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Ultrasonic Examination of Thin Iridium Hemispheres for the Multihundred Watt Heat Source

Walter A. Dudley

December 30, 1975

Research and Development Report

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Abstract

An ultrasonic method was developed for nondestructive inspection of the structural integrity of the 20-mil (0.0508-cm) thick iridium hemispheres that are used in the fabrication of Multihundred Watt (MHW) radioisotopic heat sources. A hemisphere was considered unacceptable if a back-surface ultrasonic response change was equivalent to that obtained from a 0.010-in. (0.0254-cm) diameter flat-bottomed hole in the standard. Flaws were detected in hemispheres made by the initial fabrication process. Typical flaws found ultrasonically in these units and revealed by metallography are shown. Hemispheres formed after a change to a different fabrication process were free of flaws.

Introduction

Long term space missions, such as navigational and planet flyby probes, require sources of auxiliary power that are reliable and compact. For the Mars, Jupiter, Saturn (MJS) flyby mission, the approach to supplying this auxiliary power is the radioisotopic thermoelectric generator (RTG). The heart of the RTG is the encapsulated radioisotopic plutonium-238 heat source.

The Multihundred Watt (MHW) heat source for this mission is designed to deliver a nominal thermal output of 2400 W from alpha decay. As shown in Figure 1, the MHW heat source is comprised of an array of 24 fuel sphere assemblies with an individual thermal output of approximately 100 W. The assembly consists of the following components:

1) The fuel which is oxygen-16 exchanged plutonium-dioxide shards, hot-pressed under vacuum to form a 1.5-in. (3.81-cm) diameter sphere.

2) The post-impact shell which is a welded assembly of two thin-walled iridium hemispheres. Iridium was chosen because of its high temperature strength and ductility plus its compatibility with the fuel.

3) The impact shell which is fabricated from high strength graphite. In addition to serving as a shock absorber, the graphite shell also acts as a thermal insulator.

To provide quality assurance in the production of the MHW heat source, several nondestructive techniques were used. This report describes the ultrasonic method developed to inspect the 20-mil (0.0508-cm) wall of the component hemispheres which make up the post-impact shell of the fuel sphere assemblies. In this test, commercial pulse-echo ultrasonics are used in combination with a manual scanning fixture to permit interrogation for laminar defects. For this inspection technique a hemisphere is considered unacceptable if a flaw response is detected that is equivalent to that obtained from a 0.010-in. (0.0254-cm) diameter flat-bottomed hole in a standard hemisphere.

Inspection System

To accommodate ultrasonic inspection of the iridium hemispheres it was necessary to build a specialized fixture. Because laminar defects had been observed metallographically in weld development hemispheres, the fixture was designed to facilitate detection of laminations; however, in view of the relatively small number of hemispheres to be inspected during the lifetime of the program, a manually operated fixture would suffice. Figure 2 is a photograph of the resultant inspection fixture. The post is used to hold the hemisphere during the inspection and is simply a rotatable mandrel. The manipulator in conjunction with the scanning arm permits the search unit to be aligned at normal incidence for pole-to-equator traverse of the dome region of the hemisphere. A conventional focused immersion search unit or its equivalent in a bubbler design can be used with the fixture. The latter is preferred in actual practice because of operator convenience and was used in this fixture. Figure 3 is a photograph showing the analyzer portion of the inspection system. Specifics of the analyzer and other ultrasonics used in the inspection are listed in Table 1.

