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U. S. ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE

NON-DESTRUCTIVE TESTING
OF URANIUM SLUGS

SUMMARY REPORT FOR APRIL 1952

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SUMMARY REPORT FOR APRIL 1952

The New York Operations Office during the last month has made the following progress in its non-destructive slug testing program.

Four hundred tests were made on 60 slugs of various degrees of soundness with eddy current-type inspection instruments. Four instruments were used: (1) a high frequency Multitest (30 kc), (2) a low frequency Multitest (2.7 kc), (3) Cyclograph, and (4) a General Electric Metals Comparator. The Metals Comparator was found to be inferior from the point of view of sensitivity. The Cyclograph was unstable, had an excessively long time constant, and also had low sensitivity. Neither instrument could distinguish diameter variations from seams or irregularities of heat treatment. On the other hand, both Multitests were extraordinarily sensitive and stable, with a negligible time constant, responding to hair-line seams less than a quarter inch in length at relatively high test velocities. Whereas considerable interpretation (and therefore modification) is necessary, present results indicate that the Multitest may be made to distinguish separately diameter variations, seams and other flaws, and heat treatment variations.

Pages 1 through 4 to follow display typical sets of Multitest data on four slugs: a good slug, a slug with artificial seams 1/4" in length and of various depth, a slug with several natural seams, and a slug with surface machining defects. In each case the X and

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Y coordinate recorded on the Brown graph correspond respectively to the resistive and reactive change of the impedance of the detection circuit. Theoretical analysis is necessary to interpret these changes directly in terms of the physical characteristics of the slugs.

To obviate the necessity for this analysis and also to make possible testing of the slug ends (data for which is at present obscured by an end effect), a modification of the detection circuit is planned. The following objects are in mind:

- (1) to obtain a signal which responds to flaws only, and is independent of the heat treatment and dimensions of the slug
- (2) to obtain a signal which responds only to heat treatment or grain size of the slug
- (3) to obtain a signal which responds only to dimensional variations of the slug
- (4) to permit the placement of tolerances on each of these signals so that automatic rejection by degree of unsoundness may be accomplished in each group
- (5) to minimize the end effect and permit testing of the full length of the slug.

The proposed system involves the use of four primary and a number of extra secondary coils instead of two primaries and two secondaries.

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A related study of non-destructive testing methods is being carried on in the fields of sonic and ultrasonic vibration. Observations made with the Sonigage (an ultrasonic resonance type instrument) appear to indicate preferred crystal orientation (see page 5). Planes of orientation seem to coincide with rolling directions. The development of this technique to make it a non-destructive detector for such gross orientation is under consideration. In the course of a meeting with duPont and Argonne personnel, these observations were reported and it was recommended that studies be made to determine the effectiveness of this technique as compared to X-rays. With the cooperation of the Argonne group, correlation studies have been planned with X-ray analysis of local area.

Page 6 describes how the above orientation results were repeated by an audio-frequency free-free bar resonance vibration technique. Page 7 presents preliminary attenuation studies made with the Sonigage on uranium slugs of five different grain sizes. The data indicates increase of ultrasonic attenuation with grain size and has been repeated with the Reflectoscope.

Page 8 introduces the possibility of bond study with ultrasonic resonance and is self-explanatory.

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SLUG #1 - GOOD SLUG

Test specimen shows no visual evidence of flaws of any kind. Upper graph records x - coordinate of Multitest trace taken at 30 kc, lower graph records y-coordinate. Both show unusual regularity, no evidence of seams, resistive variations, or diameter variations.

Visual inspection
Slug # 2896-2-28

(Scale matches vertical scale in graphs below; arrows indicate beginning of test area.)

X - COORDINATE
of Multitest
Plot (30 kc)

Y - COORDINATE
of Multitest
Plot (30 kc)

SLUG #2 - SLUG WITH MACHINED SLOTS OF VARIOUS DEPTHS

Test specimen was prepared by drilling out slots 1/4" long, 1/16" wide and 1/32", 1/16", 1/8", and 1/4" deep. These were then filled with sheet uranium and the entire piece stress relieved at 600°C for one hour, furnace cooled.

