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Resistance Seam Welding

Bendix Kansas City Division

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BDX-613-3557

Published July 1986

Topical Report
D. L. Hollar, Project Leader

Prepared for the United States Department of Energy Under Contract Number DE-AC04-76-DP00613.

ALLIED Bendix Aerospace

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Price Code: Printed Copy A02
Microfiche A01

MASTER

BDX-613-3557
Distribution Category UC-38

BDX--613-3557

DE86 013288

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RESISTANCE SEAM WELDING

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A parallel gap resistance seam welding head was designed and fabricated to bond aluminum foils to copper foils for an application on a flat cable. The resulting welds exhibited a crack sensitive, intermetallic weld zone. An opposed electrode resistance seam welding head was designed and fabricated as a general method to bond metal foils.

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A prime contractor with the United States
Department of Energy under Contract Number
DE-AC04-76-DP00613

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ILLUSTRATIONS

SUMMARY

Work was conducted to develop the capability to produce miniature resistance seam welds at the Bendix Kansas City Division (BKC) of Allied Corporation. This effort was initiated to weld aluminum foil to polyimide-backed copper foil on a flat cable. A parallel gap resistance welding head capable of accessing material from one side only was designed and fabricated for this purpose. Welds were made between aluminum and copper foils using the parallel gap resistance seam welding head. Bonds were made proving the welding head design was feasible. Aluminum to copper weld joints were analyzed by cross sectioning, electron beam microprobe analysis, and environmental testing. As expected with this material combination, testing indicated the presence of brittle, crack sensitive intermetallics in the weld zone.

Work was expanded to develop a general resistance seam welding process capable of welding metal foils where there was access to both sides of the material. An opposed electrode welding head was designed and fabricated for this purpose.

DISCUSSION

SCOPE AND PURPOSE

The objective of this project was to establish the capability to produce miniature resistance seam welds and determine the feasibility of this process as a method to join thin metal foils. Work was initiated for a joining application on a flat cable involving 0.002 in. aluminum foil and polyimide-backed 0.008 in. copper. A parallel gap resistance welding head capable of welding this material combination was designed and fabricated.

Work was expanded to develop a general resistance seam welding process capable of welding metal foils where there was access to both sides of the material. An opposed electrode resistance welding head was designed and fabricated for this purpose.

Reported work was accomplished between January 1981 and June 1984.

ACTIVITY

Resistance spot welding has been used at BKC since the early 1960s. Experience and understanding gained from this process were applied to the development of miniature resistance seam welding. In the resistance welding process, the two metals to be welded are clamped between two electrodes and a force is applied. A high current is passed through the two materials. The joint interface of the materials should have a high electrical resistance while the electrode-material interface should have low resistance. This current passage in conjunction with the high resistance interface causes the two materials to melt and bond to each other. In the seam welding process, electrodes move along the material as current is passed between the electrodes (Figure 1).

Parallel Gap Welding

As noted before, the aluminum-copper combination allowed access to only one side because of the polyimide insulation on one side of the copper. A parallel gap welding head was designed and fabricated.

Aluminum/Copper Welds

Joining aluminum to copper using a fusion welding process is usually avoided because of the incompatibility between the two materials. The mixture of these two metals produces a brittle intermetallic. Nevertheless, initial applications called for the joining of these two metals. Typical alloys