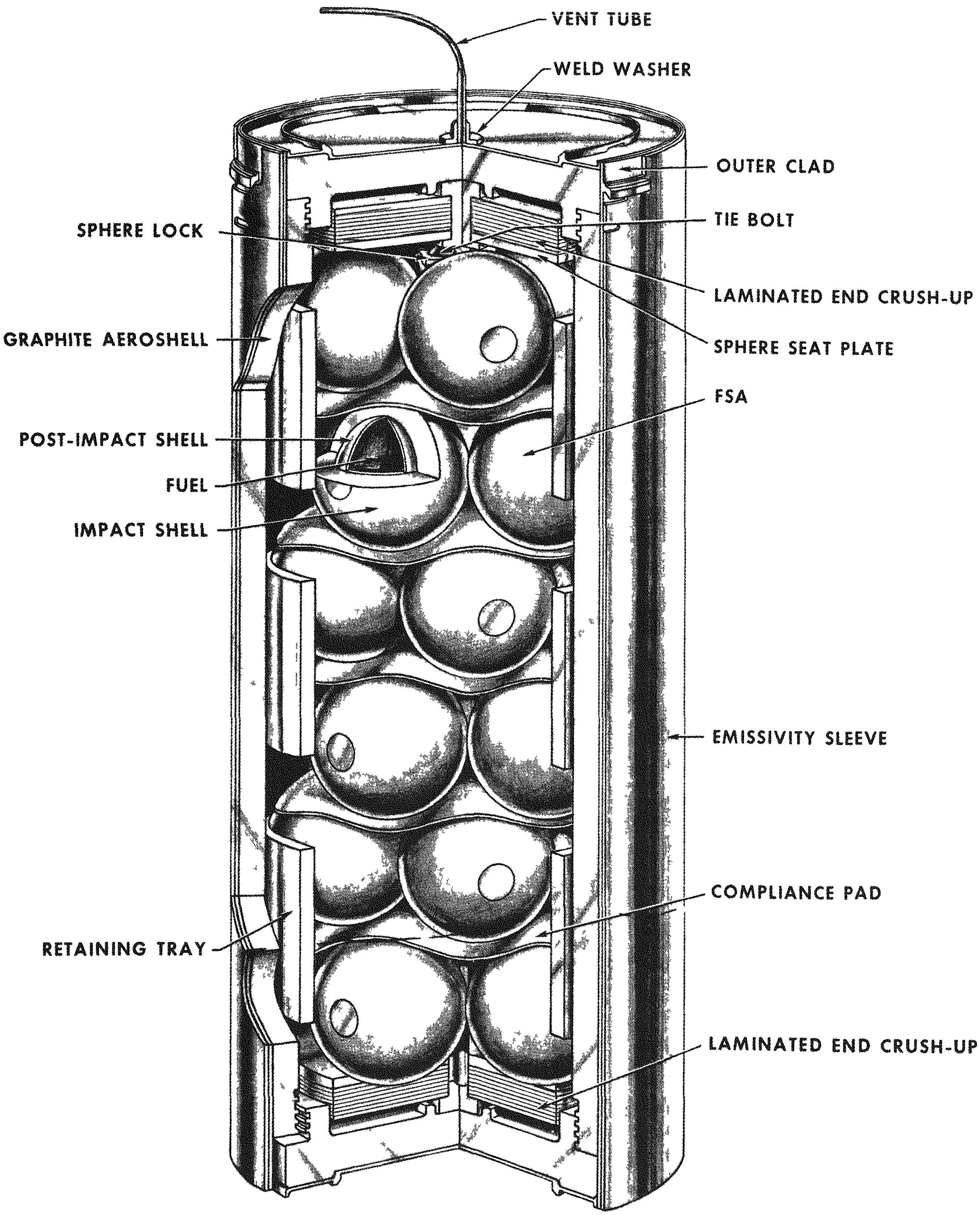

FIGURE 1 - Cutaway assembly of MHW heat source package.

