Commonw[illegible]h Edison
72 West Adams Street, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690 - 0767

May 22, 1989

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Dresden Station Unit 2
Hydrogen Water Chemistry
Fuel Surveillance
NRC Docket No. 50-237

References (a): Letter from D.M. Crutchfield to D.L. Farrar dated April 7, 1983.

(b): Letter from J.A. Silady to T.E. Murley dated November 30, 1987.

(c): Hydrogen Water Chemistry -- Fuel Materials Surveillance Program, Post-Irradiation Examination of Fuel Components after Two Cycles of Hydrogen Water Chemistry at Dresden Unit 2, by B. Cheng and R.E. Blood, GE Report NEDC-31551, February 1988, EPRI Research Project 1930-10.

Dr. Murley:

Reference (a) transmitted Amendment No. 75 to DPR-19 in support of Dresden Unit 2 Cycle 9 operation and requested that we provide hydrogen uptake measurements on GE LTA's exposed to the hydrogen environment. These measurements, following one cycle of hydrogen water chemistry at Dresden 2, were provided to the NRC in Reference (b).

Similar results obtained after two cycles of hydrogen water chemistry are reported in Reference (c). The attachment which contains excerpts from Reference (c), indicates that there are no deleterious effects on the Zircaloy components following two cycles of hydrogen water chemistry at Dresden 2.

8906050014 890522
PDR ADOCK 05000237
P PNU

A009
1/1

Please contact this office should further information regarding this matter be required.

Very truly yours,

JA Silady

J. A. Silady
Nuclear Licensing Administrator

lm

Attachment

cc: A.B. Davis - Regional Administrator, Region III
B.L. Siegel - Project Manager, NRR
S.G. DuPont - Senior Resident Inspector, Dresden

3.3 HYDROGEN QUANTITATIVE ANALYSIS

The quantitative hydrogen content analysis using a LECO system was performed on samples taken from fuel rods, water rods, and spacers. The fuel rod samples were taken at about the same elevations as the metallographic samples. The water rod and spacer sample locations are shown in Figures 4 and 5.

The hydrogen contents on the six fuel rods from the 0/2 and 1/2 bundles are shown in Table 7. It can be seen that the hydrogen contents in the F7 and G3 rods of the 0/2 bundle were less than 20 ppm at all the locations analyzed. The G6 rod of the 0/2 bundle had higher hydrogen contents at the 40-to-110-inch locations, which correspond to higher nodular corrosion at those locations. The three 1/2 cycle rods had on average higher hydrogen two times higher content than the 0/2 rod. The hydrogen contents in the two unirradiated Zircaloy-2 archive tubes are also shown in Table 7. The average hydrogen content in the archive tubes is 14 ppm.

The hydrogen contents in the two water rods from Bundle LY5458 (0/2) are shown in Table 8. The hydrogen contents at the 100- and 110-inch locations, where nodular corrosion was low, were in the range of 24 to 31 ppm. At the lower elevations,M where heavy nodular corrosion was found metallographically on the outer surface, hydrogen contents up to 110 ppm were found. The hydrogen contents in the Zircaloy-4 spacers are shown in Table 9 for Spacers 1, 2, 5, and 6. Samples were taken from the sidebands and corner-bands only. It can be seen that the hydrogen value ranges from 23 to 41 ppm, and that little variation was found from location-to-location or from spacer-to-spacer.

Table 7

HYDROGEN CONTENT IN IRRADIATED DRESDEN FUEL CLADDING AND UNIRRADIATED ARCHIVE CLADDING SAMPLES (ppm)

Bundle Number	LY5458 (0/2)			LJ4345 (1/2)		
Rod Number	F7	G6	G3	D7	E8	C7
Fuel Type	UO_2	UO_2	Gd	UO_2	UO_2	Gd
Axial Position (Inches from bottom end plug)						
110	17	26	17	43	43	47
90	15	24	11	40	36	45
38.5	15	29	14	30	29	54
30	16	14	8	32	28	39
20	14	13	10	35	48	42
10	14	14	10	64	50	183
Avg.	15	20	12	41	39	68

