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**Modifications Resulting in Significant
Increases in the Beam Usage Time of a
60 KeV Electron Beam Welder**

Ronald E. Zielinski and James L. Harrison

May 17, 1976

Research and Development Report

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Abstract

Short beam usage times were encountered using a 60 KeV electron beam welder. These short times were the direct result of a build up of a reaction product ($WO_{2.90}$) that occurred on graphite washers which housed the tungsten emitter plate. While it was not possible to prevent the reaction product, its growth rate was sufficiently altered by changing graphite materials and minor design changes of the washers. With these modifications beam usage times increased from an original 40 min to approximately 675 min.

Introduction

Short beam usage times were encountered using a 60 KeV electron beam welder manufactured by Union Carbide Welding Products-Advance Systems. The welder utilizes a cold cathode pilot gun as illustrated in Figure 1. The pilot gun bombards a square tungsten emitter plate. The plate is 0.20 in. square and 0.01 in. thick and emits the electrons which make up the welding beam. Nitrogen gas at a pressure of 50 to 200 μ m is used for ionization between the pilot gun and the tungsten emitter. This design also utilizes the gas to allow the tungsten plate to float between two graphite washers and operate at a temperature of approximately 1980°C.

Beam usage time averaged 40 min. using the standard Graphite 580 washers supplied by the vendor. Failure occurred when a reaction layer developed on the graphite. This layer contacted the tungsten plate, restricted the gas flow, and acted as a heat sink lowering the plate temperature, electron output, and weld power.

If this effect occurred during a weld cycle, a defective weld of a heat source component could be the result. The purposes of the present study were to identify the reaction layer, search out the causes of its formation, and make modifications that would increase the beam usage time to a reasonable value.

Discussion

The standard set of graphite washers was fabricated from a low-density graphite material. The top washer is shown in Figure 2. After approximately 40 min of beam usage, the tungsten emitter would freeze to the discolored graphite washers. The graphite washers had the unusual appearance as shown in Figures 3 through 5. The growth of this reaction product was so fast that in 40 min the emitter plate had firmly locked into one position and completely restricted the gas flow.

Initially, the reaction product was thought to be tungsten carbide that was being nucleated on the low-density graphite. Since no unusual events occurred during the use of the welder and since the 40 min beam usage time was repeatable, it was assumed that this was a characteristic of the welder.

If the reaction was characteristic of the welder, a change to a higher density graphite might possibly slow down the reaction rate and increase the beam usage time. New washers were fabricated from POCO AXF-5Q graphite. Using these washers a beam usage time of 80 min was achieved and, at the end of life, the failure mode

was the same as mentioned earlier. Figures 6 through 8 show that a reaction zone identical to that observed earlier was present on the graphite. The use of the more dense graphite had effectively slowed the reaction rate; however, the beam usage times were still far short of being practical.

Since the reaction rate was reduced by using a more dense graphite, it was felt that perhaps it could be further reduced by coating the graphite surface. Tungsten was considered as the best coating material since it was already present in the system. A 0.005 in. thick coat of tungsten was vapor deposited onto POCO washers. The application of this coating further slowed the reaction rate and increased beam usage time to approximately 350 min. Failure again occurred by the same mechanism mentioned previously. Figures 9 through 11 show the appearance of washer surfaces after failure.

While the 350 min beam usage time was a significant increase, it was thought that additional increases in beam usage times could be achieved by further investigation into the problem. Since even with the

FIGURE 1 - Cold cathode pilot gun electron beam welder.

FIGURE 2 - Top graphite washer used with tungsten emitter plate.

FIGURE 3 - Area on the graphite 580 washer where the reaction product had locked the tungsten emitter plate in place.

FIGURE 4 - Reaction product as it appeared on the surface of the graphite 580 washer.

FIGURE 5 - Reaction product which grew on the sidewall of the top graphite 580 washer.

FIGURE 6 - Reaction product as it appeared on the surface of the POCO graphite washer.

FIGURE 7 - Area on the POCO graphite washer where the reaction product had locked the tungsten emitter plate in place.

FIGURE 8 - Reaction product as it appeared on the surface of the POCO graphite washer.

FIGURE 9 - Reaction product as it appeared on the surface of the tungsten-coated POCO graphite washer.

coated graphite surfaces, the reaction product still appeared and resulted in failure when it grew sufficiently large to impede gas flow, a change in washer design was contemplated. By increasing the depth of the washer insert, the tungsten emitter would still be maintained in position. It would, however, be further away from the graphite surface; even if the rate of the reaction could not be slowed, it would take the growth of significantly more reaction product before the gas flow would be impeded. With these concepts in mind, the depth of the insert in the POCO graphite washer was increased from the 0.015 in. value shown in Figure 2 to 0.034 in. deep. The modified washers were not coated prior to usage.