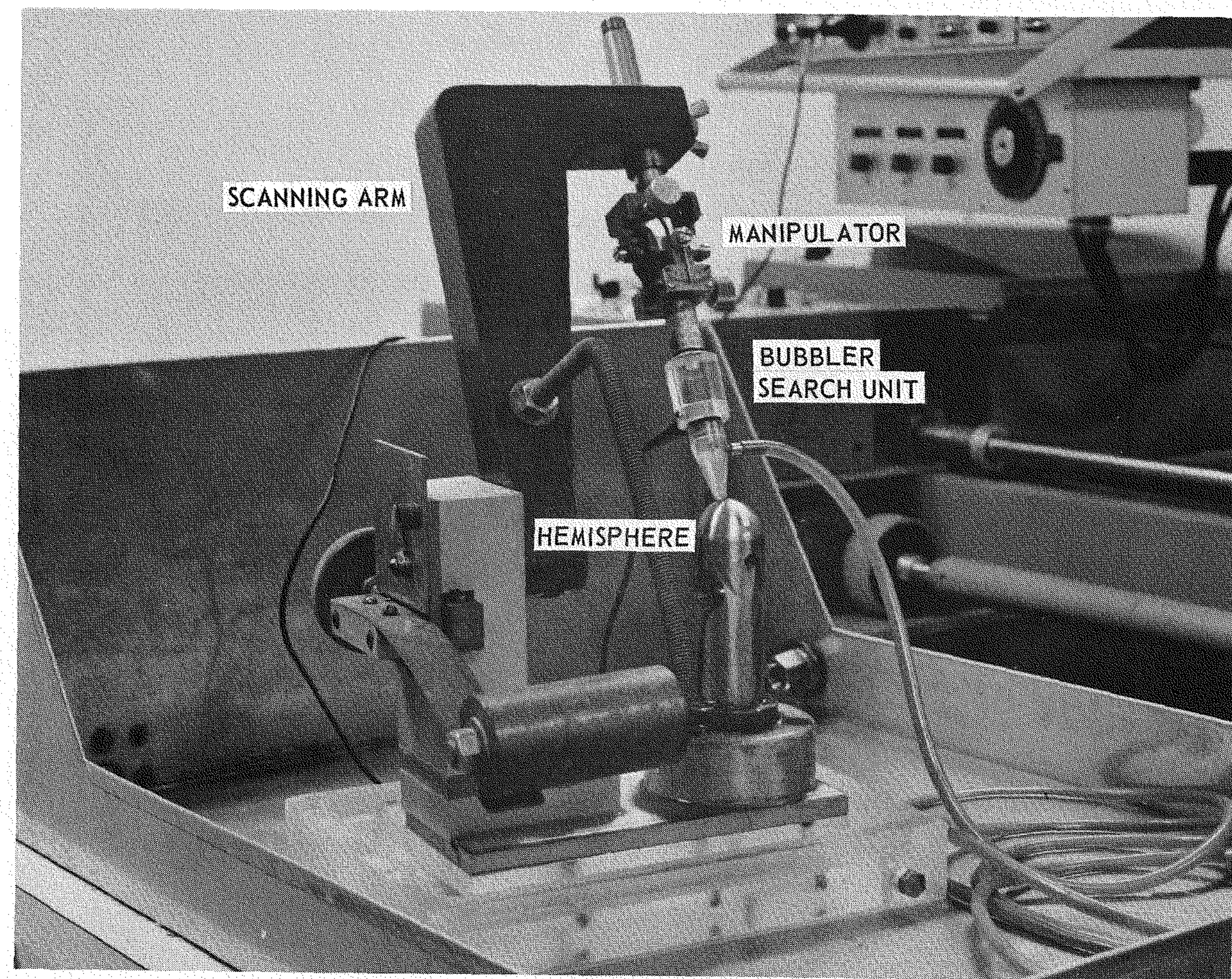

FIGURE 2 - MHW iridium ultrasonic test fixture.

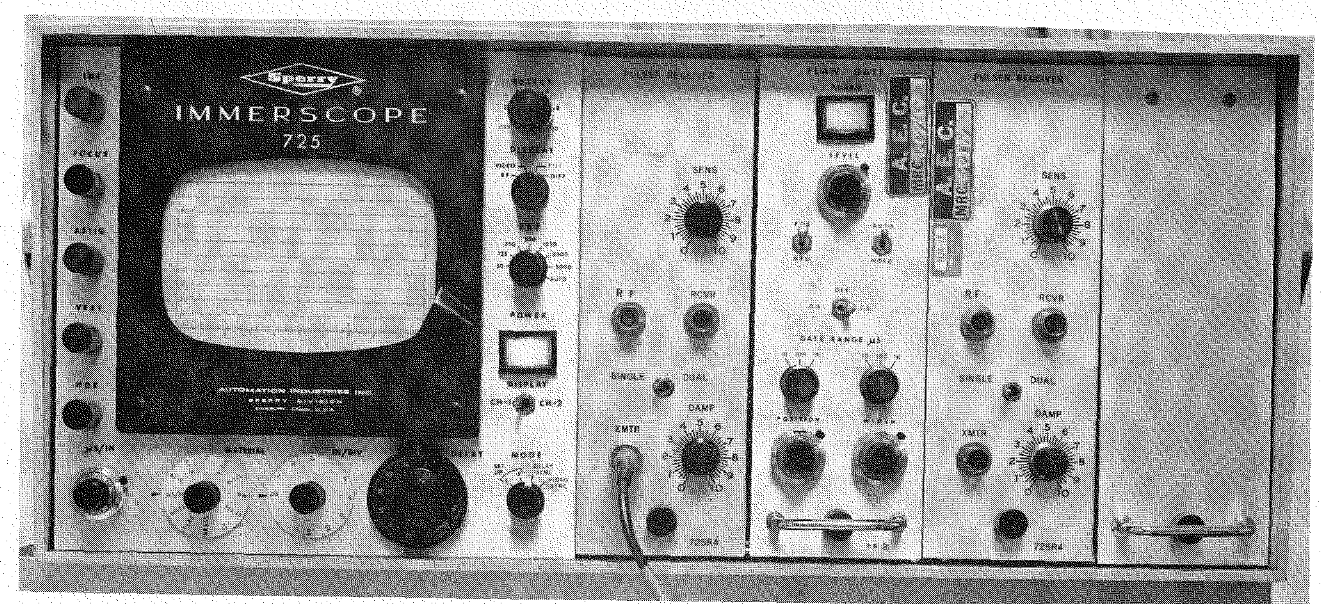

FIGURE 3 - Analyzer

Table 1

EQUIPMENT LIST

Equipment	Corresponding Illustration
Ultrasonic Analyzer (725 Immerscope modified to function with R_4 P/R module, and FG_2 Gate module or equivalent)	Figure 3
Transducer [Automation Industries, Style 57A8310 or equivalent (25 MHz; focal short, 5/16-in. diam, lithium sulphate)]	Figure 3

Inspection Procedure

Prior to inspection of a production lot of hemispheres, the ultrasonic analyzer is "peaked" to obtain optimum detection of artificial flaws placed in a standard hemisphere. To achieve "peaked" conditions, the overall gain of the analyzer is adjusted subsequent to normalized incidence of the transducer beam to detect the smallest artificial flaw in the standard, a 5-mil (0.013 cm) diameter flat-bottomed hole. However, the resulting degradation observed in the back-surface response for optimized detection of the 5-mil flaw is equivalent in actual practice to that obtained for minor variation in transducer-to-hemisphere alignment. As a consequence, the accept/nonaccept response level is based upon detection of a larger flaw size; in this case, a 10-mil (0.026-cm) diameter flat-bottomed hole with a side-wall depth of 10 mils. Location of the 10-mil diameter artificial in the standard is shown in Figure 4. Typical analyzer display of the back-surface response (echo pattern) for quality regions of the standard is shown in Figure 5; Figure 6 shows the analyzer display for detection of the 10-mil diameter artificial flaw.

