AEC RESEARCH AND DEVELOPMENT REPORT

STANDARDIZATION AND EVALUATION OF GRAIN SIZE TEST FOR URANIUM FUEL

R. D. SPICE

JULY 1964

IRRADIATION PROCESSING

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By

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Irradiation Processing Department

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INTRODUCTION

This report describes the selection of "standard" fuel cores for calibrating an ultrasonic tester designated UT-2C. The UT-2C tester measures the grain size of uranium cores before cladding for use as reactor fuel elements.

The grain structure of uranium fuel cores for reactor use must be relatively uniform and within prescribed size limits. Cores of uniformly fine grain and random orientation are more dimensionally stable under irradiation than those with large grains and preferred orientation. Dimensional instability of fuel can cause its failure in-reactor.

Reactor outages resulting from fuel core failures are extremely costly due to the loss of production time. It is therefore economical to test the grain size of uranium cores before they are clad to prevent in-reactor failures due to dimensional instabilities.

A grain size scale for the uniform classification of uranium grain size has been established by an inter-site AEC Fuel Element Development Committee (FEDC).

Designations for large grain diameters begin at A-1 and succesively smaller grain diameters progress through A-7. The FEDC's method of determining grain size is a visual comparison of 3X macrophotographs of cross sectioned standard cores with cores of unknown grain size.

It has been demonstrated that the UT-2C tester, when properly calibrated, can accurately determine grain size. Fuel cores of known uniform grain size, designated as standards, must be used in calibrating the tester to assure its linearity over the entire grain size range of interest. Details of the UT-2C tester circuitry have been published.[1,2]

SUMMARY

Through the use of calibration standards, excellent correlation is obtained between actual fuel core grain size and the UT-2C tester's output voltage. The UT-2C tester can accurately measure grain size.

A technique was developed for selecting primary grain size calibration standards from production fuel cores with the UT-2C. Primary standards are reference standards only and are not used for routine production tester setup. They are used to calibrate the tester for selection of secondary standards which are then used for routine production line testing.

More accurate results can be obtained from the tester when the calibration standards have nearly the same diameter as the fuel cores being production tested. The positioning of the transmitting and receiving transducers is critical.

The present grain size range of A-1 through A-7 can be extended to define the A-8 and A-9 categories of fine-grained uranium. These categories have already been defined electronically with the UT-2C tester.

DISCUSSION

Fuel core grain size standards for calibration purposes can be obtained • from special material made by careful control of chemistry and heat treatment, or • through selection from production material with different grain size using UT-2C. Presently, selecting standards with the UT-2C (Figures 1 and 2) is the most reliable and economical method.

The UT-2C's output is a voltage which is inversely proportional to the grain size of fuel cores (as the fuel core grain size gets smaller, the output voltage increases). Figures 3 and 4 depict a core with extreme variations in grain structure. The voltage indicated by the tester for any given grain size fuel core can be adjusted to read almost any desired voltage. It was therefore necessary to measure the grain size of several different cores ultrasonically and then examine them metallographically to determine their actual grain size. These data and subsequent adjustments to the tester resulted in the curve (Figure 5) correlating grain

