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HOMOGENEITY OF MARK VI CORES

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A. R. McJunkin

~~CONFIDENTIAL UNDOCUMENTED~~

~~May 20, 1957~~

D. M. Kaber, EAS - 10-18-73

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Introduction

A special study was initiated to determine the following items concerning the homogeneity of the uranium-aluminum cores used in the fabrication of Mark VI tubular fuel elements.

1. Axial and radial variations in uranium content throughout the core.

2. Optimum sampling points for the chemical analysis of uranium in the core.

3. Difference in the uranium content found by the analysis of massive samples and that found by the analysis of chip samples.

4. The relationship between the amount of uranium charged to the melt and the amount of uranium found by analysis of the core.

In this study, chemical determinations for uranium were made on two special cores prepared from virgin materials. Natural uranium was substituted for enriched uranium in the preparation of the cores. Period covered: September 20, 1956 to October 26, 1956.

Summary

Lathe chip samples and massive segment samples taken from five different locations in the cores (including the regular sample areas at each end) and lathe chips from the inside and outside of the machined cores were chemically analyzed using a volumetric oxidation-reduction procedure.

The data obtained from the analyses revealed that the cores are not uniform, axially or radially, in uranium content. A range of 0.98% (absolute) was found for 20 uranium determinations made on Casting No. 1, and a range of 2.67% (absolute) was found for 54 determinations made on Casting No. 2.

The uranium content obtained by averaging all determinations was found to be 15.89% on each of the cores analyzed. This was in excellent agreement with the calculated melt charge value of 15.91%. This type of sampling, however, is destructive and is not practical for routine testing.

The averages of the male and female chip samples (the technique currently used for estimation of uranium content) were 15.78% and 15.33% on cores No. 1 and No. 2, respectively, confirming previous observations that the uranium content of these samples tended to be lower than the true uranium content. The optimum practical samples appear to be male-end massive samples (16.04% and 15.83%) and male-end chip samples (16.14% and 15.86%), both of which are in closer agreement with theoretical values than the valu [redacted]

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Discussion

Preparation, Casting, and Sampling

With the cooperation of the 300-M Area Engineering Assistance Group, two special uranium-aluminum cores were cast on September 20, 1956, in Building 773-A. The raw materials used were high-purity aluminum and natural uranium metal. From the charge weights used, each melt was calculated to contain 16.01% uranium, assuming the uranium metal to be 100% pure; however, assay of the uranium indicated a purity of 99.40% resulting in a melt charge concentration of 15.91%.

The cores were cast following standard operating procedure and their appearance was described by a member of the Engineering Assistance Group as being above average with regard to surface voids. The crucible and cup skulls, dross, and miscellaneous scrap from each casting operation were collected separately, and in addition, three melt samples were taken from each of the melts. For identification, the cores were labeled Casting No. 1 and Casting No. 2.

A material balance was established for the casting operation by weighing the castings, scraps, and melt samples (table 1). These weights were also used for calculation of a theoretical uranium content for the machined core. This calculation, shown in table 2, represents Casting No. 2 only; the riser was not analyzed for Casting No. 1.

On September 25, 1956, Casting No. 1 was sampled using a lathe in Building 773-A. A sampling scheme (figure 1) was used that was designed to yield data for the various determinations listed in the Introduction. Two weeks later, Casting No. 2 was sampled in a similar manner with two modifications--closer control was maintained on the lathe settings resulting in more uniform sample size, and the core was scribed so that the relative position of the massive samples could be maintained after they were removed from the core.

The various samples were defined as follows:

1. <u>Rough chip cuts.</u> Lathe turnings from the exterior surfaces of the cores. The surfaces were removed to reduce the cores to specification size.

2. <u>Normal chip cuts.</u> Lathe turnings normally collected at each end of the Production cores and submitted to the Laboratory for analysis.

3. <u>Special chip cuts.</u> Lathe turnings from areas specifically selected for this study.

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4. Massive samples, 1/4-inch wafer. A ring cut out of the core from which small segments were taken for analysis (figure 2).

