Title
THE FAULT DIVERTER - A PROTECTIVE DEVICE FOR HIGH-POWER ELECTRON TUBES

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The Fault Diverter - A Protective Device for High-Power Electron Tubes

February 28, 1957

Mr. Mark W. Bullock
Engineering Manager
Continental Electronics Manufacturing Company
4212 S. Buckner Blvd.
Dallas 27, Texas

Dear Mr. Bullock:

I do not intend to publish my paper on fault diverters, but I have had our photographer make prints of the slides which I used. We have a fault diverter, or crowbar, on each of our machines and they have markedly improved the life of the tubes used in our oscillators.

Figure 1 shows a typical power supply with ignitron crowbar. Three phase 60 cycle power is fed through an ignitron contactor to the plate transformer and rectifier and hence through a filter to the load. In the event of a fault condition in the load the ignitron crowbar is fired short circuiting the power supply and preventing further power flow into the load. A second signal from the fault detector chassis is sent to open the ignitron contactor before sufficient power flows into the power supply to do any damage. The time required to fire the crowbar after a fault is detected is between one and ten microseconds--the former a rather fast crowbar and the latter rather slow. The time required to open the ignitron contactor is always less than eight milliseconds--the time to the next current zero in the power lines.

Figure 2 shows the basic components of an ignitron crowbar. The purpose of the 2 ohms resistor is to provide sufficient anode potential on the crowbar to permit firing under short circuit load conditions. The resistance value assumes that this crowbar is intended to fire at about 50 amperes, which provides 100 volts at the anode. The .25 henry choke limits the power supply current after the crowbar has been fired until the contactor can be opened. The holding anode may be used to prevent the arc from being extinguished in the event the positive buss should ring, as is often the case. Overlooking this condition is one of the most frequent errors in crowbar design. It is possible to omit the holding anode by locating the 1 mfd capacitor and 25 ohms resistor near the anode so as to minimize the inductance in this circuit. This capacitor and resistor also speed up the anode arc. The current transformer in the cathode of the crowbar opens the contactor in the event that the crowbar itself sparks over.

Figure 3 shows a typical fault detector. An over current is detected by means of the magnitron--typically a G.E. type 2B23. The coil in the D.C. high voltage line usually consists of about 5 turns and surrounds the magnitron.

Excessive current provides sufficient magnetic field to cut-off the current flow in the magnitron permitting the grid of V-1 to rise to positive 300 volts. This trips the Schmit trigger consisting of V-1 and the first half of V-2 which fires the thyratron, V-3, discharging the capacitor into the ignitor of the crowbar. The current trip adjustment typically provides about a five to one range of currents required to cut-off the magnitron.

The relays are employed to provide a fail safe feature. Each cathode in V-1 and V-2 must be emitting in order to close the interlock chain and keep the machine in operation. A pentagrid tube is used for the first half of the Schmit trigger which is normally not conducting. Since grid number one is maintained at zero bias, current flows through the screengrid number 2 but not number four, the current normally being cut-off by the control grid number 3. Relay number 4 insures that the filament of the thyratron is continuous and Re 5 insures that it has plate voltage. Re 6 insures that there are no cathode to filament shorts. We have found that the use of 1500 volts on the thyratron speeds up the firing of the crowbar.

Figure 4 is a diagram of the power supply for the 90 inch cyclotron at Livermore. It consists of an ignitron crowbar, surge network, 100% buck or boost induction regulator, and two three phase full wave rectifiers connected in series to produce 20 kv. Since one power transformer is connected delta-delta while the other is connected delta wye the ripple is 12 phase rather than 6 phase. The reason that we prefer two stacked 10 kv rectifiers is that we have found type 857 rectifiers to be somewhat marginal when operated at 20 kv.

The transformers connected between the 2400 volt line and the ignitron pulse chassis are potential transformers used for phasing the ignitors. The chassis employs an electronic gate which interrupts the ignitor firing upon receiving a signal from the fault detector.

The surge network is a rather large unit and prevents the snap out current (about 3 amps) of the ignitrons from producing a transient by means of the magnetizing inductance of the induction regulator. The snap out current drops to zero within one microsecond. Further transient protection is provided by the Westinghouse autovalves and the thyrite connected across the power transformer secondaries. Control of transients is the key to satisfactory ignitron performance and should be carefully considered.

Figure 5 shows the surge network cabinet, the induction regulator, and the two 300 kva plate transformers of the power supply of the 90 inch cyclotron.

Figure 6 shows the rectifier room of this machine. To the left is the ignitron contactor cabinet, rear center is the rectifier cabinet, and in the foreground is the filter and crowbar cabinet. Incidentally, the type GL 5779 is used as the crowbar in this machine. While this tube is only rated at 350 volts in rectifier service, it operates at 20 kv. in crowbar service without the slightest difficulty. In each crowbar operation the energy dissipated is only 83 watt seconds. When the high voltage buss is shortcircuited with a ground hook only a slight "click" is heard--about equal to the discharge of a ten mfd. capacitor charged to 300 volts--because most of the current is discharged through the crowbar.