Unirradiated Archive (ppm)

Tube A	Tube B
14	15
10	18
9	18

Avg. = 14 ppm

Table 8

HYDROGEN CONTENT IN WATER RODS FROM BUNDLE LY5458 (0/2) (ppm)

ELEVATION (Inches from bottom end plug)	Rod E4	Rod D5 (Capture Rod)
110	31	26
100	24	26
40	64	66
30	81	79
20	38	110
10	33	74

Table 9

HYDROGEN CONTENT IN SPACERS FROM BUNDLE LY5458 (0/2)

Spacer Number	Location in Spacer	Hydrogen, ppm
6	Corner Band 1-4	41
	Corner Band 2-4	37
	Sideband 2	27
	Sideband 4	37
5	Corner Band 1-4	35
	Corner Band 2-3	40
	Sideband 2	32
	Sideband 4	35
2	Corner Band 1-4	23
	Corner Band 2-3	32
	Sideband 2	35
	Sideband 4	33
1 (Bottom Spacer)	Corner Band 1-4	31
	Corner Band 2-3	30
	Sideband 2	23
	Sideband 4	Lost
	Avg.	33

The oxide thickness values measured metallographically are compared with the non-destructive eddy current oxide thickness measurement (ROXI) data, as discussed in the Appendix to this report. It can be seen that the ROXI data are within approximately ± 25% of the metallographical values. Because of the lack of point-to-point correlation, the correlation is considered to be good.

4.2 HYDROGEN UPTAKE

The hydride distribution in the fuel rods, as shown in the photomicrographs in Figures 19-21 and from 25-27, indicates that the uptake of hydrogen by the 0/2 and 1/2 cycle fuel rods was so low that no effect on rod performance due to hydrogen uptake is anticipated. The lower hydrogen contents in the three 0/2 cycle rods, as compared with the 1/2 cycle rods, are consistent with the lower overall corrosion found on those rods. Among the three 0/2 cycle rods, Rod G6 showed higher nodular corrosion at the higher elevations and was found to have higher hydrogen content at the higher elevations, as compared to the lower elevations and the two other lower corrosion rods, F7 and G3, as shown in Table 7. The three 1/2 cycle rods had higher hydrogen values at the 10-inch location, where a light greyish sheet oxide layer of slightly higher thickness than the adjacent area was found (Figures 9 to 11). This again suggests that the relatively higher hydrogen values at some locations of the fuel rods can be attributed often to higher corrosion at those locations. However, the significantly higher hydrogen value of 183 ppm at the 10-inch location of the Rod C7 cannot be fully rationalized on the basis of higher corrosion at that location.

The axial variation of hydrogen in the rods from the 0/2 and 1/2 bundles is compared with that of the rods from the 0/1, 3/0, and 2/1 bundles as shown in Reference 4 (Figure 42). The data at each elevation is the average of all three rods from the same bundle. It can be seen that the hydrogen contents in the 0/2 rods were about the same as that in the 0/1 rods, even though the former had one additional cycle of operation under the hydrogen water chemistry condition. The results imply that the primary controlling mechanism of hydrogen uptake in those two bundles is the degree of Zircaloy corrosion rather than the length of in-reactor exposure, since the average corrosion in these two bundles was about the same regardless of the length of exposure.

