

HEAVY ION POWER AMPLIFIER CROWBAR

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Introduction

The heavy ion rf power amplifier output tubes are protected by a fast acting crowbar on both the anode and screen power supplies. Primary protection is on the anode supply since this supply has destructive energy storage. When the anode supply is crowbarred, the screen supply must be crowbarred in order to prevent the screen grid from acting as the anode. The crowbar circuit senses the start of a tube arc by a sudden change in anode current of a tube, and shorts (crowbars) the power supply output.

The anode power supply has a maximum voltage of 10 kV at 45 Amperes peak. It has 200 μ f filter capacitor as energy storage. Thus, the supply can have as much as 10,000 Joules of stored energy ($W_s = 0.5 CV^2$). The arc discharge energy into the power amplifier tetrodes must be limited to 20 Joules or less to prevent damage to the tubes. The crowbar provides a low impedance path to safely discharge the stored energy in the power supply. It diverts the energy discharge of the supply from the tetrodes through the crowbar device.

The following discussion concentrates on the anode supply, since it has the largest stored energy of both supplies. Figure 1 is a simplified functional diagram of the anode power supply and crowbar.

Ignitron

The crowbar device is an ignitron. The ignitron uses a mercury pool as the cathode. The mercury pool and mercury vapor allow the ignitron to conduct large currents without internal damage. When the

ignitron is triggered, a peak discharge current of 5,000 Amperes will have to be handled by the ignitron. The filter capacitor in the power supply will be discharged from 10 kV to 125 V in about 1.8 msec when crowbarred. Power supply regulation will keep the terminal voltage at 125 V when operating into a short circuit (crowbarred).

A thyatron is used as the crowbar device in the screen power, since the energy is much less than the anode supply. The thyatron is much faster than the ignitron, but cannot handle as much current.

Tube Current and Main Contactor Coordination

Figure 2A illustrates the typical tube current for one of the output tetrodes during normal operation. When a tube arcs, the anode current will rise at a rapid rate determined by the L/R of the circuit. When the power supply is crowbarred, its terminal voltage will be reduced to 125 V while the stored energy is shunted through the crowbar device. The arc voltage across the tetrode is 50 V or less.

Typically the main contactors will take three cycles (50 msec) to disconnect the supply from the power source. In order to limit the discharge through the tube to 50 Joules, the anode current must be limited to 5 Amperes during the 50 msec required to disconnect the power supply from the source. A pair of 15 Ohm current limiting resistors is used in series with the anode connection to the tetrodes.

Current Sensing Transformers

Pearson Model 325 current transformers are used to monitor the anode current of the amplifier tetrodes. Both anode leads are fed through the transformers to buck out the quiescent anode current. Thus, the individual transformer monitors the differential current of the tube.

Sense Circuit

Figure 3 is a simplified functional diagram of the crowbar sense circuit. Comparitors are used to monitor the tube current measured by the transformers. The comparator will toggle whenever the tube current exceeds a preset value (nominally 15 A).

The output of the comparator is used to set flip-flop (FF) and to trigger a small pulse generator. The FF circuit will open the external interlock circuit of the power supplies. The crowbar trigger pulse used to trigger the crowbar device in the power supplies is generated by a SCR switched line type pulser. The pulse output is a 10 V, 3 μ sec wide pulse into a 50 Ohm load.

In order to retain the information of which tube arced, the other comparator output must be locked out. The lockout is accomplished by FF 3.

Testing

Typically a crowbar protection circuit is tested using a "foil test" technique. A pair of contacts is connected to the output of the power supply. One of the contacts is covered with a thin aluminum foil (such as the foil from a pack of cigarettes or chewing gum wrapper). The two contacts are brought together rapidly. With the crowbar enabled, the result is a pin hole in the foil. With the crowbar disabled, the foil will be vaporized (caution must be exercised since hot particles will be ejected and the contacts may weld together).

Several full output voltage foil tests were run on the anode supply, and resulted in minute pin holes (the foil had to be held against a strong light source to find the hole).

Applicable Documents

1. Crowbar Sense Circuit, D32-E188-4 and D32-E182-4.
2. Specification for the Heavy Ion RF Power Amplifier Power Supply, AGS-853.

