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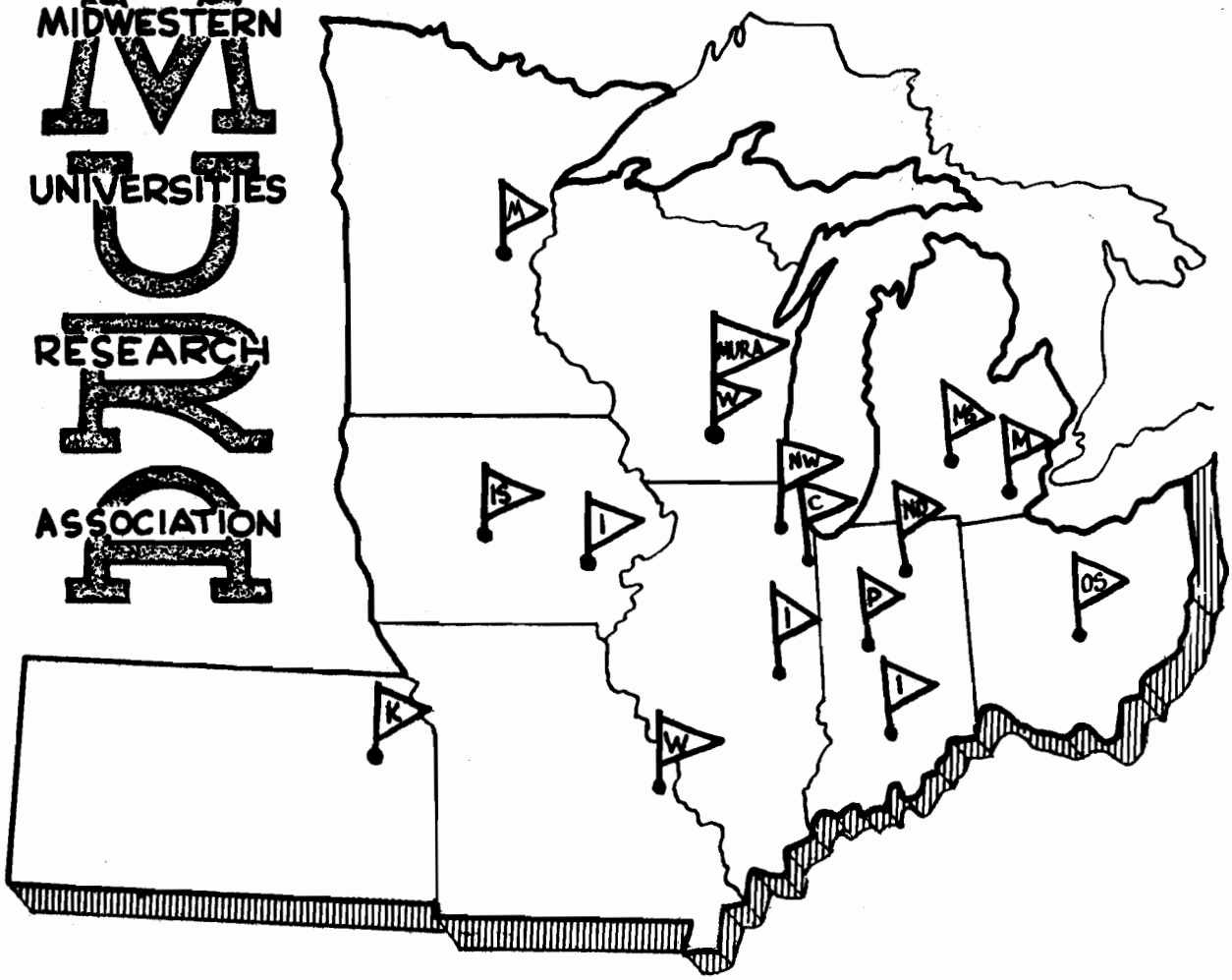

THE DISPLACEMENT RF SYSTEM OF THE WISCONSIN MODEL

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Robert Stump**

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ABSTRACT

A summary of the operation of the circuits which make up the r.f. system which provides energy to the stacked beam by phase displacement.