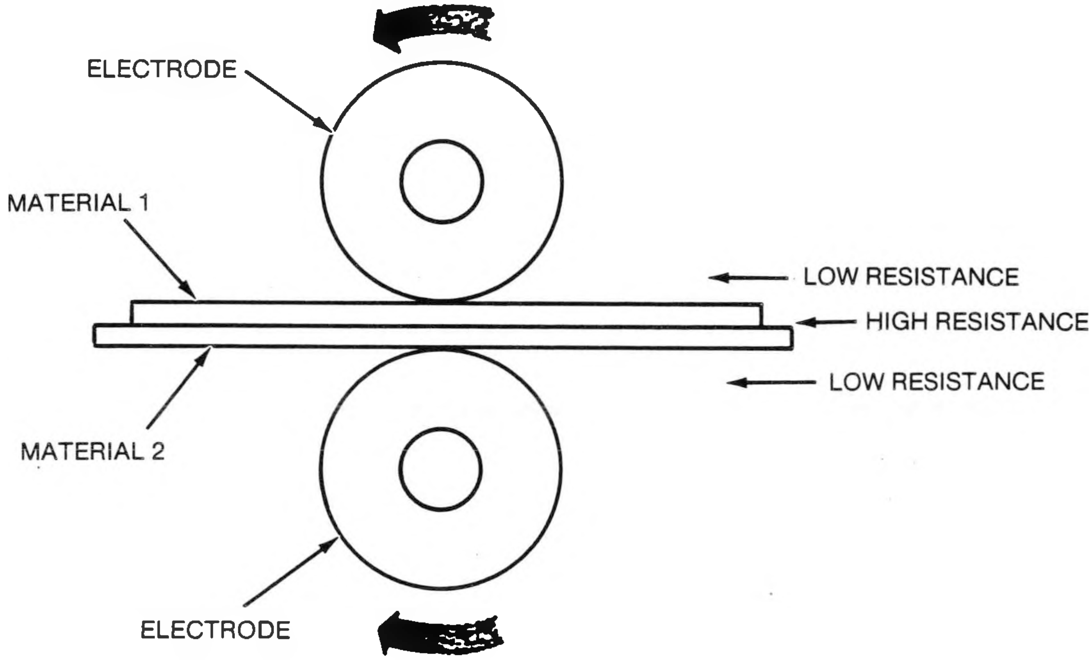

Figure 1. Opposed Electrode Resistance Seam Weld

used for weld samples were electrolytic tough pitch copper (0.008 in. thick) and 1145-H19 aluminum (0.002 in. thick). Studies were performed using an opposed electrode welding head and bonds were produced between the aluminum and copper. More studies were performed to determine the feasibility of joining this material combination with access to only one side (In the case where the copper is laminated with polyimide insulation on one side). The principle used to produce welds from one side is illustrated in Figure 2.

From these studies, it was determined that classical resistance welding theory would not completely apply to this material combination. The relatively thick copper was a much better heat conductor than the thin aluminum. Thus, the aluminum would reach a molten state long before the copper. To overcome this problem, stainless steel feeler gauge stock (0.002 in. thick) was used over the weld zone. The weld sample configuration used is shown in Figure 3. The high resistivity of the stainless steel created more heat at the Al-Cu interface and reduced deformation of the aluminum. Heat created at the Al-Cu interface bonds the two metals. This heat is not sufficient to melt the stainless steel which can be removed from the part.