Before a product hemisphere is substituted for the standard, the flaw alarm circuit of the analyzer is set to trigger on a back-surface response-change equivalent to detection of the 5-mil defect. With reference to Figure 5, this change is equivalent, for gated monitoring, to a reduction in the second back-surface echo to the 60% amplitude level. During inspection of a product hemisphere, if the alarm is triggered, the transducer alignment is checked and then the suspect region is rescanned. If the alarm is still triggering after realignment and the signal degradation is similar to that observed in Figure 6; that is, a reduction of the second back-surface echo to the 20% amplitude level or less, the hemisphere is unacceptable. For this test procedure, a degraded response still triggering the alarm but greater than 20% in amplitude constitutes a gray area and would be noted as such on the inspection report.

Actual inspection of a hemisphere is illustrated in Figure 7. With reference to Figure 7, the inspection starts at the pole region. At this location the part is scanned for a full rotation to accomplish a complete circumferential inspection. If no flaws are detected, the transducer is moved an increment of 5° towards the equator. Another circumferential scan is made at the new transducer location. This procedure is repeated until dome travel is completed. Location of anomalies detected by this scan technique are noted on the inspection report.

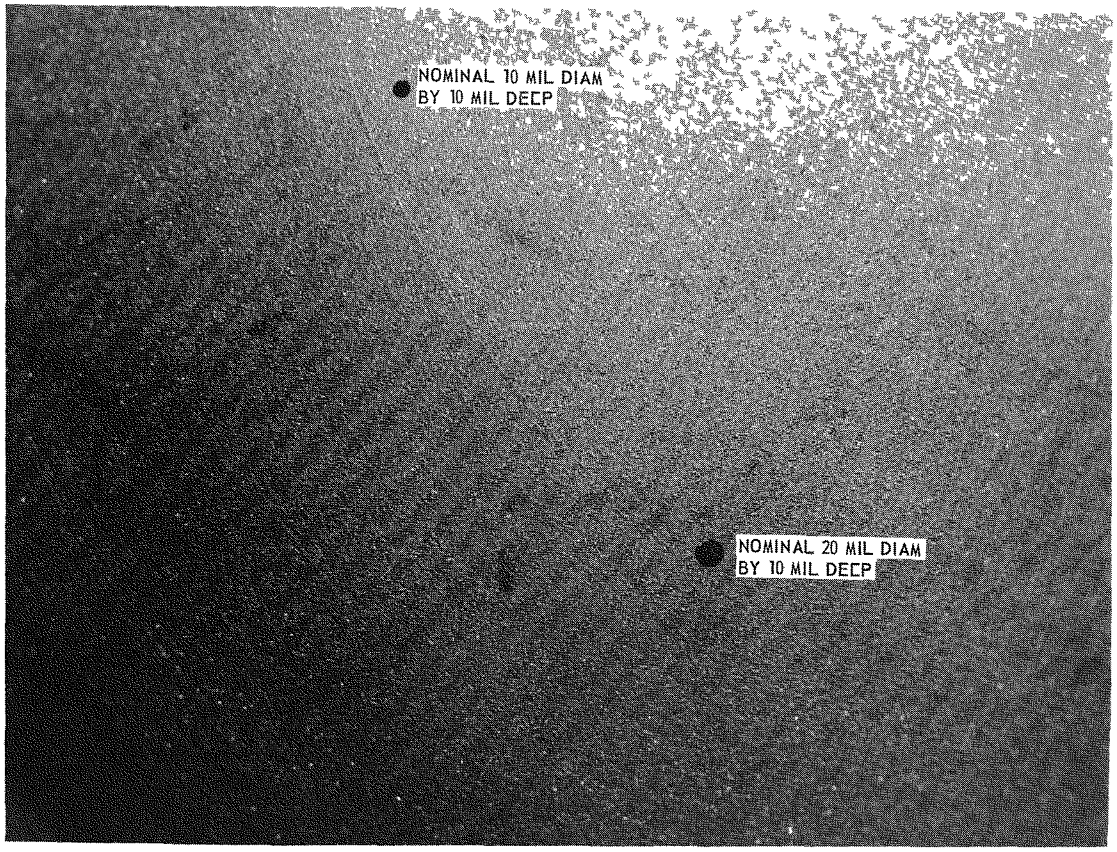

FIGURE 4 - I.D. view of standard showing location of several of the artificial flaws.