Figure 7 shows one phase of the ignitron contactor of the 90 inch cyclotron. A pair of type 5555 ignitrons are used in each line.

Figure 8 shows the nine megawatt power supply of the A48 linear accelerator at Livermore. In this case a motor-generator set is used to isolate the power supply from the line. This machine sometimes operated under pulsed conditions near 18 megawatts with a duty factor of 50% and the m-g set filters this pulse from the main power line.

This power supply does not use an ignitron contactor but uses an ignitron rectifier. After a crowbar operation the firing of the ignitors is stopped. Probably the choice of the large ignitrons as crowbars on this power supply was governed by the desirability of maintaining only one type of spare rather than power considerations.

Figure 9 shows the 110 kv to 13.8 kv line transformer of the A 48 accelerator power supply. Figure 10 shows the m-g set. Figure 11 shows the two plate transformers of the rectifier.

Figure 12 shows the power supply of the heavy ion accelerator at Berkeley. It was chosen to illustrate a pulsed system. Type 562 tubes are used in an emission limited arrangement to charge the pulse line to 40 kv. The pulse line is discharged into the oscillator by means of a triggered spark gap. In the event of a fault a second gap serves as a crowbar to divert the remaining energy in the pulse line. The inductances in series with the spark gaps saturate at a relatively low current and so are effectively removed during the main pulse of current. During the initial firing of the gap, however, they permit the cathode end of the gap to be depressed to about -100 kv by the trigger in order to insure the firing of the gap. Because the oscillator approximately matches the line, it receives only about half of the voltage which the line was charged to.

Figure 13 shows the power transformers and 562 rectifiers of the heavy ion machine. Figure 14 shows the pulse line. Figure 15 shows the spark gaps. These gaps probably will be replaced with ignitrons in the near future. Ignitrons are regarded as being more reliable than spark gaps.

Figure 16 shows the crowbar installation of the Bevatron. In the foreground is the current limiting choke, spark gap, and thyrite. Further back and to the right the 5779 crowbar can be seen.

I hope that some of this information will be of use to you.

Sincerely,

Bob H. Smith

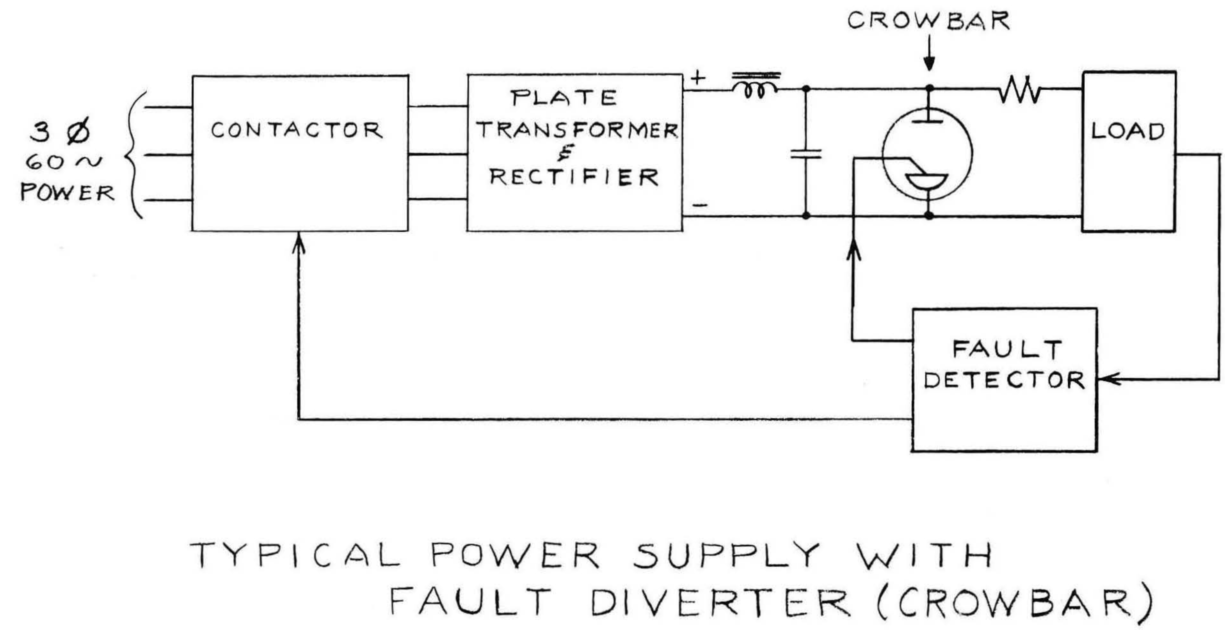

CROWBAR
3 Ø
60 ~
POWER
CONTACTOR
PLATE
TRANSFORMER
&
RECTIFIER
+
−
LOAD
FAULT
DETECTOR
TYPICAL POWER SUPPLY WITH
FAULT DIVERTER (CROWBAR)