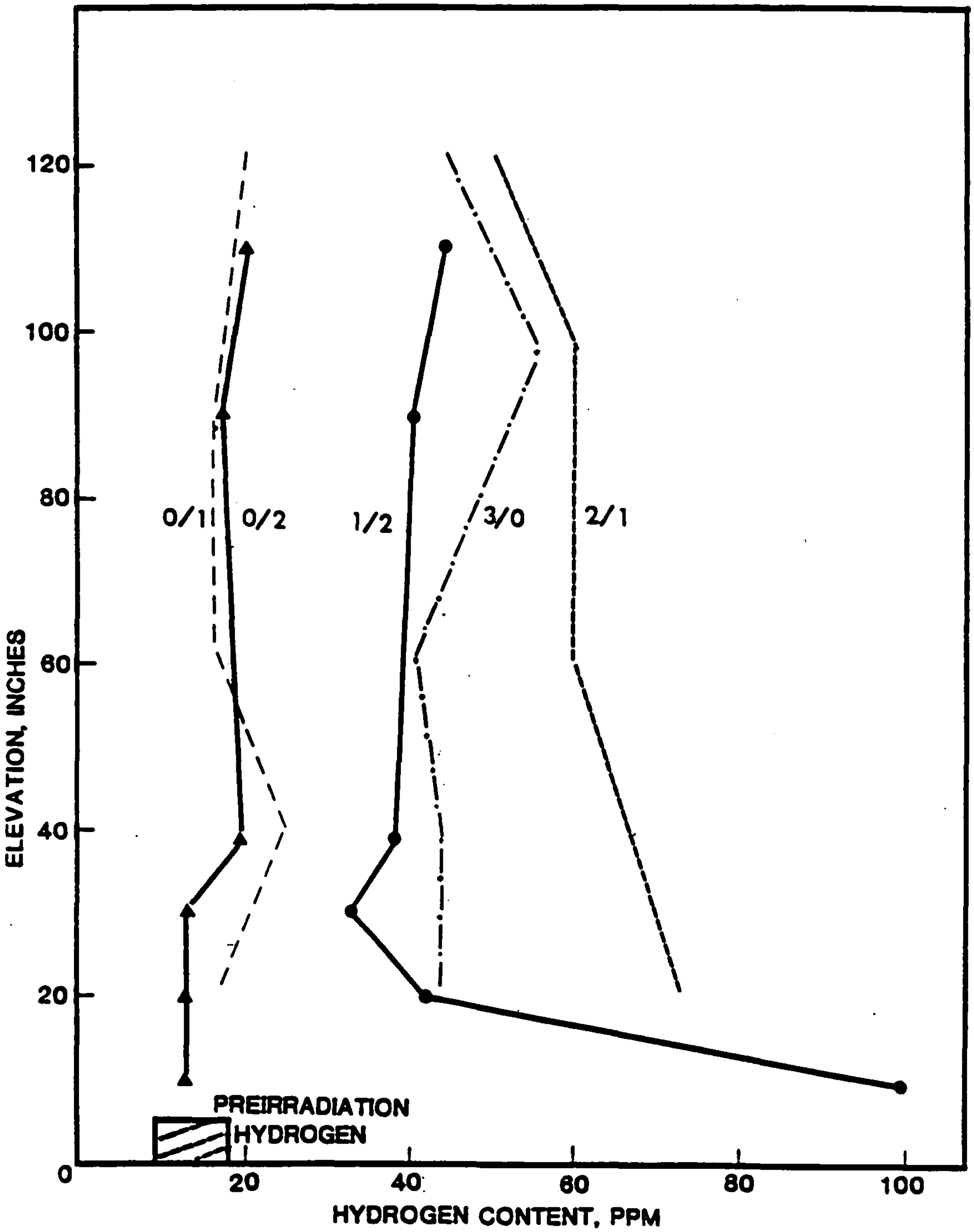

Figure 42 Axial Variation of the Average Hydrogen Content in the 0/2, 1/2, 0/1, 3/0, and 2/1 Cycle Fuel Rods

The 3 three-cycle bundles, 1/2, 2/1, and 3/0, had relatively comparable hydrogen contents in the range of 40 to 70 ppm, except the 10-inch location of the 1/2 bundle. The high average hydrogen value at the 10-inch location of the 1/2 rods was mainly due to the exceptionally high value of Rod C7. Excluding the Rod C7 data, the 1/2 rods had about the same values as the 2/1 and 3/0 rods (Figure 42). It is seen that the overall hydrogen content increases in the order of 1/2, 3/0, and 2/1 bundles. Again, this is consistent with the comparative degree of corrosion in those three bundles. On the other hand, the hydrogen values have no correlation with the number of cycles of exposure to the hydrogen water chemistry condition. The results indicate that the high hydrogen value of the 10-inch location of Rod C7 may be a deviation, rather than indicating a general trend of the effect of the HWC on Zircaloy hydrogen uptake. Overall, there is no indication that the HWC has an adverse effect on the hydrogen uptake of the fuel cladding.

