TEST RESULTS ON DUAL RESONANT POWER SUPPLY WITH FLAT TOP AND FLAT BOTTOM CURRENT

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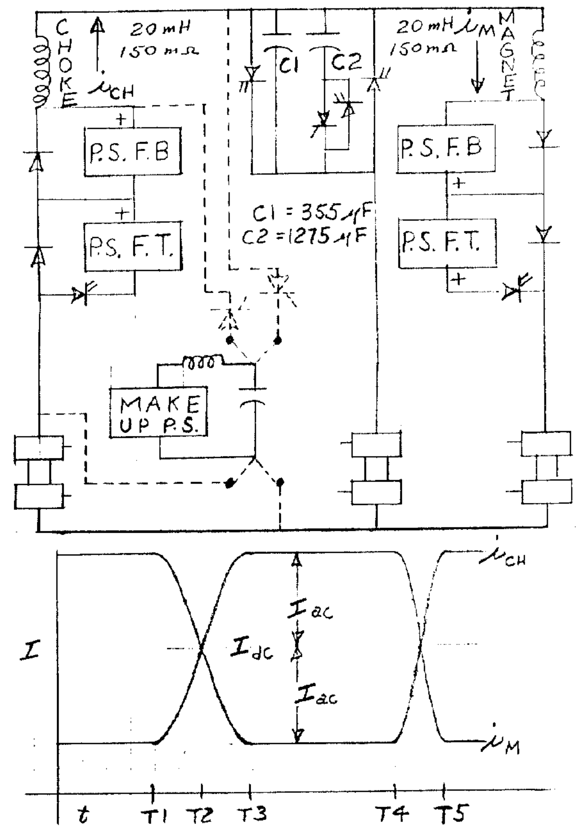
Abstract: An alternative to the linear increase and decrease of current through the magnets of a circular ring is a dual resonant frequency power supply that can maintain flat bottom and flat top currents in the magnets. This paper deals with the experimental results obtained by operating a model of such a power supply and observing the results of changes in various parameters. The model is first operated in a single-pulse mode starting from an equilibrium dc condition of the magnet flat bottom current. The effects of the circuit losses and the method of replacing energy in the system will be presented. When operating the power supply in continuous mode, it will be shown that the magnet flat bottom current and magnet flat top current can be controlled.

This paper covers experimental results obtained with a model of a dual frequency resonant power supply system. This model was built at Argonne National Laboratory by Walter Praeg and his group[1] and after being used there it was shipped to the Los Alamos National Laboratory. We have used it at Los Alamos in an effort to better understand the principles of this system.

Figure 1 shows the circuit and the magnet and choke current assuming there were no losses. Originally the system used a laminated iron core solenoid coil for the choke. The magnet was a laminated iron core dipole magnet. The inductance of the choke and magnet were not equal. In an effort to make understanding the system easier, these were replaced with two air core coils of the same physical size and number of turns so as to make the choke and magnet inductances as equal as possible. Thus, in the equation for the choke current, L_M/L_{CH} would be equal to 1 so that the current swing in the choke and magnet should be equal.

With the model we wanted to produce a magnet current wave form with a flat top value of 90 amp and a flat bottom value of 20 amp. We started with single pulse operation. Figure 2 shows a trace of the magnet and choke current with the system single pulsed and no make-up energy is added to the system during the pulse. The choke is initially at 100 amp and the magnet at 20 amp. At the end of the pulse the magnet is back to slightly less than 20 amp and the choke has recharged to about 90 amp.

Figure 3 is taken when energy from the make-up power supply capacitor is added to capacitor C1 midway between time T4 and T5. This enables the choke to recharge to its original 100 amp, but notice the magnet current is driven below its 20 amp starting value.

