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SEAM TRACKING PERFORMANCE OF A COAXIAL WELD VISION SYSTEM WITH PULSED WELDING CURRENT AND WHEN MAKING FILL PASSES

By K. J. Gangl, J. L. Weeks, and D. Todd
Rocketdyne Division
Rockwell International

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16. ABSTRACT

This report describes a continuation of a series of tests on the Coaxial Weld Vision System at MSFC. The ability of the system to compensate for transients associated with pulsed current welding is analyzed. Using the standard image processing approach for root pass seam tracking, the system is also tested for the ability to track the "toe" of a previous weld bead, for tracking multiple pass weld joints. This Coaxial Weld Vision System was developed by the Ohio State University (OSU) Center for Welding Research and is a part of the Space Shuttle Main Engine Robotic Welding Development System at MSFC.

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INTRODUCTION AND SUMMARY

Many of the production welds on Space Shuttle Main Engine (SSME) components have been converted to pulsed current GTA welding. The effects of pulsed current on the coaxial weld vision system have not previously been evaluated. Because the vision system relies on the arc light for illumination, it was thought that pulsed current might have some influence on the seam tracking performance. The present study includes an evaluation of the system's ability to detect the joint seam with pulsed current at two different frequencies and on two different plate surfaces. Pulsing was found to have essentially no effect on joint center detection at either frequency studied.

One of the features hoped for in the vision system was the ability to track previous beads when making fill passes on multiple pass welds. This is the opposite of the desired performance when passing over tack welds on the root pass. The system's performance was tested on prepared groove samples and running bead on plate. In both cases the system was entirely unable to track the toe of a previous weld — there simply was not a sufficiently distinct feature to detect. Other methods of trajectory control during fill passes will be explored in the future. The most promising method involves detection of the prepared groove edges.

BACKGROUND

Previous tests of the coaxial weld vision system (NASA Contractor Report Nos. 178537 and 178538) evaluated seam detection capability on square butt joints using constant welding current. Many of the welds on Space Shuttle Main Engine components have been converted to pulsed current because of the improved control over penetration and heat input. Because the OSU sensor relies on light from the arc for illumination, the large variation in arc intensity which occurs in typical pulsed welding was expected to influence vision system performance. The tests presented in this report thus investigated the effects of pulsed current on the quality of joint feature detection.

Another production condition not formally studied in previous tests is the system's tracking performance on the fill passes of multiple pass welds. The technique considered in the present study uses the toe of the preceding pass for position data. The desired performance for fill passes is thus opposite to that for a root pass containing tack welds. In the latter case, it is desirable for the sensor to pass over the tack welds without reacting to them. Earlier tests have shown that the system will track the root of a tack weld on a square butt joint if the plate surfaces have not been cleaned of oxide. The oxidized surface tends to accentuate the tack welds, and thus the toe of the weld would not be as easily detected under normal conditions where the oxide layer has been mechanically removed from the surface.

An alternative approach to multiple pass trajectory control has been proposed, and will be considered in future reports. The edges of a typical joint preparation can be readily detected by the sensor. This data can be used to calculate offsets from the edges of the preparation for cross seam adjustment. A third technique, which cannot be investigated with the present computer hardware, is root pass memorization.

OBJECTIVE

The objective of the present study was to evaluate the influence of pulsed current welding on seam detection capability of the coaxial weld vision system. In addition, the ability of the system to provide trajectory control during fill passes by following the toe of a previous pass was to be investigated.

EXPERIMENTAL PROCEDURE

Material Preparation

The pulsed current weld samples consisted of plates of dimensions 0.125 in. x 2 in. x 9 in. The butting surfaces were machined with a 5 deg bevel, which provided a 0.020 in. seam width. Half of the samples were sanded with a rotating drum to remove the oxide layer. The other half were welded as received.

Two types of sample were used for the multiple pass welding. The first type was a "Modified U-groove" butt joint, as shown in Figure 1. The second type of sample was simply a 0.25 in. thick plate which had been cleaned of oxide with a rotating drum sander.