Fig. 1

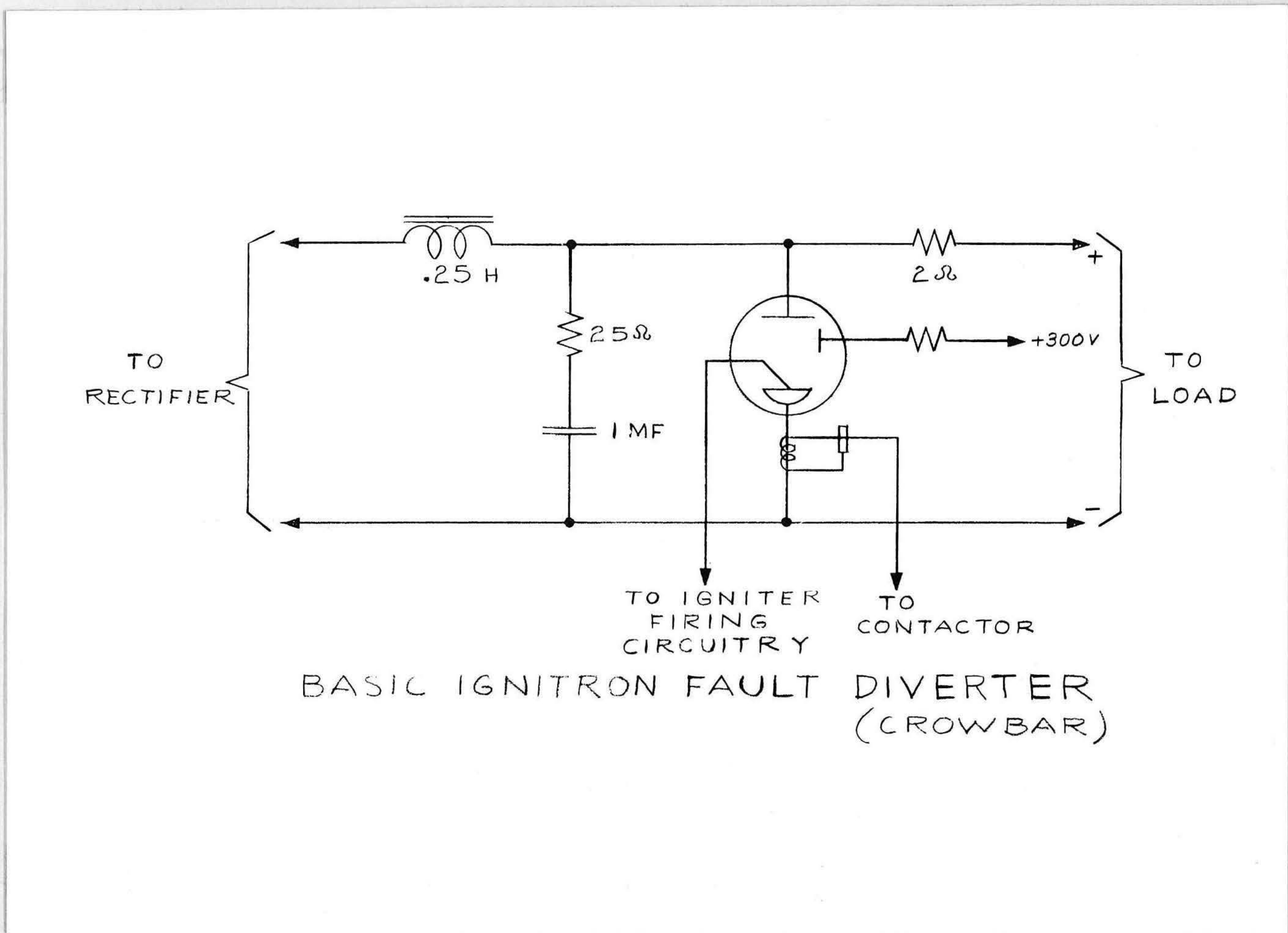