5. Riser. 1/4-inch massive segments cut out of the head or "riser" of the core at 90° intervals.

Each melt sample was taken by dipping a graphite spoon into the molten charge and removing a spoonful of the metal. After solidifying in the spoon, the metal was dumped onto the floor to cool. The samples were taken from just underneath the surface of the melt after stirring had been completed.

Cutting the massive 1/4-inch wafers from the cores was a slow, difficult, and hazardous operation with the lathe (two cutoff tools were broken). Using a 1/8-inch tool, a double cut was made in order to keep the cutout area about 1/4-inch wide. This prevented binding and overheating of the tool, and lessened the hazard involved. An area of approximately 1/2-inch-width was needed for the removal of each wafer from the cores.

In cutting the chip samples from the cores, the chip size was kept as constant as possible in order to regulate the surface area exposed to possible oxidation. A 0.020-inch lathe setting was used.

Analysis

The core samples were analyzed for uranium and iron in the Building 320-M laboratory. Iron was found to be less than 0.01%, a negligible interference, for which no correction was necessary. Uranium was determined by hydrochloric acid dissolution of the samples, reduction of the uranium in the solution with lead, and titration of the reduced uranium with a standard ceric sulfate solution. The relative precision of the method as determined in the Building 320-M laboratory is 0.82% at the 95% confidence level. The absolute precision of the analysis of a sample at the 16% ~~confidence~~ concentration level is 0.13%.

Table 3 contains a complete list of all the uranium values obtained for the determinations that were made on each of the cores.

For the massive samples, the wafer number identifies the position of the wafer in the core and the letter identifies the position of the sample segment in the wafer.

Tables 4 and 5 give a summary of the uranium results showing averages of multiple samples. These values show that the samples from the male end compare best with the theoretical values. The ranges given indicate the nonhomogeneity of the cores.

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Table 6 compares the various results to theoretical values calculated for the cores and points out the more reliable sampling locations. In these Tables, the position of the massive wafer in the core is identified by the number and the position of the sample segment in the wafer is identified by the letter.

Figure 3 presents a graphic illustration of the percent uranium found in the analysis of chip and massive samples versus the position in the cores from which the samples were taken.

Conclusions

Although analytical data on the two cores show that chips from the male end are the most representative practical samples, the wide variations observed between cores indicate that more information is needed before any conclusions may be drawn leading to changes in the sampling procedure. A study of the uranium analyses of chip samples from the male and female ends of routine production cores is being conducted to establish the relationships of these analyses with the uranium content as determined by the Nuclear Test Gage and by core density.

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Table 1. Material Balance from the Casting

	Casting No. 1	Casting No. 2
Aluminum charge, grams	9,240.354	9,240.175
Uranium charge, grams	1,760.980	1,761.320
Total charge, grams	11,001.334	11,001.495
Casting weight, grams	10,380.3	10,556.3
Crucible skull weight, grams	45.2	45.5
Cup skull weight, grams	272.5	198.6
Dross weight, grams	178.1	90.7
Miscellaneous scrap weight, grams	88.4	59.5
Melt samples weight, grams	32.6	48.8
Total weight recovered, grams	10,997.1	10,999.4
Percent recovery	99.97	99.98

Table 2. Calculation of a Theoretical Uranium Value for the Machined Core

"Riser" weight	3319.2 gm
Scrap - melt sample weight	1169.1 gm
Scrap - "riser" weight	4488.3 gm
Casting No. 2 charge weight	11001.5 gm
Scrap - "riser" weight	4488.3 gm
Machined core weight	6513.2 gm
Uranium content of "riser" (15.60% x 3319.2 grams)	517.8 gm
Uranium content of scraps* (15.75% x 1169.1 grams)	184.3 gm
Total uranium content scrap and "riser"	702.1
Weight of uranium in melt charge (99.40%)	1750.7 gm
Weight of uranium in scrap and "riser"	702.1 gm
Theoretical weight of uranium in machined core	1048.6

Theoretical % uranium in machined core $\frac{1048.6 \times 100}{6513.2} = 16.10\%$

* The scraps were not analyzed; the uranium value of the melt samples is used as the best available assumption.