Procedure

The programmed path was a straight line, which corresponded to the joint position.

Two sets of welding parameters were used in the pulsed welding tests, as follows:

1) Primary current: 150 A
   Background current: 50 A
   Arc voltage: 13.3 V
   Pulse frequency: 1.0 Hz

2) Primary current: 130 A
   Background current: 50 A
   Arc voltage: 12.6 V
   Pulse frequency: 5.0 Hz

The welding parameters used for the multiple pass welds were as follows:

Current: 105 A
Arc voltage: 11.6 V
Wire feed: 15 ipm

The wire feed entry angle was set at 45 deg, so that the wire did not enter the joint detection window.

Evaluation

The results were evaluated entirely from the strip chart recording of joint detection confidence level. A higher value of confidence level indicates better feature detection and is therefore more desirable. The maximum valid level corresponds to the number of rows in the image processing window. For the present tests, the joint window was $40 rows high ($ indicates hexidecimal base) while the pool window contained $53 rows. For the purpose of comparison between the conditions tested, the average and/or median confidence levels were estimated from the strip charts.

RESULTS

The strip chart recordings from pulsed current welds conducted on as received plate surfaces are shown in Figures 2 and 3. Little difference was seen between the frequencies studied, and the results in general were similar to those for constant current welds. Traces for typical constant current welds are displayed in Figure 4. Figures 5 and 6 contain the recordings for pulsed current welds conducted on plates cleaned of oxide. Again, there was little difference between the two frequencies studied. Shown in Figure 7 is the confidence level trace from a constant current weld conducted on the same plate surface. The average confidence level was approximately the same for both pulsed current and constant current.

A typical strip chart recording of the confidence level from a fill pass is shown in Figure 8. All of the beads displayed this low confidence level, which was below the threshold. The signal which did show up was essentially background noise which does not correspond to any feature.

DISCUSSION

Contrary to expectations, pulsed current had very little effect on the ability of the OSU vision sensor to detect the weld seam, despite the fact that the sensor's sampling rate, 5 Hz, is identical to one current pulse rate studied. No provision was made to sequence the sensor sampling to the current pulsation. Sequenced sampling at the background current level would probably degrade feature detection, while sampling at only primary current might improve performance. It is possible that the servoed iris has a response time adequate to compensate for the change in light intensity between the primary and background currents studied, but further study is required to verify this.

With the present configuration of the system, tracking previous weld beads when running fill passes does not appear to be feasible. Although some tracking of the toe of tack welds has been found to occur when welding on oxidized surfaces, the tracking was sporadic. In a production situation of course, the surfaces would always be cleaned of oxide, and in this condition there simply is not a sufficiently distinct feature at the toe of a weld to detect it. Future work will consider fill pass tracking based on the edges of the prepared groove. This technique should provide superior results because the detected features are more distinct and more consistent.

CONCLUSIONS

Based on the experiments conducted in the present study, the following conclusions may be drawn:

1) Under the conditions tested, pulsed current did not noticeably alter the joint detection ability of the vision sensor. Also, no difference was observed between different pulse frequencies.

2) The present coaxial vision system, using the arc for illumination, does not appear to be able to track the toe of previous welds when making fill passes. Alternative methods are being investigated.