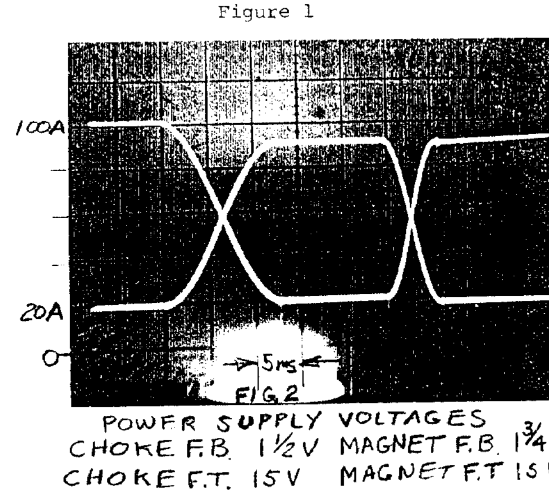


NO LOSSES, T1 THRU T3, T4 THRU T5

$$i_M = I_{dc} - I_{dc}\cos\omega t$$

$$i_{CH} = I_{dc} + \frac{L_M}{L_{CH}} I_{dc}\cos\omega t$$

Figure 1



POWER SUPPLY VOLTAGES
CHOKE F.B. 1½ V   MAGNET F.B. 1¾ V
CHOKE F.T. 15 V   MAGNET F.T 15 V

Figure 2

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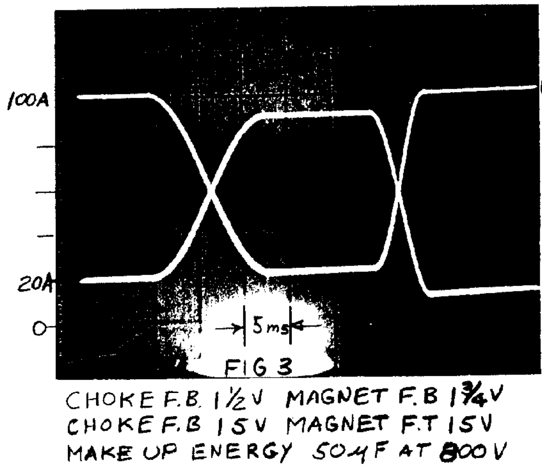

Figure 3

Figure 4 is taken when energy from the make-up power supply capacitor is added to the choke after time T5. This recharges the choke to its original 100 amp, but had no effect on the magnet flat bottom current. Since this seemed to be a desirable feature, this method of adding energy was used.

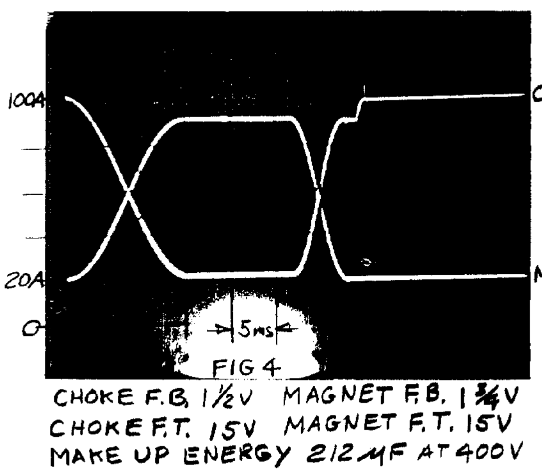

Figure 4

It is not necessary for the choke current to have a flat top or flat bottom. The only thing necessary is that at time T1 the choke current must be at the proper value so the magnet can be driven up to the desired flat top current at the end of the acceleration wave shape (T1 to T3). Therefore, the choke power supplies were removed from the circuit. Before starting to pulse the system there is now only about 10 amp flowing around the circuit formed by the choke, magnet, and magnet flat bottom power supply. Neither bypass gate turn-off thyristor (GTO) is on. The system is now run in a continuous pulse mode since now the choke is not charged to its required initial value since there are no choke power supplies. Figure 5 shows the circuit now used and the wave form of the magnet and choke current. By adjusting the magnet power supplies and the amount of make-up energy the desired magnet flat top current is achieved, but notice the magnet flat bottom current has a slope.