The axial variation of hydrogen in the Zircaloy-2 water rods and Zircaloy-4 spacers from the 0/2 bundle is shown in Figure 43, using the data in Table 8. Higher hydrogen values in the range of 80 to 110 ppm were found on both Water Rods D5 and E4 at the 10-to 40-inch locations. At the upper elevations (100- to 110-inches) of both rods, the hydrogen contents in the Zircaloy-2 water rods were equivalent or slightly less than the values in the Zircaloy-4 spacers. The high hydrogen peaks at the 10-to 40-inch locations of the water rods also correspond to high nodular corrosion at those locations.

The spacers showed slightly higher corrosion at the higher elevations (i.e., Spacers 5 and 6 at the 100- and 120-inch locations, respectively). This corresponds to slightly higher hydrogen contents in Spacers 5 and 6, as compared with that in Spacers 1 and 2. Overall, the axial hydrogen distribution patterns of the water rods and spacers shown in Figure 43 qualitatively correlates well with the axial corrosion patterns of the corresponding components.

When the hydrogen data of the 0/2 bundle water rods and spacers in Figure 43 are compared with the data obtained on the 0/1 bundle components, it can be

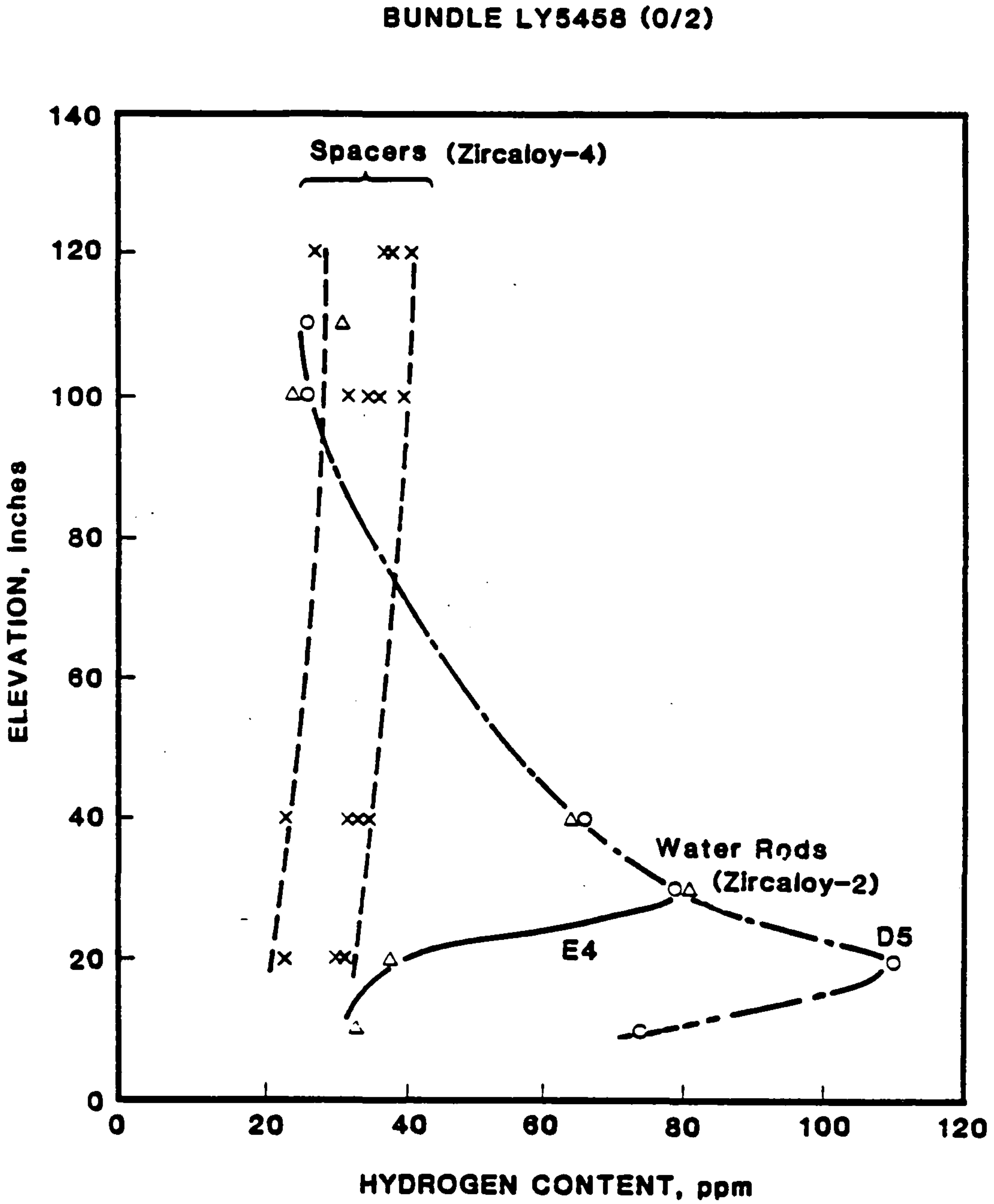

Figure 43 Axial Variation of the Average Hydrogen Content in the Water Rods and Spacers From Bundle LY5458 (0/2)

seen that the hydrogen values in the former increased by about 20-30%, except the 0/2 bundle water rods, which had up to 200% increase at the 30- to 40-inch locations. The 0/2 cycle water rods also had substantially higher hydrogen contents at the 20- to 40-inch locations than the fuel rods from the same bundle. This is due to higher corrosion found on the water rods at those locations and possibly also because of high heat fluxes on the fuel rod surfaces, which would promote removal of hydrogen from the surface, hence, reducing absorption of hydrogen by the fuel cladding.