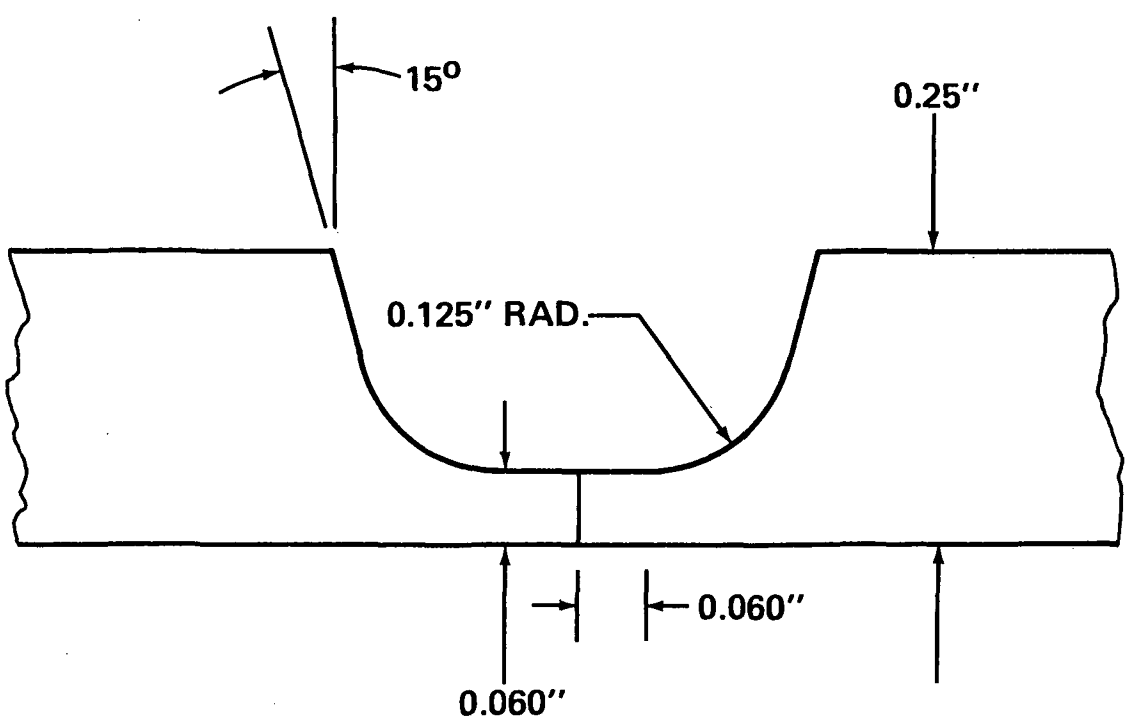


Figure 1. Modified-U groove joint preparation.

