ATTACHMENT 3

CHEMICAL ANALYSIS

OF

REACTOR VESSEL HEAD

TORUS-TO-DOME WELD SAMPLES

FROM

H. B. ROBINSON UNIT 2

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INTRODUCTION

The purpose of this analysis is to determine the copper and nickel contents of the H. B. Robinson Unit 2 reactor vessel limiting intermediate-to-lower shell girth weld. Since sampling of the reactor vessel girth weld is impractical, an analysis by indirect methods was necessary. A review of the reactor vessel weld fabrication records showed that the same weld wire heat and flux type was used in welding the torus-to-dome weld seam as was used for the intermediate-to-lower shell girth weld seam. Thus, the chemistry of a sample taken from the torus-to-dome weld represents the chemistry of the limiting intermediate--to-lower shell girth weld. In addition to copper and nickel, the torus-to-dome weld was analyzed for carbon, manganese, phosphorus, sulfur, silicon, molybdenum, vanadium, and chromium. The results of this analysis shall be justified so that they can be used in safety related analyses for the H. B. Robinson Unit 2 reactor vessel.

BACKGROUND

Current pressurized thermal shock regulations use the copper and nickel contents of reactor vessel materials to predict the reduction in vessel fracture toughness due to neutron irradiation. However, many older plants, like the H. B. Robinson Unit 2 reactor vessel, were fabricated prior to the realization of copper and nickel's deleterious effect upon neutron embrittlement, and thus their elemental contents were not officially documented. Older plants that lack the copper content of the limiting beltline materials and welds have been required to use 0.35 wt. % copper for predicted changes in fracture toughness. Without a known nickel content, these plants are again required to use a conservative estimate of the nickel content for predicting changes in fracture toughness.

To update the H. B. Robinson Unit 2 reactor vessel material properties, a review of the weld records from the vessel fabricator, Combustion Engineering, was undertaken. It was discovered that the limiting reactor vessel beltline intermediate-to-lower shell weld and the reactor vessel head torus-to-dome weld had been fabricated with the same weld wire heat. Although the inaccessibility of the beltline weld made it impractical to sample, the reactor vessel head weld could be sampled and analyzed as a means of updating the reactor vessel beltline weld properties.

With an updated chemistry of the limiting weld, the future plant operating limits can be based on the actual chemistry instead of conservative approximations.

DISCUSSION

A review was conducted of all applicable weld procedures available from Combustion Engineering (C-E) in an attempt to correlate the procedures used in welding beltline region seams with those used in welding head seams. Table 1 is a summary compilation of information extracted from weld procedures and weld inspection records retrieved from Combustion Engineering on the welds of interest. Figure 1 pictorially identifies the welds of interest with their seam number and weld wire/flux type.

Table 1 shows that the torus-to-dome weld composition is representative of the limiting intermediate-to-lower shell weld. Both welds were made with 3/16" diameter Raco 3, Heat # 34B009 weld wire, with a 1/16" diameter Ni-200 addition and Linde 1092 flux. Although different flux lots were used, this would not lead to a difference in copper and nickel levels in the welds. Even though the head torus-to-dome weld was made with a single arc and the beltline intermediate-to-lower girth weld was made with two arcs in tandem, under both the single and tandem arc processes, the Ni-200 wire addition was regulated so that an approximately 1.0 weight percent nickel addition was aimed for. The travel rate and amperage differences affect only the weld penetration and bead size. The volume of weld metal deposited would not vary and thus, neither would the elemental composition. In summary, since no elemental composition difference is expected between single and tandem arc processes, samples of the torus-to-dome weld will be representative of the intermediate-to-lower shell girth weld.

