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A 7 Ω, 1 Mv 50 nsec Water Dielectric Pulse Generator

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A 7 Ω water dielectric Blumlein generator having an open circuit voltage of 1 MV and a nominal pulse length of 50 nsec has been built at NRL. Tests with a copper sulphate load are almost complete. Its operation with an electron beam tube will begin in May 1968. The folded coaxial Blumlein pulse former is shown in Fig. 1. Fig. 2 is a photograph of the complete generator.

The Blumlein pulse forming principle was chosen rather than a simple charged line to achieve the 1 MV open circuit capability with only a 500 kV charge voltage. The pulse former could then be charged by the NRL type air core transformer driven by a D.C. capacitor bank - a system which has been thoroughly tested and used at 500 - 600 kV.

The 8 in. i.d. of the outer pipe and the 2-3/4 in. o.d. of the center pipe were chosen to match corresponding dimensions of a 41 Ω oil dielectric generator used previously. The length of the intermediate pipe is 33 in. giving a pulse length of 50 nsec. The AWRE water breakdown data supplied to us by J.C. Martin was used to choose the diameter of the intermediate pipe so that breakdown would be equally likely from it to either the outer or center pipes. This provides maximum energy storage in the available volume. The resulting intermediate pipe is 6 in. o.d. with a 1/16 in. wall. The impedance of the inner coaxial line is then 5.1 Ω and the outer 1.9 Ω.

The primary storage of the system consists of two Axel 0.55 μF capacitors in parallel driving a single turn primary, 8 turn secondary air core transformer through a Trigatron gas gap switch of NRL design. The single turn primary is a 10 in. wide copper strap 29 in. in diameter. Inside this strap is the 8 turn secondary wound from an insulated wire consisting of the center conductor and polyethelene dielectric of RG-19/U coaxial cable. A cross section of the transformer winding is shown in Fig. 3. The voltage on the intermediate pipe of the generator, as charged by the transformer, is shown in Fig. 4. (The internal water switch was spaced so as not to close for this picture.) The risetime to peak voltage of 1.2 μsec agrees with the calculated design value.

When the pulse forming section is charged to supply a 1 MV open circuit voltage it is operating at 90% of the breakdown voltage predicted by Martin's data. Occasionally a breakdown has occurred between the intermediate and outer pipes when operating at full voltage. This puts a dent in the intermediate pipe about 1/4 in. deep, but does not otherwise damage the generator.

A test was performed to check J.C. Martin's data for breakdown due to streamer growth from the positive electrode with an area of about 5500 cm^2 by charging the intermediate pipe up to breakdown voltage without the center pipe in place. In 9 breakdowns the average was only about 2% lower than Martin's data, extrapolated to 5500 cm^2, with a standard deviation of 13%. With all pipes in place all of the breakdowns except one have occurred within the outer coaxial line. Since breakdown should be equally likely to occur due to streamers from the brass outer or stainless steel center pipes, a thin stainless steel liner will be put inside the brass outer pipe to see if electrode material has an effect on the breakdown.

Fig. 5 shows the feed through insulator for the high voltage lead from the transformer to the intermediate pipe. It is an 18 in. long 8 in. diameter lucite cylinder filled with water and has worked satisfactorily at 500 kV. Before this feed through was installed, the original nylon insulator had some outside surface discharges to the outer pipe at about 250 kV.

The water treatment system for this pulse generator is a closed circuit in which the water leaves the pulse former, is pumped to the top of the room and enters the deaerator shown in Fig. 6. The deaerator is elevated about 16 ft so that the vacuum at the input of the circulating pump at floor level will not be too great, reducing the efficiency of the pump and drawing in air bubbles if the pump were not properly sealed. This deaerator consists of an 8 in. diameter, 5 ft long lucite vacuum chamber (maintained at about 23 in. of Hg vacuum) in which the water trickles down over a large surface made up of many sheets of perforated aluminum. The deaerator is capable of removing all of the small bubbles (of 1/8 in. diameter or less) from the system within two to three hours. Upon leaving the deaerator the water passes through the circulating pump, an ion exchange demineralizing filter, and a diatomaceous silica particle filter before returning to the pulse forming section near the high voltage lucite feedthrough shown in Fig. 5.