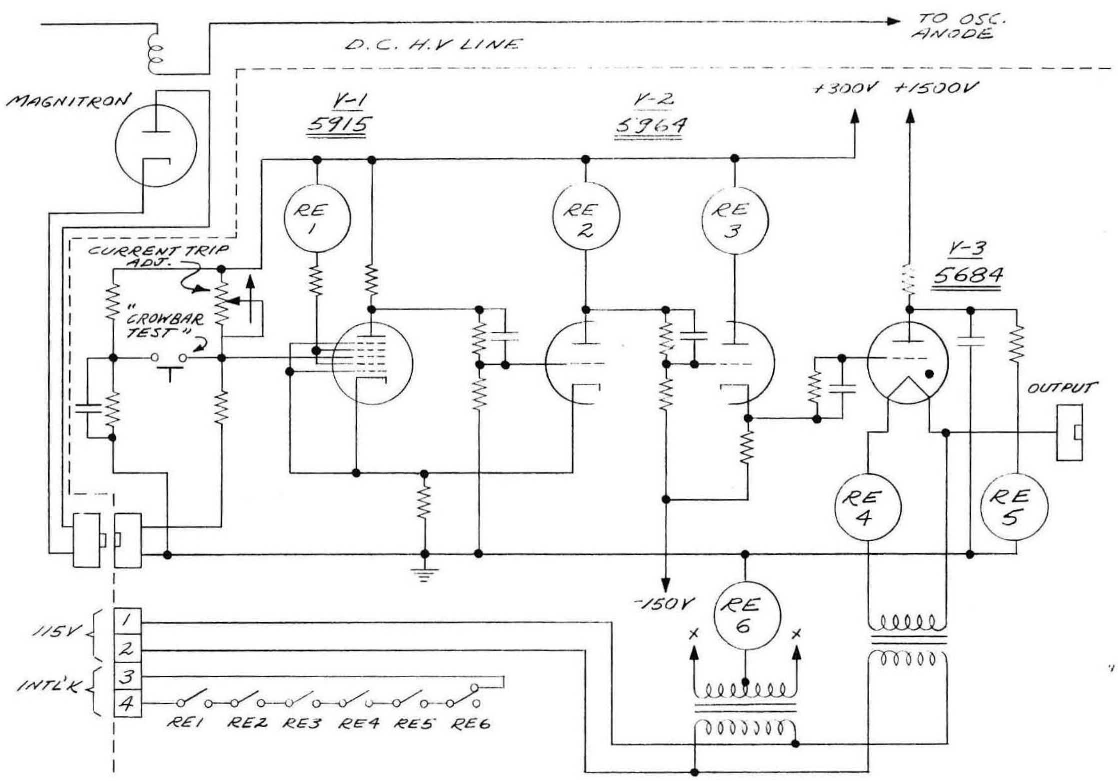
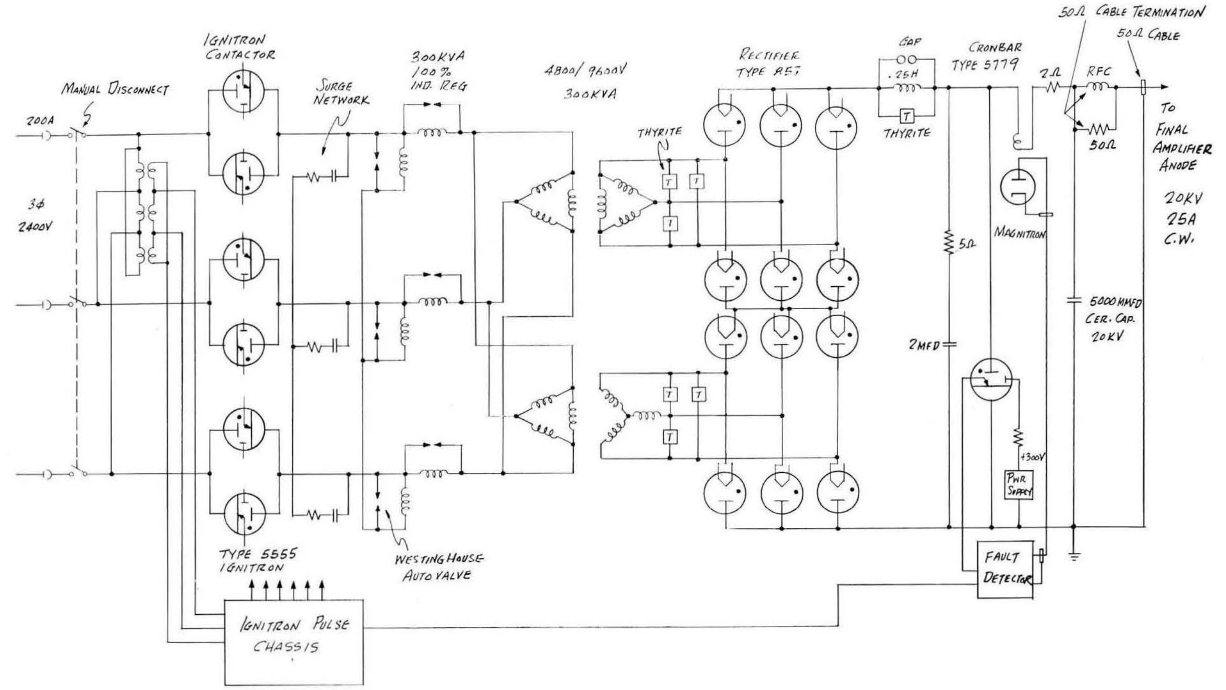