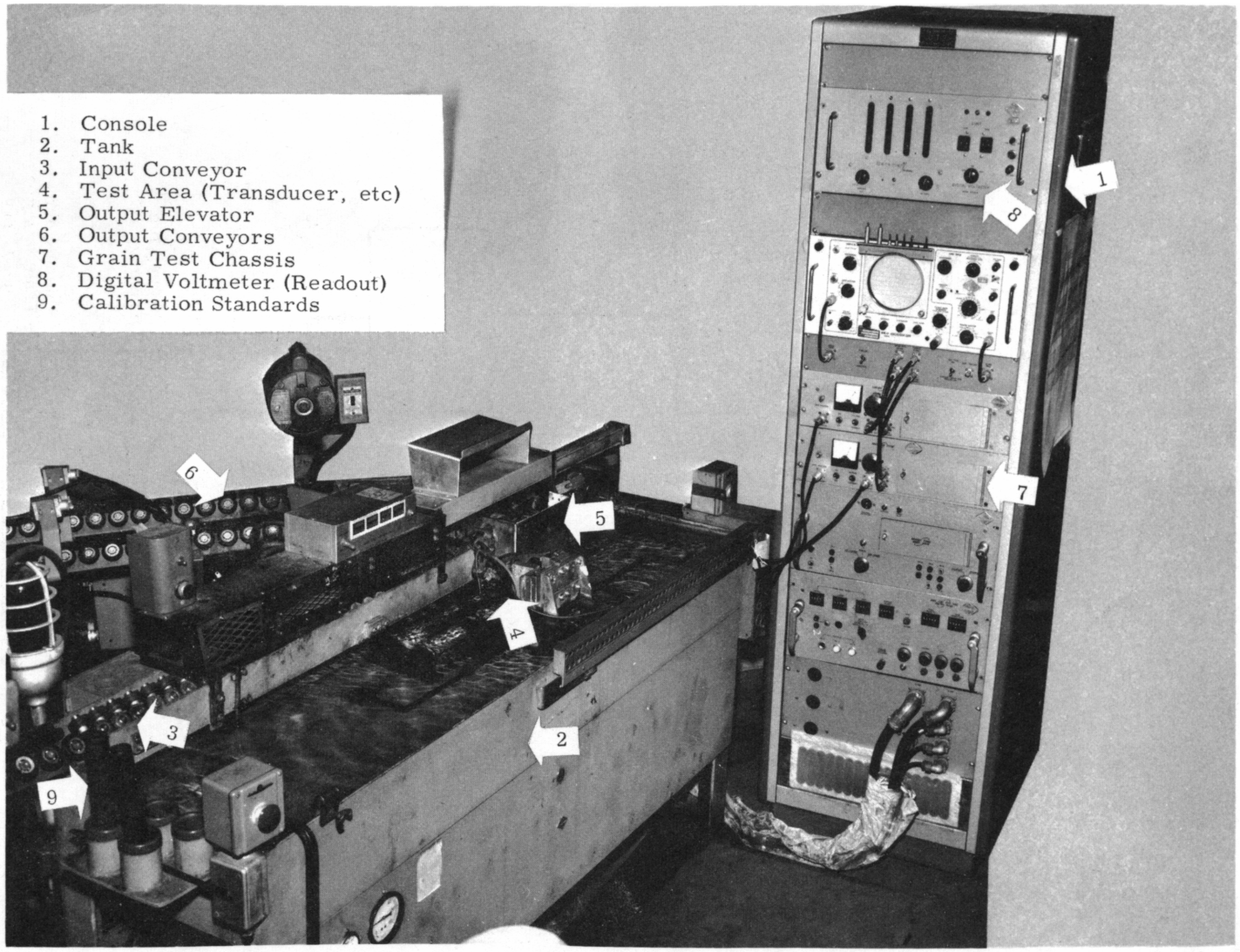

FIGURE 1

UT-2C Bare Uranium Core Tester

size with tester output voltage. When the tester is properly calibrated with known standards and ready for operation, the transducer height must be adjusted for maximum signal output for the size fuel core under test (Figure 2). The curves in Figure 6 represent the relationship between tester output voltage and transducer height. Maximum output voltage occurs at different transducer heights for fuel cores with different diameters. Experiments indicate that all cores having the same outer and inner diameters, pass maximum ultrasonic energy at the same transducer height. All voltage readings, taken in subsequent tests were taken with the transducers adjusted for maximum signal amplitude on the fuel cores under examination.