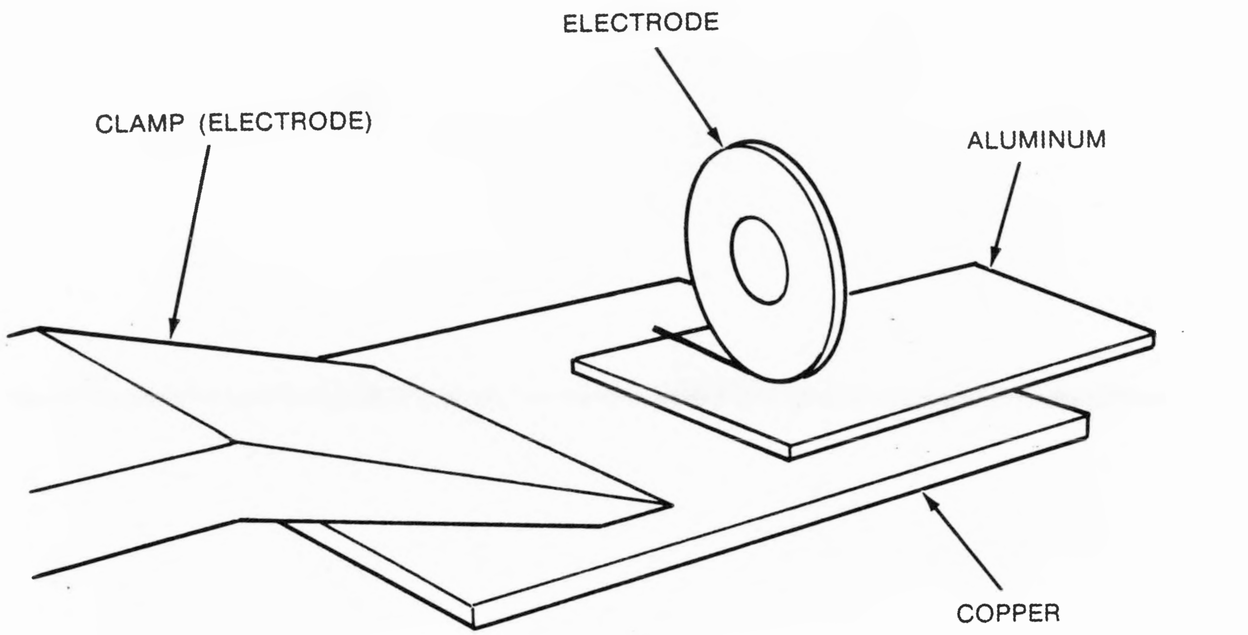

Figure 2. Parallel Gap Resistance Seam Welding

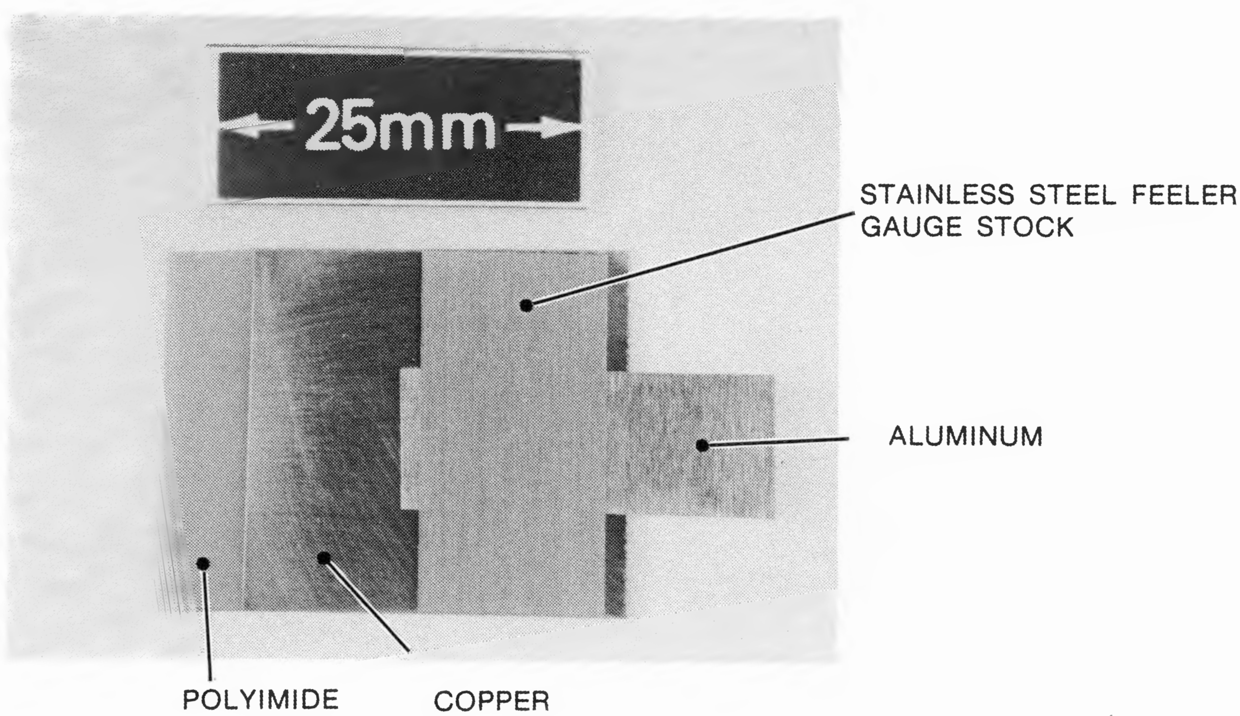

Figure 3. Parallel Gap Weld Sample Configuration

Parallel Gap Welding System

The complete welding system consists of the welding head, power supply, current monitor, and force monitor (Figure 4). The welding head consists of a rolling electrode, a moving table to hold the part or parts to be welded, and a busbar on the table with clamp electrodes that complete the circuit. The rolling electrode is narrow (0.020 to 0.030 in. typical). This creates a point of high resistivity at the weld interface. The clamp electrode is large in the area of contact with the copper for low resistance and little heat creation. Weld material is clamped to the table (Figure 5). As the table moves it trips a switch which fires the power supply. Current passes through the weld material for a preset number of cycles (60 Hz line frequency). The amount of time the current is on coupled with the movement of the electrode determines the length of the weld. With multiple clamps and switches, several welds can be made with one pass of the electrode. Force is applied to the rolling electrode through a spring loaded element. This element is fitted with a strain gage for force measurement. Table velocity is coordinated to match the rotational velocity of the electrode. The power supply is a single phase, AC resistance welding power supply. It is capable of supplying continuous current to the weld joint. The current monitor measures the average RMS current supplied by the power supply and reflects the amount of heat created at the weld. The current monitor is meaningful only when a known number of current cycles are applied to the weld. The force monitor displays the amount of force applied to the rolling electrode and read by the strain gage.

