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Ultrasonic Characterization and Evaluation of CM Graphite Billets (U)

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ULTRASONIC CHARACTERIZATION AND EVALUATION OF CM GRAPHITE* BILLETS (U)

J. H. Gieske and D. E. Bishop
Nondestructive Testing Technology Division 9352

March 1975

Abstract (U)

A Total of 22 CM graphite billets were ultrasonically scanned with a minicomputer based data acquisition and display system. Pulse echo data along with sonic velocity and relative attenuation data were obtained for the entire volume of each billet. All billets exhibited about the same characteristics. One billet was selected to be sectioned in order to evaluate the ultrasonic pulse echo data by other NDT tests. Different distributions of material porosity were found to correlate with the pulse echo data.

* Union Carbide Product

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ULTRASONIC CHARACTERIZATION AND EVALUATION OF CM GRAPHITE BILLETS

Introduction

Several different lots of CM graphite billets were received by Sandia to be used for test nose plugs for evaluating fuzing in the Mark 4 development program. All the billets received were considered "rejects" for one reason or another. One lot of 10 billets was rejected as a normal lot because during one phase of its processing cycle, the temperature reached a value beyond specifications. A second lot of 10 billets was rejected because chlorine gas was introduced into the processing chamber during the final phase of its process. Several other billets from other lots were rejected because of x-ray indications, or other indicators not within an accepted billet's specifications.

Since all billets were "rejects" it was decided to perform ultrasonic pulse echo tests on a number of billets from each lot in order to evaluate and rank them from most suitable to less suitable billets for their intended use. The results of the pulse echo tests showed that the majority of the CM billets had a large number of low amplitude ultrasonic echoes from the core of the billets.

Since no observation of this type was observed in a normal ATJ-S* graphite billet, the billet 56B-8 was sectioned in a manner to investigate the cause of the pulse echo returns. This report presents the ultrasonic results of billet 56B-8 and its sliced parts along with DXT (radiation gaging) and dye penetrant results of the sliced parts.

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* Union Carbide Product

Experimental Setup and Calibration

A minicomputer ultrasonic data acquisition and display system was used for all the ultrasonic tests.[1,2,3] Reference 1 describes the first generation system and Ref. 3 describes the third and latest version of the ultrasonic computer interface used in the system. All parts to be scanned were sprayed with a PVC strippable coating and placed in an immersion water tank. An ATJ-S test block[4] was used to set the sensitivity of the system by adjusting a time dependent gain ramp to obtain appropriate echo emplitudes from flat-bottom holes at various depths within the test block.

The gain ramp which is triggered just prior to arrival of the front surface echo of the test part was used in order to compensate for scattering and attenuation of the ultrasonic wave with depth. Figure 1 shows the oscilloscope traces of the gain ramp and the ultrasonic video display of the front surface and back surface echoes from the ATJ-S test block at the thickness of 2.5 in. A 2.25 MHz, 0.5-in. diameter transducer was used with a water path of about 4 in. and the gain ramp was adjusted such that an even distribution of low echo amplitudes was obtained for the full 2.5 inches of the ATJ-S graphite. Under these conditions the front and back surface echo amplitudes were approximately equal.

With this gain curve, the signal from the 0.031-in. diameter flat-bottom hole of the test block at 1-in. depth was 95 mV and and 0.062-in. diameter flat-bottom hole at 2-in. depth was slightly over 100 mV as seen on the oscilloscope screen. All ultrasonic echoes above 20 mV are recorded by the ultrasonic computer interface. A full-scale signal of 100 mV was taken as a reference signal of amplitude 0 dB and all recorded signals are based on the logarithmic scale from -15 dB to 0 dB corresponding to signals with amplitudes in the range 20 mV to 100 mV. Any signal over 100 mV was recorded as 0 dB.

Results

The pulse echo results of all the CM graphite billets showed more or less the same characteristics. What was especially interesting was the fact that a large amount of low echo indications were received from the core of the billets. Figure 2 is an example of the display of the pulse echo data obtained from billet 56B-8. Shown in Fig. 2 is a top view of each 45° pie-shaped segment of the billet with a depth view of the same segment shown to the right of the top view. Each dark spot in the figure represents a location in the billet where an echo of amplitude greater than -12 dB was recorded.

A 100% scan of the radial velocity and relative attenuation of the ultrasonic wave in the billet was also obtained and the results are shown in Fig. 3. The radial velocity throughout the whole billet was very uniform, i.e., to within 2%. The relative attenuation of the back surface echo showed large variations and the white areas in the figure show where the amplitude was below -15 dB from a reference amplitude of 0 dB which was set at the average amplitude of the back surface echo.

To evaluate the meaning of the ultrasonic data, billet #56B-8 was sliced into several pieces as shown in Fig. 4. One 3/4-in. thick slab was machined from the end of the billet where relatively few pulse echo indications were recorded. Another 3/4-in. slab was taken from the middle of the billet. Both these slabs were scanned for pulse echo indications in the axial direction with the same gain setting as used for the billet. These pulse echo results are shown in Fig. 5. Again, the slab from the middle of the billet showed a higher density of pulse echo indications than the slab from the end of the billet.

Ultrasonic velocity data was also obtained from the slabs and velocity value contours for the axial direction are shown in Figs. 6 and 7. Here no significant difference between the two slabs is observed.

The two slabs were also scanned for density variations by the DXT technique using a 60-mil diameter collimated x-ray beam. No distinguishable density variations were found in the slabs nor were the slabs different in density from each other by more than 1%.