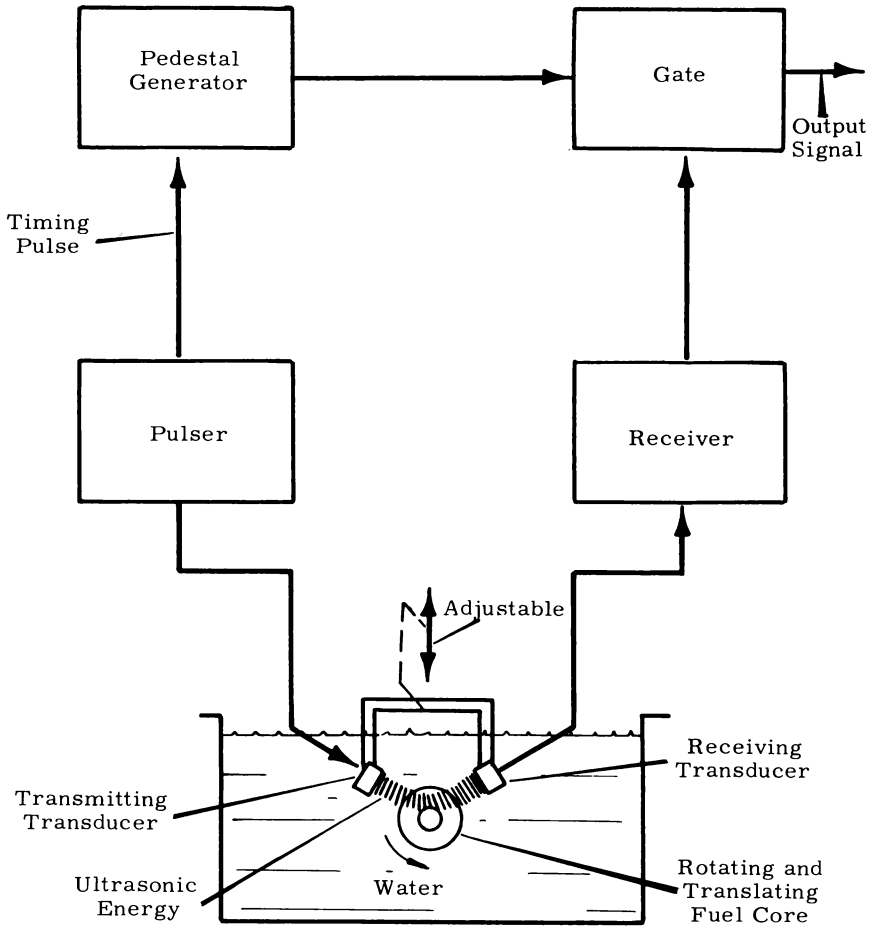

FIGURE 2

Grain Size Test Schematic Diagram

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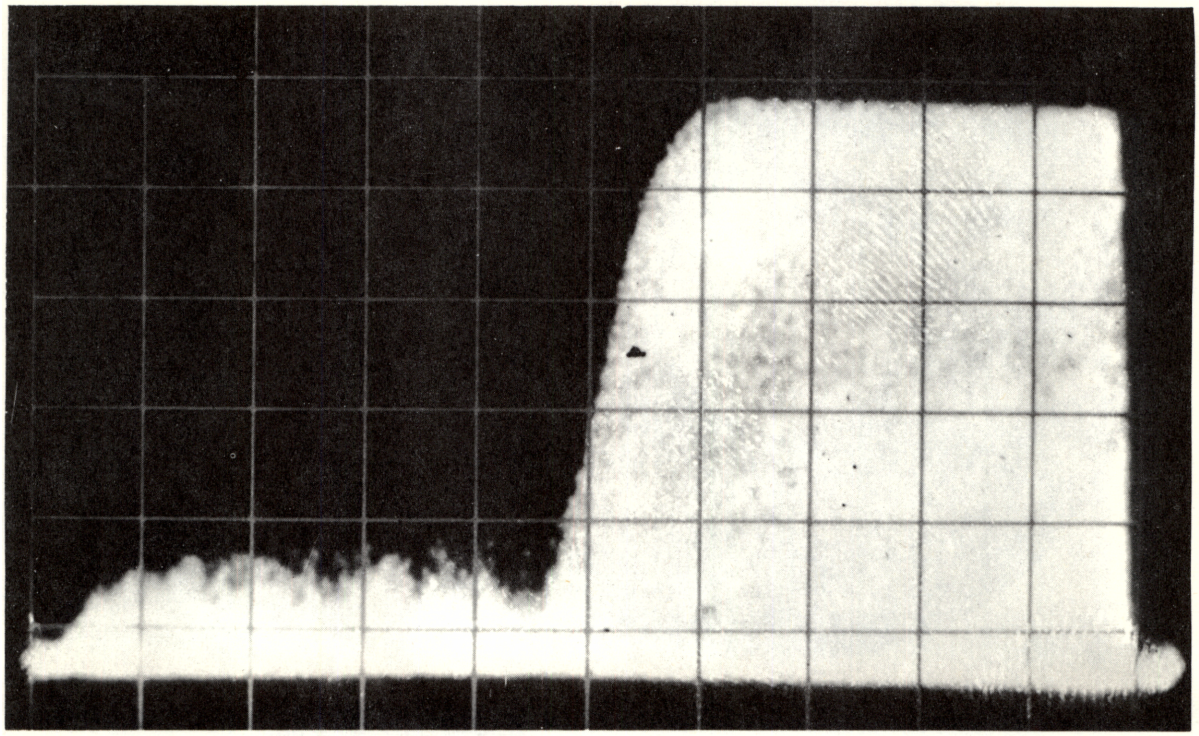
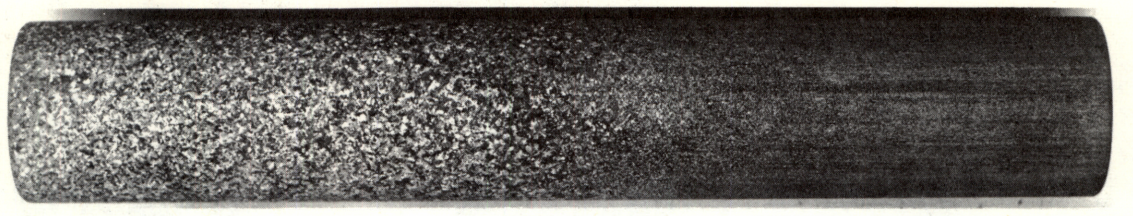


A.



B.