Joint Analysis

A resulting weld appears in Figure 6. Figure 7 shows the reverse side (polyimide side) of the welded sample. Heat during welding causes an area of delamination beneath the weld. Inspection of this area shows little effect on the polyimide. However, the adhesive that bonds the polyimide to the copper has melted and darkened. Various methods were used to analyze the resulting welds. Cross sections were made to view the weld. Samples were cut across the width of the weld. This produces a view of non-affected aluminum and copper and the weld zone (Figure 8). Electron beam microprobe analysis was used to determine the amount of mixing of the metals. Results showed little penetration of the aluminum into the copper and a large amount of penetration of the copper into the aluminum. By weight, over 50 percent of the material in the weld zone is copper (Figure 9). This mix ratio of aluminum and copper and the results of hardness testing, which showed the material in the weld zone to be harder than both the aluminum or copper, indicate the formation of intermetallic compounds. Environmental testing (moisture resistance, temperature cycle, temperature shock, sine vibration,

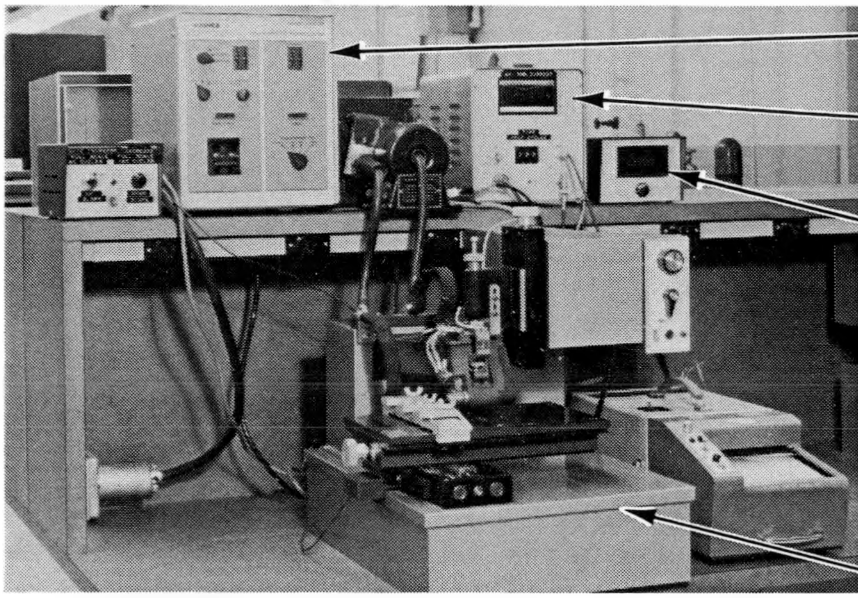

Figure 4. Parallel Gap Welding System

broadband random vibration, and mechanical shock) provided evidence that cracks present along the edge of the seam would propagate toward the center of the seam.

<u>Opposed Electrode Welding</u>

For feasibility studies of resistance seam welding compatible thin metal foils with access to both sides, a more standard welding head configuration was desired. An opposed electrode resistance seam welding head was designed and fabricated by taking what was learned from the parallel gap welding head design and changing and adding features.

