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Author(s): J. D. Paul, H. E. Williams III

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FILAMENT HEATER CURRENT MODULATION FOR INCREASED FILAMENT LIFETIME

J. D. Paul, H. E. Williams III
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

A circuit to eliminate 100 ampere heater currents from filaments during the arc pulse was developed. The magnetic field due to the 100 ampere current tends to hold electrons to the filament, decreasing the arc current. By eliminating this magnetic field, the arc should be more efficient, allowing the filaments to run at a lower average heater current. This should extend the filament lifetime. The circuit development and preliminary filament results are discussed.

1. Introduction

The surface conversion H-minus ion source employs two 60 mil tungsten filaments which are approximately 17 centimeters in length. These filaments are heated to approximately 2800 degrees centigrade by 95-100 amperes of DC heater current. The arc is struck at a 120 hertz rate, for 800 microseconds and is generally run at 30 amperes peak current. Although sputtering is considered a contributing factor in the demise of the filament, evaporation is of greater concern. If the peak arc current can be maintained with less average heater current, the filament evaporation rate for this arc current will diminish. In the vacuum of an ion source, we expect the filaments to retain much of their heat throughout a 1 millisecond (12% duty) loss of heater current.

2. Modulator

As shown in figure 1, the modulator is configured as a difference amplifier comprised of power MOSFET devices so as to minimize the effect of large pulsed output currents on the power supply regulation. The heater current through each of the filaments is controlled by a separate difference amplifier to allow for balancing of the currents. The amplifiers are operated as closed-loop constant-current sources which can switch the current path from the filament to another transistor and back.

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Several problems were encountered during the development of the system. The first of these was cooling. The filaments operate at approximately 10 volts and 100 amperes which requires 1000 watts of power. The constant current source requires a minimum of 2.5-3.0 volts to ensure proper operation. At 100 amperes, this circuit must dissipate 300 watts. The filament transistor handles about 100 watts. During the period in which the heater current is pulsed off, the other transistor is required to absorb the 1000 watts that the filament uses. The total average power dissipation is approximately 500 watts per amplifier so our modulator chassis had to be capable of dissipating 1000 watts without a significant temperature increase. Since the chassis was intended for use in the H-minus Dome 80kV Equipment Rack, it had to be rack-mountable and as small as possible. Therefore, cooling requirements were of considerable importance. Another difficulty was the tendency of electronic amplifiers to oscillate when switching large currents. Component selection and circuit layout were paramount to the stability of the system. Finally, we needed to protect the system from the high energy spikes which frequent the ground plane when the 80kV column in the Dome sparks to ground. The stored energy in one of these spikes can be upwards of 50 joules, more than sufficient to destroy most unprotected electronic components. Judicious selection and placement of assorted transzorbs and MOV's (metal-oxide varistors) was required for operation in a high voltage environment. Nevertheless, susceptibility to spark damage remains a problem.

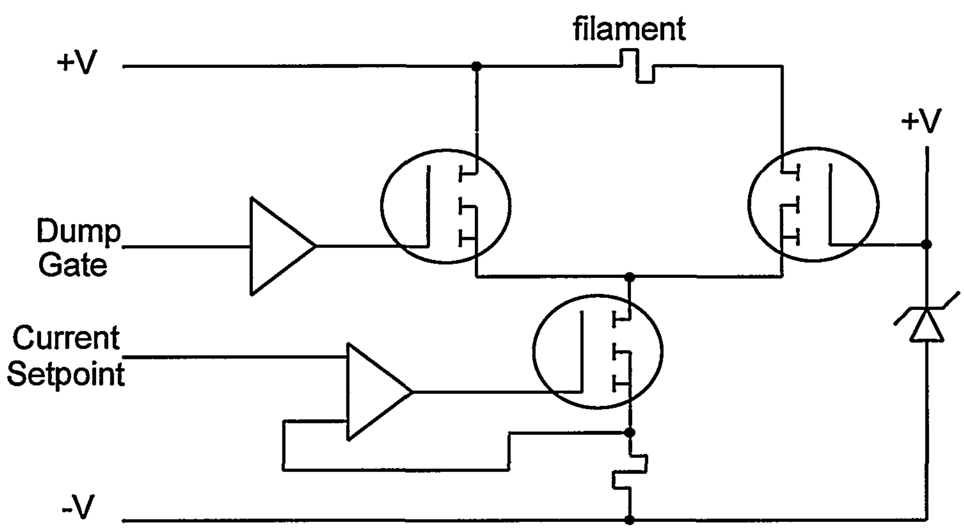

Figure 1. Filament Modulator - Difference Amplifier

3. Filament Modulator

Operation of the Filament Modulator is timed to ensure that the DC heater current is approximately zero and stable prior to the striking of the arc. The relative timing of the "Dump" gate, triggering the shunting of the heater current from the filament to the other transistor, and the "Source" gate, triggering the arc are shown in figure 2. The Dump gate begins approximately 100 microseconds prior to the Source gate to allow the filament to settle prior to applying the 200 volt arc pulse to the connection in figure 1. The Dump gate is 1000 microseconds long to extend approximately 100 microseconds beyond the falling edge of the arc pulse. This is to minimize sputtering of the filament and oscillations in the drive circuits. To maintain the necessary filament temperature for electron emission, we had to maintain a certain average heater current. Therefore, the average heater currents were used to compare the "modulated" filaments with the "unmodulated" filaments. The standard by which we compared was Arc Efficiency or the ratio of peak arc current to average filament heater.