.25 H
2 Ω
+
25 Ω
+300 V
TO
RECTIFIER
TO
LOAD
1 MF
−
TO IGNITER
FIRING
CIRCUITRY
TO
CONTACTOR
BASIC IGNITRON FAULT DIVERTER
(CROWBAR)

Fig. 2



TYPICAL FAULT DETECTOR & CROWBAR FIRING CIRCUIT

Fig. 3



500KW POWER SUPPLY AND CROWBAR OF 90" CYCLOTRON AT LIVERMORE

Fig. 4

Fig. 5

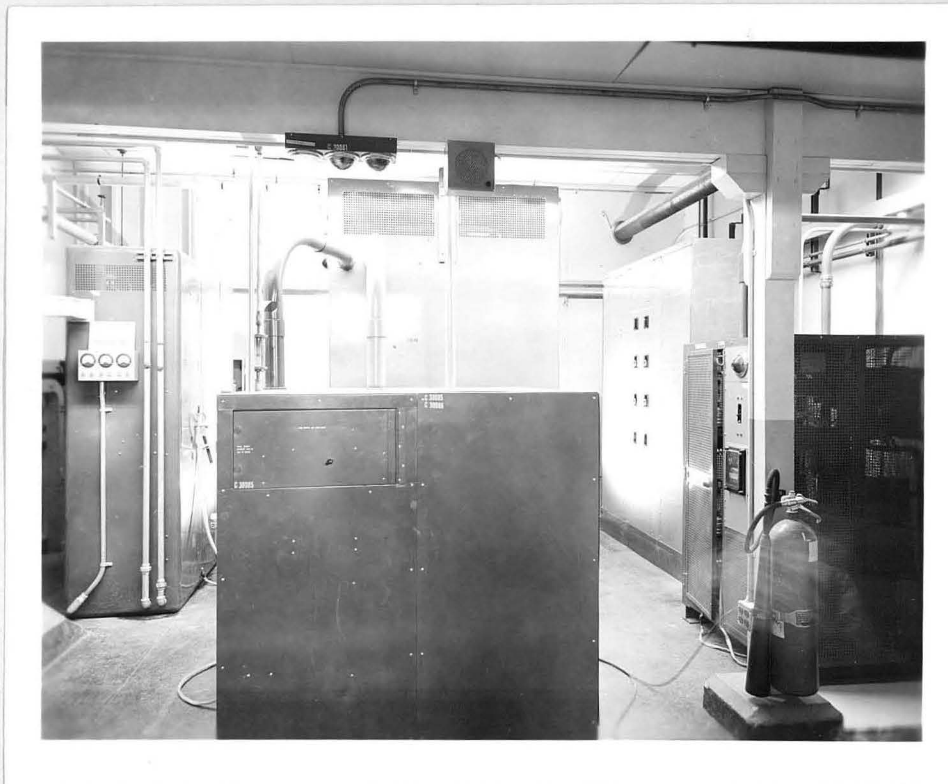


Fig. 6

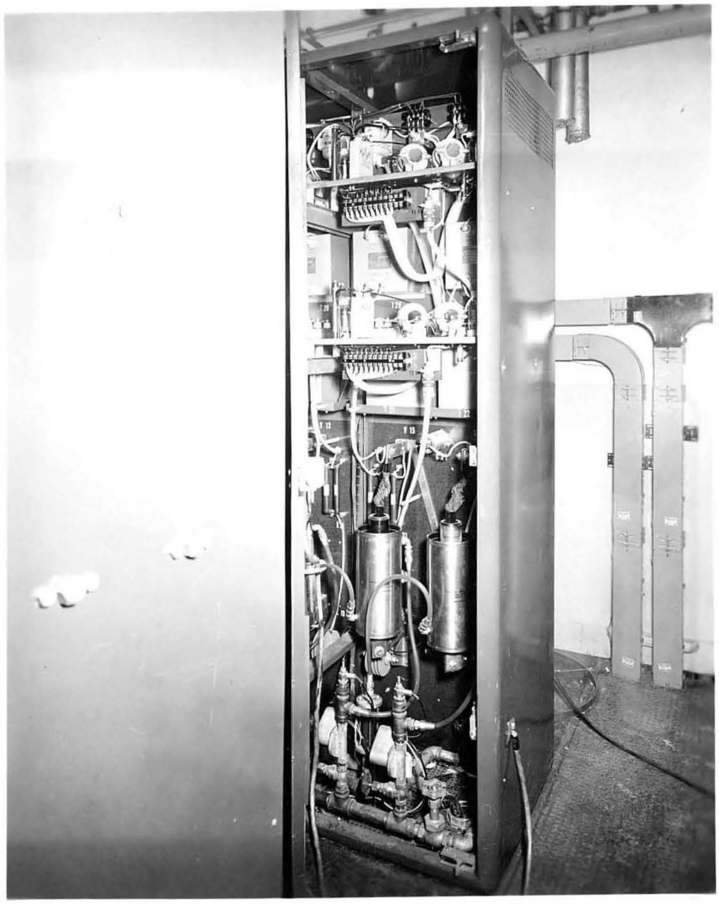


Fig. 7