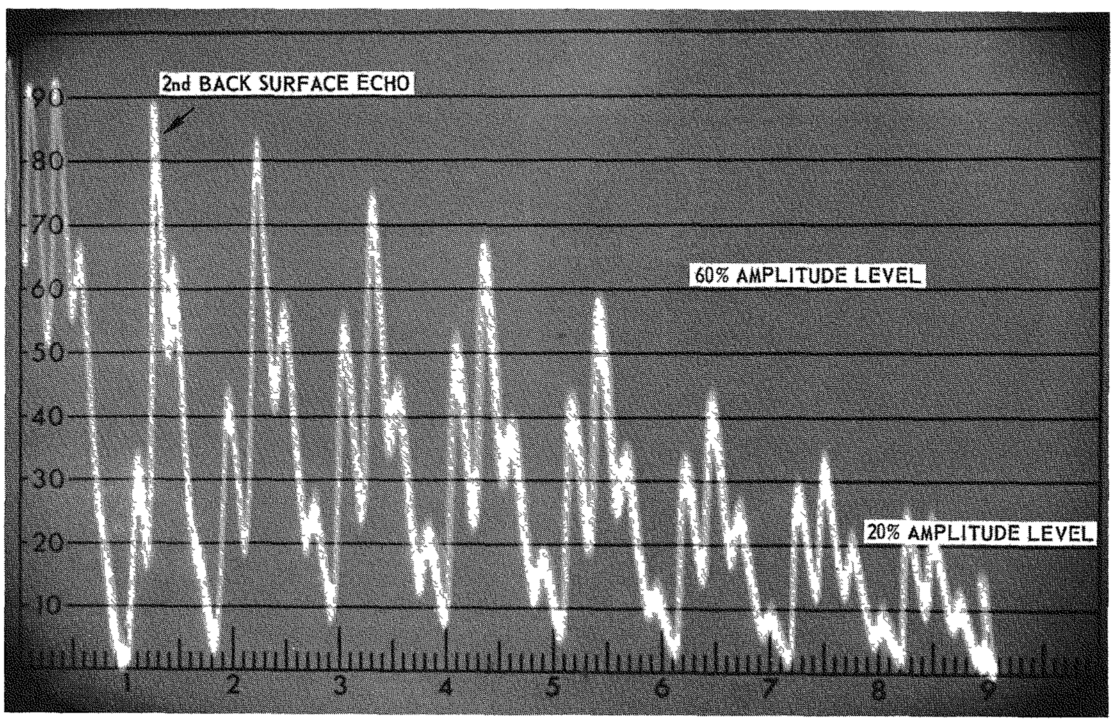

FIGURE 5 - Analyzer video display of quality region of standard.

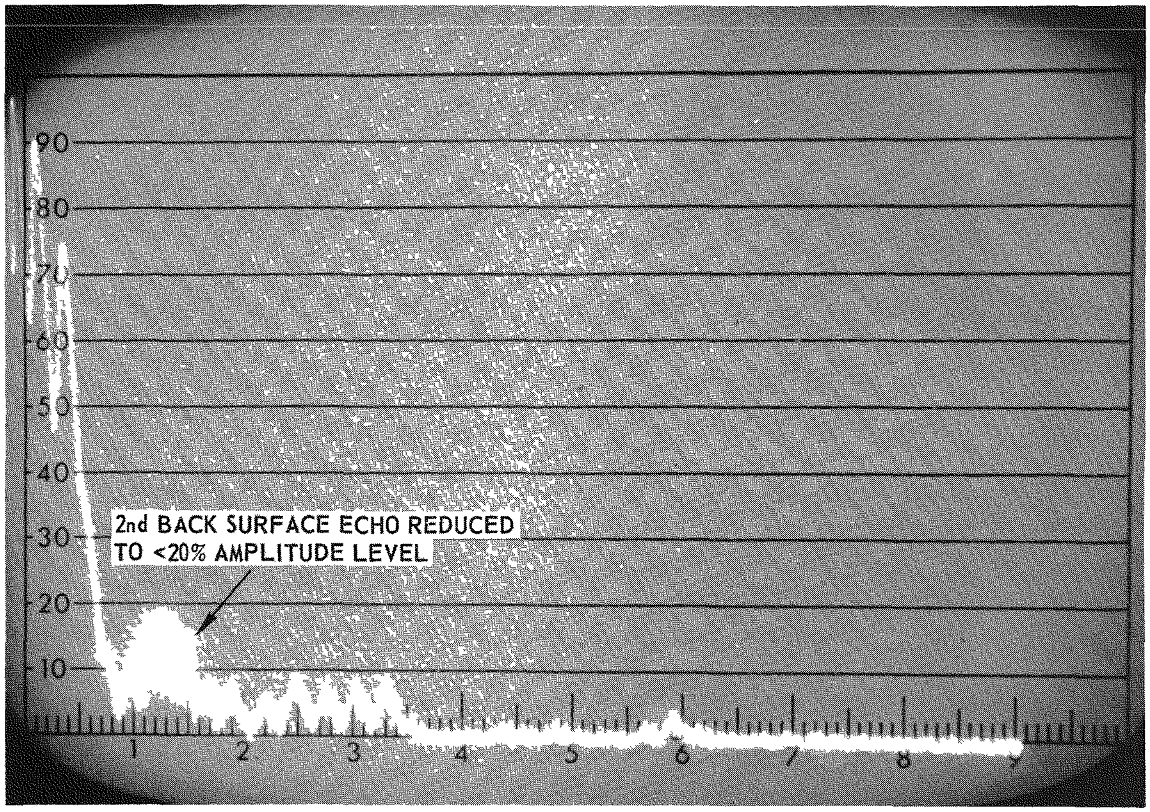

FIGURE 6 - Analyzer video display for detection of 10-mil diameter defect in standard.

