

APPLICATION OF FLEXIBLE TRANSDUCER ARRAY TECHNOLOGY TO MEASURE  
EROSION-CORROSION IN CARBON STEEL PIPING

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INTRODUCTION

The Portable Automated Remote Inspection System (PARIS) manufactured by Failure Analysis Associates, Inc. (FaAA) was originally designed to inspect graphite epoxy composites. Recently, FaAA has investigated the application of PARIS to measure wall thinning in carbon steel components. The results of this investigation are the subject of this paper.

The unique feature of PARIS is its large area, flexible transducer array. Figure 1 shows an 8- by 8-inch PARIS array with 1024 addressable elements. The flexibility of the PARIS array permits it to conform and acoustically couple to curved surfaces such as piping and elbows. The principle advantages of using PARIS for wall thinning measurements are that it can rapidly perform the inspection, log the results and guarantee 100% coverage.

EXPERIMENTAL RESULTS

Tests on three different samples are discussed in this paper. The first sample is a 1/2-inch thick plate with a variety of machined features to simulate wall thinning. Results from the plate demonstrate some of the display capabilities of PARIS. The second two samples are sections of 14-inch diameter pipe elbow. Both of these samples suffered severe wall thinning due to erosion experienced in-service.

Figure 2 shows the back side of Sample 1, a 1/2-inch thick plate of ASTM Spec. A36 carbon steel. The plate is 16- by 16-inches square and was machined with various features to simulate wall thinning due to corrosion or erosion. These patterns were chosen because their distinct shapes and various depths are easy to recognize in the ultrasonic scans.

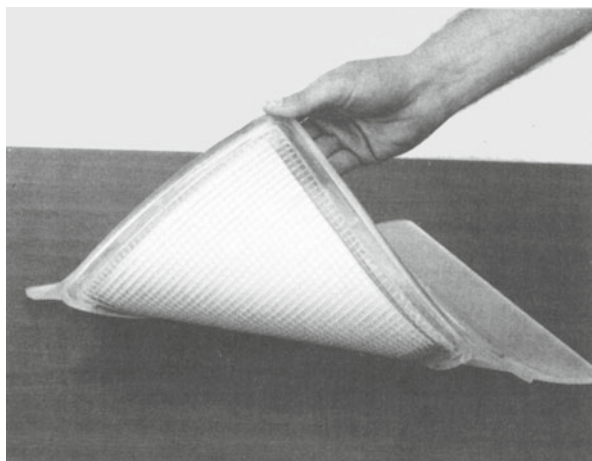


Figure 1. 8- by 8-inch PARIS array.

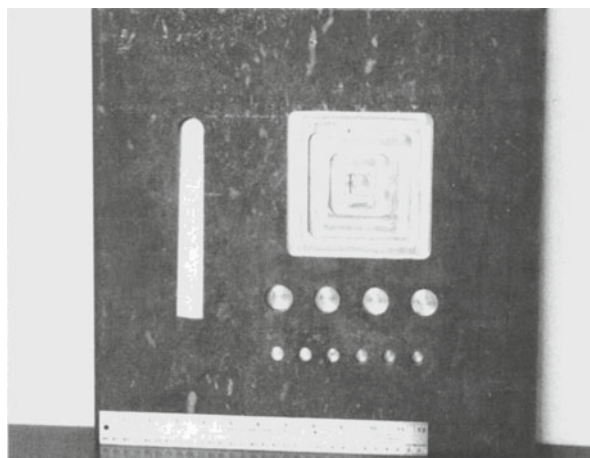


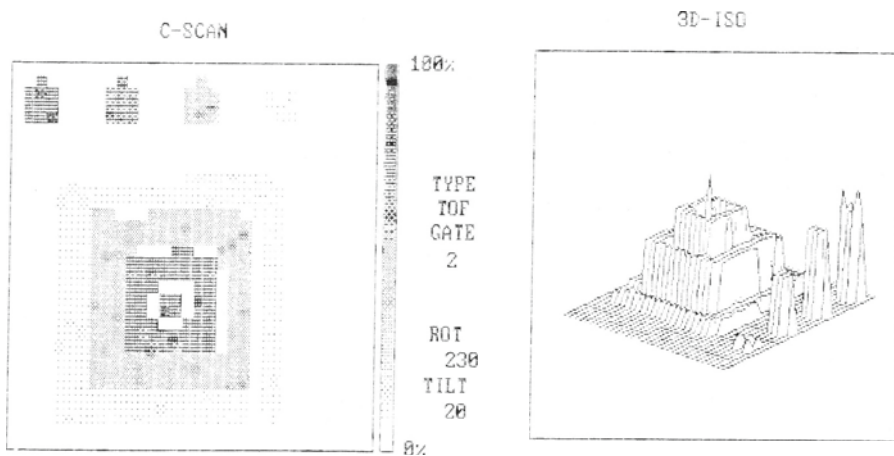
Figure 2. Sample 1, 1/2-inch Carbon Steel Plate.