FIGURE 3

A. Memoscope Representation of Ultrasonic Attenuation Characteristics of a Uranium Fuel Core

B. Grain Structure of the Fuel Core Represented in the Above Memoscope Picture

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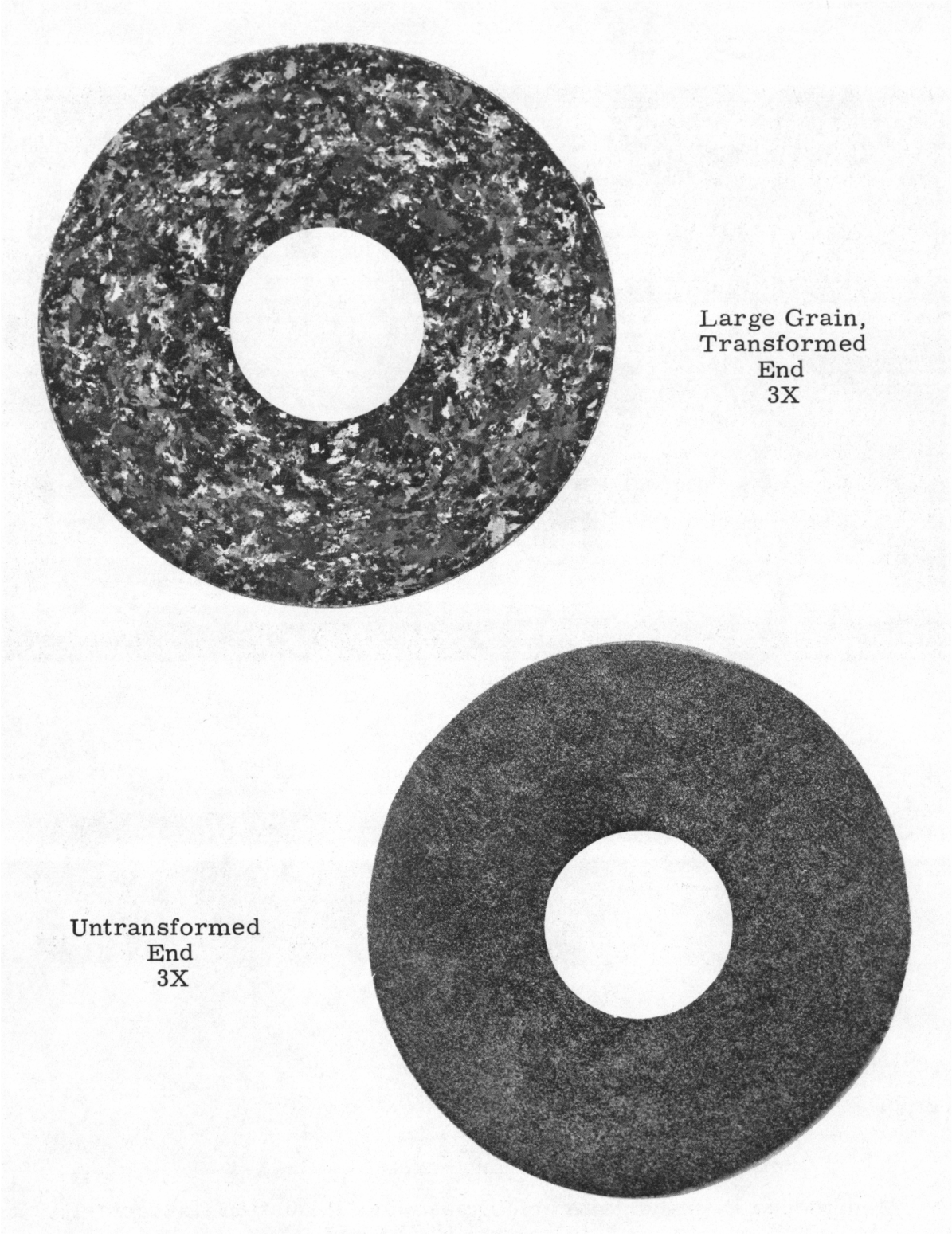

FIGURE 4

End Macrophotographs of the Core Shown in Figure 3

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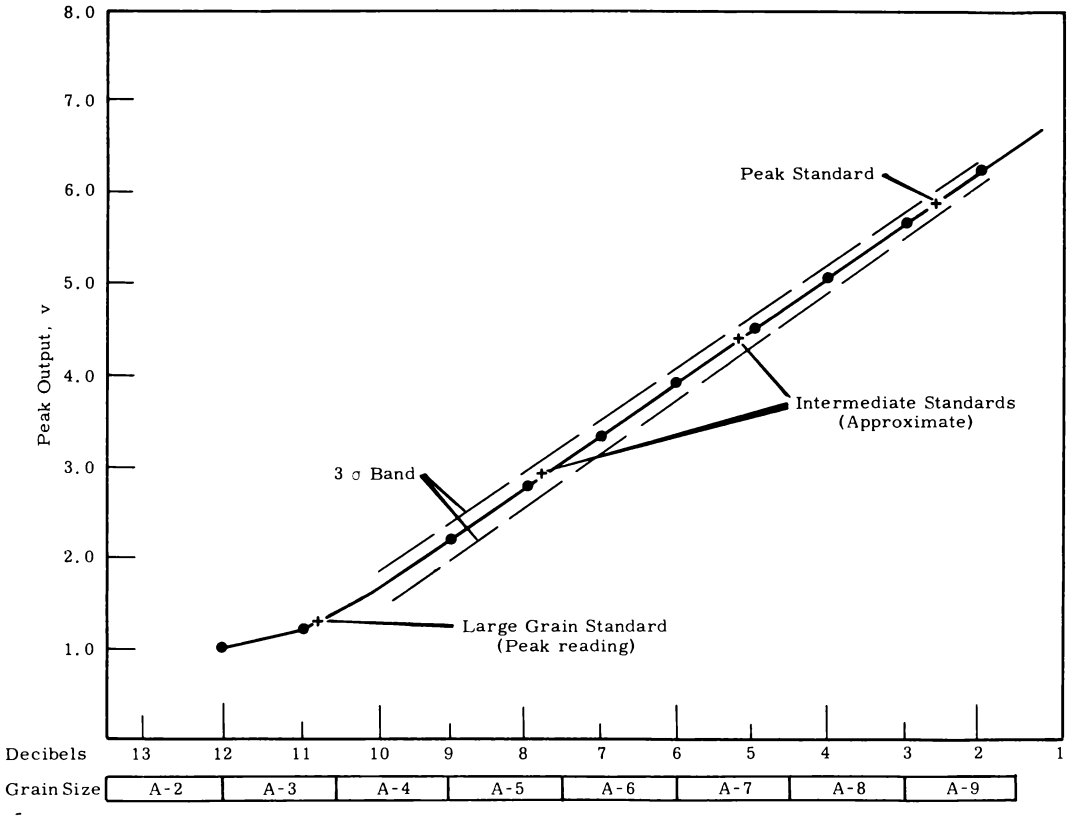