The large 3-in. thick slab was polished and examined on both ends with a dye penetrant. Figure 8 shows the results obtained. The bright areas in the pictures indicate areas where the penetrant is most readily absorbed by the material and therefore indicates areas of porosity. The dye penetrant technique clearly shows that the surface at the middle of the billet has more porosity than the surface at the end of the billet.

The 3-in. thick slab was then sliced with a plane parallel to the axis of the billet and the dye penetrant test was performed on the exposed surface. The result shown in Fig. 9 indicates that the porosity is indeed confined to the core of the billet and has the general shape predicted by the pulse echo data. It is also seen that some fairly large pores exists within the billet as is seen by the bright spot shown in the upper part of Fig. 9.

At the present time no "accepted" CM graphite billets were available for pulse echo testing; however, a test shape which was machined from an "accepted" CM graphite billet was available.* An attempt was made in evaluating the "rejected" material in comparison with the "accepted" material using this test shape.

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* Some time subsequent to preparation of this report, Sandia participated in a "Round Robin" test evaluation of NDT techniques using five full-size "as fabricated" CM graphite billets of preproduction hardware material. The five billets provided by Lockheed Missiles and Space Company, Inc. were ultrasonically scanned in the same manner as mentioned in this report. The ultrasonic data of the five "Round Robin" billets are presently being drafted and a report of these results will be submitted to LMSCI. A comparison of the test results of the five "Round Robin" billets with the test results of the billets reported in this paper shows no significant difference in the ultrasonic pulse echo data.

Pulse echo data was taken along the conical section of the test shape with the same procedure used for the billets. The pulse echo display of the data obtained is shown in Fig. 10 where a schematic of the cross-section of the test shape and the depth to which the data is displayed is also shown. The conical section was scanned through a distance of 4 inches and the depth is the same as that displayed for the billet.

As seen in Fig. 10 a larger number of low amplitude echoes were recorded in the same range of amplitudes as displayed in Fig. 2 for billet 56B-8. Since the configuration for scanning the test shape is different than for scanning a billet, it was decided to machine a second test shape to the same dimensions as the "accepted" material test shape from billet 57B-2. The pulse echo data of billet 57B-2 looked very similar to that of billet 56B-8. After this billet was machined the test shape was scanned in exactly the same way as the test shape of "accepted" material. The results are displayed in Fig. 11. Here it is seen that the number of echoes displayed is substantially smaller than the number displayed in Fig. 10. The pulse echo plot of Fig. 11 also looks very similar to the pulse echo plot of the billet 57B-2, so that the geometry of the test shape did not alter the pulse echo data by any significant amount. From the dye penetrant results of billet 56B-8, it appears then that this material is less porous than that of the "accepted" material.

Summary

The ultrasonic pulse echo results of the CM graphite billets received by Sandia indicated material discontinuities concentrated in the core of the billets. By slicing one of the billets and performing dye penetrant tests on the exposed surfaces, a distribution of porosity within the material correlated with the pulse echo results. The billets examined were termed "rejects" from accepted CM graphite billets.

Pulse echo data was also obtained for a machined test shape of "accepted" CM graphite material. Comparison of this data was made with the data from an identical test shape machined from one of the "rejected" CM graphite billets. A significantly larger number of low amplitude pulse echo indications were recorded from the test shape of "accepted" material; whereas, the test shape of "rejected" material showed results very similar to those obtained from its billet form. The conclusion is that the two materials have different porosity distributions.

The influence of the porosity observed by the dye penetrant technique on the mechanical properties of the graphite composite was not persued here but may be of interest for a more complete evaluation of the CM graphite composite.

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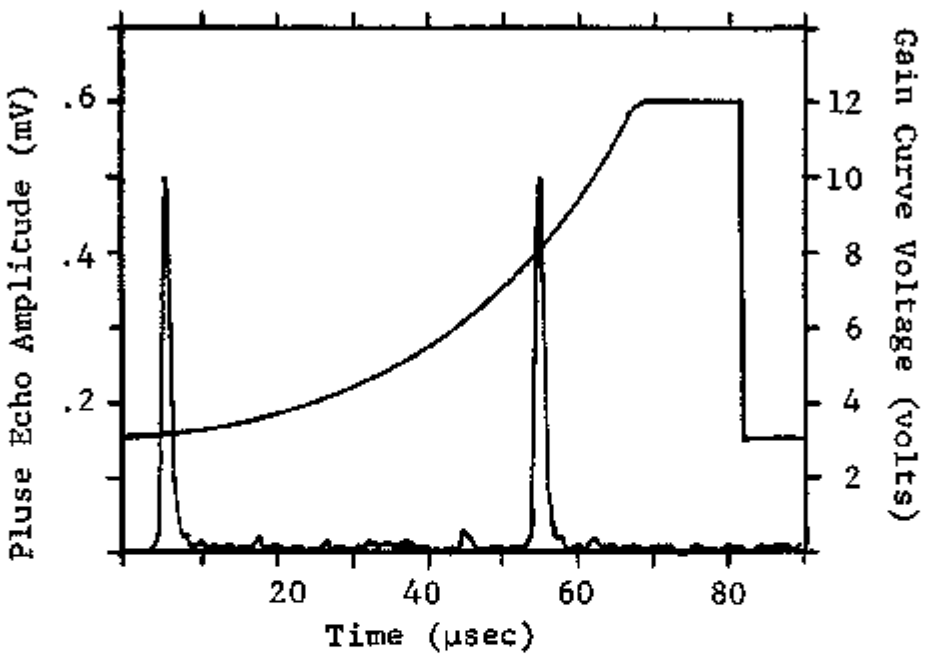