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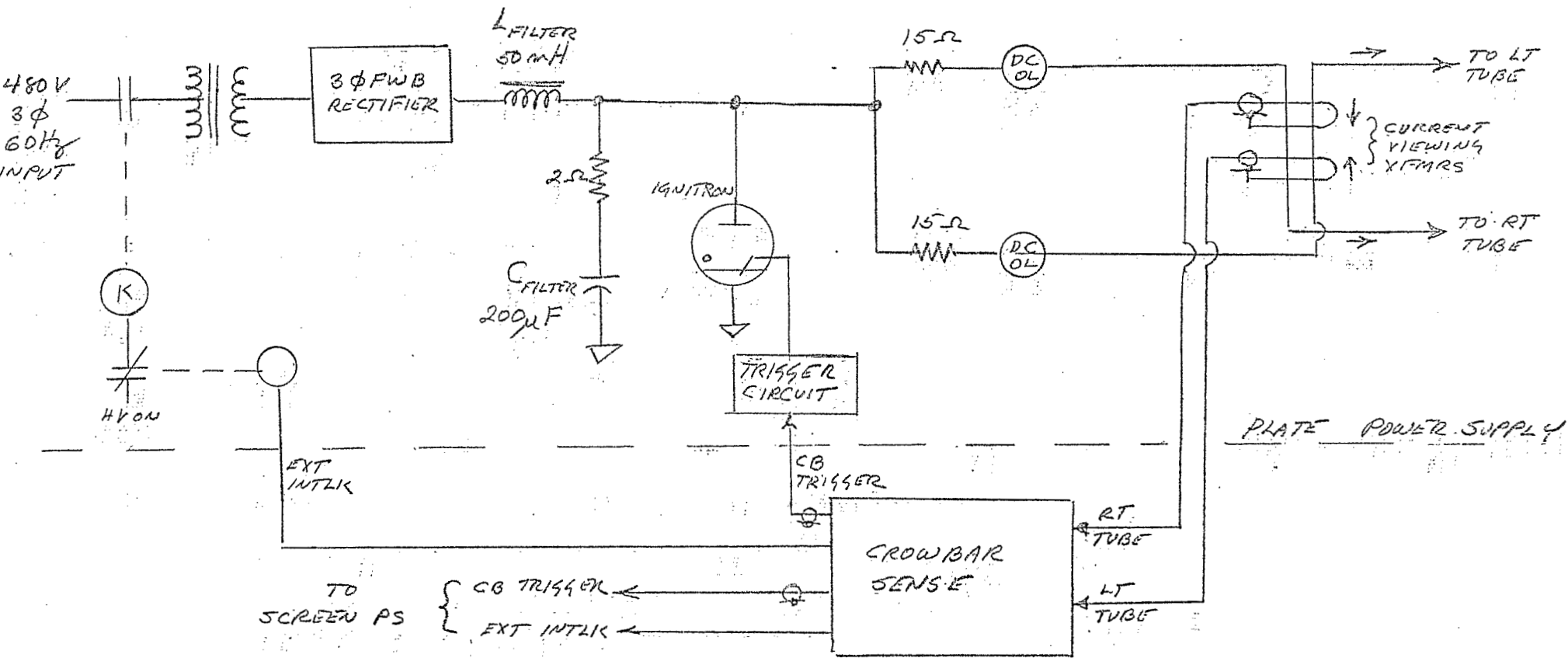