Visual inspection
Slug #6339-B-23

X - COORDINATE
of Multitest
Plot (2.7 kc)
(low sensitivity)

Y - COORDINATE
of Multitest
Plot (2.7 kc)
(low sensitivity)

SLUG #3 - SLUG WITH NATURAL SEAM

Visual Inspection
Slug #2896-4-4

0" 1" 2" 3" 4" 5" 6" 7" 8"

X - COORDINATE 30 kc Multitest

X - COORDINATE repeated

X - COORDINATE repeated with slug reversed

Y - COORDINATE 30 kc Multitest

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SLUG #4 - SLUG WITH MACHINING FLAW AND MINUTE SEAMS

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Test specimen has pitted and gouged surface due to machining failure. The volumetric nature of this flaw is displayed by the sharp deflection of the Y - Coordinate even at low sensitivity. Several hairline seams of about 1/4" length are also visible.

Visual Inspection
Slug #2908-3-20

X - COORDINATE
of Multitest
Plot (30 kc)
(low sensitivity)

Y - COORDINATE
of Multitest
Plot (30 kc)
(low sensitivity)

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PREFERRED CRYSTAL ORIENTATION
IN ALPHA ROLLED | SR SLUGS

ALPHA PHASE STRESS RELIEVED
(600°C: 1 hour, furnace cooled)

(Ultrasonic frequency is plotted horizontally, energy absorbed, vertically, at approximately 11° intervals for a quarter turn around the circumference of the slug. There is evidence of preferred orientation at about 0° and 90°. These photographs were taken on the Scintec, an ultrasonic resonance type instrument. Evidence of the same ~~no~~ ^{plane} was obtained using shear wave transmission and flexural vibration. See text and following page.)

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PREFERRED ORIENTATION BY FREE-FREE BAR RESONANCE

To confirm the results of the Sonigage ultrasonic resonance method presented on the preceding page, the uranium bar was set into vibration as a free-free beam at its fundamental mode of vibration (Fig. 1). It was determined that the natural frequency of this beam is of one value when the bar is in one principal plane and of another value when the bar is vibrated in the principal plane at 90° to the first. The axes of symmetry are the same as determined by the sonigage. The present frequency change is however different as would be expected as different areas are subjected to stress in the two cases and as the stresses are in different direction. The damping constants are measured for each of these two principal resonances. It has been observed for one specimen that the internal friction increases with decreasing temperature in the temperature range near that of room temperature. Polar diagrams (Fig. 2) have been plotted to show the specimen response as a function of angular position about its two axes when excited by each of the two resonant frequencies of the bar.

ULTRASONIC GRAIN SIZE STUDIES ON FIVE VARIOUSLY PREPARED HANFORD SLUGS

Frequency Range 3

Frequency Range 5

SLUG HELD AT 720° C
FOR 7 MINUTES,
AIR COOLED.

SLUG HELD AT 720° C
FOR 70 SECONDS,
WATER QUENCHED

REGULAR ALPHA
ROLLED SLUG

SYLVANIA POWDER
U SLUG

Grain size: 10 - 15
microns

SYLVANIA POWDER

UH₃ SLUG

Grain size: 5 - 10
microns

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ULTRASONIC TESTING OF BONDS

It was found in April at NYOO that certain ultrasonic resonance methods may contribute toward an automatic test of bond soundness between can and slug. Tests were made on Hanford slugs prepared and canned by the Sylvania method with certain known degrees of unbonding. Unbonded areas down to a quarter inch in diameter were located readily with the Sonigage by measuring the ultrasonic absorption spectrum at regular intervals on the surface. The test is made easily and quickly. A normal 'sound bond' harmonic pattern is shown in Fig. 1. The general decrease of absorption shown in Fig. 2 indicates a point at which there is lack of bond. The single resonance which rises here reveals that the can is vibrating independently at its own natural resonance frequency. The wave length of this resonance can be measured and turns out, as expected, to be one half the thickness of the can.

FIGURE 1 - GOOD BOND

FIGURE 2 - POOR BOND (Can vibrating independently at its own resonant frequency.)

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