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The displacement r.f. system supplies energy to the stacked beam in the Wisconsin Model. At some point during the acceleration cycle the displacement system is triggered after which the following steps take place:

1. The voltage amplitude increases suddenly to some pre-set level (~200 volts) with a frequency of 23.11 mc.
2. The amplitude remains constant. The frequency increases linearly with time to 23.36 mc in about 1.75 milliseconds.
3. The voltage drops suddenly to zero and the frequency returns to 23.11 mc in a time of about .25 milliseconds.
4. The process 1, 2, 3 called hereafter a pass, is repeated 2, 3, 4, or 5 times, depending on settings of the system.

Three control circuits and a test circuit make up the unit which performs this function. The circuits are described below.

I. Displacement Oscillator - Drawing No. E5D1465.

The displacement oscillator cycle is initiated by a positive pulse at Trigger In. Tube V_1 is a single shot multivibrator - the length of the gate out determines the number of r.f. passes through the stacked beam. The gate length is controlled by the Modulation Cycles switch (coarse control) and potentiometer (fine control). The gate from V_1 turns on the free-running multivibrator V_3. The length of time for one pass is controlled by the Modulation Cycle Length potentiometer. Tube V_2A prevents the gate of tube V_1 from closing in the middle of a pass. The 82k resistor from pin 6 V_1 to pin 1 V_3 is required to prevent the first r.f. pass from being much longer than succeeding ones. It is desirable that the first pass be a little longer than later ones. This is

provided by the circuit. Tube V_4 gives short recovery time to the multivibrator V_3.

The positive gate from V_3, after suitable shaping, goes to the Waveform Generator at Frequency Gate Out. From the Waveform Generator, a waveform to control the frequency variation returns to Frequency Control In. The oscillator uses Hughes Diodes HC7006 for frequency modulation. The oscillator operates at one-sixth the required frequency to increase its stability.

The amplitude of the voltage on the cavity is controlled by $V_{9,\ 10,\ 11,}$ 14, and 15. The control voltage from the Waveform Generator Voltage Amplitude In is a dc voltage variable from -70 (zero output) to +5 (maximum output). The Cavity Voltage In is the rectified voltage on the gap with a 100 k ohm resistor between the cavity diode and the cable. The negative gate from V_6 is flat bottomed since V_6 is turned off during the pulse. The pulse is slowed by V_{16} to give the frequency time to arrive at the correct starting value before the amplitude increases.

The amplitude modulation is controlled by the difference amplifier of which V_9 is the first tube. As long as pin 2 V_9 is more negative than pin 7, no r.f. appears on the cavity. During the negative gate the r.f. adjusts itself so that pins 2 & 7 remain at essentially the same voltage. The rectified cavity voltage is then given by:

$$V = \frac{110}{43} \times 150 + 10\ V_o$$

where V_o is the Voltage Amplitude In (ranging from -70 to +5 volts). Thus, V varies linearly with V_o from $V = 35$, $V_o = -35$ to $V = 435$, $V_o = +5$, and is zero for $V_o < -35$ volts.

II. Waveform Generator - Drawing No. E5D1523

A positive gate at Frequency Gate In is inverted by V_1 and then cuts off V_2 and V_{13}. The bootstrap sawtooth generator gives a linear voltage rise at the cathode of V_5. V_6 is a constant current tube so that along the resistor string between pin 8 V_5 and pin 5 V_6 there is a linear voltage rise, starting from a voltage determined by the position along the resistor string.

When V_{13} is cut off, the condenser C_1 is charged to about 100 volts by the diode $V_{14}A$. Further charging is through the diodes V_7 - V_{12}. The shape of the voltage waveform on C is determined by the rate of the sawtooth rise (set by P_7) and the current limit set by the potentiometers P_{1-6}. All the diodes V_7 - V_{12} are initially cut off. During the sawtooth rise, at a time determined by the rate of rise of the sawtooth and the position in the resistor string, the diode begins to conduct. The current increasing linearly with time until the plate voltage reaches the value set by the clamping voltage on pin 5. The current then drops slowly as the potential on C rises.

The waveform on C goes through the cathode follower V_4b to the cathode follower V_{16} and to the output. $V_{14}b$ is a limiter to prevent excessive output voltage which might damage the diodes in the oscillator. V_{15} and the 330k resistor to the cathode of V_4b form a voltage divider to set the dc output level. The level is adjusted by P_8.