Results

Figures 8 through 10 are photomicrographs taken of areas in which flaws were detected ultrasonically and confirmed upon metallographic inspection. In general, the defects are grain boundary separations. Where defects extend to the surface, correlation with dye penetrant inspection was also obtained. The various grain sizes and defects present in the hemisphere are probably a result of the fabrication process. Only 15 hemispheres, representing a sampling of the units made by the initial process, were examined ultrasonically. However, flawed regions were detected in seven of these 15 hemispheres. A direct consequence of this ultrasonic sampling as well as other reasons forced a change to a new fabrication method.

Figure 11 is a photomicrograph showing structure typical of hemispheres made by the new fabrication process. For all new process hemispheres examined to date (more than 200), there has been no ultrasonic indication of anomalies. The first two production lots of new-process hemispheres (48 hemispheres) were given a 100% volume inspection, which amounts to a 1° polar scan travel. However, since these items were free from defects, all subsequent hemispheres were examined at the current 5° increment scan which is equivalent to a 40% volume inspection. Occasionally there have been dye indications of flaws below ultrasonic detectability. However, the dye indications were related to cosmetic defects and generally disappeared after one or more polishings.

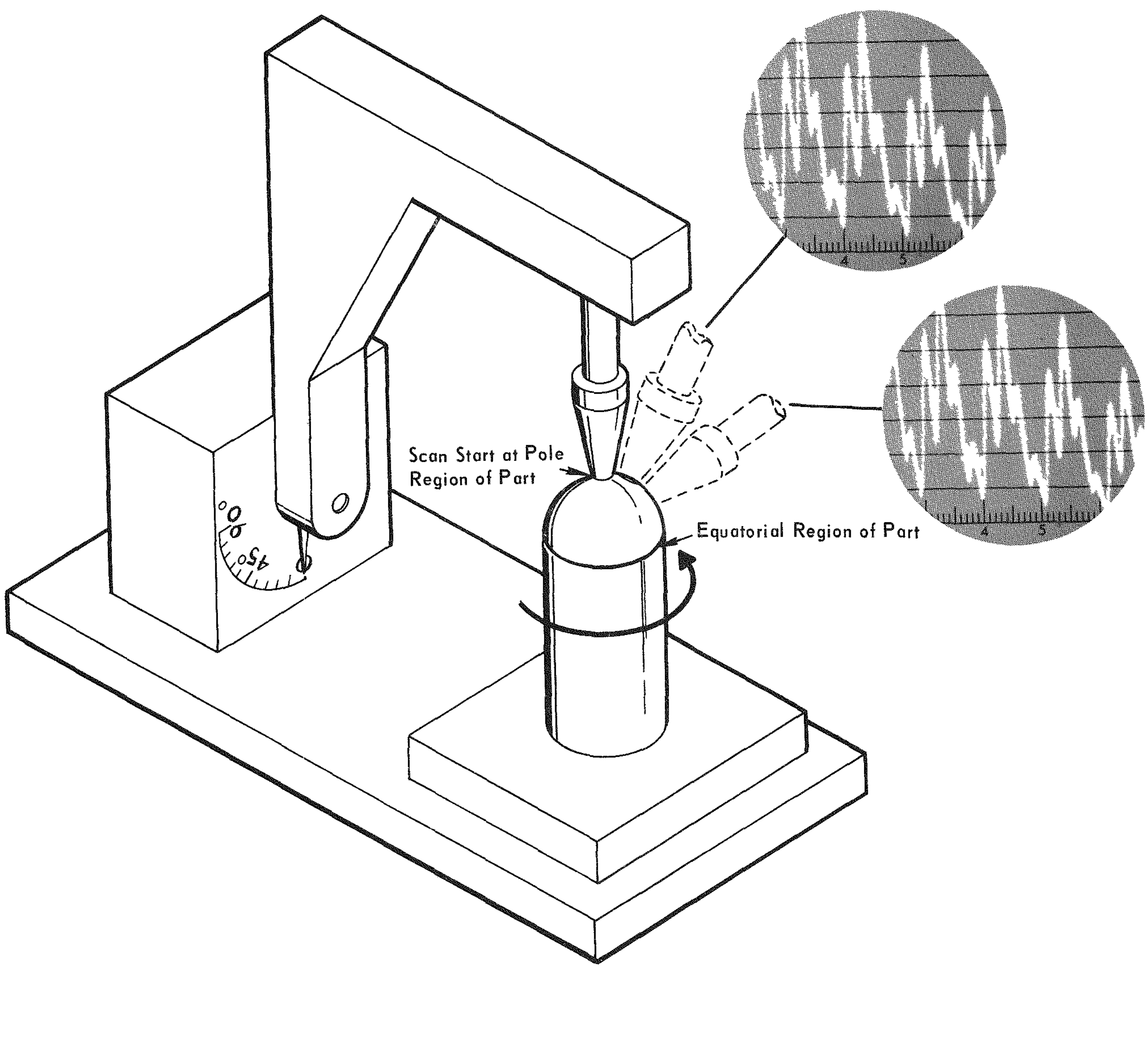

FIGURE 7 - Illustration of inspection

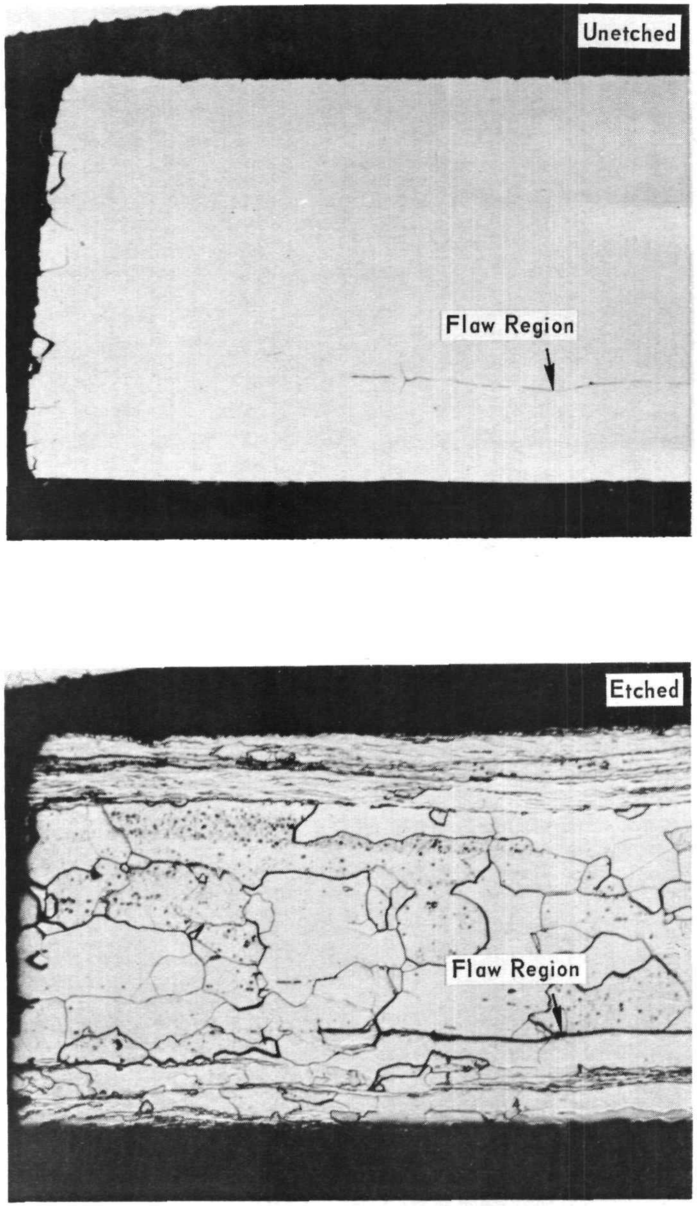

FIGURE 8 - Photomicrographs of destructive test results of initial process material.

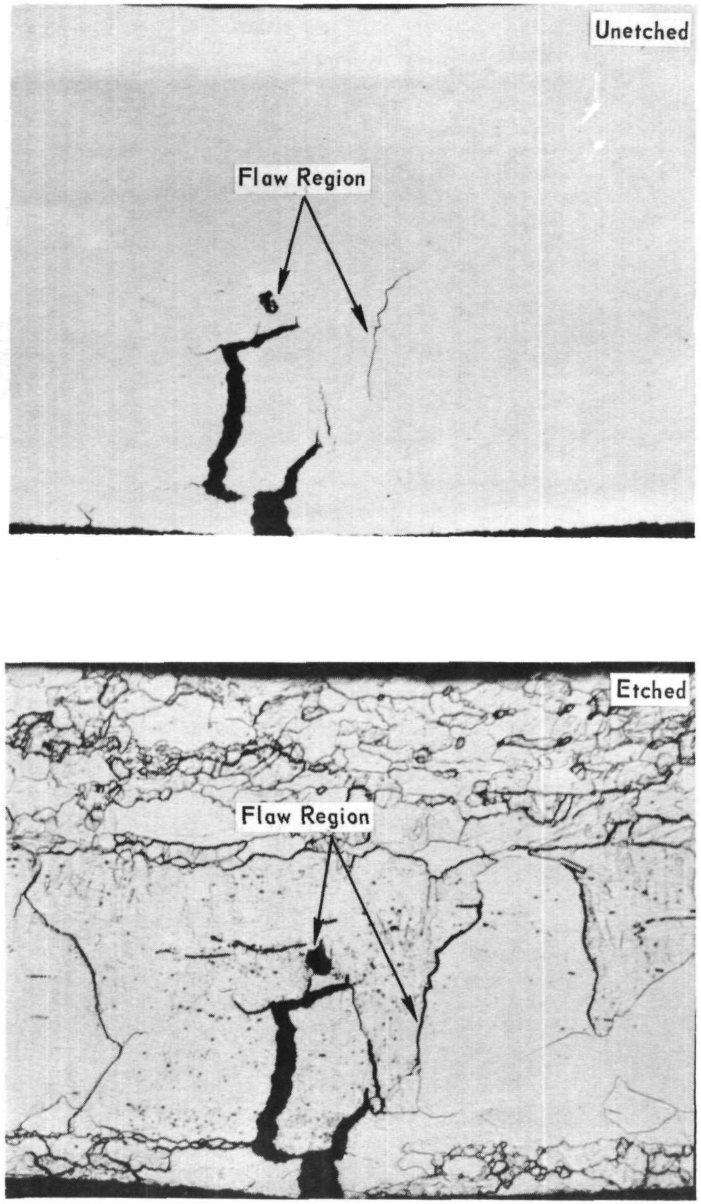

FIGURE 9 - Photomicrographs of destructive test results of initial process material.