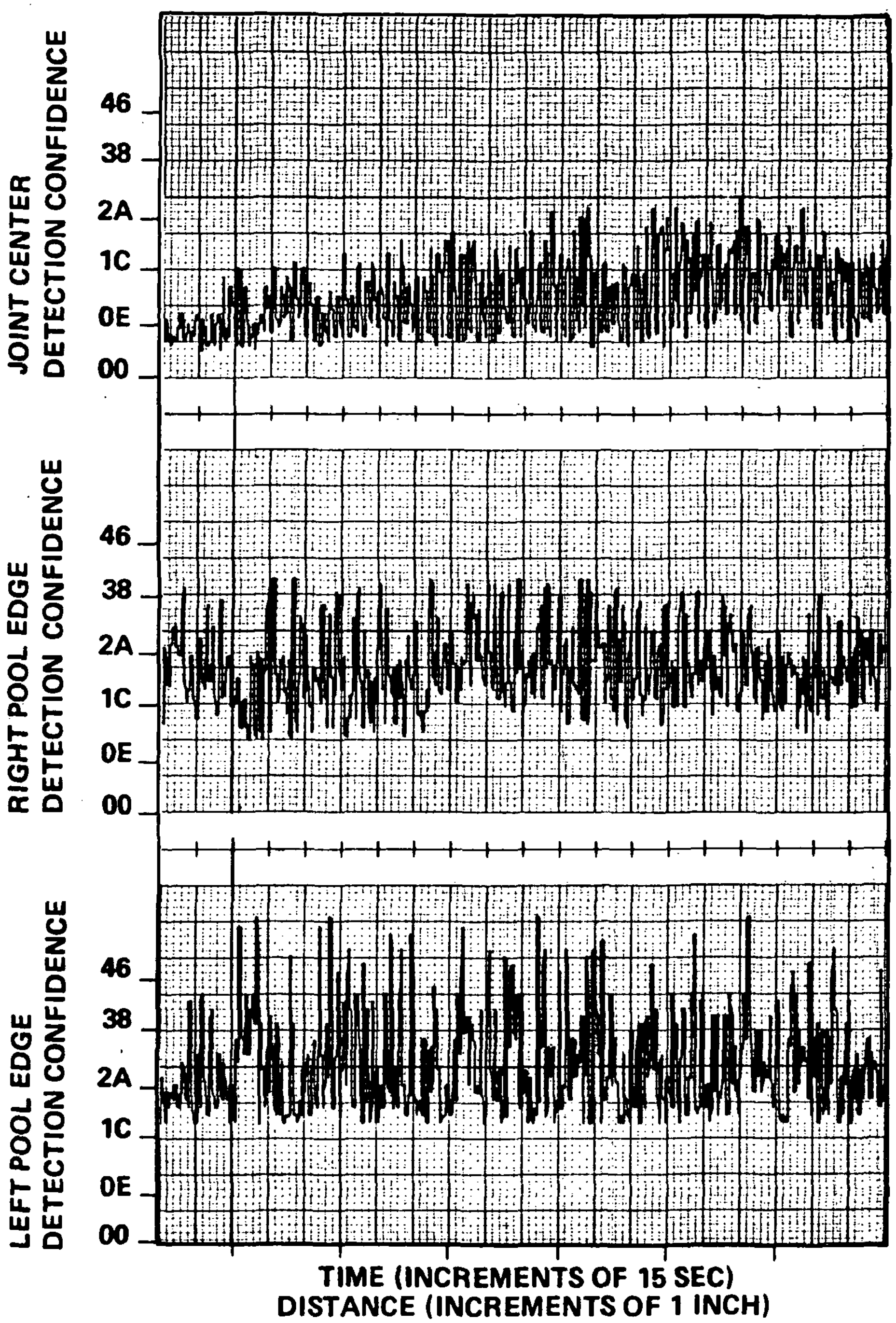


Figure 2. Strip chart recordings for weld run on sanded plate, at 1 Hz pulse frequency.