The four larger holes in the plate are one-inch diameter drilled to within 0.440, 0.290, 0.200 and 0.045 inches of the front surface. The six smaller holes are 0.500-inch diameter and range from 0.425-inch to 0.050-inch from the front surface. The slot is one inch wide and is tapered from the back surface to approximately 0.070 inches from the front surface. The square stepped pyramid is milled in four progressively deeper 0.75-inch wide steps. The shallowest step is approximately 0.060 inches from the back surface and the deepest is 0.400 inches from the back surface.

Figure 3 shows a time-of-flight C-scan and 3D isometric image from an ultrasonic inspection of a section of the plate. A 64 square inch area was inspected using a PARIS array with 1024, 1/4- by 1/4-inch elements. The total scan time is approximately one minute. The array was positioned on the plate over an area that includes the stepped pyramid and the four one-inch diameter holes. Depth is displayed on the time-of-flight C-scan using the gray scale shown to the right.

The 3D isometric display to the right of the C-scan provides the same information but with depth information displayed as the third dimension. In this display, the bottom of the plate is the level area at the bottom of the 3D image. The relative depths of the one-inch diameter holes and steps of the pyramid are clearly visible in this display.

Figure 4 shows Sample 2, a section of 14-inch pipe elbow with nominal 3/8-inch wall. The inside and outside surfaces of the sample are shown in Figures 4a and 4b, respectively. The dark patch on the outside surface of the sample, visible in Figure 4b, is the area where the inspection was performed. The dark color is due to the water that was used for couplant.



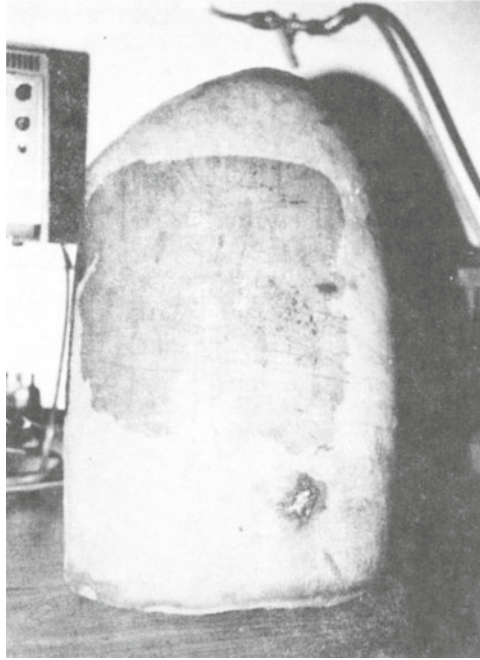
\*PRESS FUNCTION KEY FOR DESIRED ACTION.



Figure 3. Time-of-flight C-scan and 3D Isometric Images for Sample 1.



(a) Inside Surface



(b) Outside Surface

Figure 4. Sample 2, 14-inch Pipe Elbow.

The total time required for instrument setup and inspection was about twenty minutes. Sample preparation consisted of removal of the surface dust with a wet cloth. A water mist was sprayed on the surface prior to placing the array. After the array was vacuum clamped to the sample, the inspection was completed in approximately one minute.

Figure 5a is an enlargement of the inside surface of the elbow with a border superimposed on the figure to indicate the approximate inspection area. Figure 5b shows the raw time-of-flight C-scan image resulting from the inspection. In Figure 5b, the upper left corner of the image is oriented to the lower left corner of the dark area of Figure 4b. Comparison of Figures 5a and 5b shows the reversal of the image resulting from the inside view of the sample in Figure 5a.

Using the gray scale to the right of the C-scan image and comparing Figures 5a and 5b, shows that the uniform light shade in the C-scan represents the nominal thickness of the sample. The areas of wall thinning are clearly visible in Figure 5b by their darker shading.

Figure 6 is a result of post processing the raw time-of-flight data. In this figure, the data have been smoothed by linear interpolation and the image was reversed from left to right to correspond to the inside view of the sample shown in Figure 5a. The lighter area in the lower right of Figure 6 is the result of poor coupling due to the condition of the outside surface of the sample. As has been discussed, very little surface preparation was performed prior to performing the inspection.