Figure 1. Oscilloscope Display of the Gain Curve Used in Testing the CM Graphite Billets and the Resulting Ultrasonic Video Display for a 2.5-in. Thick ATJ-S Graphite Test Block

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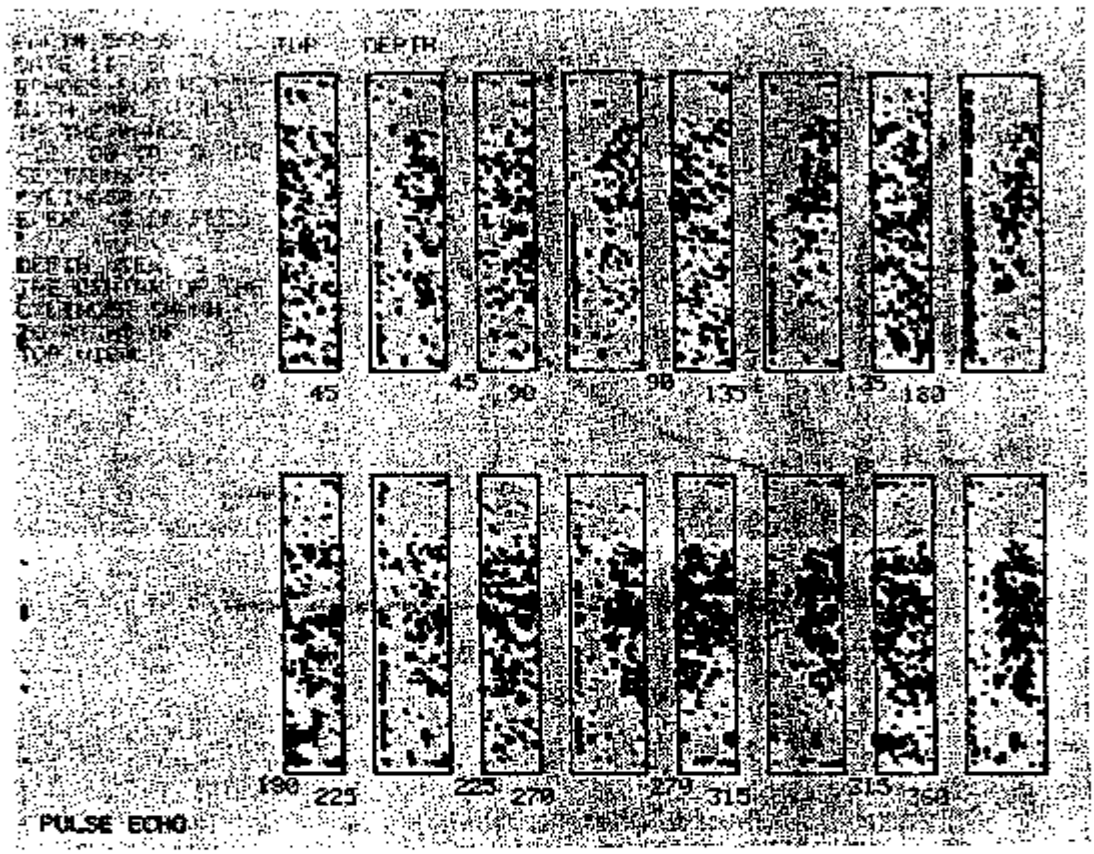

Figure 2. Pulse Echo Data for Billet 56B-8 Displayed with Top and Depth Views. Depth View Shows Data from the Outer Surface of the Billet to the Center of the Billet for Each 45° Section.

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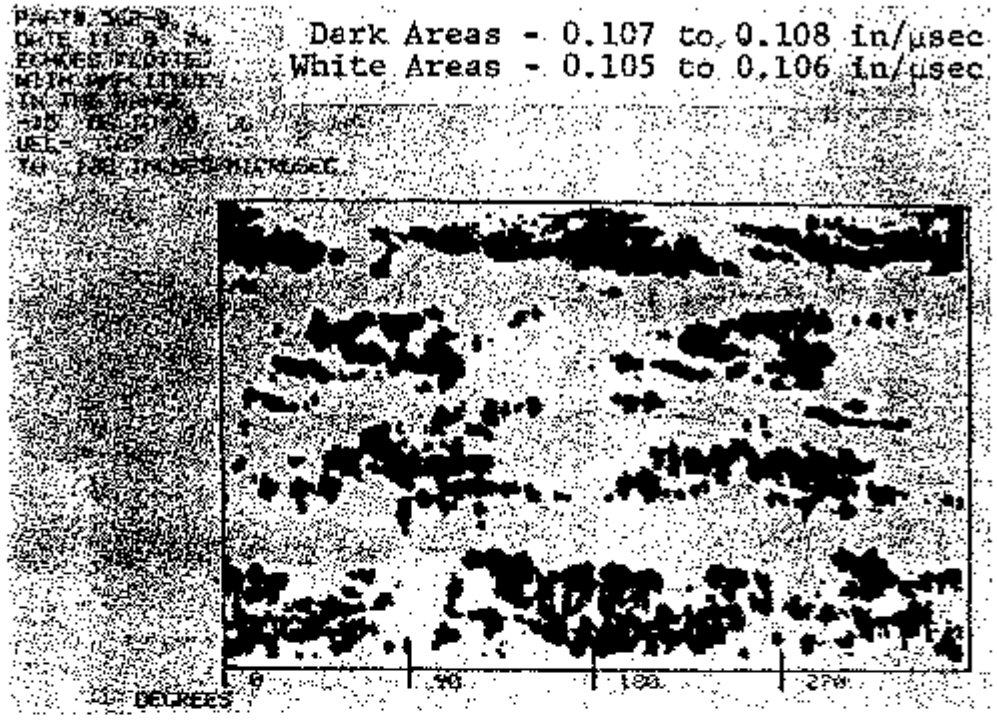
[redacted]