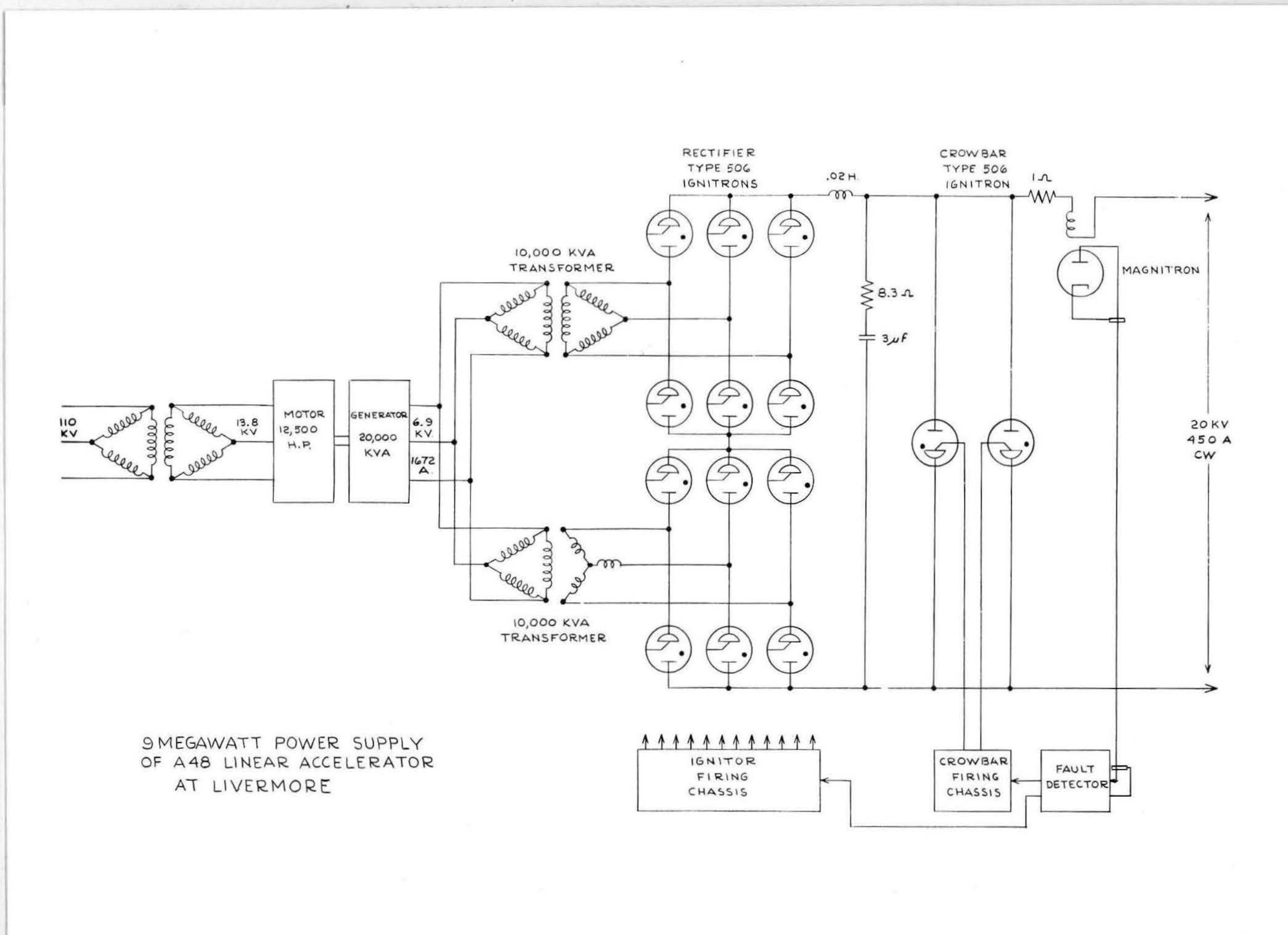

RECTIFIER
TYPE 506
IGNITRONS
.02 H.
CROWBAR
TYPE 506
IGNITRON
1Ω
10,000 KVA
TRANSFORMER
MAGNITRON
8.3 Ω
3 μf
110
KV
13.8
KV
MOTOR
12,500
H.P.
GENERATOR
20,000
KVA
6.9
KV
1672
A
20 KV
450 A
CW
10,000 KVA
TRANSFORMER
9 MEGAWATT POWER SUPPLY
OF A48 LINEAR ACCELERATOR
AT LIVERMORE
IGNITOR
FIRING
CHASSIS
CROWBAR
FIRING
CHASSIS
FAULT
DETECTOR