The hydrogen pickup fraction is calculated using the oxide thickness values, nodular coverage fractions, and hydrogen content data listed in Tables 3, 4, 2, 7, and 9, respectively. The oxide thickness on both the outer and inner surfaces (when applicable) and the percent nodular oxide coverage were incorporated to calculate the effective oxide thickness shown in Table 10. Table 10 lists the pickup fraction at various elevations for the two water rods and spacers from the 0/2 bundle, and all six fuel rods from the 0/2 and 1/2 bundles. Both the unadjusted and adjusted hydrogen pickup fractions are shown. The latter were calculated after subtracting the average pre-irradiation hydrogen content, 14 ppm, as shown in Table 7, from the actual hydrogen content values. It can be seen that the adjusted hydrogen pickup fractions of the 0/2 fuel rods are less than 2%, which is far less than the values calculated for the spacers and water rods from the same bundle. The difference is again attributed to the existence of heat flux on the fuel rod surface. The Zircaloy-4 spacers and the Zircaloy-2 water rods have about the same hydrogen pickup fraction, in the range of 4-10%. The discharged 1/2 rods have an oxide thickness range of 10-15 μm and a hydrogen pickup fraction of 3-7%, except the 10-inch location of Rod C7, where an adjusted hydrogen pickup fraction of 30% is estimated. There is no clear indication from the data to allow an explanation of this anomaly. The unadjusted hydrogen pickup fractions in Table 10 are generally in the range of 5-14%. The values are in agreement with the range of data generated on a group of Zircaloy-2 and Zircaloy-4 coupon samples irradiated in the Steam Generating Heavy Water Reactor-Winfrith.[15]