FIGURE 5

UT-2C Peak Output Voltage vs. Grain Size
(With 3σ confidence band)

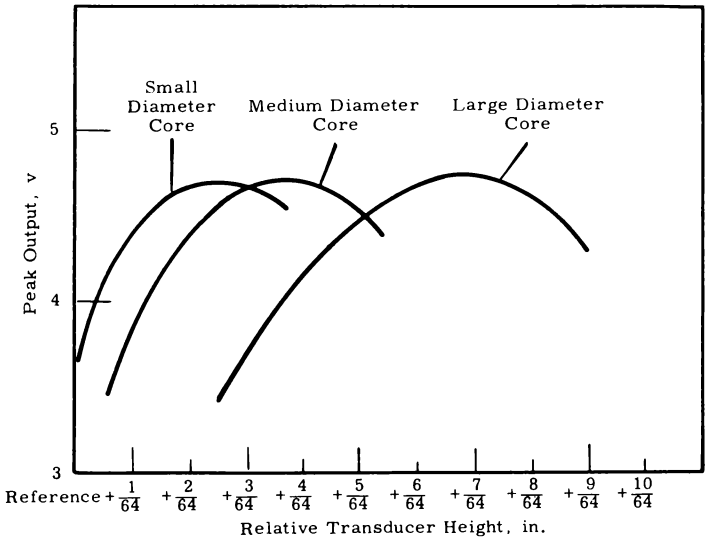

FIGURE 6

Fuel Core Output Voltage vs. Transducer Height

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Primary calibration standards are needed for use as reference for tester setup. The selection of primary standards is done with the UT-2C tester.

To select primary calibration standards each fuel core selected as a potential primary standard is retested several times and carefully examined for nonhomogeneneous characteristics which would make their use as standards undesirable. Primary standards are retained for use as permanent references to check existing secondary standards or to select new secondary standards.

It was decided that primary calibration standards were needed at HAPO in the A-2 through A-9 regions (Figure 7).

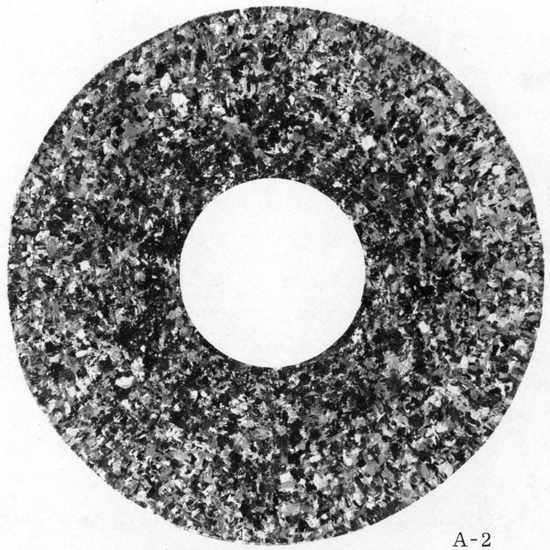
Table I shows the relative UT-2C output voltage range for each of these regions. Several cores in each desired category were selected with the UT-2C.

TABLE I

UT-2C OUTPUT FOR RANGES A-2 THROUGH A-9

Grain Size	Voltage Range
A-2	0 to 0.5
A-3	0.5 to 1.3
A-4	1.3 to 2.2
A-5	2.2 to 3.1
A-6	3.1 to 4.0
A-7	4.0 to 4.9
A-8	4.9 to 5.8
A-9	5.8 to 6.7

When the final selection of standard cores was made at HAPO, only those cores with voltage readings within ±0.1 v were retained in each category for use as primary standards. One core from each category was then put on the rolls and rotated in place under the test head at a point where the tester output voltage was the same as indicated when the pieces were previously tested. The rotating core was then scribed at the point at which the ultrasound entered the core. One core in each voltage range was thus scribed and identified for grain size certification. The remaining cores were retained for future use as standards.