Since the torus-to-dome weld was shown to be representative of the intermediate-to-lower girth weld, solid samples of the torus-to-dome weld were removed from the head of the H. B. Robinson Unit 2 reactor vessel. Solid samples were removed so that analyses could be run at different depths within the same sample. Two solid wedge shaped samples, 1/2 inch deep, were removed from the weld, one at the 45° azimuthal angle between CRDM Housings 26, 31, 46 and 51, and another at the 225° azimuthal angle between CRDM Housing 28, 35, 48, and 55. The samples were removed transverse to the weld to insure that at least part of the sample would contain weld metal at all depths.

The samples were polished and etched to verify that the samples were weld metal. Figure 2 shows that the sample removed from the 45° location is approximately 2/3 weld metal and 1/3 base metal. Figure 3 shows that the sample removed from the 225° location is entirely weld metal.

After verifying that the samples were indeed weld metal, they were prepared for chemical analysis. Small slices were taken thru-depth from the weld metal end of the 45° sample and from the 225° sample, and then sectioned into thirds, depthwise, for analyses of the upper one-third depth and the lower one-third depth, hereafter spoken of as the top surface and 1/2" depth samples, respectively (Figure 4). The samples were analyzed for C, Mn, P, S, Si, Mo, V, Cr, Ni, and Cu. The nickel and copper analyses were performed using inductively coupled plasma (ICP) emission spectroscopy. This technique offers excellent quantitative analysis capabilities, and is judged the most accurate method available for determining the copper and nickel content of the H.B. Robinson weld sample. The results of the analyses are listed in Table 2. The National Bureau of Standards' materials used in calibrating the ICP emission spectroscopy equipment are listed in Table 3. The great precision and sensitivity of ICP emission spectroscopy is reflected in the extremely low percentages of error for this method; especially for copper and nickel which show percentages of error of 3.8 and 2.9 percent, respectively.

The results of the copper analyses were very consistent, with the average of all the analyses being 0.187 wt. %. This value is in excellent agreement with a statistical evaluation of weld copper content made earlier by Westinghouse.[1)] Westinghouse concluded that the average as deposited copper content of Heat 34B009 is 0.18 wt. %. In addition, the copper results of the chemical analyses agree well with the conclusion of a detailed survey of C-E welds fabricated with RACO 3 wire made by Dr. T. U. Marston of EPRI.[2)] The EPRI survey concluded that the average as deposited copper content of welds fabricated with RACO 3 wire was 0.19 wt. %.

The results of the nickel analyses were initially less clear. The average of the analyses at the top surface was 0.38 wt. % Ni, and 0.80 wt. % at the 1/2" depth location. It appears that the Nickel-200 addition was terminated on the last pass or passes used to make up for mismatch between the adjoining plates. (During the locating of the torus-to-dome weld it was discovered that the weld was 4 1/2" wide at the top surface instead of the theoretical joint design of 1 1/2" wide, indicating a mismatch between the adjoining plates.) The results of the analyses would substantiate this practice since the analyses at the same depths on the two samples were consistent. The drop in nickel content from the 1/2" depth to the surface would be a result of dilution of the nickel by subsequent passes. In order to determine the approximate depth at which the Ni-200 wire was terminated, multiple electron microprobe point nickel analyses were made from the weld samples' top surface to the 1/2" depth. The resultant nickel analyses are given in Figure 5. The 45° and 225° nickel profiles show that the dilution zone of reduced nickel content is limited to the upper one-third to one-half of the weld sample. Thus, the 1/2" depth samples analyzed by ICP emission spectroscopy are completely out of the dilution zone. As such, the average of the 1/2" depth location analyses made by ICP emission spectroscopy, 0.80 wt. %, is determined to be the weld nickel content. (Although the point microprobe analyses did give quantitiative results, the accuracy of this method for determining the overall weld composition is less accurate than that of ICP emission spectroscopy. This is due to the localized nature of this analysis method and the problems this incorporates into equipment standardization and limited point analyses.)