Beam usage time was increased to approximately 675 min with the use of the modified washers. Failure again occurred when the reaction product grew to a sufficient size to impede the gas flow. Figure 12 shows the appearance of the modified washer prior to use, while Figures 13 through 15 show the surfaces after failure.

While it is felt that further improvements might further delay the reaction layer build-up, they do not seem to be practical since after 675 min of beam usage time, the tungsten emitter plate becomes badly

deteriorated (Figures 16 and 17) and a change is advisable. Additional examination of the reaction layer that builds up on the graphite, proved it to be $WO_{2.90}$, not tungsten carbide as originally thought. The oxygen source might possibly have been in the contaminants in the nitrogen flow gas. The flow gas used in the welder was analyzed by mass spectrometric analysis and determined to be 99.768 mole % N_2 with the major impurity identified as 0.191 mole % O_2 . Utilizing the modified POCO graphite washers in the system, the flow gas was changed to 99.960 mole % N_2 with the major impurity identified as 0.010 mole % O_2 and the system was put back into operation. Figures 18 through 21 show the surface of a washer that had been maintained in this new environment. Total beam usage time for this sample was approximately 400 min and there was no evidence of the onset of failure. However, the same reaction product, identified earlier, was readily apparent and approaching the size that would eventually result in failure. Figure 21 shows that the tungsten emitter plate was free-floating and assumed two prior positions before the one it had apparently been locked into by the growth of the reaction product. The use of the higher purity nitrogen gas did not appear to have any significant effect on the reaction product and by estimating the level of

FIGURE 10 - Area on the tungsten-coated POCO graphite washer where the tungsten emitter plate was locked into position.

FIGURE 11 - Surface of the reaction product pressed against the tungsten emitter plate at the point where it was locked into the tungsten-coated POCO graphite washers.

FIGURE 12 - Surface of modified top POCO graphite washer prior to use.

FIGURE 13 - Surface of the modified top POCO graphite washer after failure.

FIGURE 14 - Reaction product layer on the surface of the modified top POCO graphite washer in an area under the tungsten emitter plate where it was locked in place.

FIGURE 15 - Bottom washer complement of the top washer shown in Figure 13. The outline of the tungsten emitter plate is clearly visible in the reaction product layer.

reaction product growth on the POCO graphite washers it was felt that no more significant increases in beam usage time can be achieved by its use.

Why a decrease in O_2 contamination by a factor of 20 in the system has little or no effect on the growth of the reaction product is difficult to explain at the present time. However, the oxygen in the system gas appears to be the only source of oxygen for the reaction. If strict oxide evaporation and condensation onto the graphite is the controlling process, the reaction rate should be approximately six times faster for the system with the lower purity gas. This does not appear to be true in this case. It is entirely possible, however, that at the conditions to which the tungsten emitter plate is exposed,

very little oxygen (<10 ppm) is necessary to cause the reaction product and an excess of oxygen has little additional effect. This would account for the fact that for two different levels of oxygen impurity no measurable difference in the reaction growth rate is noted and there appears to be no difference in the physical appearance of the tungsten emitter plate even though it should be oxidizing approximately six times faster in the impure environment. Although it is intriguing, the problem does not merit further investigation at the present time since the modifications already performed on the system have shifted the controlling influence of the beam usage time from the growth of the reaction product to the useful life of the tungsten emitter which from metallographic evidence seems to be in the neighborhood of 675 min.

FIGURE 16 - Surface of a tungsten emitter plate after 675 min of beam usage time. The dark area in the center of the micrograph is a hole.

FIGURE 17 - A detailed micrograph of the hole shown in Figure 16.

FIGURE 18.- Surface of the modified top POCO graphite washer used in the system with the high-purity N_2 gas.

FIGURE 19 - Reaction product formed on the surface of the modified top POCO graphite washer used in the system with the high-purity N_2 gas.

FIGURE 20 - A higher magnification micrograph of the reaction product shown in Figure 19.

FIGURE 21 - Reaction product formed on the bottom complement of the washer shown in Figure 18. The three seating positions of the tungsten emitter plate can readily be observed. The tungsten emitter plate was beginning to be permanently set in the third position.

Summary

This study has shown that short beam usage times of a 60 KeV electron beam welder were the result of a tungsten oxide build-up that occurred on the graphite washers housing the tungsten emitter plate which produces the electron weld beam. While the growth of the tungsten oxide could not be prevented, its growth rate was significantly modified by changing the graphite washer material and making minor design changes in the washers. These minor changes in the system increased beam usage time from an original 40 minutes to approximately 675 minutes.

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Consultants

C. F. Curtiss

University of Wisconsin

C. F. Eck

Miamisburg, Ohio

H. W. Mattson

Monsanto Company

D. F. Griffing

Miami University

R. E. Miers

Ft. Wayne, Indiana

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University of Cincinnati

H. F. Swift

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D. White

University of Pennsylvania

D. K. Nowlin, ALO (2)

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