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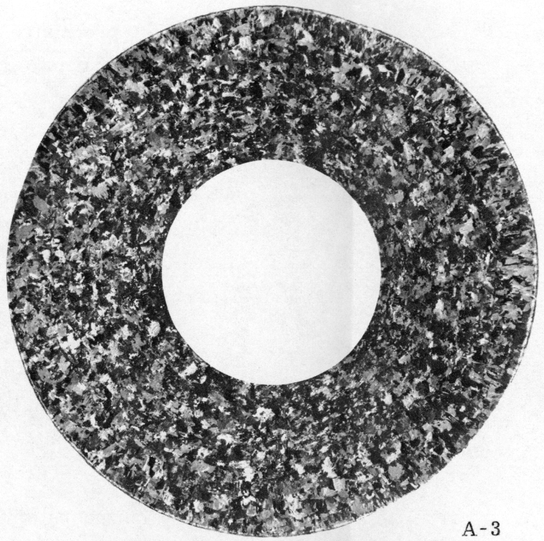

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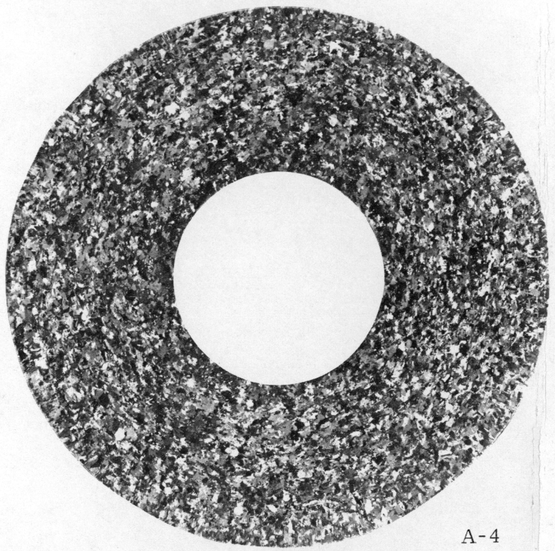
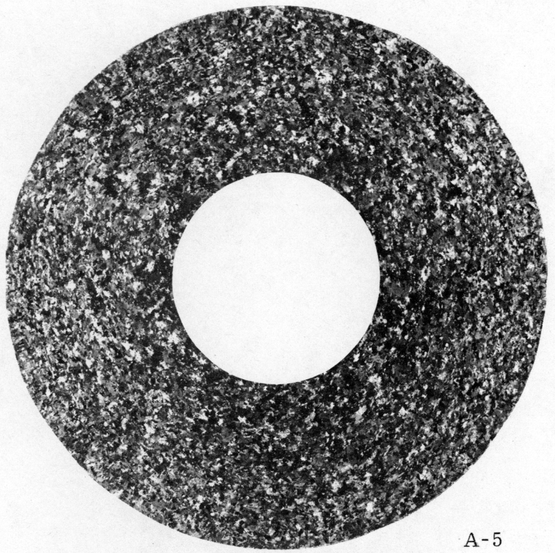
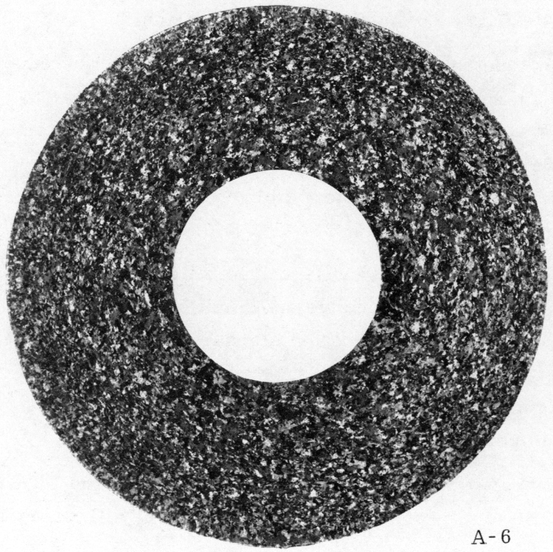