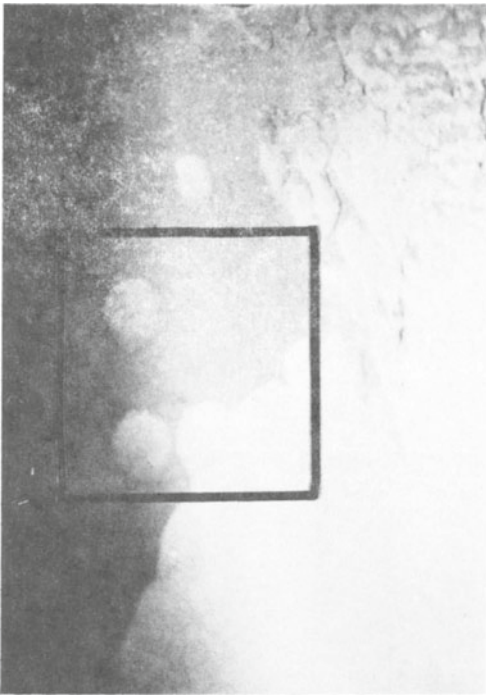


Figure 5a. Inspection Area.

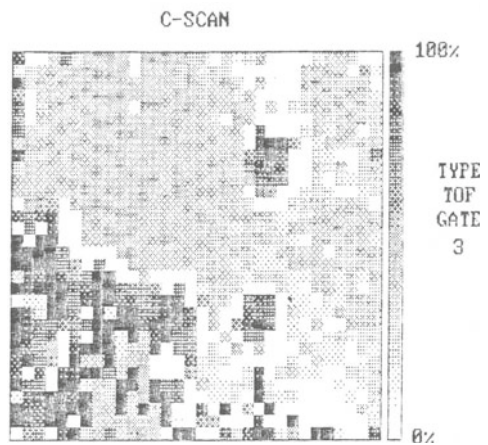


Figure 5b. Time-of-Flight C-scan from PARIS.

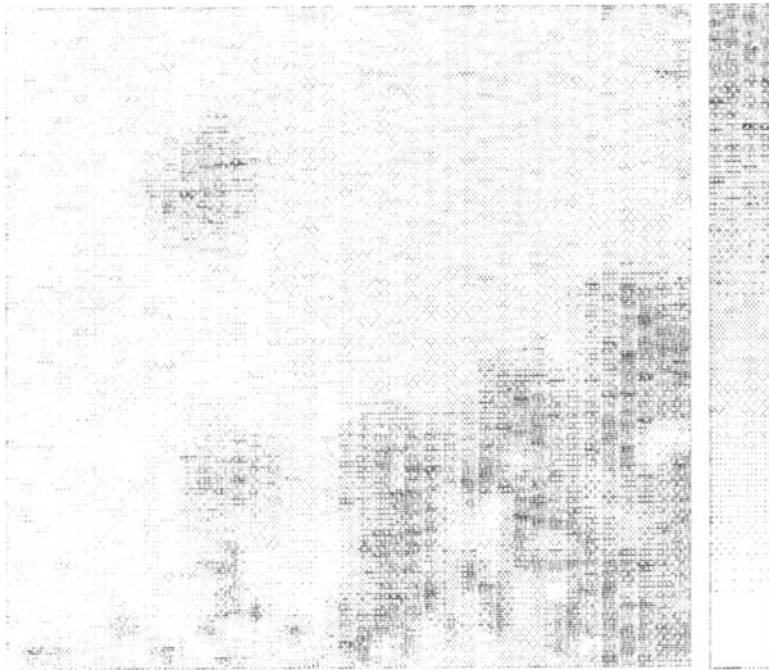


Figure 6. Time-of-Flight C-scan after Post-processing.



Figure 7 shows Sample 3, also a 14-inch diameter pipe elbow with 3/8-inch wall. Wall thinning is visible in this figure as the lighter shaded areas. The darker hourglass shaped region in the center of the elbow, is an area with the nominal wall thickness. A time-of-flight C-scan of a 64-square inch area of the elbow is shown in Figure 8. The lightly shaded areas correspond to the nominal thickness of the elbow and the dark areas indicate regions of wall thinning.