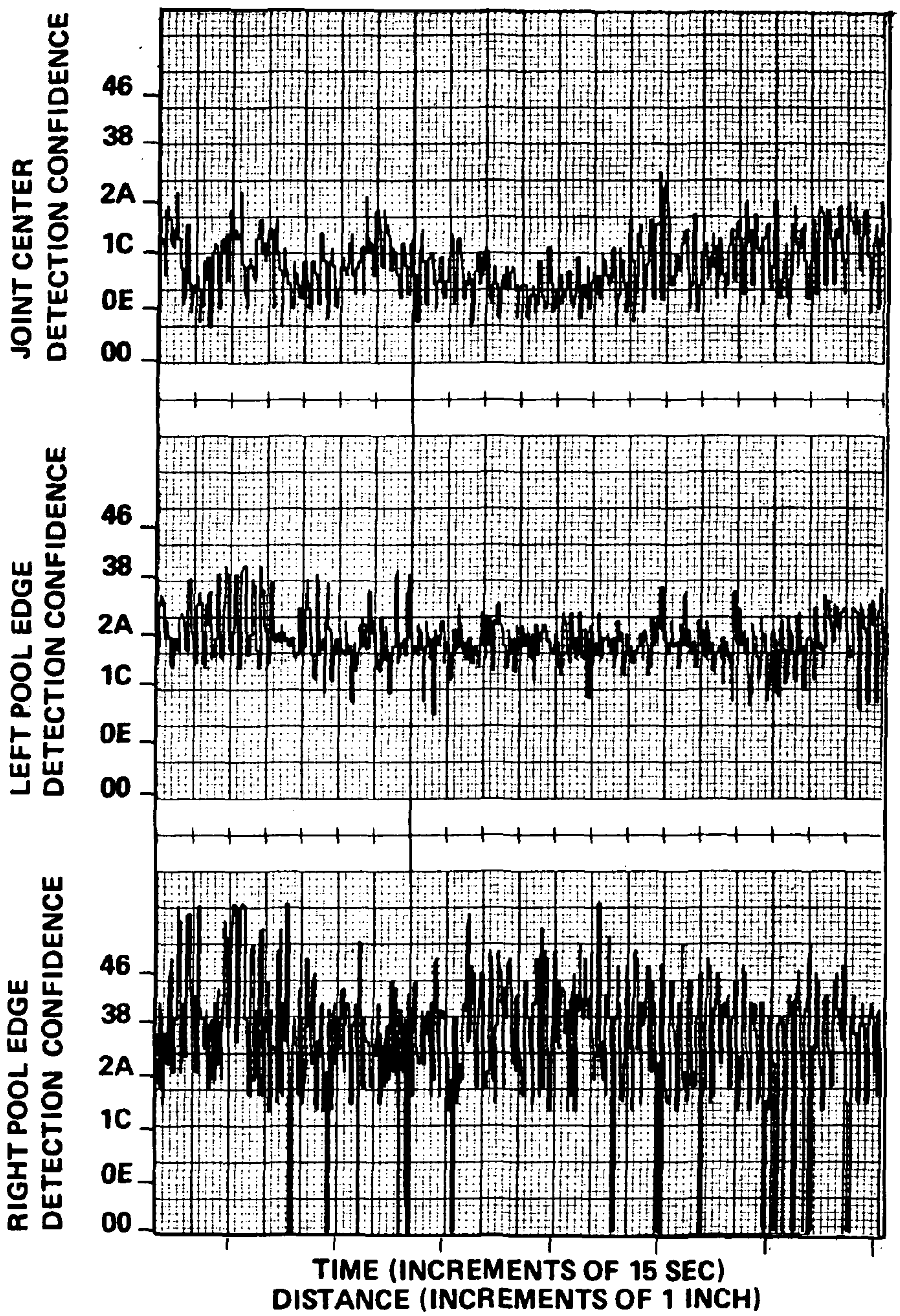
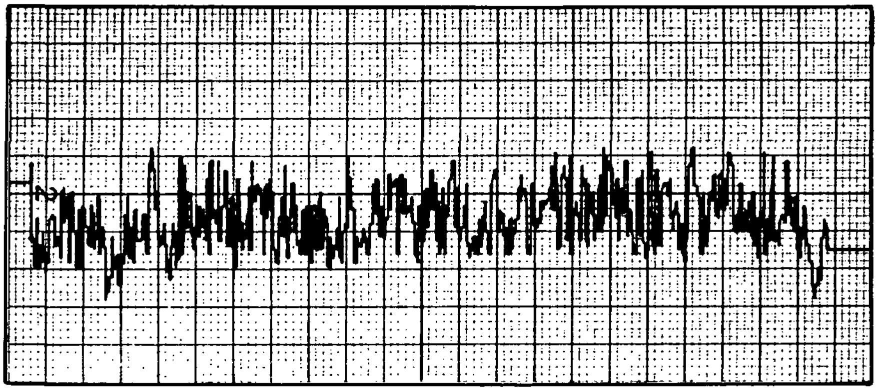
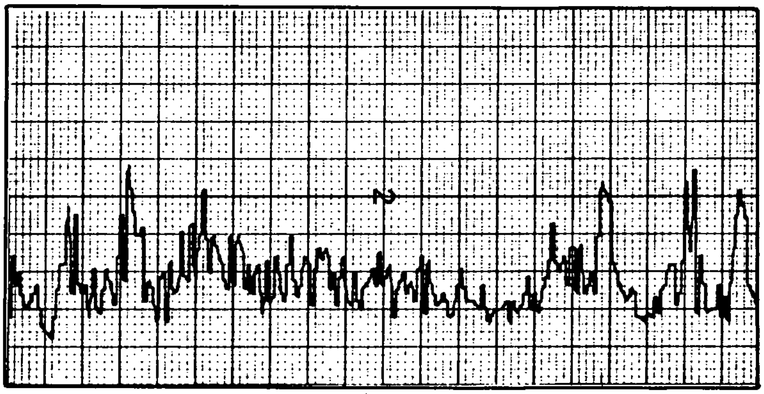


Figure 3. Strip chart recordings for weld run on sanded plate, at 5 Hz pulse frequency.



a) WELD RUN ON "AS RECEIVED" SURFACE



b) WELD RUN ON SURFACE CLEANED OF OXIDE

Figure 4. Typical strip chart recordings for constant current welding.