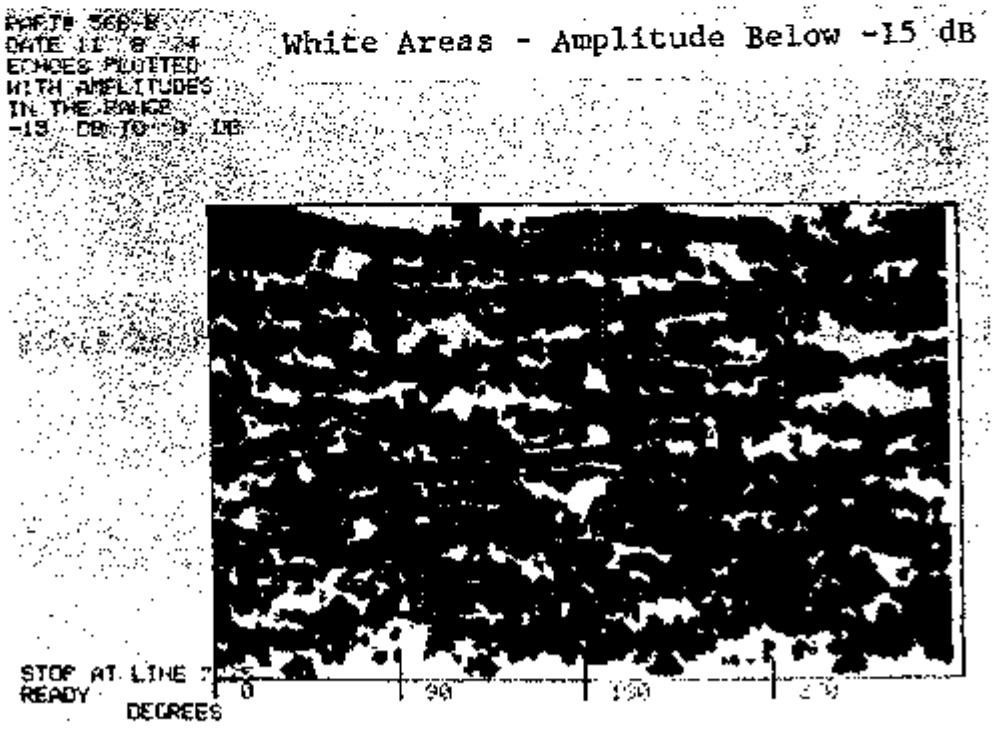


Figure 3. Ultrasonic Velocity and Attenuation Plots for Billet 56B-8.

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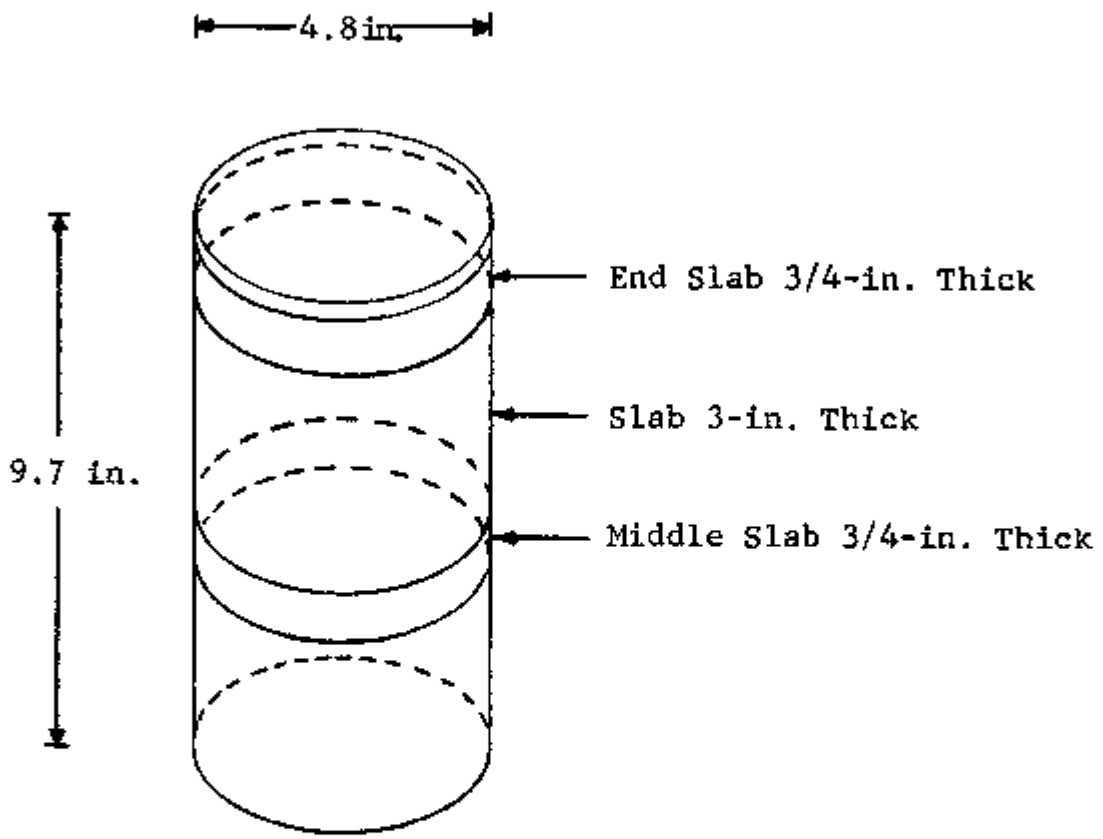