Fig. 8

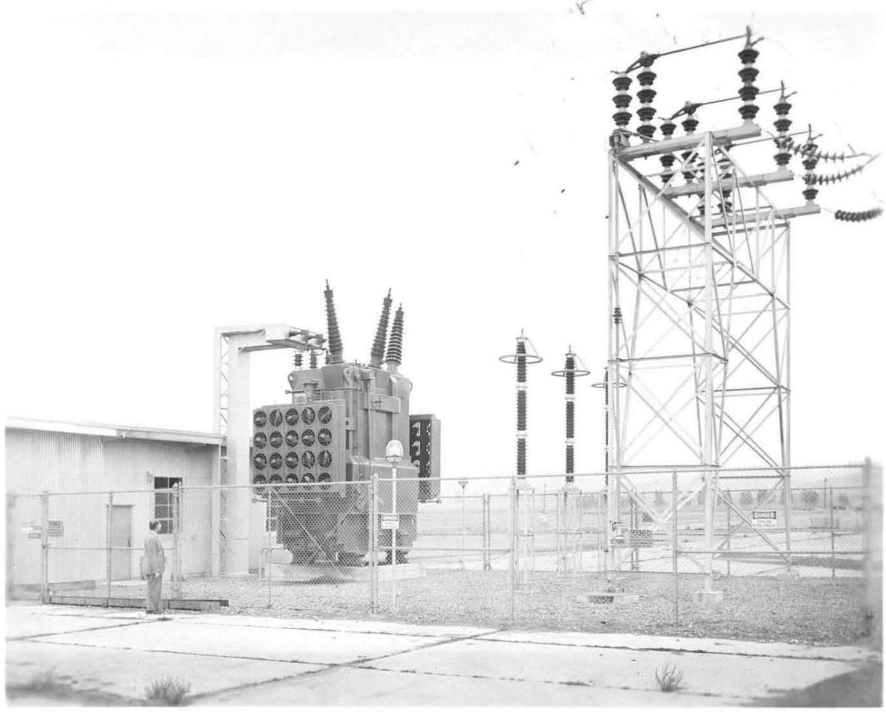
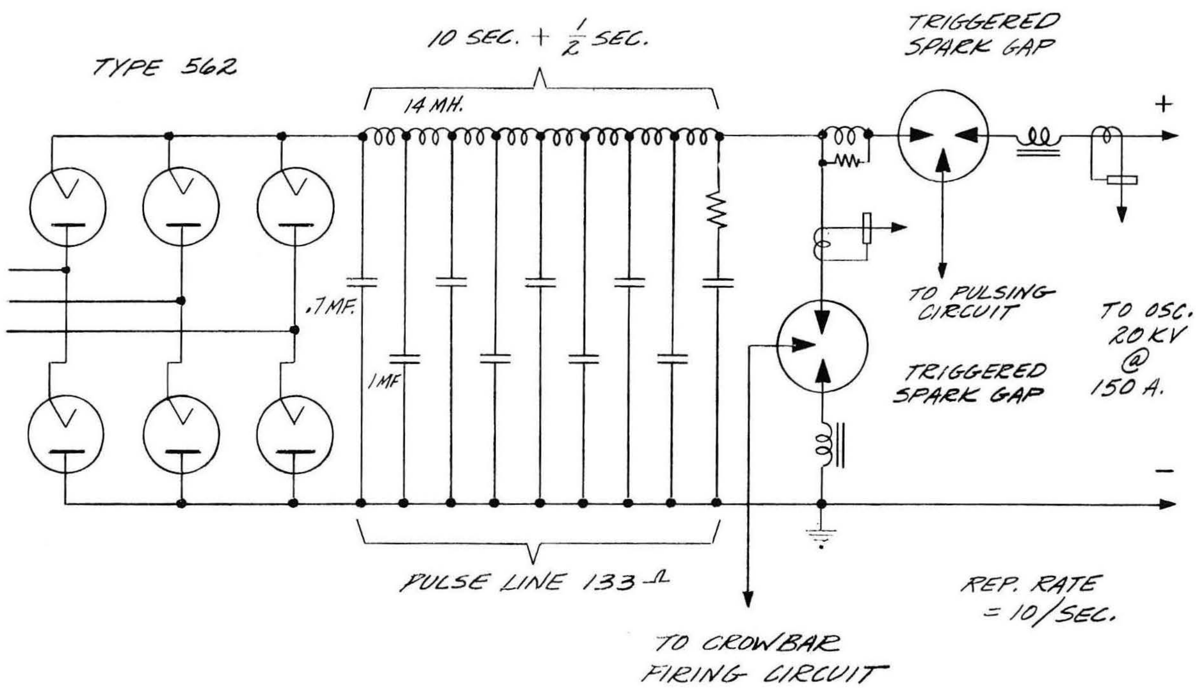