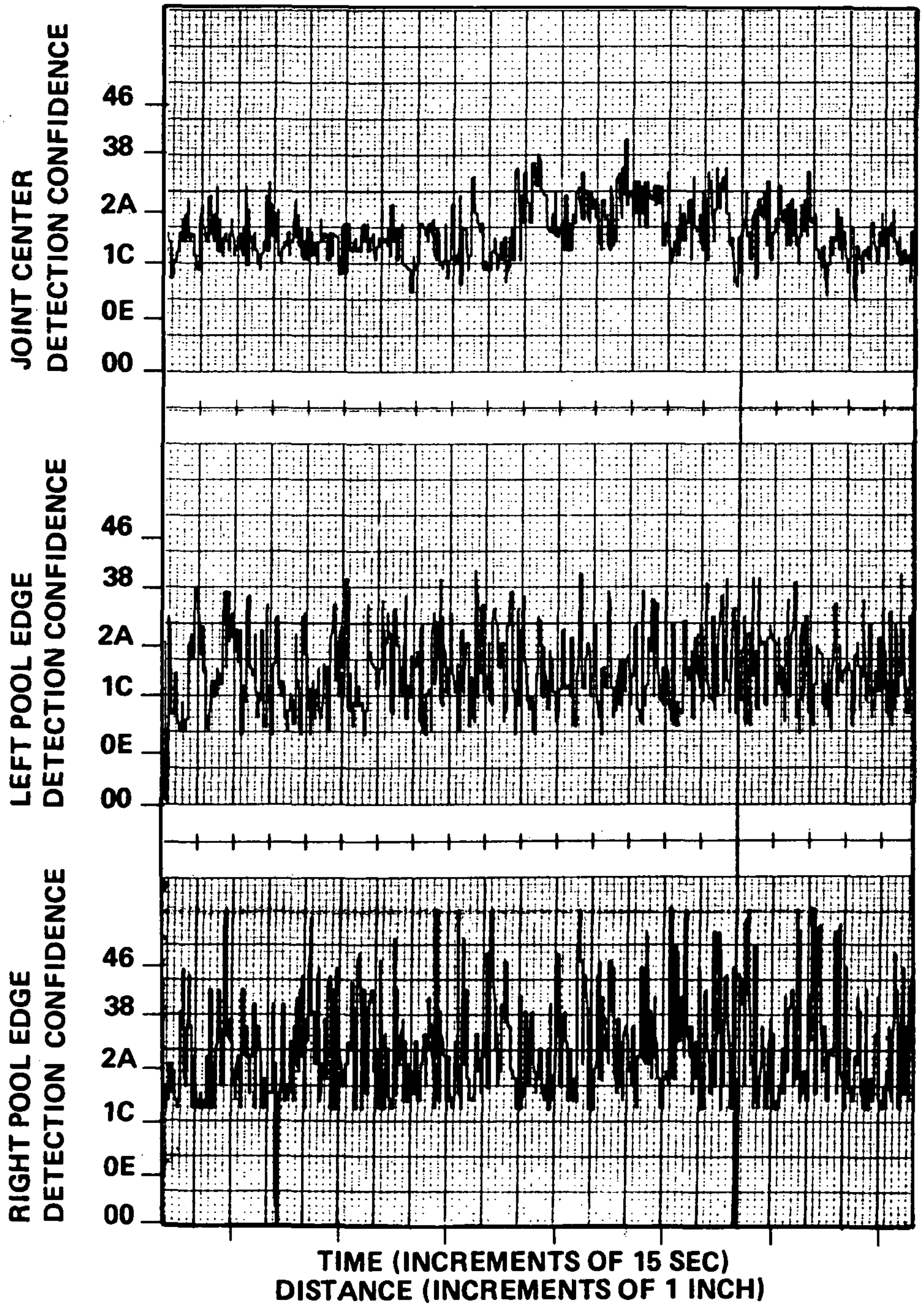


Figure 5. Strip chart recording for weld run on oxidized surface, at 1 Hz pulse frequency.