Pulse voltages in the generator are recorded with an oscilloscope and high voltage probe[1/]. The intermediate pipe voltage monitor is calibrated _in situ_ with a pulse of known voltage. Such a calibration pulse, shown in Fig. 7, is obtained by resonance charging the intermediate pipe capacity

1/ Leavitt, Shipman and Vitkovitsky, Rev. Sci. Instr. 36, 1371 (1965).

(18 nF) directly from the primary capacitor bank (1.1 μF) whose voltage is measured with an electrostatic voltmeter. Since the pipe capacity is much less than that of the bank the voltage increase ratio of 1.97 is very insensitive to errors in the individual capacitance values. The accuracy of the calibration is thus essentially limited by the accuracy of the electrostatic voltmeter.

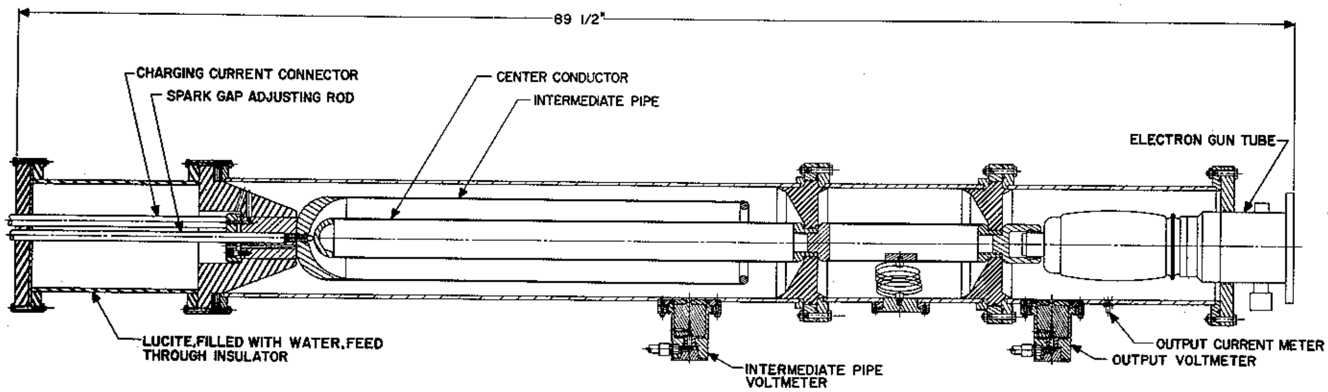
Fig. 8 is a photographic record of the voltage on the output end of the intermediate pipe and output current and voltage with a matched copper sulphate load. Fig. 9 is a photographic record of the same waveforms but with a faster sweep speed for the output voltage and current so that the shapes can be observed in more detail. This Blumlein pulse forming circuit is made up of 5 Ω and 2 Ω lines, with the 5 Ω line switched. Its output into a matched load is expected to be a decreasing staircase of 50 nsec steps with the amplitude of each step 43% of that of the preceding one. The voltage shapes compare favorably with those which were expected.

Fig. 10 shows the leading edge of the output voltage pulse on a matched load displayed on an oscilloscope with a risetime of about 2.5 nsec. The 10%-90% risetime of the output voltage is 7 to 8 nsec.

Fig. 11 shows that the output prepulse with an open circuited load is 21 kV negative corresponding to 1 MV generator voltage.

The overvoltaged water gap switch in the Blumlein circuit has been somewhat disappointing in that the standard deviation in firing potential has been about 17%. Thus, only 50% of the firings will be within a probable error of 11.5% of the mean potential, and 10% of the shots will differ from the mean by more than 30%. An elkonite (Tungsten copper alloy) 3/8 in. diameter hemispherical negative switch electrode on a 3/8 in. diameter adjustable length rod is used opposite a 2-3/4 in. diameter hemispherical stainless steel positive electrode.