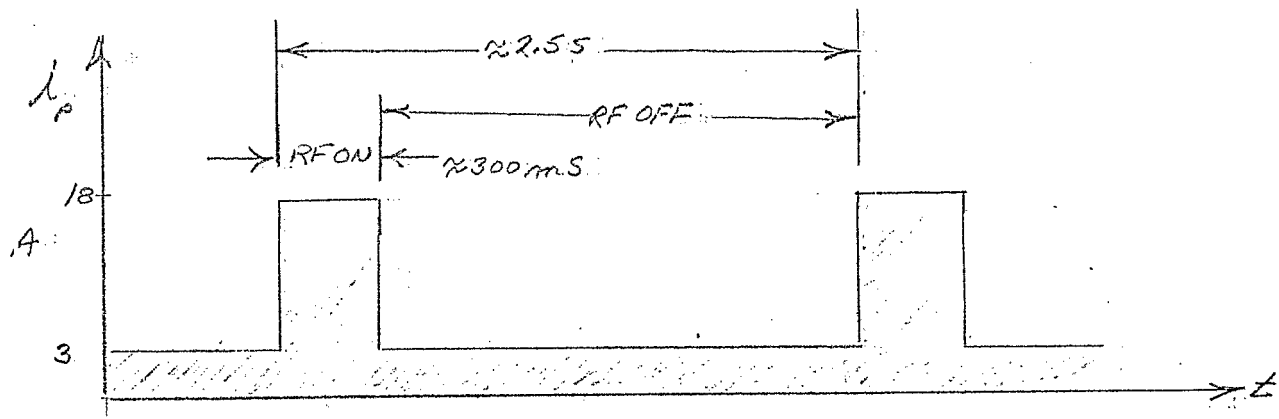
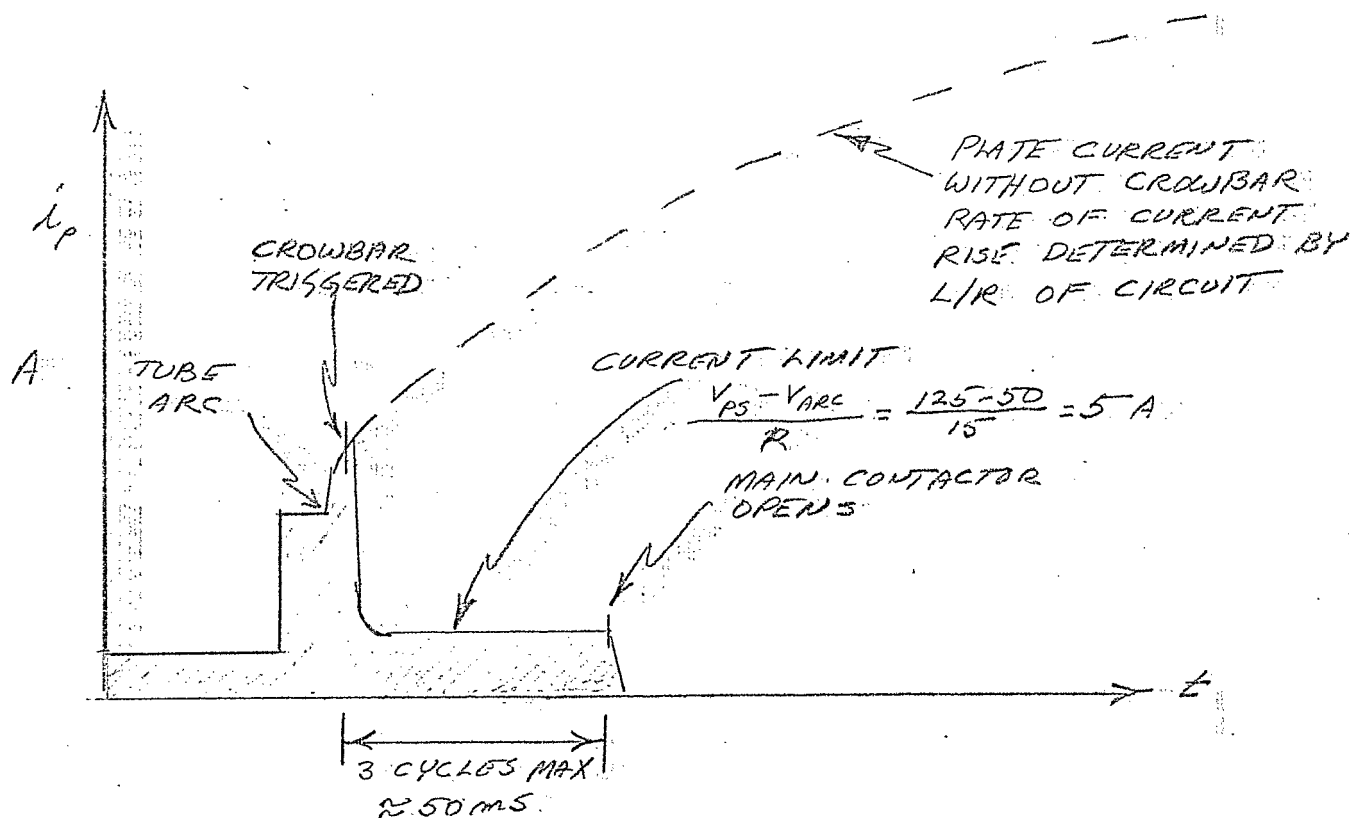


