**NONDESTRUCTIVE TESTING OF ISOTOPE
CONTAINMENT CAPSULES
SNAP-15A**

R. W. STEFFENS AND F. M. COFFMAN

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NONDESTRUCTIVE TESTING OF ISOTOPE
CONTAINMENT CAPSULES
SNAP-15A

By

R. W. Steffens and F. M. Coffman

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ABSTRACT

Because of the potential hazards associated with the core material contained in an isotope source, it is imperative that the container integrity be established so that the source can be safely used. Ultrasonic non-destructive testing (NDT) has been shown capable of providing quality assurance data on final capsules as well as information feedback for process control purposes.

Ultrasonic NDT was investigated for monitoring the weld quality of the peripheral end-cap weld on SNAP-15A isotope containment capsules. Weld parameters of interest were (1) weld penetration, (2) cavities at the weld root, and (3) intergranular cracking near the boundary of the recast weld volume. The ultrasonic techniques were evaluated by comparing metallographic data with the respective ultrasonic data obtained on five inert-core weld samples. Results showed that weld penetration could be measured with an accuracy of $\pm 5\%$ of full penetration. The basis for a technique to detect cavities at the weld root was established, and an ability to detect intergranular cracking was indicated. The scope of this investigation did not include full development of the ultrasonic tests.

In addition to a description of the ultrasonic test that was found to be advantageous for monitoring the SNAP-15A weld parameters, this report (1) displays weld evaluation data obtained by metallographic analysis, (2) outlines additional NDT development requirements for more complete weld evaluation, and (3) displays the test results obtained on six fueled capsules.

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NONDESTRUCTIVE TESTING OF ISOTOPE
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R. W. Steffens and F. M. Coffman

INTRODUCTION

Because of the toxic and radioactive nature of the core material contained in an isotopic source, it is imperative that the container integrity be established so that the source can be safely used. Establishment of the integrity of the closure weld on the containment capsule is of particular concern due to the discontinuous capsule configuration at the weld joint. Development of nondestructive tests (NDT) for the establishment of isotope container integrity was initiated in 1963 at the Pacific Northwest Laboratory (PNL) in support of the promethium encapsulation program. This NDT program has since been expanded to include testing of (1) Phase I SNAP-21 and SNAP-23 capsules, (1) (2) promethium Microthruster capsules, and (3) Series 1, SNAP-27 capsules.

During the above projects, ultrasonic NDT has been shown to be valuable for certification of the welds on the final capsules and for use in weld evaluation during the weld design phase. A feasibility study was performed to show the applicability of ultrasonic NDT for the certification of the weld integrity on SNAP-15A capsules. This report (1) describes ultrasonic techniques found to be advantageous for monitoring the SNAP-15A weld parameters, (2) displays weld evaluation data obtained by metallographic analysis, (3) outlines additional NDT development required for more complete weld evaluation, and (4) presents test results obtained on six fueled capsules.

(1) R. W. Steffens, H. N. Pederson, and F. M. Coffman. Nondestructive Testing of Isotope Containment Capsules Phase I SNAP-21 and SNAP-23, BNWL-528. Pacific Northwest Laboratory, Richland, Washington.

DISCUSSION

CAPSULE AND WELD DESCRIPTION

Mound Laboratories supplied five inert (nonradioactive core) weld samples for use in defining the applicability of ultrasonic NDT to the SNAP-15A weld configuration. In addition, six fueled (radioactive core) capsules were supplied for subsequent weld evaluation. The pertinent physical characteristics of these capsules are shown in Figure 1. The containment capsules were fabricated from a Haynes-25 cylindrical can and a Haynes-25 end cap. The capsules parameter of interest is the peripheral weld that seals the joint between the end cap and the counterbore wall in the cylinder.

WELD CHARACTERISTICS

Before proceeding with a discussion of the ultrasonic techniques employed, a discussion of weld characteristics is in order. Four characteristics found during metallographic analysis of the inert samples are shown in Figure 2. Well formed welds are shown in Figures 2A and 2B where 79% penetration and full penetration were obtained without detriment to the weld integrity. Figure 2C shows a weld with 79% penetration and intergranular cracking near the boundary of the recast weld volume. Figure 2D shows a fully penetrated weld with a cavity at the weld root. An effective quality assurance program should be able to classify these four weld configurations nondestructively.

CAPSULE COMPATIBILITY WITH ULTRASONIC NDT

To obtain reproducible ultrasonic test results, a smooth, dimensionally consistent outer surface area is required to prevent excessive beam scattering where the ultrasonic beam enters the test sample. The flast surface of the end cap and the smooth cylinder wall provide sufficient dimensional consistency. Sophisticated transducer alignment procedures and equipment are required due to the small area of the end cap and the sharp radius of the cylinder.

