31.6	0.556 0.351 -36.9	0.411 0.248 -39.7					

Legend (top to bottom in each cell):
- ← RPD REFERENCE LBP SCHEME
- ← RPD VLL SCHEME
- ← Δ% RPD

FIGURE B-7

Peripheral Power Distribution Comparison for VLL and LBP Fuel Shuffle Schemes

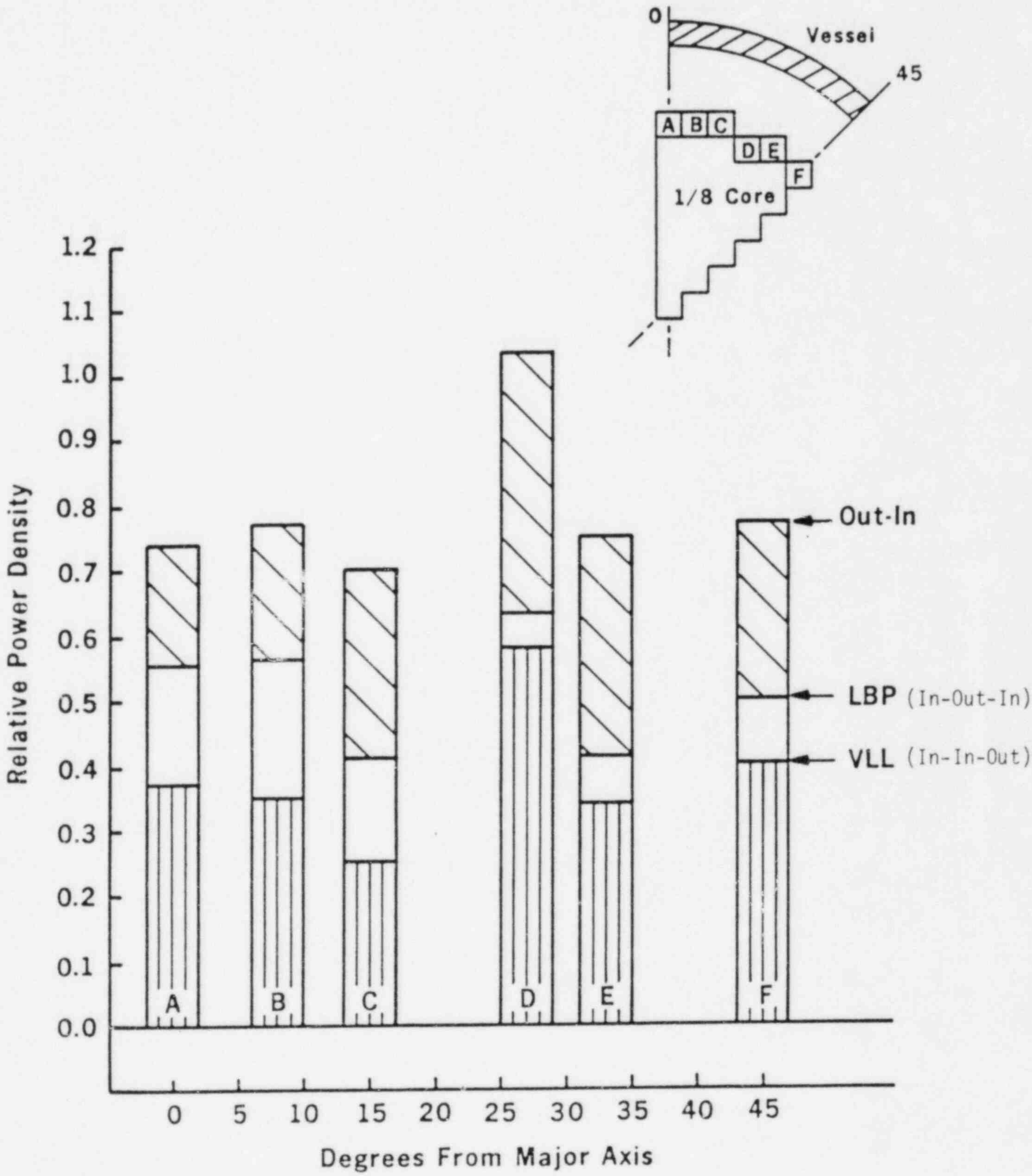


FIGURE B-7

Peripheral Power Distribution Comparison
for VLL and LBP Fuel Shuffle Schemes