Figure 4. Sketch of Billet 56B-8 and Locations of Slabs

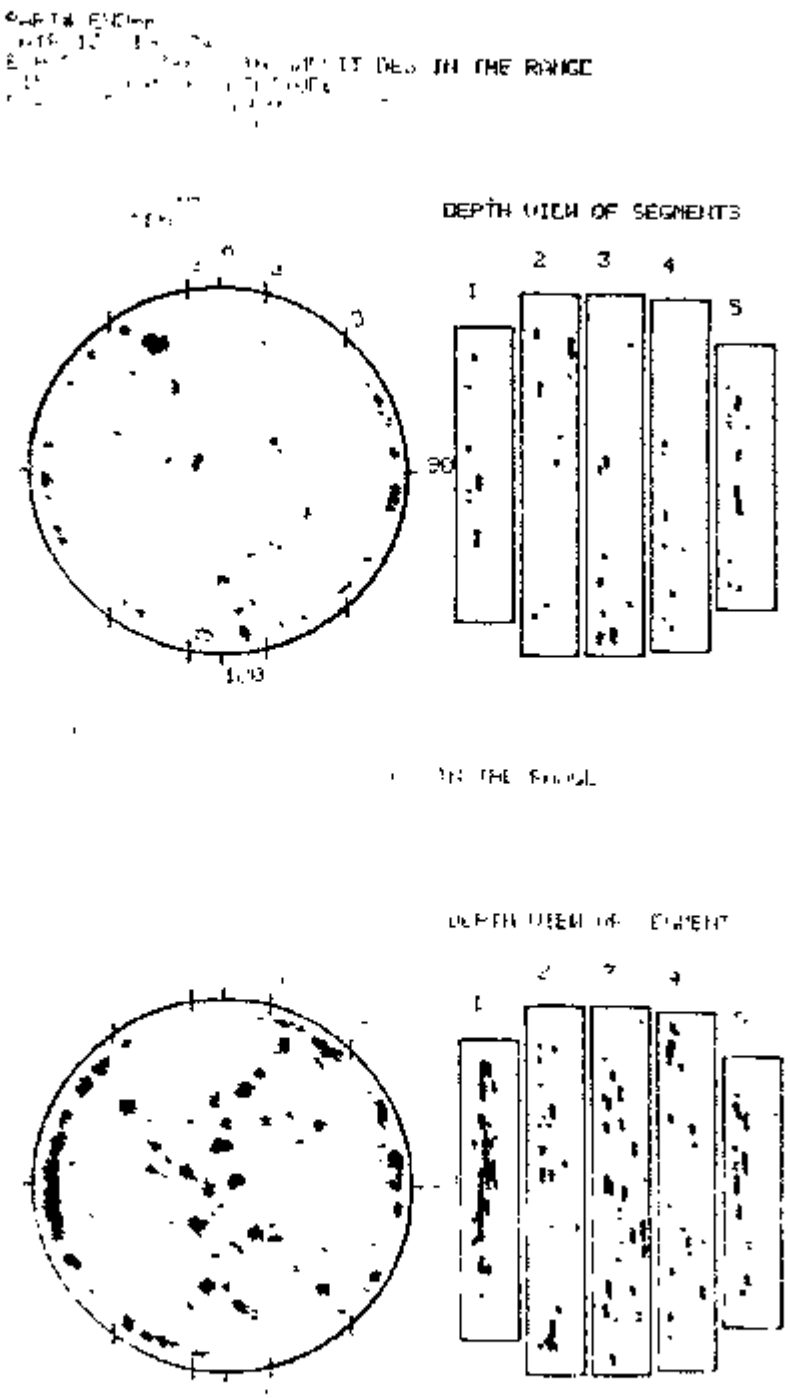


Figure 5. Top and Depth Views of Pulse Echo Data from 3/4-in. Thick End Slab and 3/4-in. Thick Middle Slab.