A. SNAP-15A Capsule in Test Holder

B. Cross-Section of SNAP-15A Peripheral End-Cap Weld

FIGURE 1. Capsule Characteristics of SNAP-15A Weld Samples

A. Well Formed Weld 79 Percent Penetration

B. Well Formed Weld: Full Penetration

C. Intergranular Cracking Near Boundary of Recast Weld Volume

D. Cavity at Weld Root

FIGURE 2. Characteristics of Peripheral End-Cap Weld on SNAP-15A Weld Samples

The unwelded joint length (see Figure 1A) is inversely proportional to the depth of the weld penetration. This length is readily monitored with an ultrasonic beam aligned obliquely incident on the end cap and thus, a practical method for measuring weld penetration exists. Since the weld root cavity characteristic is closely associated with the unwelded joint length, the same ultrasonic beam may be used to detect this weld configuration. The detection of intergranular cracking near the boundary of the weld volume is an elusive condition to detect.

The laboratory equipment used to perform this study is shown in Figure 3. The versatile ultrasonic test tank provided (1) three-dimensional transducer alignment, (2) two-dimensional capsule rotation, and (3) calibrated horizontal transducer translation. The broadband ultrasonic tester provided excitation for the ultrasonic transducer and amplification of the detected ultrasonic signals. The oscilloscope provided visual data readout, and the associated camera provided permanent recording of the pertinent waveforms.

DESCRIPTION OF ULTRASONIC TECHNIQUES

The above equipment was used to scan and monitor the ultrasonic signals reflected from the inner corner of the end cap and from the inner counterbore corner on each of the five inert weld samples. The location of signal variations were recorded and metallographic analysis was performed to correlate these signal variations with the physical characteristics of the welds. Characteristics of the five inert weld samples included (1) weld penetration from 67% to full penetration, (2) a cavity at the weld root, (3) intergranular cracking around the boundary of the weld volume, and (4) mild weld drop-through. Thus, examples of naturally occurring defects were provided in addition to examples of adequate integrity. The variations in the ultrasonic signals indicating the above weld characteristics are discussed in the following sections.

FIGURE 3. Electrical and Mechanical Equipment for Ultrasonic Nondestructive Testing of Isotope Capsules

WELD PENETRATION MEASUREMENT

Weld penetration is ultrasonically measured as shown in Figure 4. An ultrasonic beam is aligned on the end cap such that a shear wave, which propagates radially toward the outside of the cylinder at 45° with respect to the surface, is generated in the end cap. When the ultrasonic beam is centered on the inner corner of the end cap, the magnitude of the reflected ultrasonic energy is dependent on the length of the unwelded joint. Thus, the signal from the inner end cap corner is a measure of weld penetration. The oscillogram in Figure 4 shows a typical, clearly defined signal received when there is no deformation at the inner corner of the end cap.

In order to correlate actual unwelded joint length with the amplitude of the ultrasonic signals, inert sample No. 3 was quartered axially; part of each quarter was polished, etched, and photographed; and the unwelded joint length was measured. The metallographic data were graphically compared with the ultrasonic data, as shown in Figure 5, and a rough correlation was found to exist.

Ultrasonic data pertaining to the unwelded joint length on inert sample No. 4 was recorded using the same test parameters employed to obtain the ultrasonic data on sample No. 3. The data from sample No. 4, shown in Figure 6, was used as a reference for testing the six radioactive capsules. Sample No. 4 is being retained as a standard for future SNAP-15A testing and for use in evaluation of the ultrasonic tester that is being fabricated at PNL for installation at Mound Laboratories.

As may be noted in Figure 6A, the pulse height of the ultrasonic signal from the counterbore corner had a 50 mV variance. This variance was typical of those observed on each of the five inert capsules. These variances are believed to be due to slight misalignment of the ultrasonic beam. Thus, the quality of the ultrasonic test would be substantially improved if more sophisticated transducer alignment mechanisms were available. Rigid dimensional specifications on the capsule would also assist in test standardization and signal interpretation.

FIGURE 4. Ultrasonic Measurement of Weld Penetration on SNAP-15A Weld Samples

FIGURE 5. Comparison of Ultrasonic Pulse Height with Metallographic Measurement of Weld Penetration on Weld Sample Number 3

As shown in Figure 4 the energy distribution through a cross-section of the ultrasonic beam follows a Gaussian type distribution. The resulting nonlinear effect on the measurement of unwelded joint length necessitates careful calibration of the ultrasonic signal amplitude with unwelded joint length if quantitative results are required. Although the scope of this study did not justify the development of extensive calibration procedures, the data obtained on capsules 3 and 4 were sufficient for the qualitative testing of the six fueled capsules.