CONCLUSIONS

Both the intermediate-to-lower shell girth weld and the torus-to-dome weld were made with 3/16-inch diameter Raco 3, Heat # 34B009 weld wire with a 1/16-inch diameter Ni-200 wire addition and Linde 1092 flux. Based upon the chemical analyses of two solid wedge shaped samples removed from the torus-to-dome weld it can be concluded that the copper content of the Raco 3, Heat # 34B009 welds in the H. B. Robinson reactor vessel is 0.187 weight percent. Based upon the chemical analyses at the 1/2-inch depth of the torus-to-dome weld samples, the nickel content of the Raco 3, Heat # 34B009 weld wire with Ni-200 addition, welds in the H. B. Robinson reactor vessel is 0.80 weight percent.

In summary, based upon the chemical analyses made, the H. B. Robinson reactor vessel welds made with 3/16-inch diameter Raco 3, Heat #34B009 weld wire with a 1/16-inch diameter Ni-200 wire addition and Linde 1092 flux have:

- An average copper content of 0.187 wt. %, and,
- An average nickel content of 0.80 wt. %.

REFERENCES

1. Yanichko, S. E., E. H. Williams and M. K. Kunka, "Evaluation of H. B. Robinson Unit 2 Reactor Vessel Beltline Region Weld Material Chemistry," May 1983, unpublished.

2. Marston, T. U., "H. B. Robinson Reactor Vessel and Surveillance Weld Properties," 1983, unpublished.

TABLE 1 - SUMMARY INFORMATION ON WELDS OF INTEREST

HEAD/ BELTLINE	SEAM	SEAM #	INFORMATION SOURCE: WELD PROCEDURE	INFORMATION SOURCE: REFERENCE PROCEDURE	WELD WIRE TYPE	WELD WIRE DIAMETER	WELD WIRE HEAT	Ni ADDITION	FLUX TYPE	FLUX LOT NO.	WELD WIRE: SINGLE OR TANDEM FEED	WELD WIRE: FEED RATE (IPM)	Ni-200: FEED RATE (IPM)	TRAVEL RATE (IPM)	AMPS	VOLTS	THEORETICAL w/o OF WELD: RACO 3	THEORETICAL w/o OF WELD: Ni-200
Head	Torus-to Dome	7-277B	6866-WS-3(a)	SAA-33H(1)	Raco 3	3/16"	348009	Yes	Linde 1092	3692	Single	≈85[3]	≈7[4]	13	650	31	99.0	1.0
Beltline	Int-to-Lower	11-273	WG-6866-273-1	SAA-33J(1)	Raco 3	3/16"	348009	Yes	Linde 1092	3724	Tandem	≈83[1]	6	22	600/550[2]	31	99.1	0.9

1) Each wire fed @≈41.5 IPM. Info. source - conversation w/CE
2) One wire @ 600 amps and one @ 550 amps.
3) Info source - conversation w/CE.
4) Calculated, given aim Ni addition of 1% (6866-WS-3(a))

TABLE 2

CHEMICAL ANALYSES OF H. B. ROBINSON UNIT 2 TORUS

TO DOME WELD, WELD WIRE HEAT NO. 34B009

Element \ Sample Location	Weld Sample Analyses (Wt. %)[a]			
	45° at Top Surface	45° at ½" Depth	225° at Top Surface	225° at ½" Depth
C	.144	.144	.145	.142
Mn	1.20	1.20	1.20	1.22
P	.012	.011	.012	.011
S	.016	.016	.015	.015
Si	.23	.25	.22	.21
Mo	.51	.51	.52	.52
V	<.008	<.008	<.008	<.008
Cr	.038	.038	.038	.038
Ni	.43	.75	.32	.84
Cu	.202	.180	.182	.183

(a) Analysis techniques used:

P - colormetric

Si - gravimetric

C, S - combustion

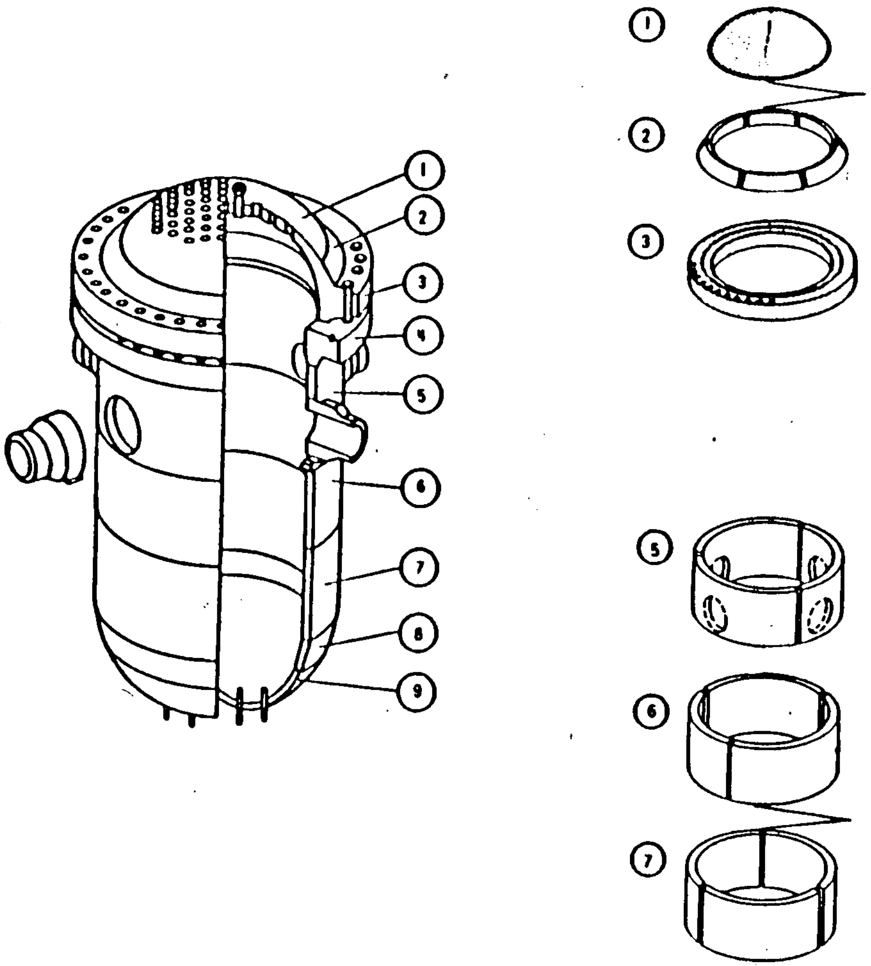
Remainder - inductively coupled plasma (ICP) emission spectroscopy

TABLE 3

STANDARDS USED FOR

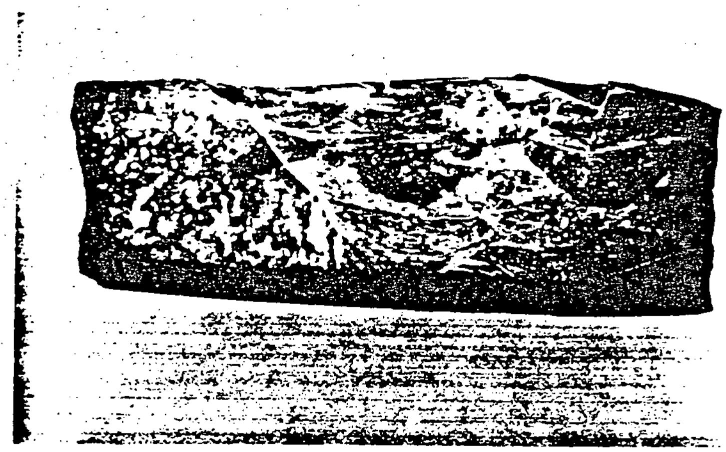
ICP EMISSION SPECTROSCOPY

STANDARD / ELEMENT	NUMBER	CERTIFIED ANALYSIS	LAB ANALYSIS	% ERROR
Mn	NBS-1168	0.47	0.45	4.3
Mo	NBS-1168	0.20	0.19	5.0
V	NBS-1165	0.002	<0.008	---
Cr	NBS-1165	0.004	0.004	0
Ni	NBS-1168	1.03	1.00	2.9
Cu	NBS-1168	0.26	0.25	3.8