Opposed Electrode Welding Head

The initial design requirements called for two rotating electrodes, one above the other. The electrodes should have the same diameter and rotate at an equal speed. The weld metal should pass between the electrodes, with a force applied to the top electrode. It was also desired to have a table located in front of the electrodes to which material could be clamped during welding. The table speed would be synchronized with that of the electrodes.

The final design resulted in the weld head in Figures 10 and 11. Electrodes are located on rotating shafts. The shaft for the upper electrode extends to allow up and down movement of the electrode for part clearance and force adjustment. The bottom

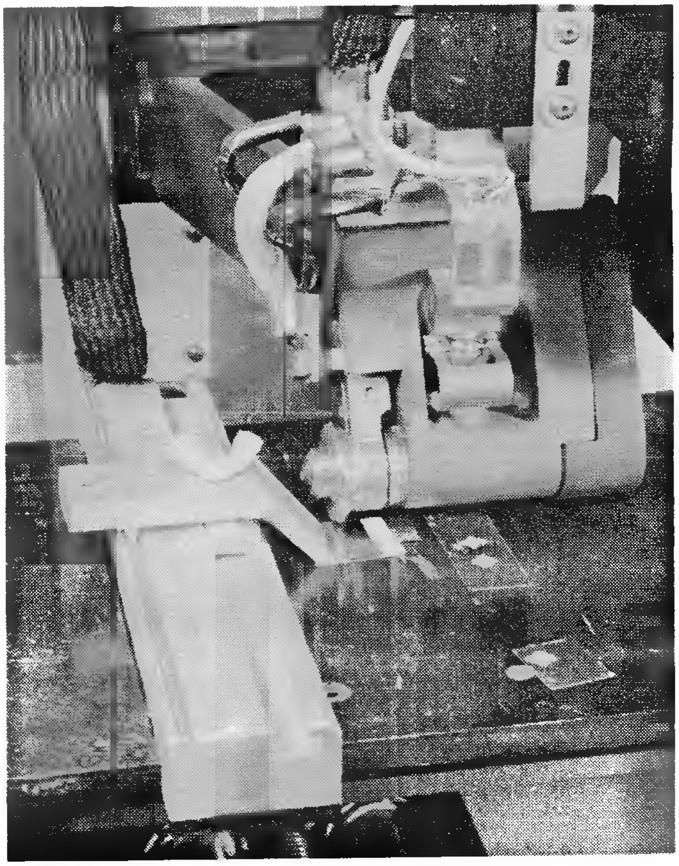

Figure 5. Weld Sample Ready for Welding

electrode is adjustable in and out for electrode alignment. An "off the shelf" force gauge was incorporated for electrode force measurement. A tachometer was added to provide a readout of electrode speed. The force gauge readout, tachometer, and speed adjustment are all located on the welding head. The table, located on a track in front of the electrodes, is clutched so it can move during welding or remain stationary.

The top electrode is counterbalanced and spring loaded for accurate force measurement. For current transfer to the electrode, the opposed electrode weld head uses machined, high current density copper graphite brushes. These provide good electrode shaft contact and high current carrying capability. Power supply connections are made directly to the brushes. Electrodes were designed to be easily replaced. Electrodes of various widths and materials can be used.

The weld head was coupled with an AC welding power supply. The RMS current monitor can be used with the system if a known number of current cycles will be used to produce the weld.

