Showing Off

Electronic and computer circuits today are wimpy. Yes, they are fast, but they don't have any high voltages. Computers run on voltages lower than those in flashlights. Component sound systems are all solid state, again with low voltages. But there was a time when electronic circuits used vacuum tubes. Those were the days of insulators made of glass and high voltages, which nearly cost me my life.

Before transistors, vacuum tubes did the work of amplification. A high voltage, often several hundred or even several thousand volts, pulled electrons from the cathode of a tube. The cathode was heated with a filament, which was the red glow often seen (and nostalgically loved) in tubes of old. The hot cathode would bounce electrons off the metal, and they would feel the high voltage pull of the "plate" of the tube. Of the electrons would go, pulled through a vacuum inside the tube toward the plate. Their travel was regulated by a wire mesh grid, with a control voltage that could control the migration of the electrons. Since the grid was not heated, electrons would not bounce off the grid. But a field of electrons on the grid between the cathode and plate would discourage electrons from getting through the grid (like charges repel) and on to the plate. So a change in voltage on the grid could control the current - the movement of electrons - from cathode to plate. That was basically how a tube worked.

Now for me that meant there were two ways I could get into trouble with tubes. One way was by not respecting the vacuum inside the tube, and the other was by not respecting the high voltages that would be present.

I built radio transmitters, among other things. I almost always built them from salvage equipment and from other non-working equipment. Transmitter tubes were perhaps the hardest thing to come by. New, they were very expensive. They were usually nearly burned out when I could get them used, since they did most of the real work in a radio transmitter. The tube used in the "final" output stage of one transmitter was a 6146. I was lucky to find one that wasn't new but which was mostly still in perfect shape. Almost perfect that is.

The 6146 has what's known as a "plate cap." On most tubes, the connections to the various elements - filament, cathode, grid, plate - are made out the bottom of the tube through the socket. On transmitter tubes, since the plate voltage is considerably higher, it's easier to bring the plate connection out the top of the tube. That's done by connecting a wire inside the tube to the plate, and by running that wire out through the top of the tube, through the glass, to a cap on top of the tube. Then a clamp could be put on the plate cap and high voltage could be safely applied to the tube.

The 6146 I had acquired was perfect, except that the plate cap had broken off. That's why internally it was as good as a new tube. Only the tiniest stub of the wire that originally went through the glass and attach to the plate cap remained. My mission was to take a file and to file down the glass to where I could attach another wire to what was left of the plate wire. Now putting a file to a glass envelope which surrounded the high vacuum of a transmitting tube was not smart. If the glass should crack, the tube would implode and my hands would be full of little bits of glass and metal. So I took the file and ever so slowly scraped gently, gently until I could attach my own wire. I beat the odds on that one. I was not as lucky on another danger that transmitting tubes offered: high voltage.

For transmitting tubes, the desired result is a lot of power. The more power, the stronger the signal that can be sent out. Power is the product of two things: voltage and current. An ordinary household light bulb has a power rating of 100 watts. That means that for 110 volts, about 0.9 Amperes of current will flow through the bulb. 110 volts times 0.9 Amps is 100 watts. Transmitters work the same way except that vacuum tubes can't carry Amperes of current. In a light bulb, electrons travel across a low resistance filament. In a transmitter tube, the electrons need to jump across a vacuum. So currents are lower. For more power, then voltages must be higher. Much higher. A one kilowatt transmitter might have a plate voltage of 4000 volts and a current of 0.25 Amperes. It was just such a transmitter that I was working on one day in 1963.

My girlfriend was Tanja Randolph. She and I were very close, even though we weren't allowed to see each other. But we found ways to spend some time together, and one day she visited me at the Electronics Hobby Shop at Lockbourne AFB where we lived near Columbus, Ohio. I had my transmitter working that day, and I decided to impress her. I had to "show off." Now how do you show off a transmitter? Do you put some oscilloscope probes here and there and show waveforms as in a old science fiction movie? No. Do you hook up a voltmeter and say "This reading means that it's working?" No.

What you do is take advantage of the fact that there is a lot of radio frequency energy present at the plate cap of the transmitter's final amplifier. Yes, there is a 4000 volt plate voltage potential, but that's "direct current," that is, a steady state voltage. Stay away from that! But there is also an alternating current signal at the transmitter plate, and that's where the fun is. The alternating current at the radio frequencies is usually coupled to an antenna and used to broadcast for hundreds of miles. But you can take all that energy off the plate cap right there if you want and it makes for a dandy display. And it's usually perfectly safe.

I took a pair of metal pliers whose handles were coated with a thin layer of rubber. Holding the pliers in my hand, the layer of rubber acted as an insulator against the 4000 volt direct current potential, while the combination of my hand, the layer of rubber, and the metal pliers acted as what's known as a capacitor, which can pass a small amount of alternating current. I won't go into the technical details, but when I held the tip of the pliers near the transmitter tube plate cap, with my other hand on the chassis, I was able to convince the radio frequency energy -- the alternating current -- to jump from the plate cap to the tip of the pliers, and into my arm, headed for the chassis ground through my body to my other hand. Very very impressive, as the blue-white arc jumped through the air, seemingly into my body. I was not hurt, because the high frequency of the transmitter and the nature of the alternating current made the signal turn around and reverse before the electrons got very far into my body at all. My hand got warm, nothing more.

The show was especially impressive with the lights out. But once in the dark, it was hard to see exactly where the plate cap was. That's when I actually touched the plate cap with the tip of the pliers and the full force of 4000 volts was in the pliers. In a thousandth of a second, the rubber insulation broke down on the pliers, putting the full 4000 volts in my hand. An excellent ground return was provided by my other hand on the chassis and Wham in one incredible jolt, I was literally thrown back across the room. Every muscle in my body flexed as hard as it could under the severe electrical shock, and flexed just once. If the net result of all my muscles flexing at once had not knocked me back away from the transmitter, this story would not be written today. At least it wouldn't have been written by me.