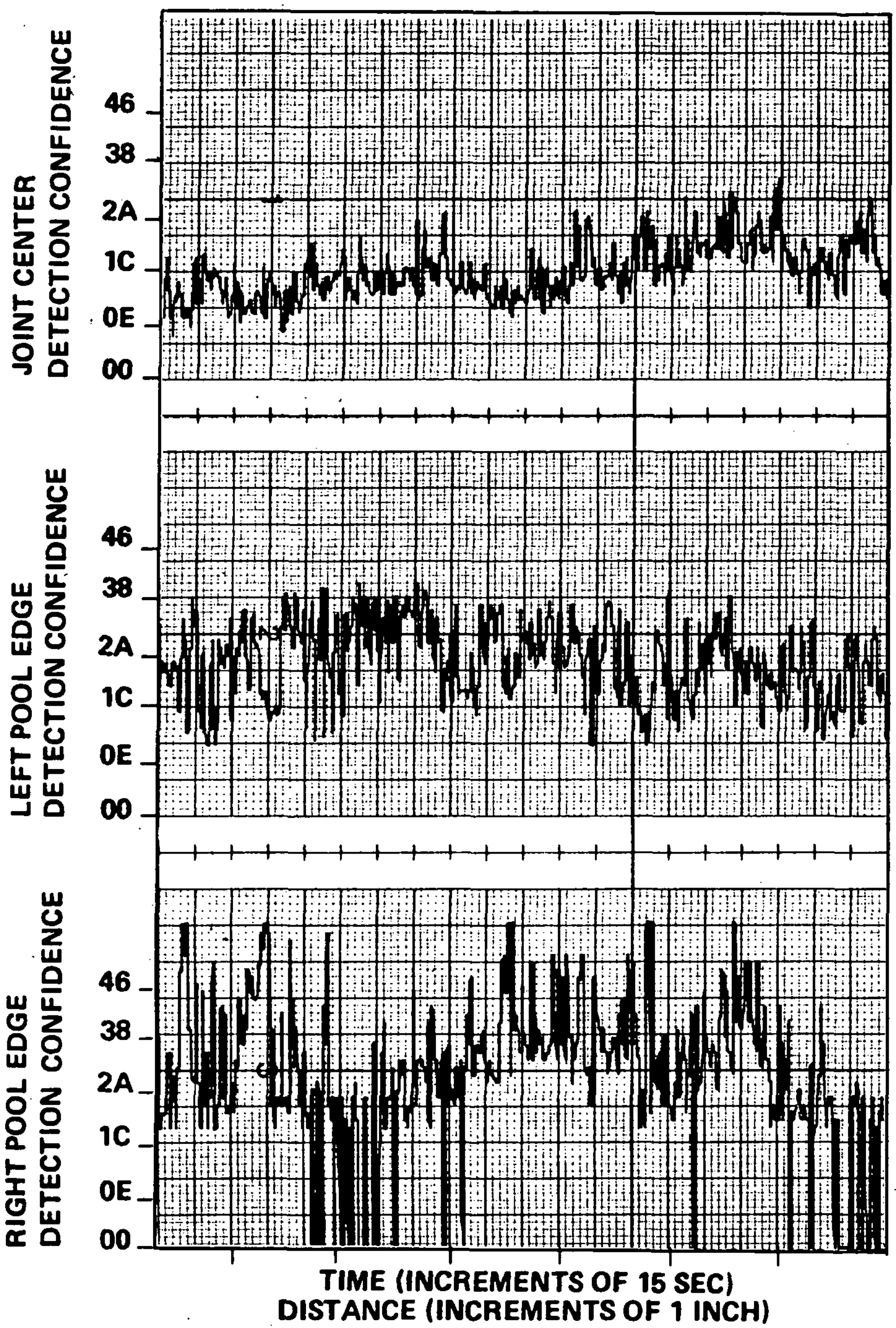


Figure 6. Strip chart recordings for weld run on oxidized surface, at 5 Hz pulse frequency.

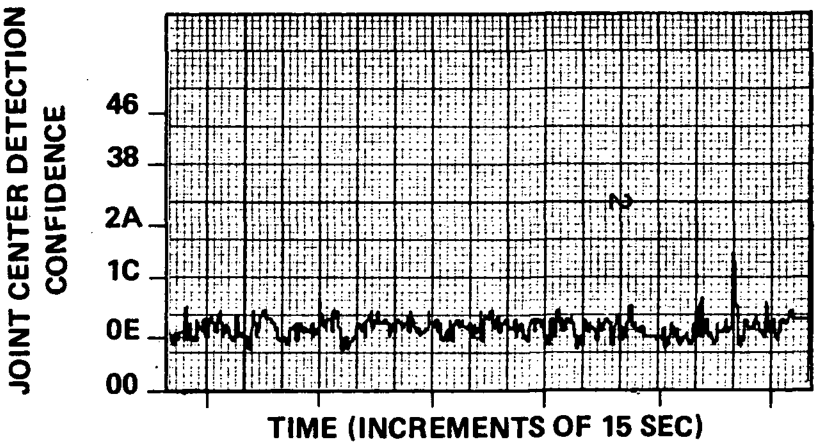


Figure 7. Strip chart record of fill pass run on modified U-groove.

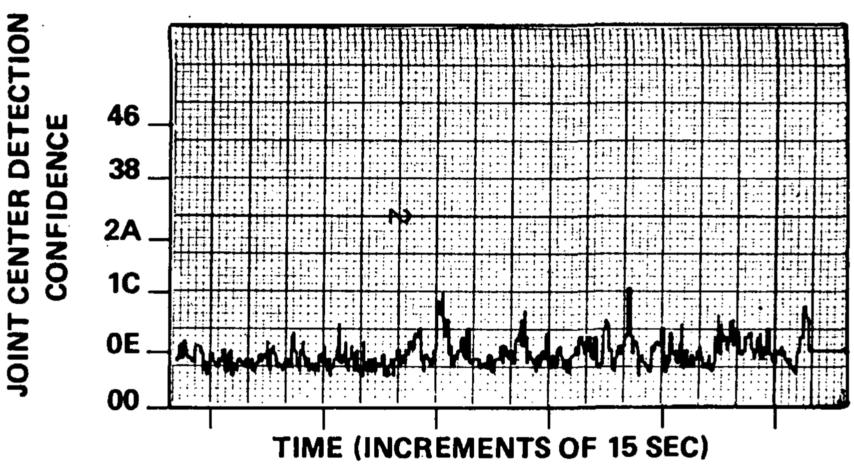


Figure 8. Strip chart record of bead on plate weld run on toe of previous weld pass.

CONCURRENCE

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By K. J. Gangl, J. L. Weeks, and D. Todd

Rocketdyne Division of Rockwell International

J. K. Watson

J. K. WATSON
Rocketdyne

Clyde S. Jones

C. S. JONES
Metals Processes Branch

P. H. Schuerer

P. H. SCHUERER
Process Engineering Division

APPROVAL

SEAM TRACKING PERFORMANCE OF A COAXIAL WELD VISION SYSTEM WITH PULSED WELDING CURRENT AND WHEN MAKING FILL PASSES

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

E. C. McKannan

R. J. SCHWINGHAMER
Director, Materials and Processes Laboratory

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