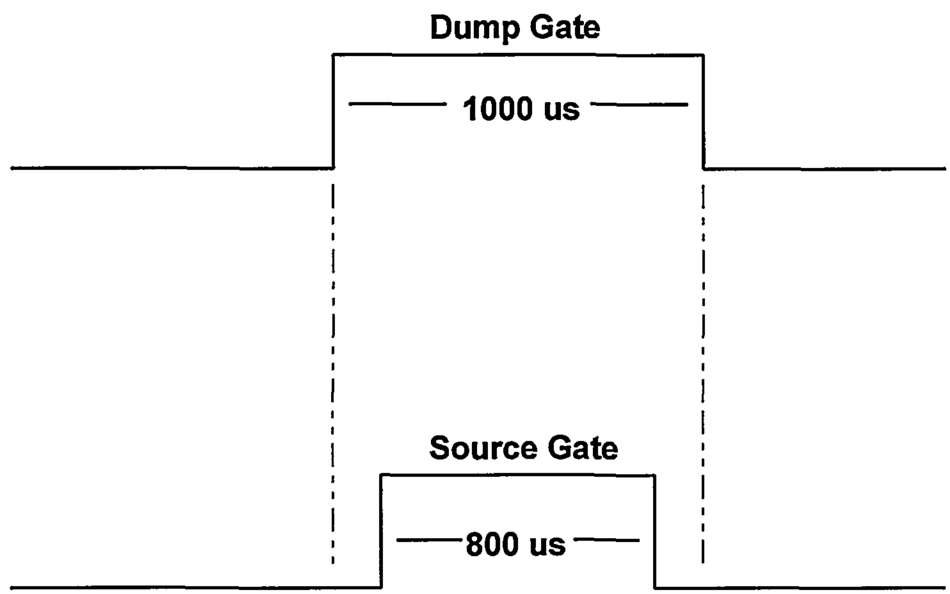

Figure 2. Relative Timing of Source and Dump Gates

As illustrated in figures 3 and 4, the modulated filaments tend to produce a given peak arc current at a considerably higher arc efficiency (lower average heater current) than the unmodulated filaments. This supports the notion that the elimination of the DC magnetic field around the filaments allows for an increase in arc current emission.