WELD	WELD WIRE HEAT/FLUX TYPE
7-277B/DOME PLATE-TO-TORUS	34B009 + Ni - 200/1092
11-273/INTERMEDIATE SHELL-TO-LOWER SHELL	34B009 + Ni - 200/1092

FIGURE 1: ROBINSON UNIT 2 REACTOR VESSEL WELDS OF INTEREST.



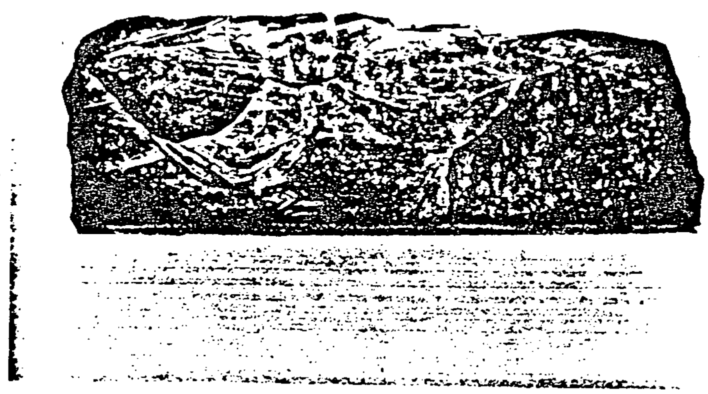


FIGURE 2: MACROGRAPHS OF 45° SAMPLE REVEALING THE WELD STRUCTURE

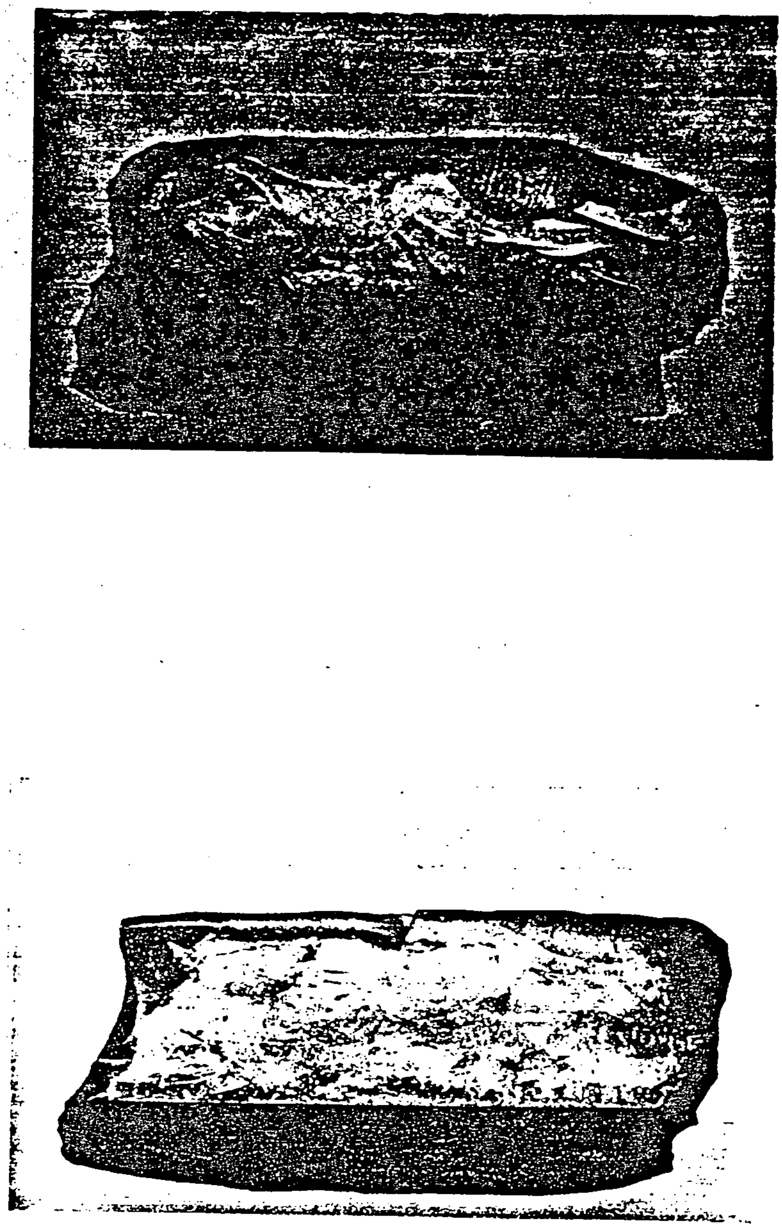


FIGURE 3: MACROGRAPHS OF THE 225° SAMPLE REVEALING THE WELD STRUCTURE