FLAW DETECTION

The major problem in detecting flaws associated with a dimensionally small weld configuration is the interpretation of the flaw signals in the presence of signals from joint corners and weld bead reflections. Since the signals from the inner end-cap corner and counterbore face are present during the inspection of the weld, these signals must be constantly monitored so they are not mistaken for flaw indications or vice versa. The ultrasonic 45° shear detection technique described herein relies upon the typical signal waveforms and transducer positions recorded during the monitoring of the inner end-cap corner and counterbore corner for reference signals. Radical changes in end-cap corner and counterbore face waveforms indicates a flaw. The position of the flaw is found by observing the change of transducer position from the direct corner alignment and the time required for the ultrasonic signal to return to the transducer when the flaw signal is maximized.

Figure 7 shows the growth and decay of the received ultrasonic reflection obtained from an inner 45° corner as shear wave traverses across the corner. Note, the initial appearance of the signal is furthest in time from the surface noise as the beam approaches the corner, and closest in time as the beam traverses past the corner.

If flaws occur near the corner, variances will be observed in the waveform of the direct corner reflection. When the ultrasonic beam is aligned directly on the corner, the signal from a crack or

FIGURE 7. Characteristics of an Ultrasonic Signal as the Transducer Is Translated Across an Inner Corner

void on the inner surface of the end cap or on the end of the unwelded joint will appear closer in time to the surface noise than the corner reflection. This is referred to as a leading edge signal. Actual location of the flaw is obtained by translating the transducer toward or away from the reference corner. An inner surface flaw signal will grow as the transducer is moved away from the corner, and a joint tip defect will grow as the transducer is moved toward the corner. A cavity detected with a leading edge signal at the weld root on inert weld sample No. 1 is shown in Figure 8.

Many leading edge signals were detected while the inner counterbore corner reflection was being monitored. These signals were generally low amplitude, and little significance was placed on them until intergranular cracking was discovered during the metallographic analysis (Figure 2D). Detection of these cracks is quite difficult due to their interwall random orientation. Rigid dimensional control of the capsule in the weld area and improvement in transducer alignment and capsule rotation mechanisms would improve resolution of these cracks. The ultrasonic testing station being developed at PNL for installation at Mound Laboratory has taken the transducer alignment and capsule rotation requirements into consideration.

WELD EVALUATION ON SIX PLUTONIUM FILLED CAPSULES

The weld penetration on six plutonium filled SNAP-15A capsules was monitored as described in the procedure in the Weld Penetration Measurement section of this report. In addition, the containers were scanned using the 45° shear wave flaw detection technique described in the Flaw Detection section.

The results of the weld penetration tests are given in Table I. Included in this table is the average, minimum, and maximum penetration on each sample. The ultrasonic data for each capsule is graphically displayed in the Appendix. Included in each Appendix figure is (1) a graph of the percent penetration as a function of the peripheral position

FIGURE 8. Cavity at Weld Root Detected with Leading Edge Signals on Inert Weld Sample Number 1

around the weld and (2) a graph of the pulse height of the ultrasonic reflections from the counterbore corner. Only one capsule, No. 158, displayed questionable weld characteristics. No defect indications were observed in the containers.

TABLE I. Tabulation of Weld Penetration for Six Radioactive SNAP-15A Isotope Containment Capsules

Capsule Number	Percent Weld Penetration	
	<u>Average</u>	<u>Variation</u>
150	74 ^σ %	65 - 87 ^σ %
151	92 ^σ %	90 - 94 ^σ %
157	68 ^σ %	57 - 78 ^σ %
158	Weld exhibits destruction of both inner and outer counterbore corners.	65 - 100 ^σ %
169	65 ^σ %	54 - 74 ^σ %
188	83 ^σ %	74 - 90 ^σ %

CONCLUSIONS

Through this study, ultrasonics has been shown beneficial for the establishment of the weld integrity on SNAP-15A isotope containment capsules. Using the ultrasonic techniques described in this report, weld penetration was measured with an accuracy of $\pm 5\%$ and gross cavities at the weld root were detected. Although the possibility for detecting intergranular cracking around the weld boundary with ultrasonic techniques was indicated, a more extensive development program would have to be performed to obtain test certification. The laboratory equipment used was sufficient for this feasibility study. However, the small size of these capsules necessitates the use of sophisticated transducer alignment procedures and capsule rotation equipment if intergranular cracking is to be reliably detected.

The basic weld configuration displayed on these SNAP-15A capsules is typical of welds observed on several other small sized capsules. Thus, a more detailed program for developing reliable ultrasonic techniques for certifying the SNAP-15A weld configuration would also be valuable on a general basis.

APPENDIX

ULTRASONIC DATA PERTAINING TO WELD EVALUATION
ON SIX RADIOACTIVE CORE SNAP-15A CAPSULES

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-1. Ultrasonic Data on Capsule Number 150

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-2. Ultrasonic Data on Capsule Number 151

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-3. Ultrasonic Data on Capsule Number 157

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-4. Ultrasonic Data on Capsule Number 158

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-5. Ultrasonic Data on Capsule Number 169

A. Ultrasonic Signal from Counter Bore Corner

B. Percent Penetration of End-Cap Weld

FIGURE A-6. Ultrasonic Data on Capsule Number 188

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