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Table 3. Complete Tabulation of All Uranium Analyses

Sample Identity	Casting No. 1	Casting No. 2
Normal Chip Cut		
Male	16.14	15.86
Female	15.42	14.81
Special Chip Cut		
Male	16.02	15.73
Middle	15.95	16.17
Female	15.65	15.18
Chip Cut		
Inside Machine Casting	15.45	14.09
Outside Machine Casting	15.33	15.28
Melt Sample		
No. 1	15.81	15.76
No. 2	15.71	15.76
No. 3	15.73	15.73
Massive Sample		
Wafer No. 1		
a	16.04	16.19
b	-	16.36
c	-	16.59
d	-	16.40
e	16.04	15.47
f	-	16.76
g	-	16.10
h	-	16.04
Wafer No. 2		
a	16.09	16.31
b	-	16.21
c	-	16.29
d	-	16.14
e	16.31	15.92
f	-	16.26
g	-	16.15
h	-	15.90
Wafer No. 3		
a	15.86	16.09
b	-	16.15
c	-	15.82
d	-	15.77
e	16.29	15.80
f	-	15.34
g	-	16.16
h	-	16.15
Wafer No. 4		
a	16.05	15.88
b	-	16.01
c	-	16.29
d	-	16.33
e	16.10	16.05
f	-	16.52
g	-	16.23
h	-	15.76
Wafer No. 5		
a	15.98	15.71
b	-	15.84
c	-	15.87
d	-	15.83
e	15.91	14.98
f	-	15.82
g	-	15.88
h	-	15.70
Riser		
a	-	15.52
c	-	15.68
e	-	15.52
g	-	15.69

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Table 4. Uranium Values of Samples Taken from the Useful Sources of Sampling

	% Uranium	
	Casting No. 1	Casting No. 2
Theoretical		
Melt charge	15.91	15.91
Machined core	-	16.10
Chip Samples		
Male	16.14	15.86
Female	15.42	14.81
Average	15.78	15.33
Massive Samples	(2)*	(8)*
Male	16.04	16.31
Female	15.95	15.70
Average	16.00	16.01
Melt Samples		
1	15.81	15.76
2	15.71	15.76
3	15.73	15.73
Average	15.75	15.75

* Number of determinations.

Table 5. Summary of Analytical Results for Both Cores

	Casting No. 1			Casting No. 2		
	% U	No. of Analyses	Range	% U	No. of Analyses	Range
Melt Samples	15.75	3	0.10	15.75	3	0.03
Chip Samples						
Male & Female	15.78	2	0.72	15.33	2	1.05
Massive No. 1						
Male end						
a,e	16.04	2	0.00	15.83	2	0.72
a,c,e,g				16.09	4	1.12
a,b,c,d, e,f,g,h				16.31	8	1.29
Massive No. 5						
Female end						
a,e	15.95	2	0.07	15.25	2	0.73
a,c,e,g				15.61	4	0.90
a,b,c,d, e,f,g,h				15.70	8	0.90
Massive No. 1 & No. 5						
a,e	16.00	4	0.13	15.54	4	1.21
a,c,e,g				15.85	8	1.61
a,b,c,d, e,f,g,h				16.01	16	1.78
All Determinations*	15.89	20	0.98	15.89	54	2.67

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Table 6. Comparison of the Results with the Theoretical Uranium Content

	Difference in % U Charged (15.91) and % U Found		Difference in % U of Machined Core (16.10, theoretical) and % U Found
	Casting No. 1	Casting No. 2	Casting No. 2
Melt Samples	-0.16	-0.16	-0.35
Chip Samples, Male & Female	-0.13	-0.58	-0.77
Massive No. 1 Male end			
a,e	+0.13	-0.08	-0.27
a,c,e,g	-	+0.18	-0.01
a,b,c,d, e,f,g,h	-	+0.40	+0.21
Massive No. 5, Female end			
a,e	+0.03	-0.57	-0.85
a,c,e,g	-	-0.30	-0.49
a,b,c,d, e,f,g,h	-	-0.21	-0.40
Massive No. 1 & No. 5			
a,e	+0.08	-0.32	-0.56
a,c,e,g	-	-0.06	-0.25
a,b,c,d, e,f,g,h	-	+0.06	-0.09
All Determinations*	-0.02	-0.02	-0.21

* Includes all analyses except the "riser."