4.3 EFFECT OF HYDROGEN WATER CHEMISTRY

The effect of hydrogen addition in the feedwater on the corrosion and hydriding of fuel components at Dresden-2 can be evaluated by comparing the corrosion and

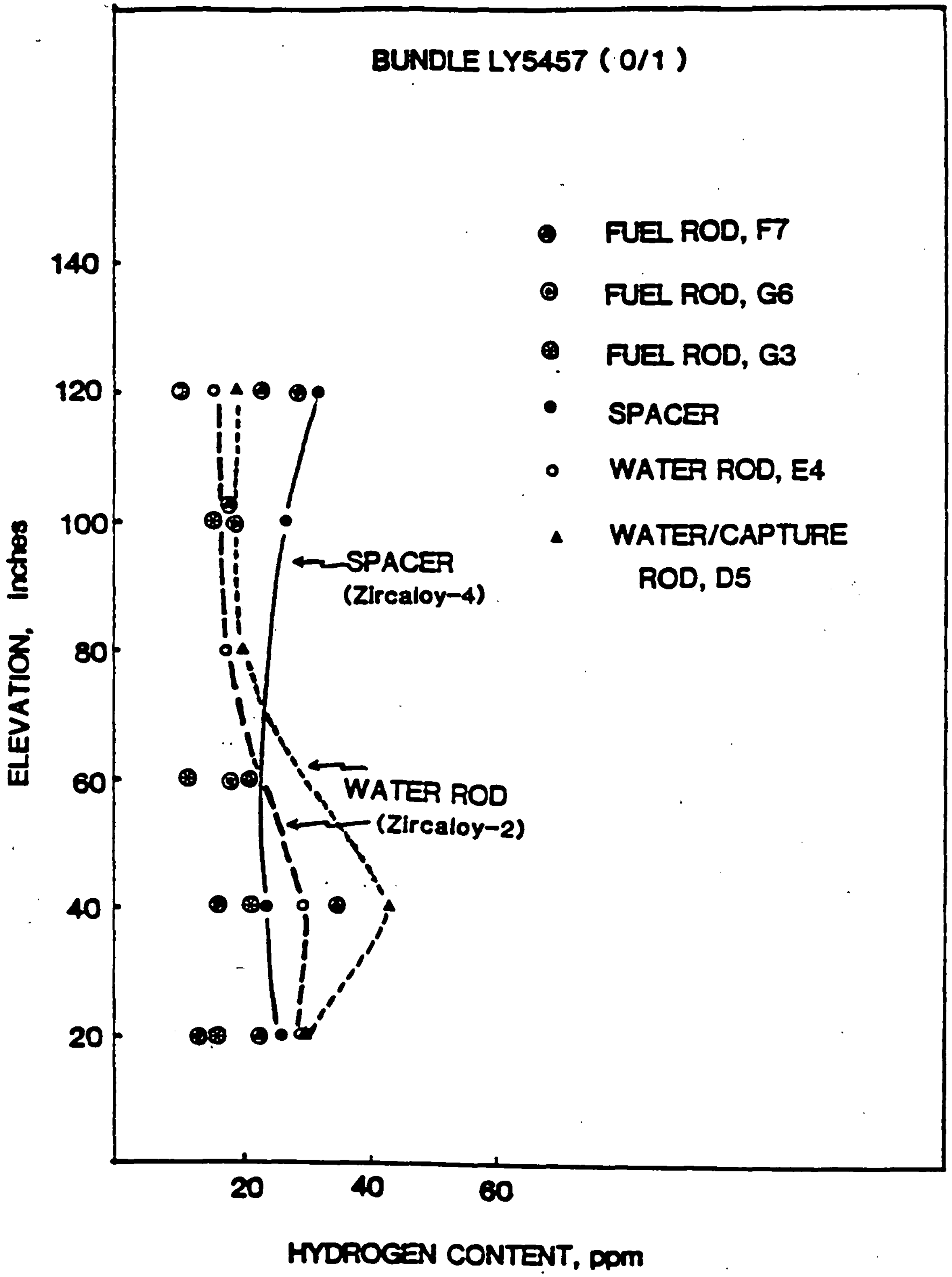

Figure 44. Hydrogen Content as a Function of the Axial Location for the 0/1 Bundle Fuel Rods, Spacers, and Water Rods