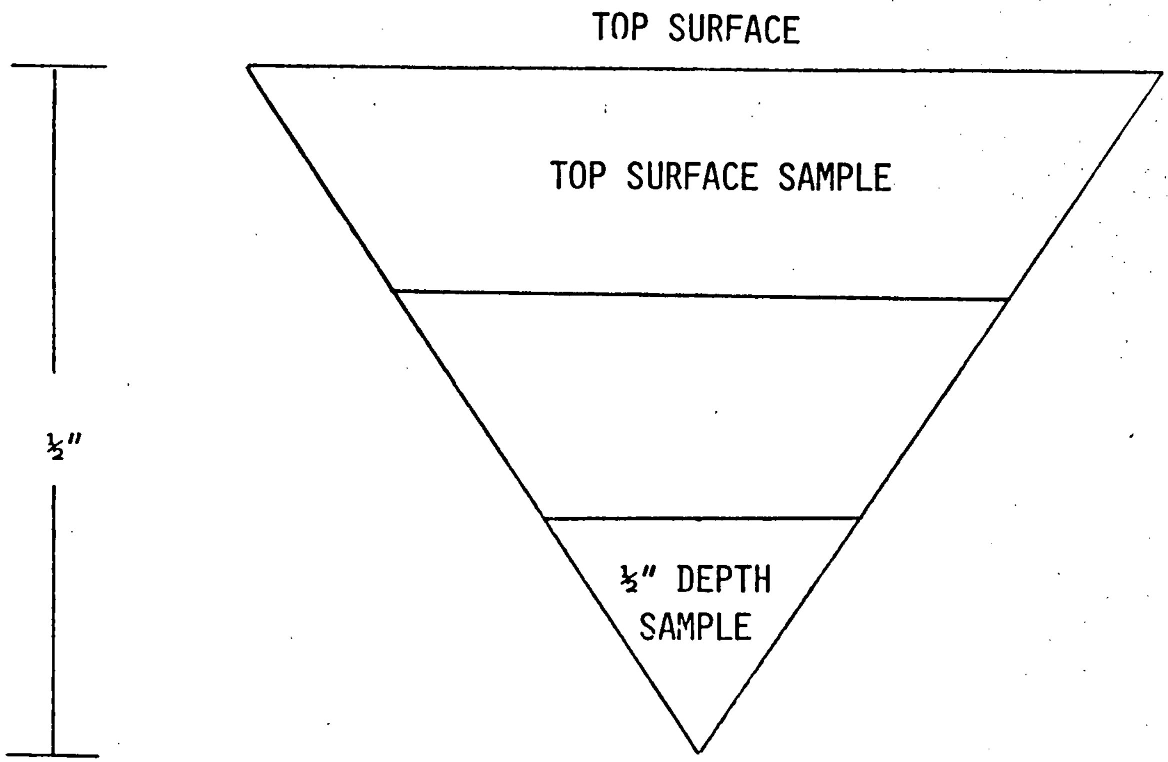


FIGURE 4: SAMPLE SECTIONING FOR CHEMICAL ANALYSIS

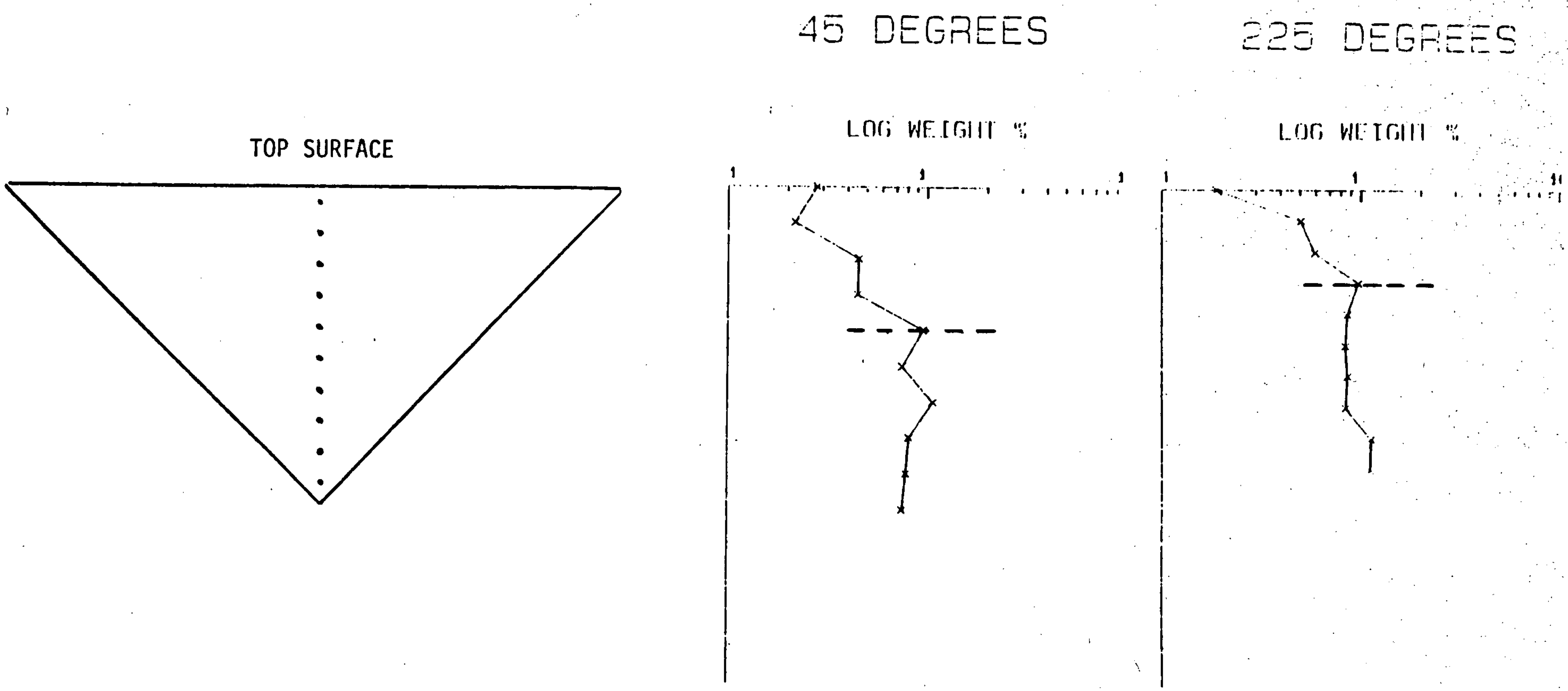


FIGURE 5: THRU-DEPTH NICKEL ELECTRON MICROPROBE SCANS OF 45° AND 225° SAMPLES