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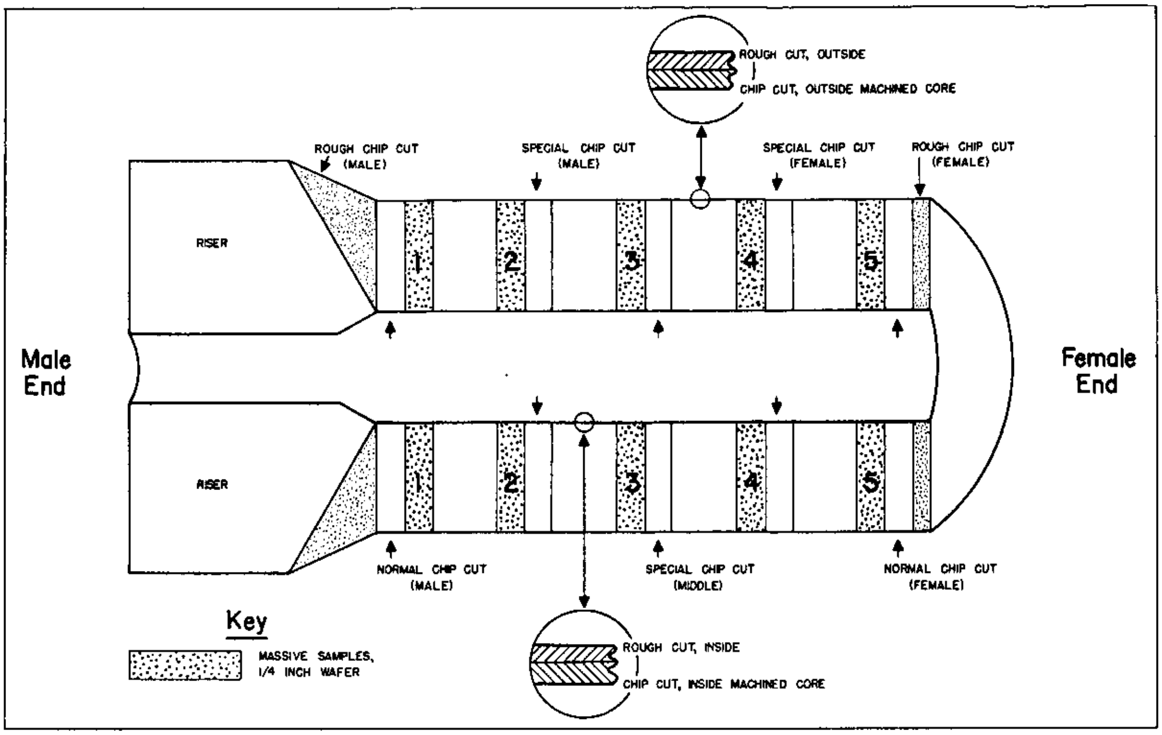