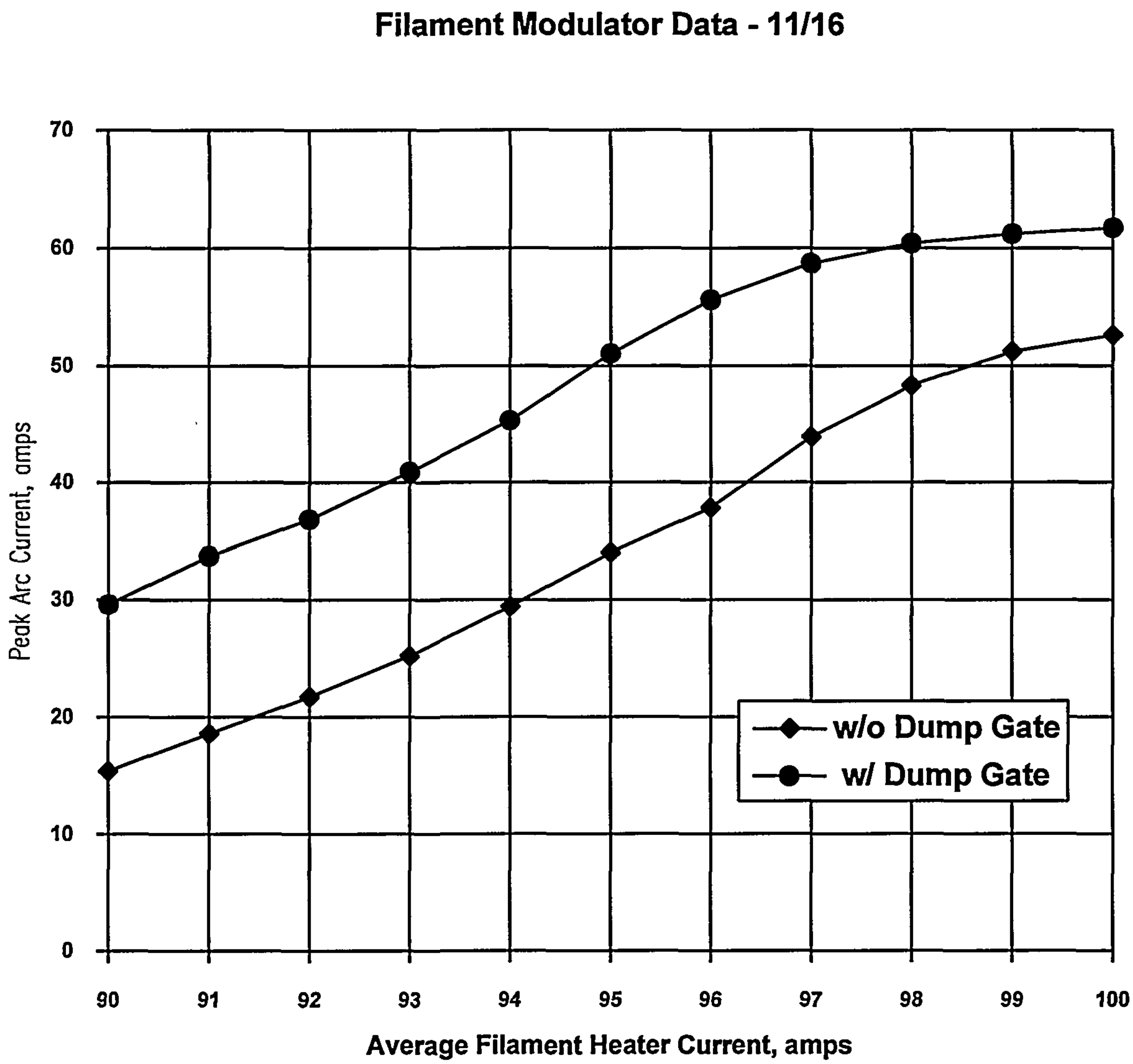

Figure 3. Arc Efficiency - Modulated vs. Unmodulated Filaments

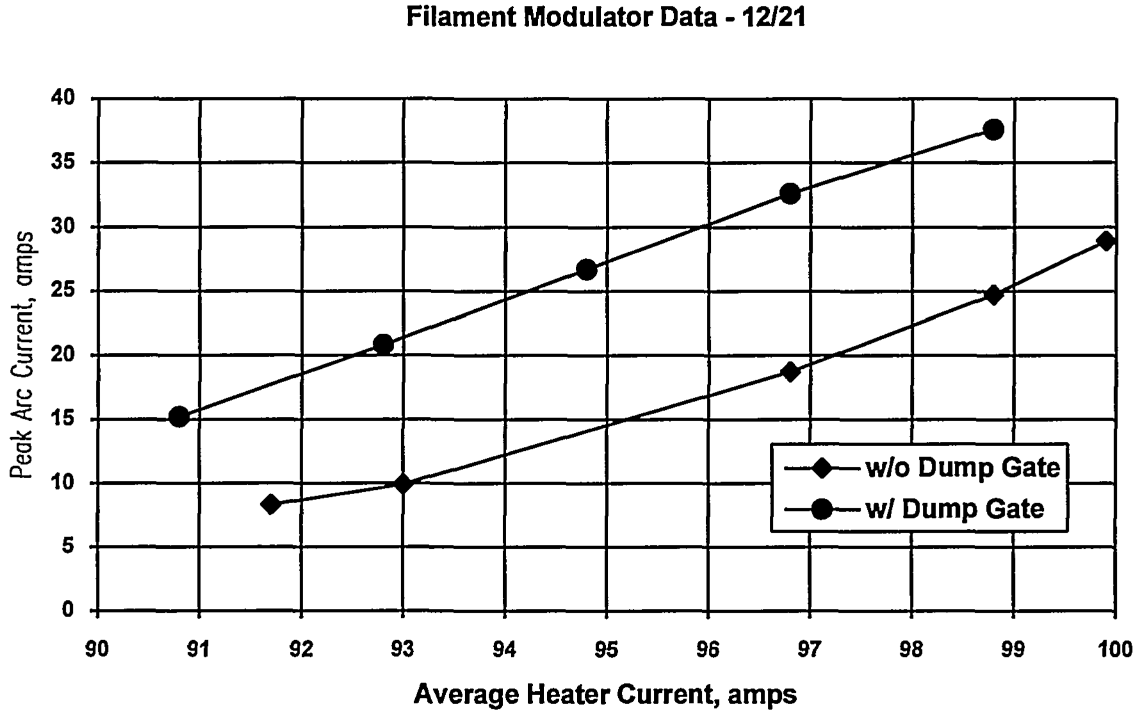

Figure 4. Arc Efficiency - Modulated vs. Unmodulated Filaments

4. Conclusions

A compact, high current modulator prototype for the investigation into filament heater current effects has been designed and built. Preliminary test results show an increase in Arc Efficiency with a decrease in filament heater current during the arc pulse. Although the contributions of tungsten sputtering and arc current heating in the filament have not been addressed here, we may conclude that further studies could lead to a considerable improvement in filament lifetime.

5. Acknowledgments

The authors would like to thank Andrew Browman and Rob York for their assistance in the design and development of the modulator and Wade Potter for his expertise in the fabrication of the electronic and mechanical systems.

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