Fig. 9

Fig. 10

Fig. 11



BASIC CIRCUIT OF ANODE POWER SUPPLY & CROWBAR OF HEAVY ION ACCELERATOR

Fig. 12

Fig. 13

Fig. 14

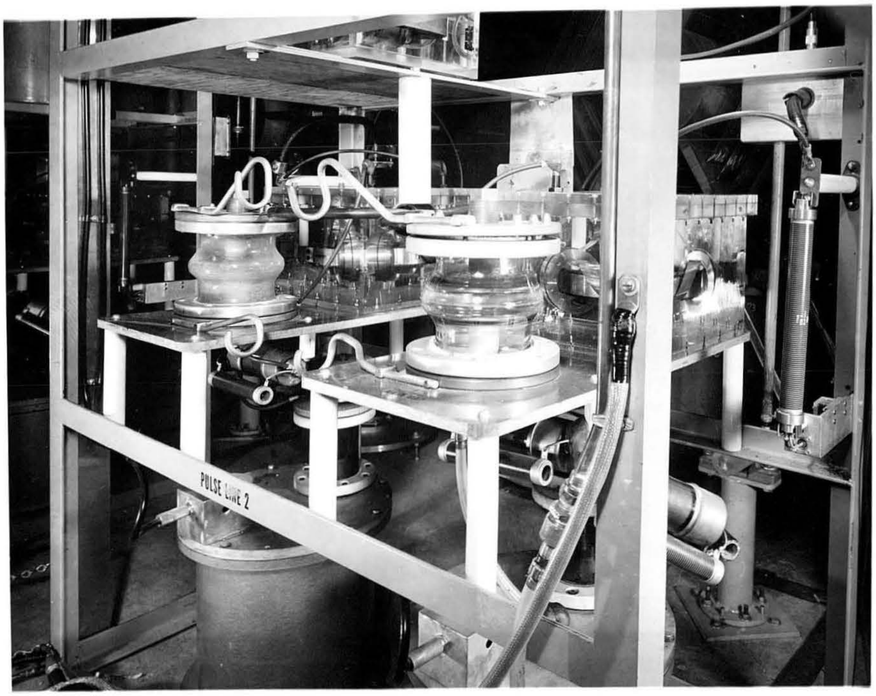


Fig. 15

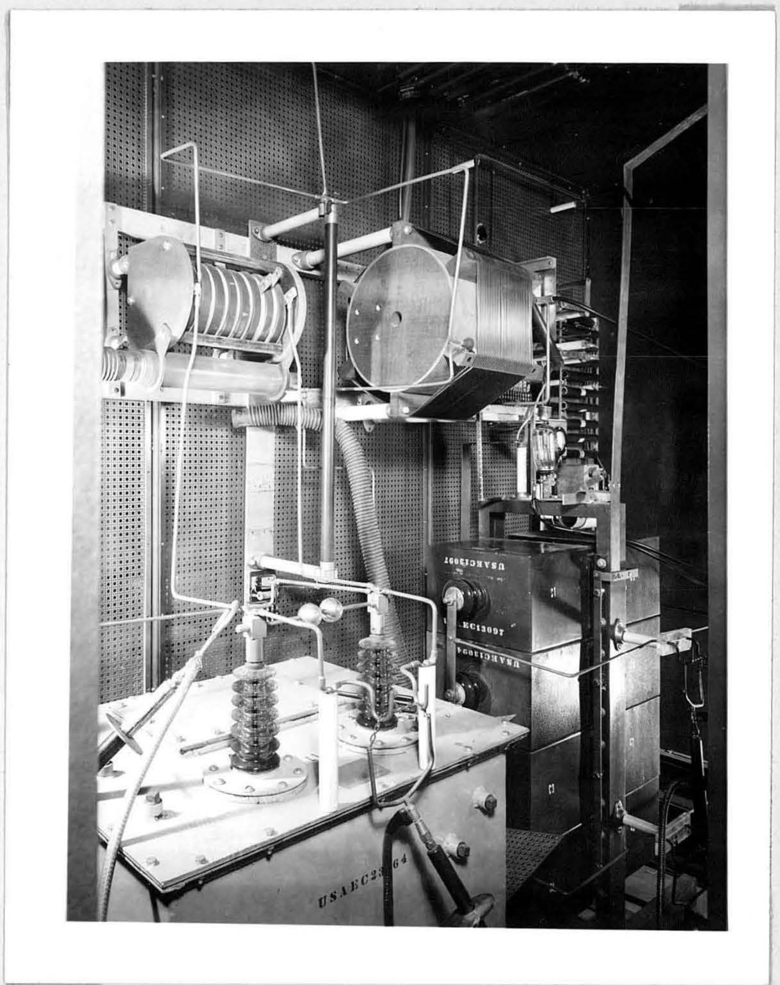


Fig. 16