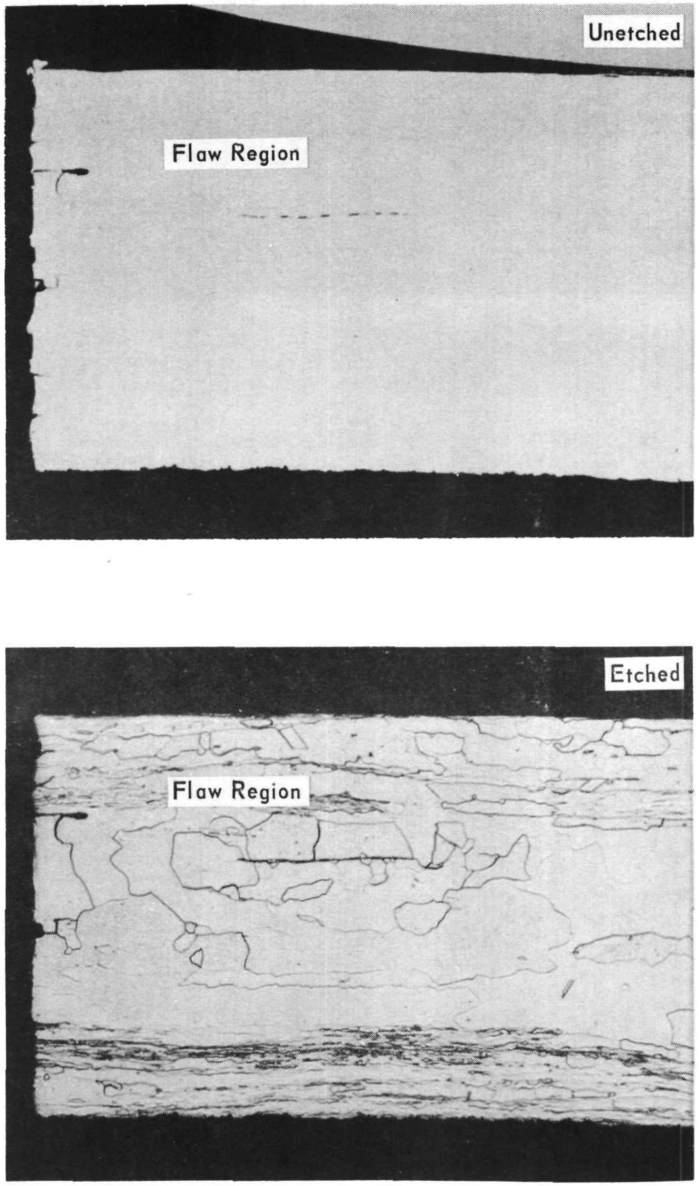

FIGURE 10 - Photomicrographs of destructive test results of initial process material.

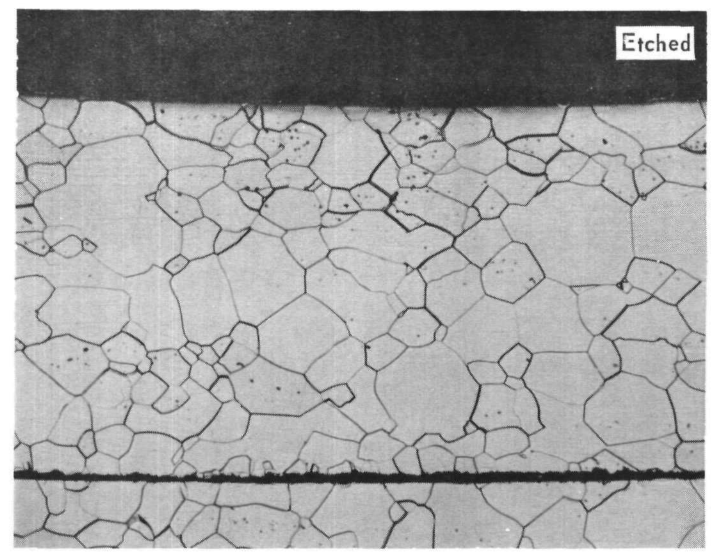

FIGURE 11 - Photomicrograph of typical new process material.

Summary

An ultrasonic technique and appropriate hardware were developed for inspection of thin-walled hemispheres of iridium. Confirmation of flaws determined ultrasonically was obtained by metallographic examination.

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