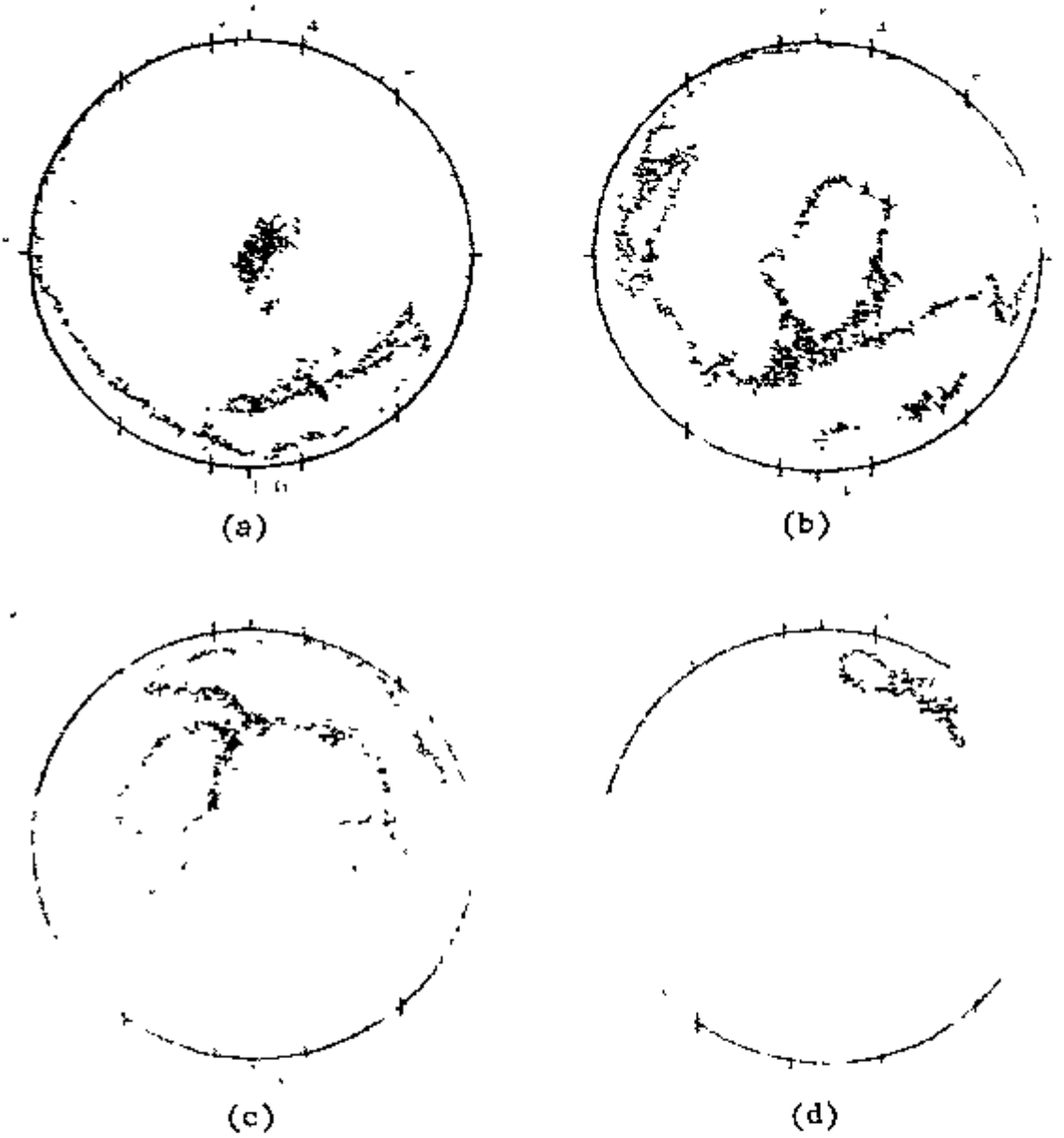


Figure 6. Ultrasonic Velocity Contours for 3/4-in. End Slab.
(a) 0.0845 in/μsec, (b) 0.0855 in/μsec,
(c) 0.0865 in/μsec, (d) 0.0875 in/μsec.