Figure 1. Axial Bisection of a Mark VI Core
Showing Location of Sampling Points

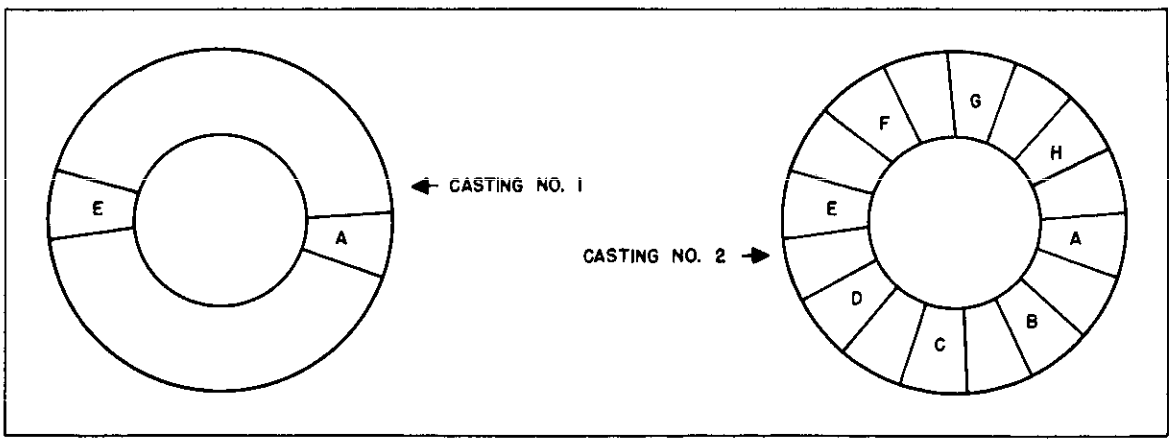

Figure 2. Locations of Sample Segments
in the Massive 1/4-inch Wafers

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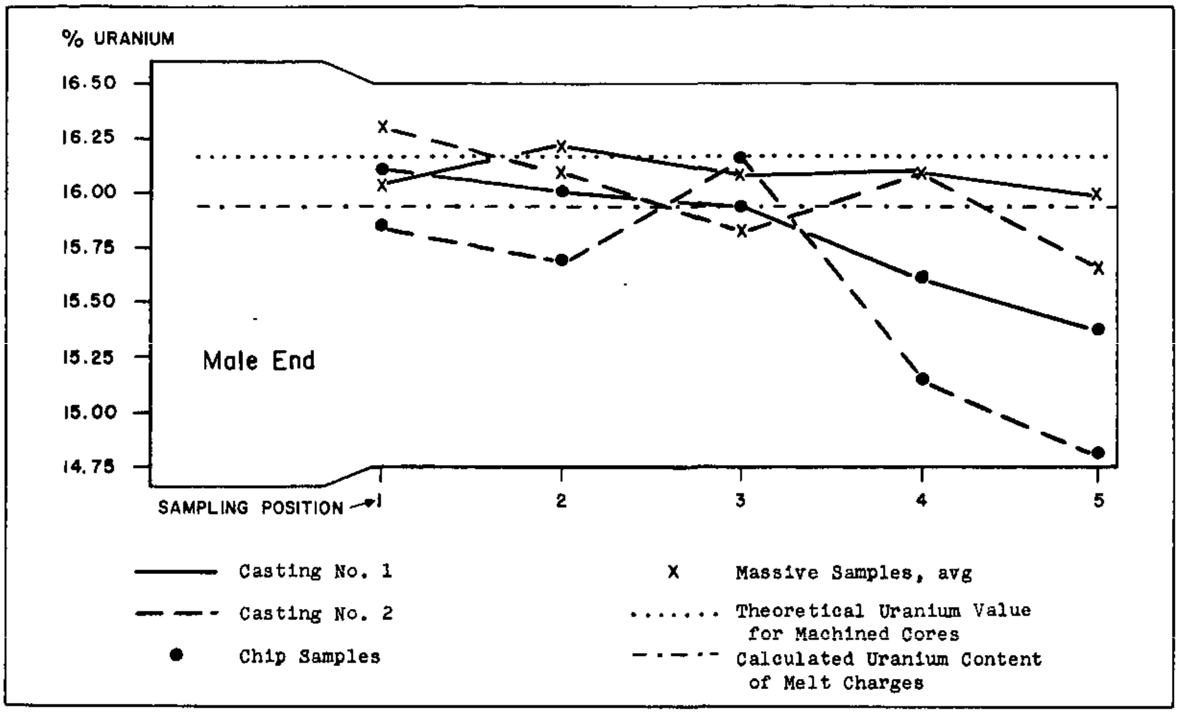

Figure 3. Graphical Presentation of Percent Uranium with Respect to Sample Position

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