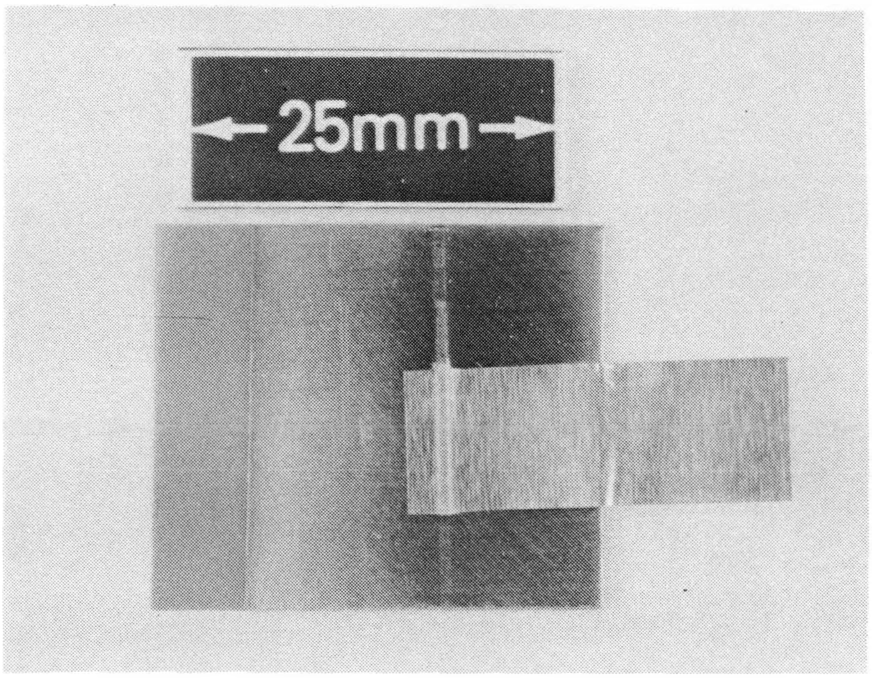

Figure 6. Parallel Gap Resistance Seam Weld

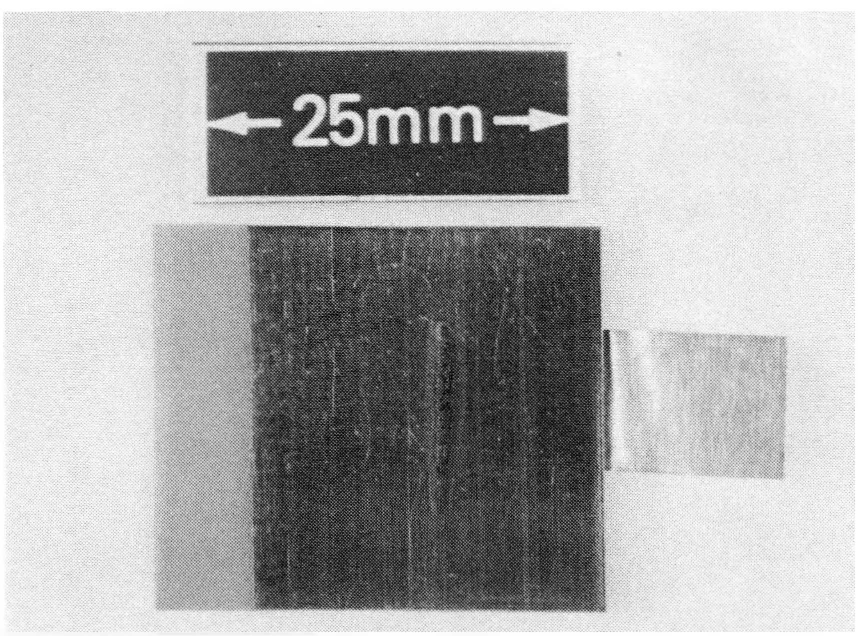

Figure 7. Opposite Side of Parallel Gap Resistance Seam Weld

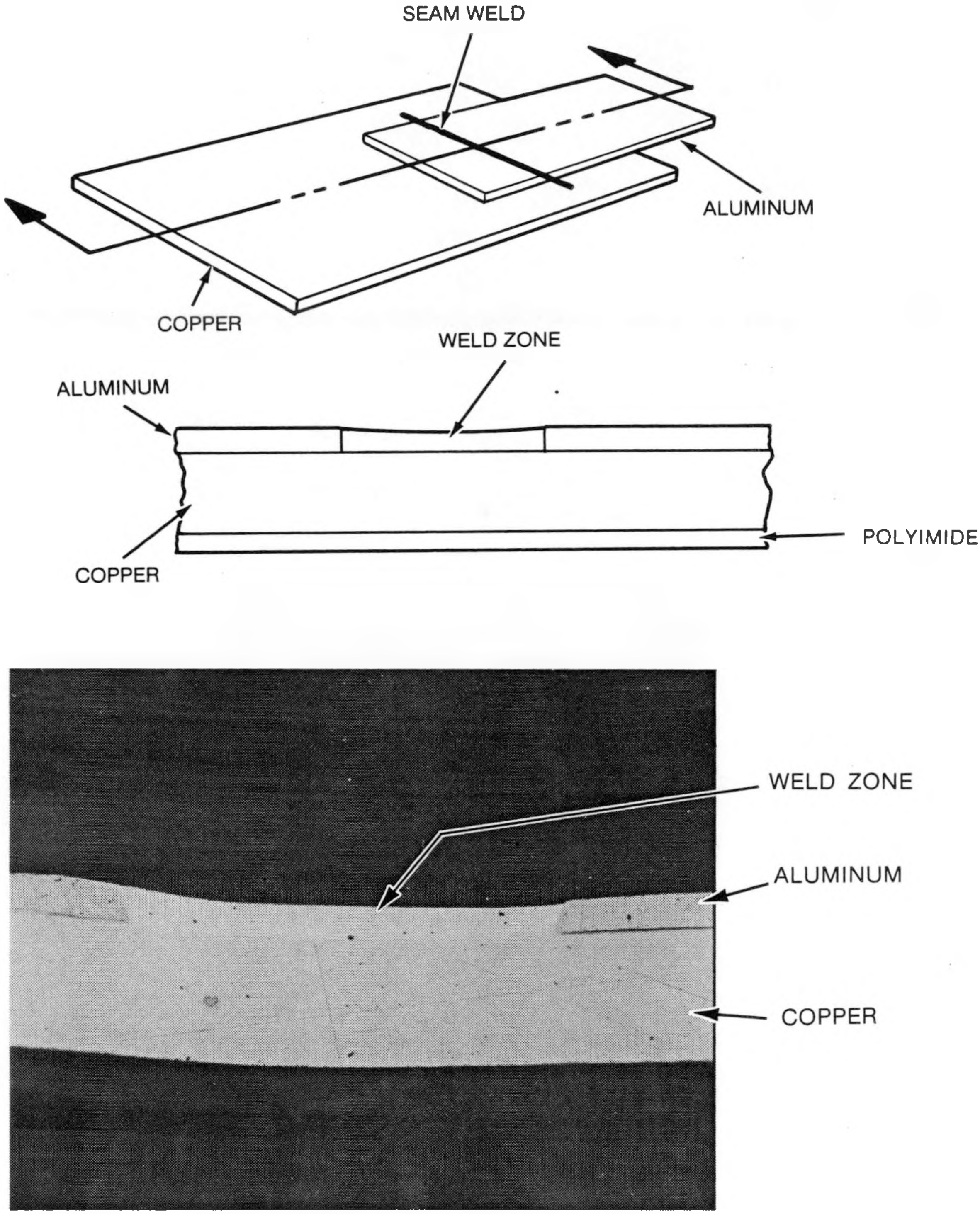

Figure 8. Parallel Gap Seam Weld Cross Sectioning

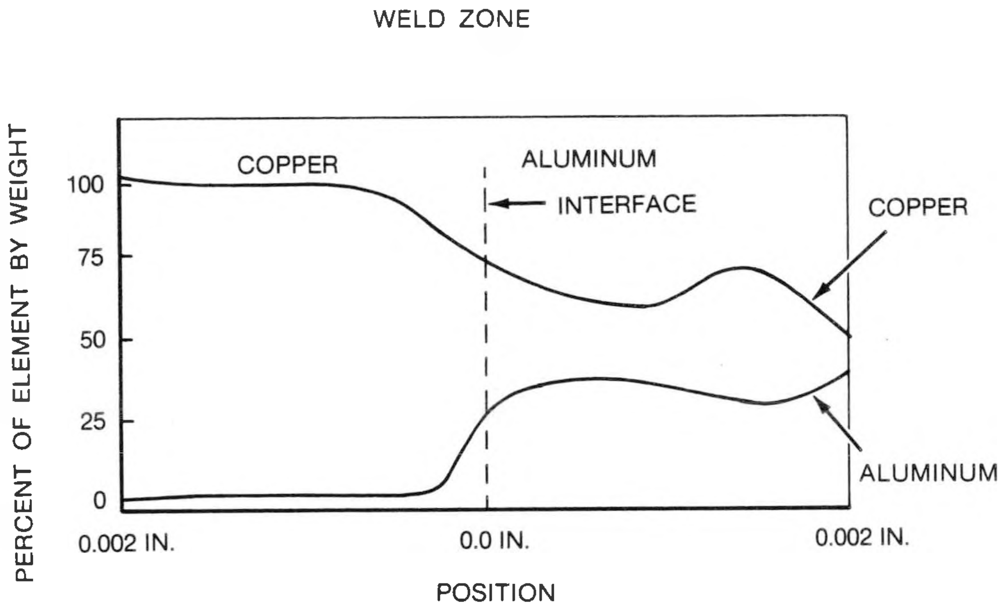

Figure 9. Copper Penetration in Weld Zone

Weld Schedule Development

Weld schedule development incorporates the following parameters: electrode material, electrode force, electrode speed (weld speed), and power supply current settings (heat adjustment).

Electrode material selection is based on the metal being welded. Generally, a low resistance is desired at the electrode/weld metal interface. Electrode materials selected were copper-chromium and molybdenum. Electrode contact resistance is also affected by the electrode force. The