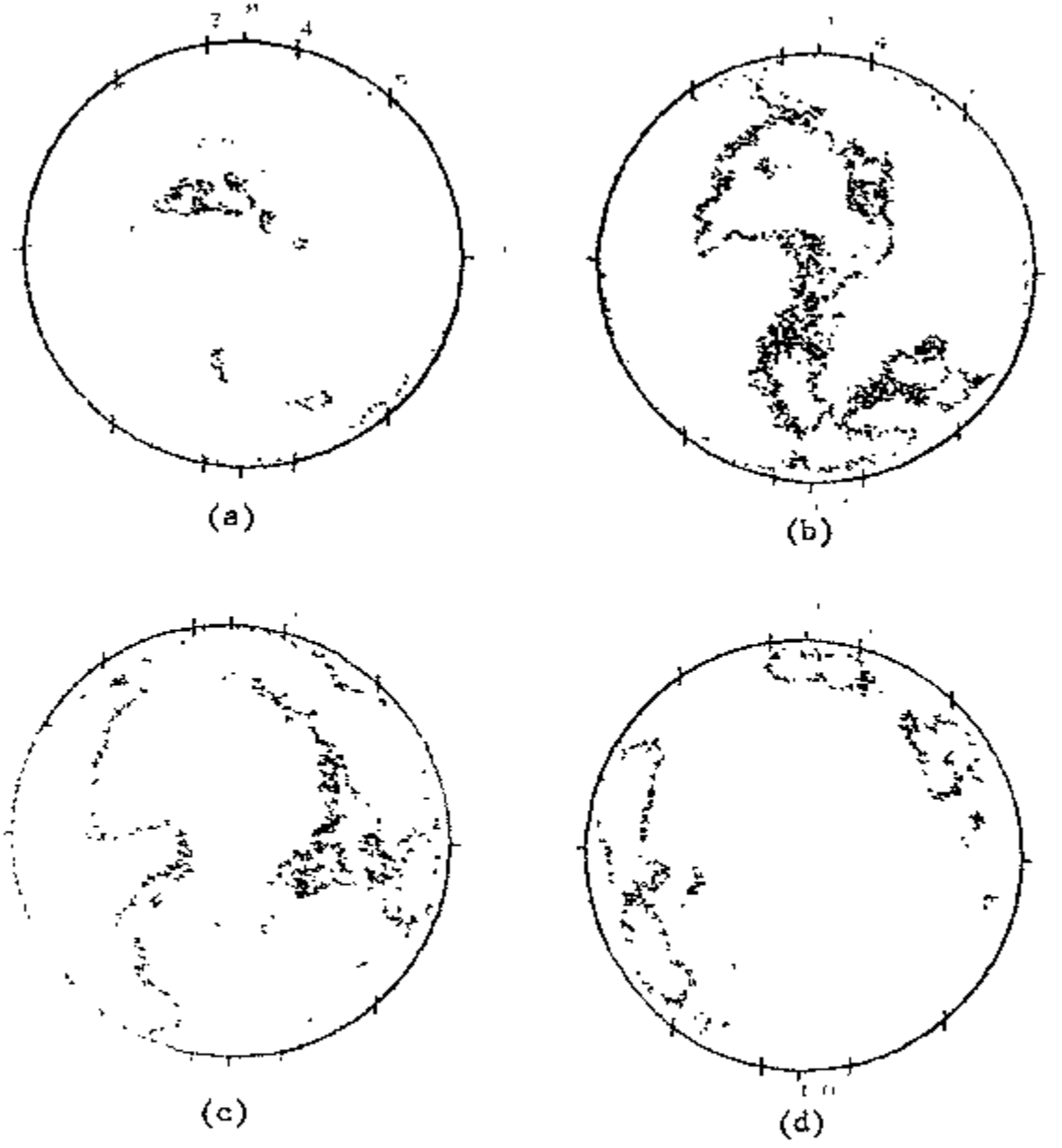
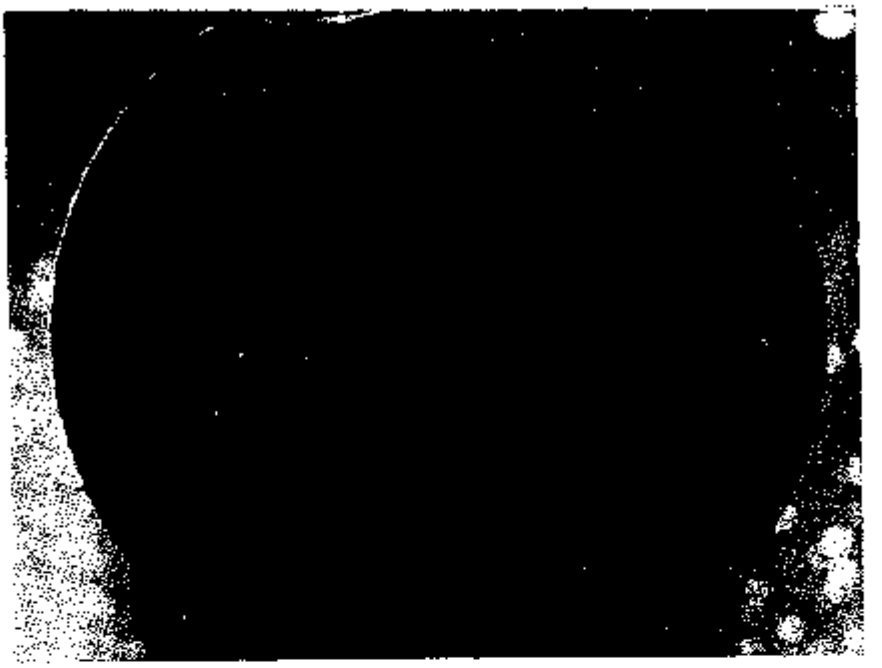
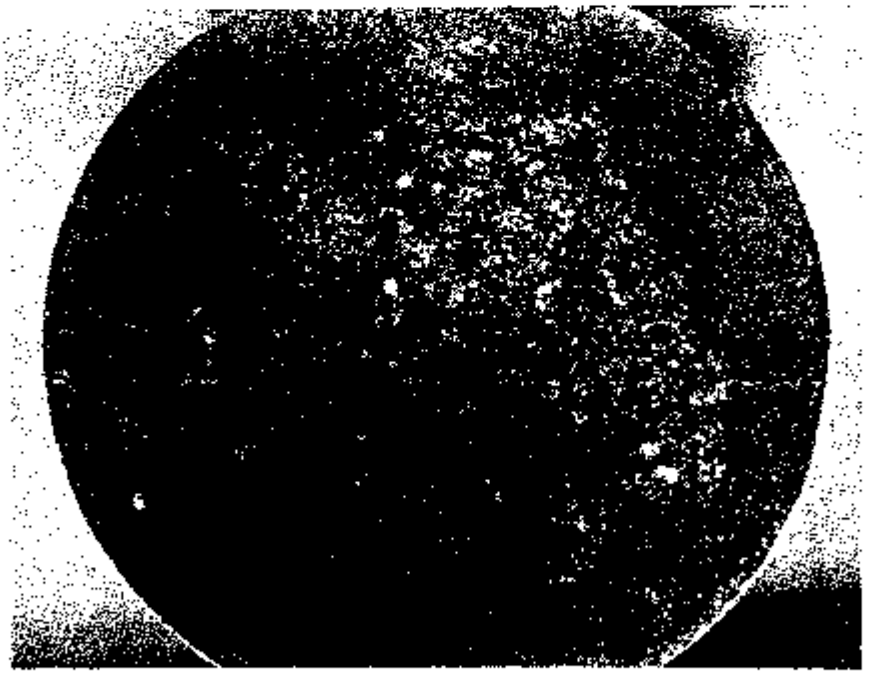


Figure 7. Ultrasonic Velocity Contours for 3/4-in. Middle Slab
(a) 0.0850 in/μsec, (b) 0.0860 in/μsec,
(c) 0.870 in/μsec, (d) 0.0880 in/μsec.