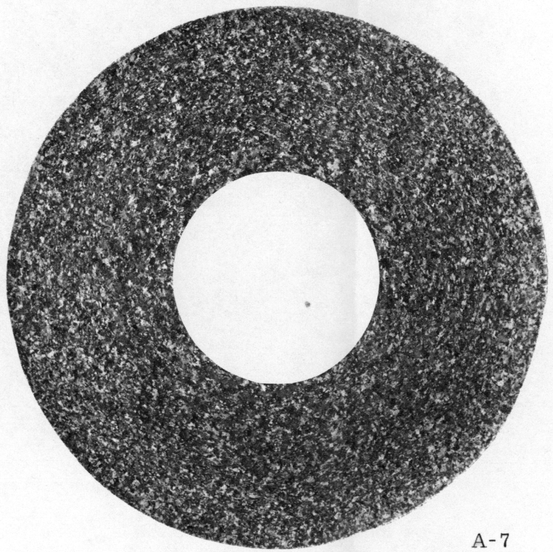
A-4



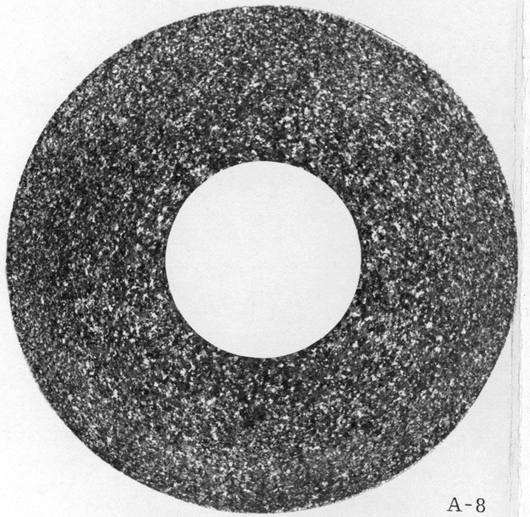
A-5



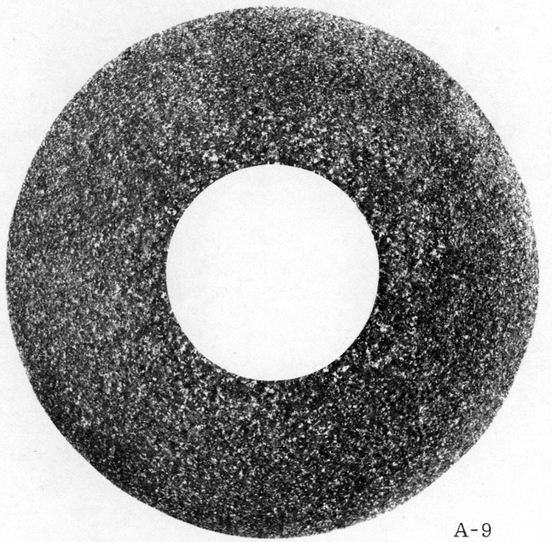
A-6



A-7



A-8



A-9

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FIGURE 7

Calibration Standards for A-2 Through A-9 Regions

The procedure was repeated for each size fuel core for which primary standards were made. All of the scribed cores were sent to the metallographic laboratory. The laboratory sectioned each core at the scribed point and subjected them to metallographic examination. "A" numbers corresponding to observed grain size were assigned to each core using procedures determined by the FEDC's Standards report, dated April 27, 1960. Figure 7 shows macrophotographs of fuel cores with grain sizes A-2 through A-9.

The grain sizes assigned by the analytical laboratory were then plotted versus the output voltages indicated by the UT-2C tester. All of the certified primary standards coincide with the curve plotted in Figure 5. Correlation between the tester output voltage readings and metallographic examination indicates that fuel core grain size can be predicted with a high degree of accuracy with the UT-2C tester.

The laboratory certified primary standards were subsequently used during the selection of operating secondary standards. Secondary standards are fuel cores used for UT-2C tester "on-the-line" calibration.

Next, tests were conducted at HAPO to determine the effect a reduction of tester sensitivity had on its ability to reject untransformed cores. Four untransformed cores were examined ultrasonically under laboratory conditions to determine the effect of a sensitivity reduction. Figure 8 illustrates almost no change in indicated tester voltage for an untransformed core with a 1 v sensitivity reduction.

To assure the UT-2C's reliability and reproducibility, the calibration standards should be spaced along the curve shown in Figure 5. Tests have indicated that using at least four calibration standards assures good tester linearity. These standards should consist of one large-grain standard, one small-grain standard, and two equally spaced midrange standards. These are the operating secondary standards.

When properly calibrated with known standards (Figure 5) the UT-2C demonstrates good reliability and reproducibility. The UT-2C will read out