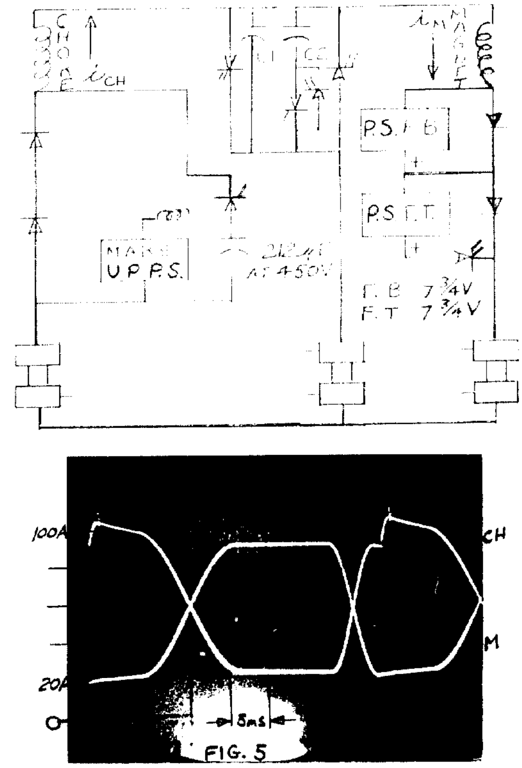

Figure 5

To get the desired magnet flat bottom current a method of reducing the magnet voltage during magnet flat bottom only was added to the circuit. A resistor was added in series with the magnet, which is short-circuited all the time except during magnet flat bottom time (T5 through T1). Figure 4 shows the circuit and the desired wave form.

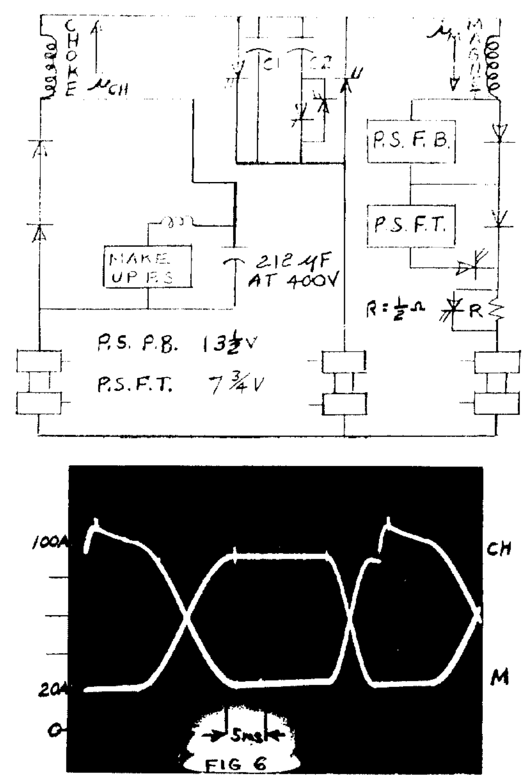

Figure 6

Depending on ratio of magnet flat top current to magnet flat bottom current and the ratio of the effective magnet resistance to the bypass circuit effective resistance, it could be necessary to introduce a bucking voltage in the magnet circuit to achieve the desired magnet flat bottom current. In a real system this could be achieved by having the magnet flat bottom power supply to operate as an inverter during the magnet flat bottom time period.

Summary

The model indicates that the system does not require choke power supplies and that the magnet flat top and flat bottom currents can be achieved by having a programmable magnet power supply and controlling the make-up energy added to the circuit. The following table summarizes the effect of the model's four controls on the magnet wave shape.

MODEL CONTROLS

1. Magnet P.S. Voltage during Acceleration and Reset
2. Magnet P.S. Voltage during Magnet Flat Top
3. Magnet P.S. Voltage During Magnet Flat Bottom
4. Energy Added to Choke Every Pulse

CONTROL	EFFECT			
	Magnet Flat Top		Magnet Flat Bottom	
	Initial Value	Slope	Initial Value	Slope
1	X		X	
2	X	X		
3			X	X
4	X			

Reference

[1] W. F. Praeg, "A Multi-Function Ring Magnet Power Supply for Rapid-Cycling Synchrotrons."