(a)



(b)

Figure 8.
Dye Penetrant Results of Surfaces on the 3-in. Thick Slab.
(a) Near End of Billet, (b) Near Middle of Billet.

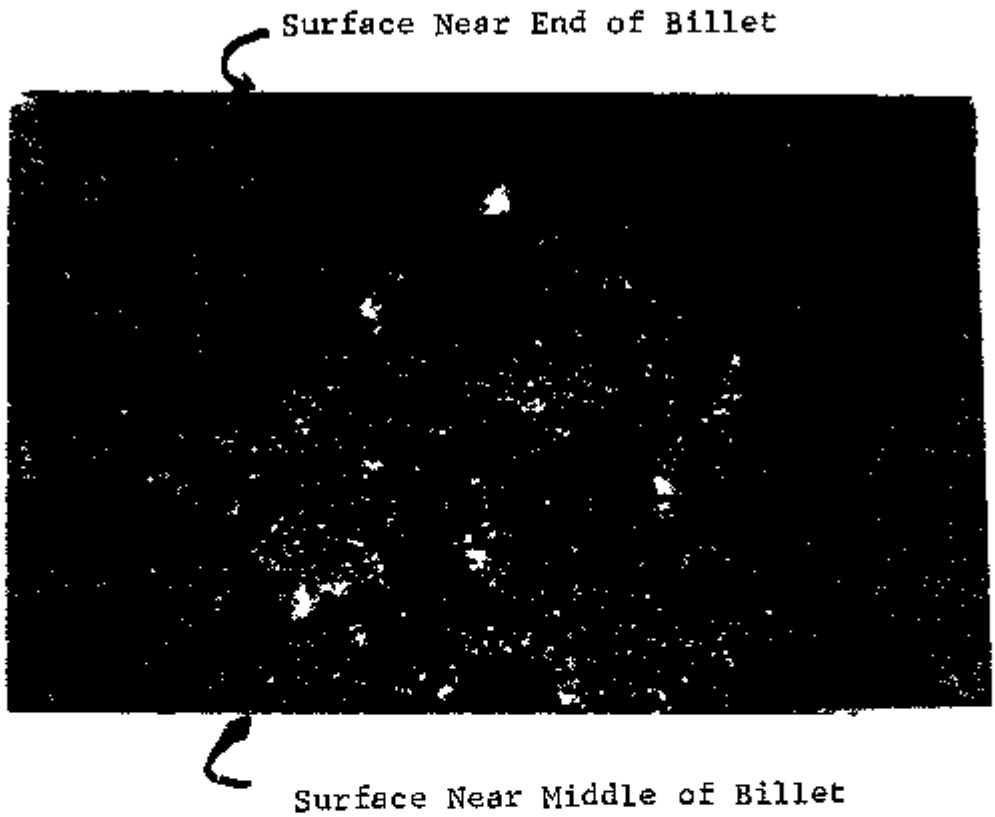


Figure 9. Dye Penetrant Results of Surface Parallel to the Axis of the Billet for the 3-in. Thick Slab.

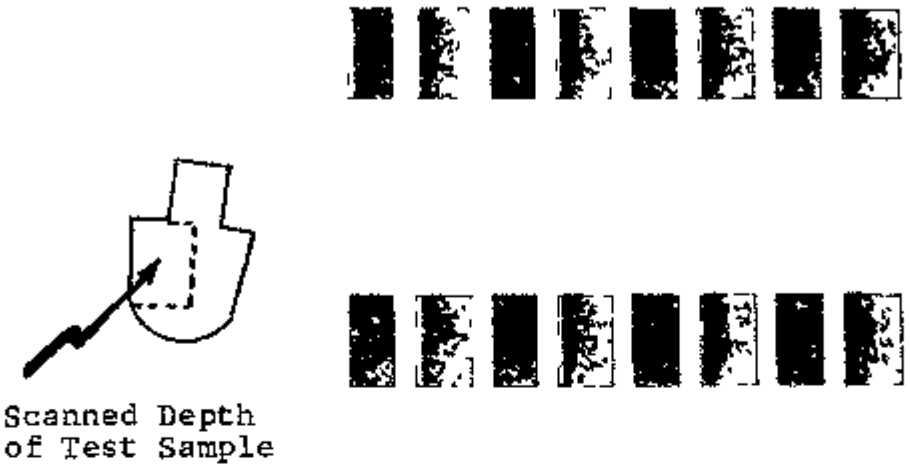


Figure 10. Pulse Echo Data for Test Shape of "Accepted" Material.

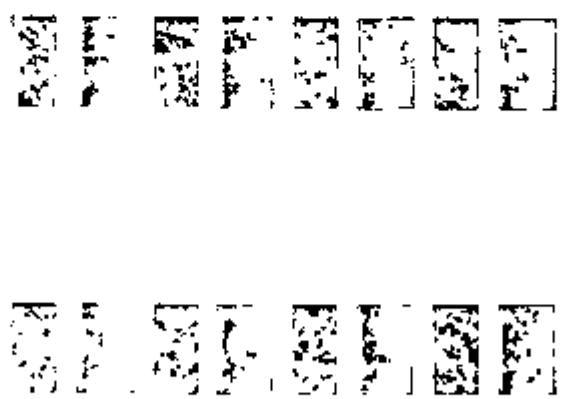


Figure 11. Pulse Echo Data for Test Shape Machined from Billet 57B-2.

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4. Bishop, D. E., "Calibration of a Computerized Ultrasonic System for ATJ-S Graphite Testing," Sandia Laboratories SLA-73-0224, March 1973.

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