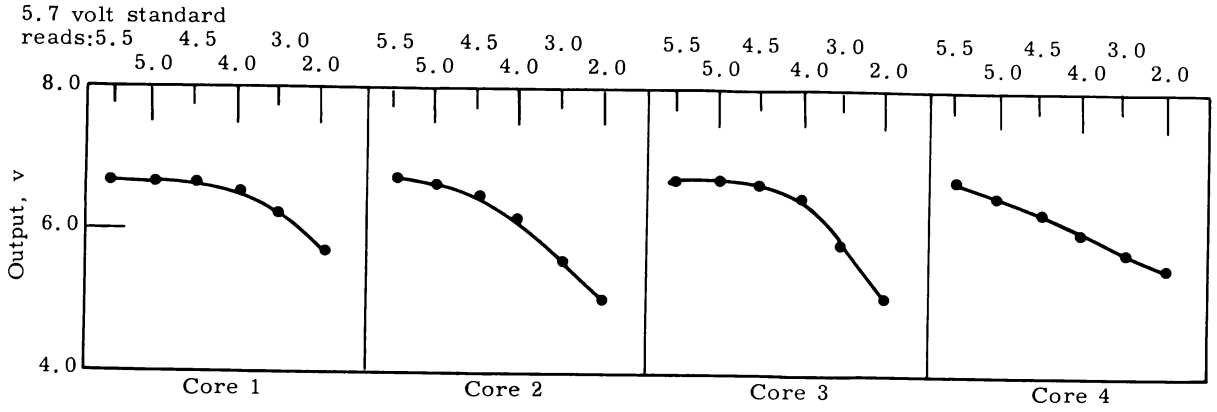

FIGURE 8

UT-2C Output Voltage Characteristics for Untransformed Cores
(At different tester sensitivities)

voltages within ±0.1 v for several successive tests of any given core. Normal tester drift is under ±0.2 v for any given 8 hr period.

The Process Capability of the UT-2C tester is σ equal to 0.04. Using this Process Capability an estimate of the probability of the UT-2C accepting an untransformed (8 v or more) core is extremely remote or less than 0.001%.

Figure 9 shows the measurement error trends of the HAPO UT-2C production testers. The data used to determine these errors were obtained from multiple testing of several cores run on each tester at randomly spaced time intervals. No adjustments were made to the tester. The fourth quarter, 1963, and first quarter, 1964, sections of Figure 9 show the results obtained after the standards program was initiated.

CONCLUSIONS

When properly calibrated with standards of known grain size, the UT-2C tester is an accurate device for measuring the grain size of unclad uranium cores.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of W. Stevenson in obtaining statistical data.

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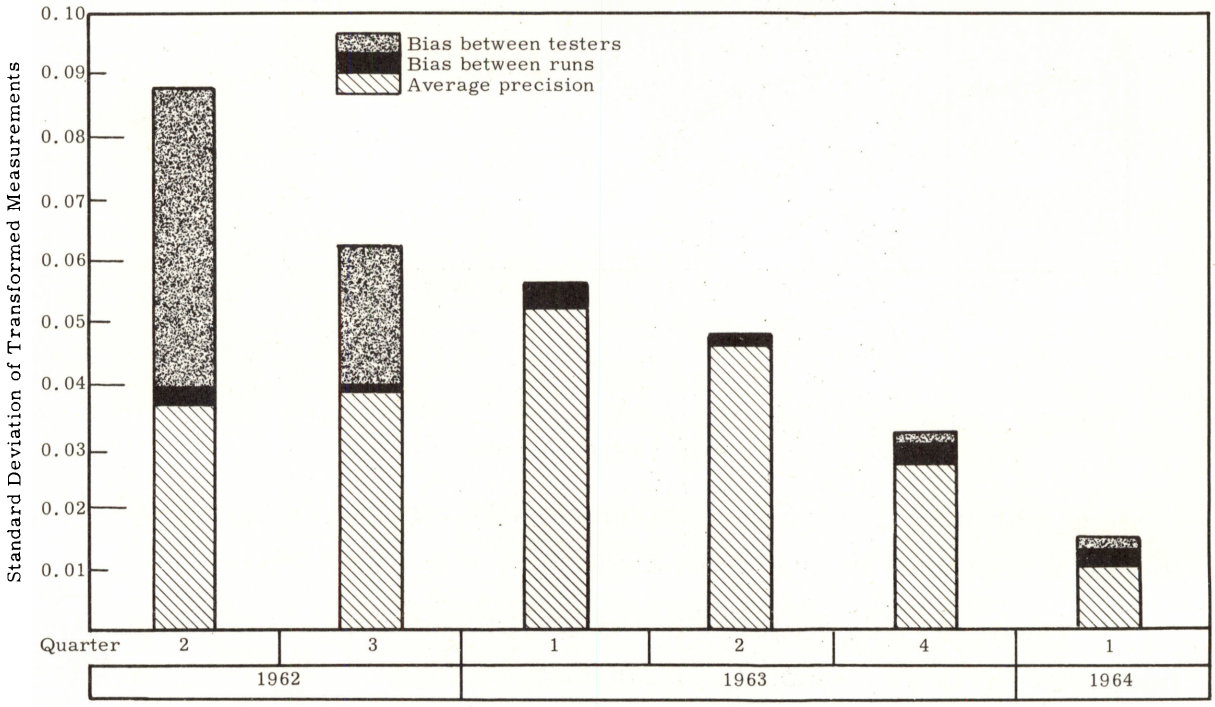

FIGURE 9

Measurement Error Trends UT-2C
(Peak at 5.4 v)

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2. C. L. Waldkoetter and C. L. Frederick. Fuel Core Tester - UT-2, HW-85701. July 18, 1960.

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