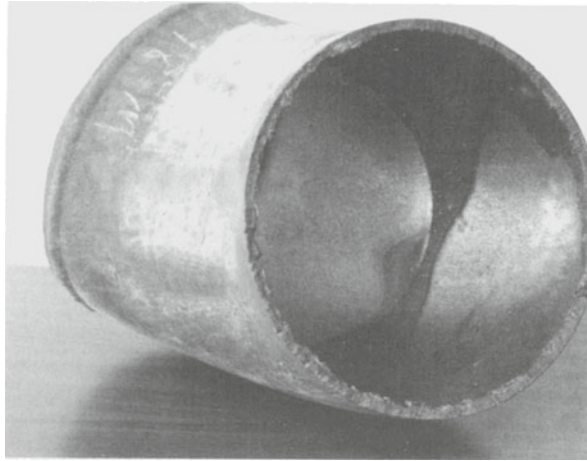
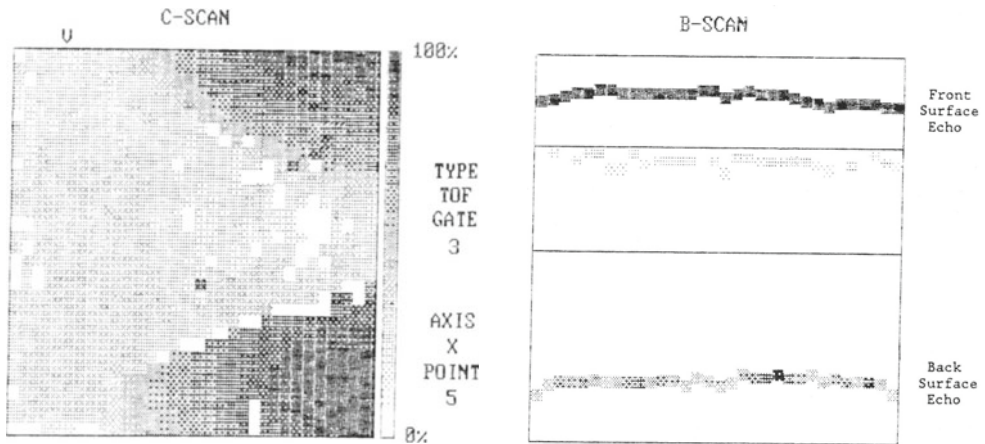


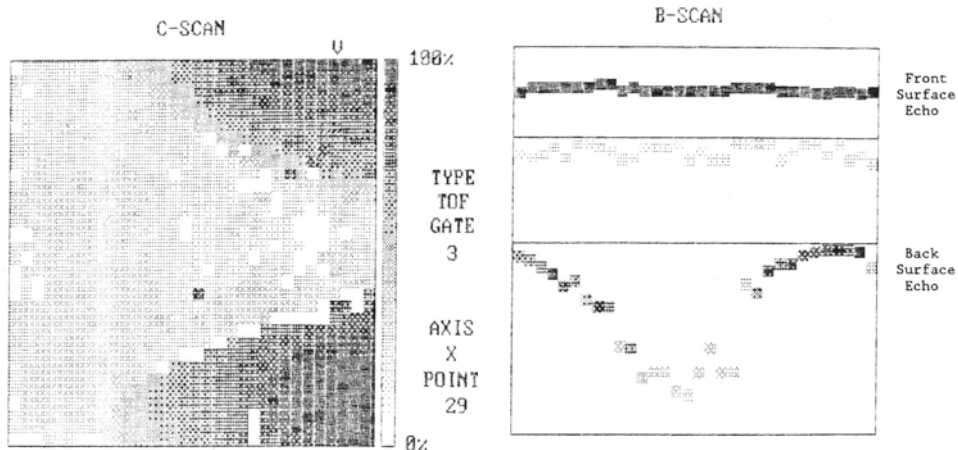
Figure 7. Sample 3, 14-inch Pipe Elbow.



\*PRESS FUNCTION KEY FOR DESIRED ACTION.



Figure 8. Time-of-flight C-scan and B-scan Images for Sample 3.



\*PRESS FUNCTION KEY FOR DESIRED ACTION.



Figure 9. Time-of-flight C-scan and B-scan Images for Sample 3.

Another way to view the data is to use the B-scan shown to the right of the C-scan in Figure 8. This image displays a vertical slice through the volume indicated by the cursor located on the top border of the C-scan. The vertical slice, displayed from left to right on the B-scan, shows the location of the peak amplitude of both the front and back surface echoes. The distance between these two signals is proportional to the wall thickness. In Figure 9, the cursor has been moved to the right side of the C-scan. The extent of the wall thinning in this area is visible in the B-scan by the reduced distance between front and back surface echoes.

#### CONCLUSIONS

These tests have demonstrated the potential of PARIS to measure wall thinning in power plant piping components. The advantage of PARIS in this application is that large areas can be mapped for wall thinning very rapidly with 100% coverage. In addition, the wall thickness measurements are automatically logged and presented immediately to the operator as an image.

#### ACKNOWLEDGEMENT

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