V_{18} and P_9 form the voltage supply for the Voltage Amplitude Control and P_{10} gives a voltage reference which prevents excessive screen voltage on the modulator. (Screen Modulation Limiter Out). If this voltage is connected

to both the Modulation Limiter and the Modulation connections on the Power Amplifier, a constant screen voltage occurs on the modulator. This is useful when no modulation is desired, as during tuning of the circuit.

This unit is remote.

III. Power Amplifier - Drawing No. E5D1510

The power amplifier includes a frequency doubler (V_2) tripler (V_3 and V_4) and amplitude modulation control (V_8 and V_9).

The plate at V_1 is tuned to 3.63 mc. The transformer L_2L_3 is tuned to 7.67 mc and the transformer $L_4L_5L_6$ is tuned to 23.2 mc. All other transformers are tuned to 23.2 mc. All of the transformers give a band width of about 1.5 mc. Thus, no retuning is required with small shifts in frequency. The coupling to the tank is much larger than required for the band width, so beam loading will not affect the cavity voltage. With currents in the stacked beam of over 50 amperes, it may be necessary to increase the size of the coupling loop. A larger loop will give lower voltage and some care must be taken to tailor the coupling loop to the requirements of voltage and beam loading. The changing of the coupling loop is a simple operation, and should be done after the requirements of the machine are known.

The power tubes PL-172's have bad secondary emission from the suppressor grid. The tubes are protected by a relay which removes both plate and screen voltage from the tubes when an excessive voltage develops on the suppressor. When the tune-operate switch on the control panel is in the tune position, the 300 volt supply is turned on when the -150 volt supply comes on.

In this case, when the suppressor relay operates, to turn off the 1500 and 500 volt supply, the 300 volt supply is left on. This supplies enough voltage to the suppressors to hold the relay, and it becomes impossible to turn the 1500 volt supply on without first turning the 300 volt supply off momentarily. In the operate position, the 300 volt supply turns on with the 1500 volt supply so that when the relay turns the system off, it may be turned on again immediately.

Bias adjustments, test points, etc. are obvious.

To tune the amplifier, the Screen Modulation and Screen Modulation Limiter should both be connected to the Screen Modulation Limiter and set at some reasonable positive voltage. This gives an unmodulated output so that a sweep frequency oscillator may be used for alignment.

To tune the cavity, there is a vacuum capacitor for fine adjustment, and condensers (50 and 25$\mu\mu$f) may be attached to the gap in resistor clips. To tune the high level output of a sweep frequency, the generator is coupled very loosely to the plate of one of the PL-172's. (The voltage is off, of course.) The voltage on the gap is then observed on the gap diode. For this measurement, the voltage on the diode should be observed directly by removing the cable from the BNC, grounding the 100k resistor, and connecting the scope cable directly to the diode plate. The tank is under-damped so there is a double-peaked response. The operating frequency should lie midway between the peaks. With this tuning, beam loading has a minimum effect.

IV. Test Unit - Drawing No. E5C1273A

The test unit consists of two ports, a mixer unit to determine the cavity

frequency and a four position selector to observe various waveforms in the unit.

The mixer unit V_1 - V_5 gives the beat between the oscillator and any test oscillator. A 90 KC oscillator gives additional 90 KC markers on either side of the reference frequency. The 90 KC markers are removed by a switch on the rear of the unit.

The four position selector has inputs to four tubes. Of the four tubes, one is conducting as determined by grid voltages on the four. The plates are in parallel, and go to a common cathode follower for transmission to an oscilloscope in the control room. There are voltage dividers on the input of V_6 and V_9 so that these signals will be of reasonable size. The signal on V_6 is the screen modulation voltage, on V_9 is the rectified cavity voltage. V_8 shows the frequency modulation signal and V_7 is connected to a small pickup loop in the tank. Due to capacity in the circuit, the signal from V_9 does not follow the rapid turn-off of the cavity voltage, so that is appears that the cavity voltage does not drop to zero on the recycle. However, this is a peculiarity of the observing circuit. Likewise, the signal from V_7 is not particularly constant in this case, the reason being the poor response of a number of circuits, including the oscilloscope, to the 23 mc signal.

The remote section of this circuit consists of a four position switch which removes the bias on the grid of the tube, the signal of which is to be observed.