greater the force, the less resistance there is at the metal interface. Less resistance results in less heat at the joint. Electrode force should not be so low that a high electrode contact resistance results in arcing at the electrode.

Electrode force coupled with electrode rotation results in a working effect on the metals during welding and this aids in the welding process. Weld speed and power supply current settings affect the heat applied at a certain point along the seam.

Weld schedule development would involve an experiment involving a number of samples in which the above parameters would be adjusted to provide the desired melt at the weld metal interface.

Figure 10. Opposed Electrode Seam Welder

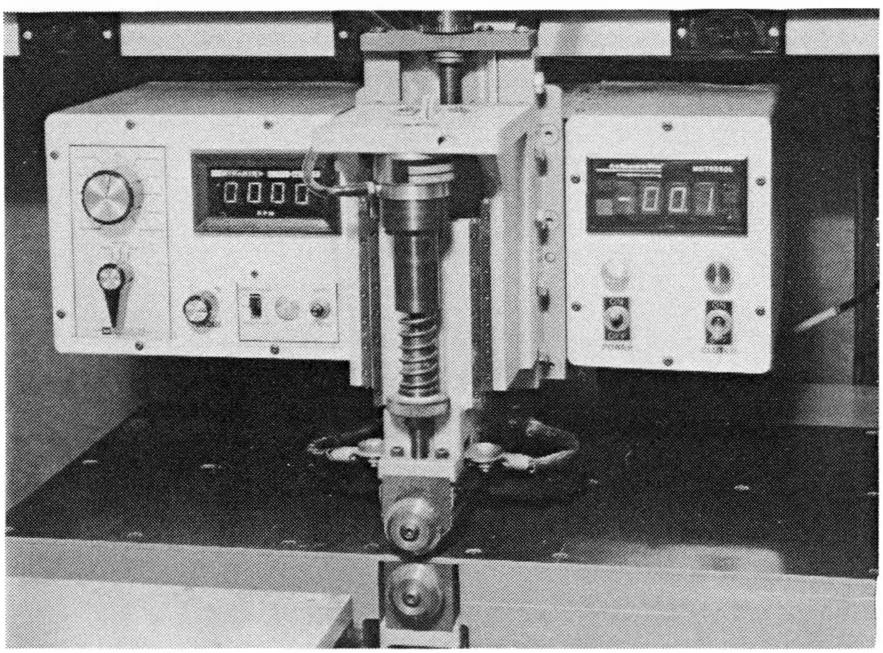

Figure 11. Close-Up of Opposed Electrode Seam Welding Head

ACCOMPLISHMENTS

The theory behind the design of a parallel gap resistance seam welding head was proven to be correct. This allowed attempts to be made to bond aluminum to copper foils with access to only one side of the metals. Aluminum to copper bonds were produced but exhibited the hard, brittle intermetallic bond that can be expected when these two metals are combined. This bond proved to be extremely crack sensitive at the aluminum copper interface.

An opposed electrode resistance seam welding head was designed and fabricated as a more standard weld head configuration to be used to weld compatible metal foils with access to both sides.

In most cases, resistance seam welding with continuous alternating current results in a large amount of heat input into the weld zone. This is observed by the effect of heat on adhesives, insulators, and other organic materials that may be near the weld.