Table 10

CALCULATION OF HYDROGEN PICKUP FRACTIONS FOR FUEL AND WATER RODS

Rod Type	Elevation, (Inches)	Eff. Oxide Thickness,μm	Theoretical Hydrogen,ppm	Actual Hydrogen,ppm	% Pickup	% Corrected*
Water Rods (Zircaloy-2)						
0/2 - D5	30	3+ 14 = 17	646	79	12	10
0/2 - D5	110	3 + 6 = 9	342	26	8	4
0/2 - E4	30	3 + 21 = 24	912	81	9	7
0/2 - E4	110	3 + 6 = 9	342	31	9	5
Spacers (Zircaloy-4)						
0/2 - 2	40	7.2	274	31	11	6
0/2 - 5	100	8.4	319	36	11	7
0/2 - 6	120	8.4	319	36	11	6
Fuel Rods (Zircaloy-2)						
0/2 - F7	20	3	114	14	12	0
0/2 - F7	30	3.5	114	16	14	2
0/2 - F7	110	4.7	178	17	10	2
0/2 - G3	30	4	152	8	5	0
0/2 - G3	110	4	152	17	11	2
0/2 - G6	30	4.7	178	14	8	0
0/2 - G6	110	13.7	519	26	5	1
1/2 - C7	10	15	570	183	34	30
1/2 - C7	30	10	380	39	10	7
1/2 - C7	110	13	494	47	9	7
1/2 - E8	30	12	456	28	6	3
1/2 - E8	110	15	570	43	8	5
1/2 - D7	30	10	380	32	8	5
1/2 - D7	110	18	684	43	6	4

*Corrected by subtracting an average preirradiation hydrogen value of 14 ppm from each hydrogen reading.

hydrogen data obtained on the fuel components having variable history of exposure to normal and HWC conditions.

The low corrosion and hydriding results of the 0/1 and 0/2 bundles (Figures 37, 38, and 42) clearly indicate that, as long as the Zircaloy material has good corrosion resistance, the HWC condition does not have an adverse effect on the in-reactor performance characteristics. The relatively low and narrow oxide thickness range of the 1/2, 2/1, and 3/0 cycle rods (Figures 39 and 40) and the slightly lower hydrogen contents in the 1/2 rods as compared to the other rods both also suggest that the hydrogen addition in the feedwater did not have a clear adverse effect on fuel rods having prior exposures to the normal water chemistry condition at Dresden-2.

Although the trend of benign effect of hydrogen water chemistry on fuel components at Dresden-2 is becoming evident, the high hydrogen uptake and pickup fraction (30%) at the 10-inch location of the Rod C7 would lead to questions regarding the hydrogen uptake characteristics of fuel rods having high corrosion from prior exposure to normal (oxidizing) water chemistry, as suggested by Cox.[16] This possibility exists, since the hydrogen addition is expected to modify the water chemistry characteristics of the bottom 20 to 30 inches of the core much more than at higher elevations. Thus, any effect of the hydrogen water chemistry on Zircaloy hydriding characteristics is expected to be more significant at the bottom 20 inches of the fuel rods. Future work is needed to clarify this question.

In addition to the fact that hydrogen water chemistry does not have an adverse effect on high corrosion-resistant cladding, results from the present program also suggest that the hydrogen water chemistry may have a beneficial effect on Zircaloy corrosion and, hence, hydrogen uptake. In particular, there is an absence of oxide growth with time when comparing the data obtained on the 0/1 and 0/2 cycle components. This can be attributed to a change in either the Zircaloy material characteristics, or the hydrogen water chemistry, or the Dresden-2 plant water chemistry purity, or a combination of these factors.