FIGURE 1
SIMPLIFIED FUNCTIONAL DIAGRAM
ANODE PS CROWBAR



A. TYPICAL ANODE CURRENT PER TUBE



B. ANODE CURRENT WITH TUBE ARC

FIGURE 2. TUBE CURRENT

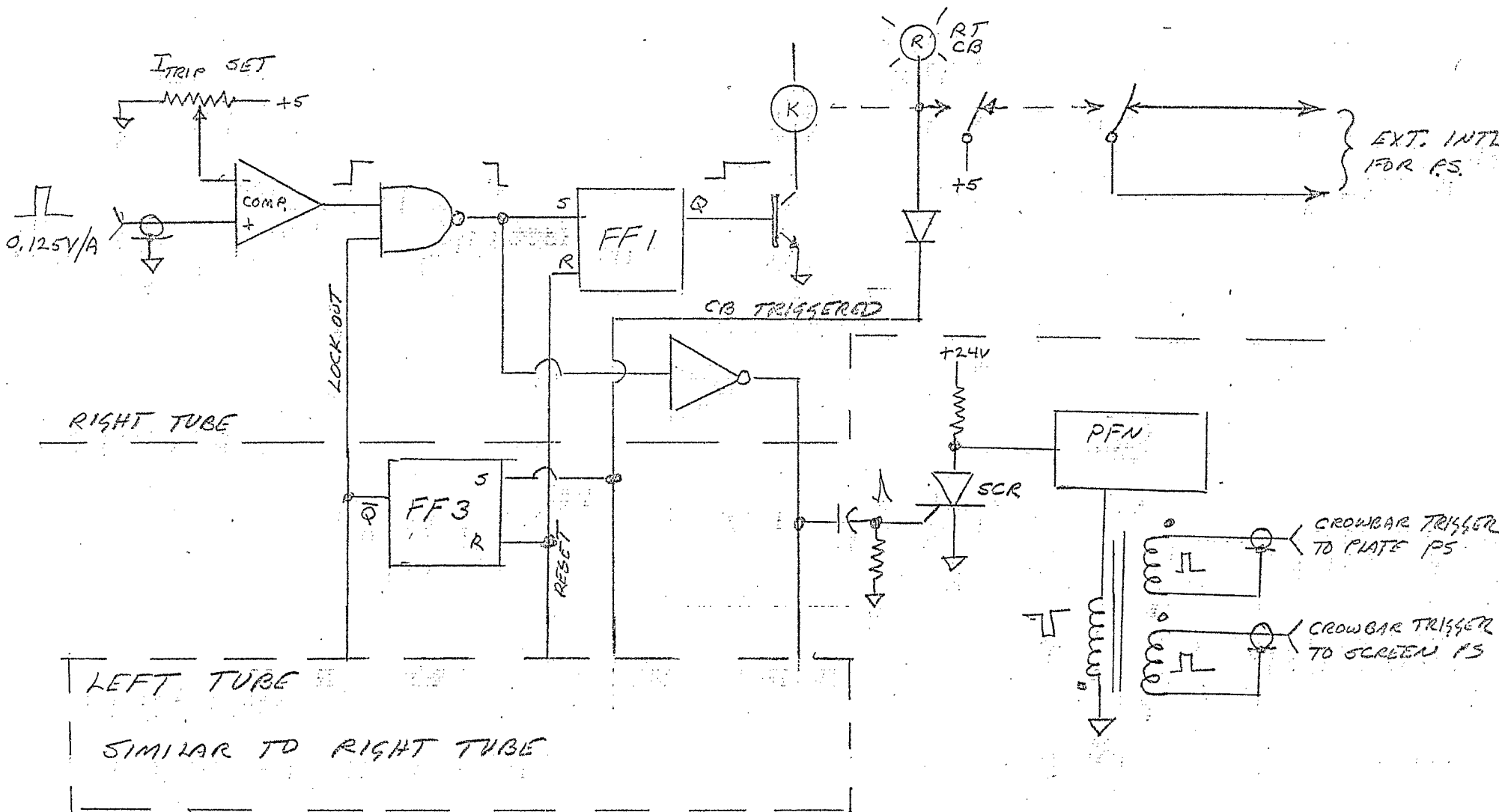


FIGURE 3
SIMPLIFIED FUNCTIONAL DIAGRAM
CROWBAR SENSE