There is a possibility that the energy contained in the stair stepping tail (after the first 50 nsec) of the unbalanced Blumlein circuit pulse might cause needless anode damage on some types of beam tube. For this reason, and also in order to be able to operate above 500 kV a balanced Blumlein circuit section has been designed as shown in Fig. 12. This 20 in. section would simply replace the present 8 in. section as shown. Breakdown on this design should occur at about 719 kV and all of its stored energy would be delivered into a matched load in the first 50 nsec pulse.



7 OHM UNBALANCED BLUMLEIN GENERATOR

FIG. 1

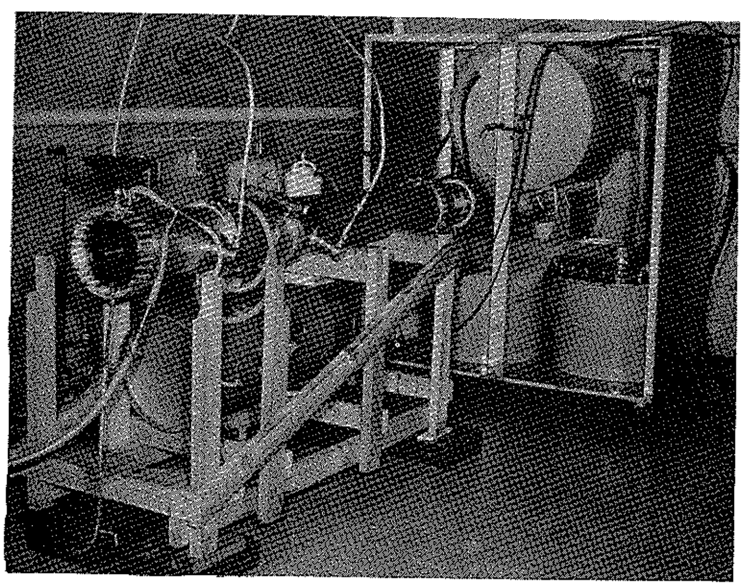


Figure 2 Photograph of the 7 ohm water dielectric generator

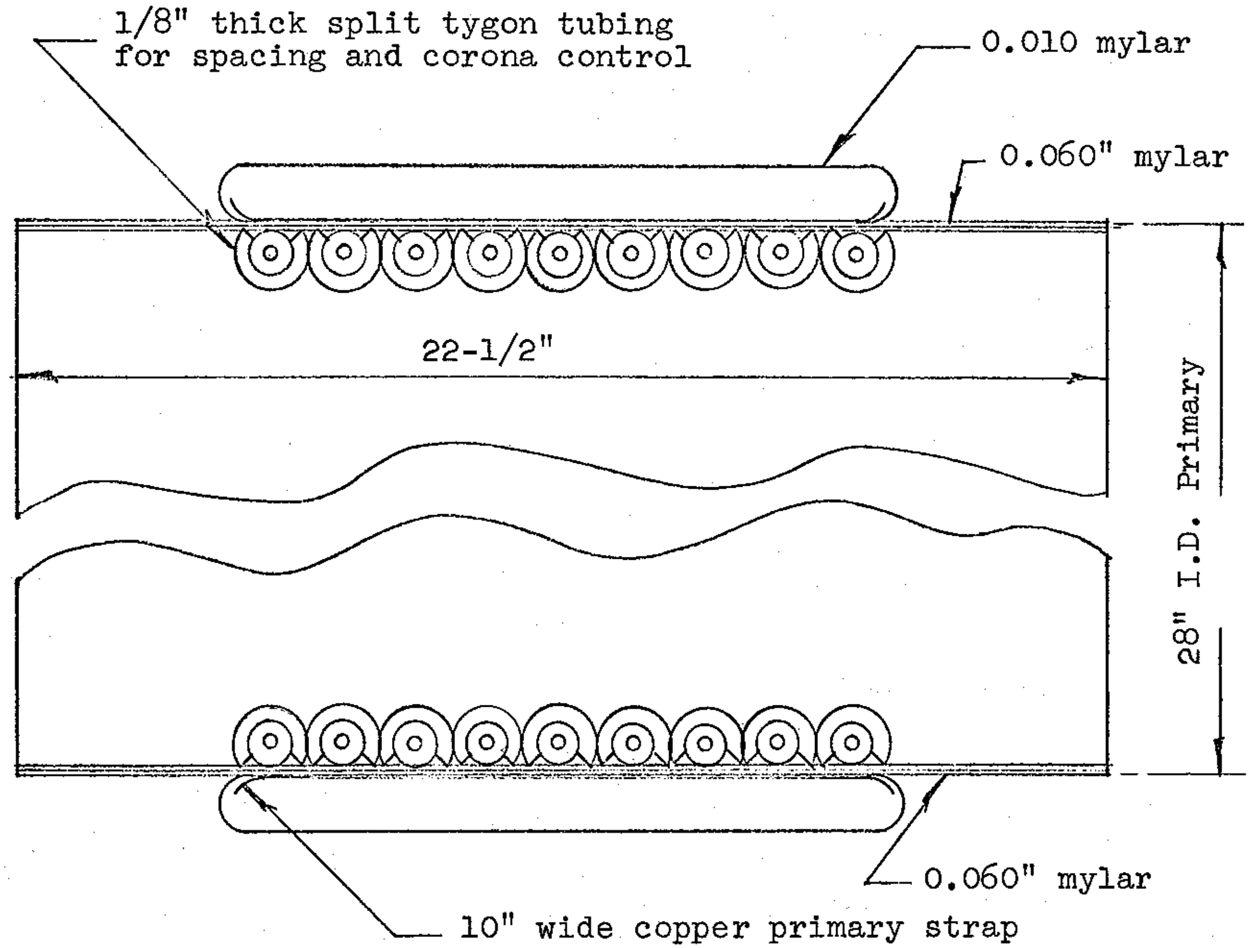
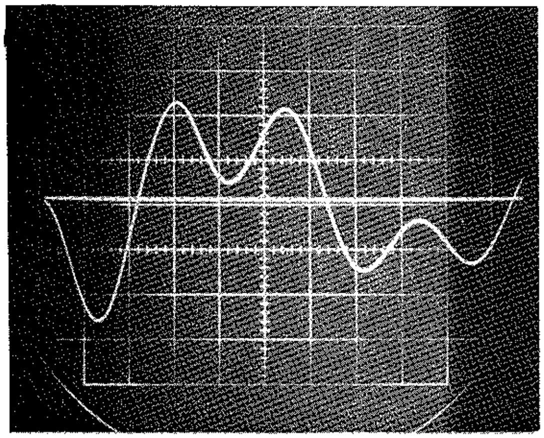

1/8" thick split tygon tubing
for spacing and corona control
0.010 mylar
0.060" mylar
22-1/2"
28" I.D. Primary
0.060" mylar
10" wide copper primary strap

FIGURE 3



1 μsec/cm

Figure 4 Transformer output into the intermediate pipe of the 7 Ω dielectric generator (no water switch action) (turns ratio 8:1, step up ~ 5.4:1).

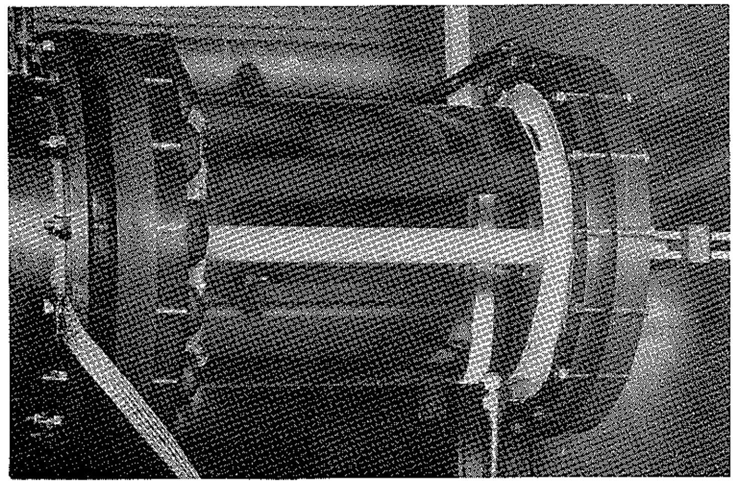


Figure 5 Water filled lucite high voltage feed through insulator

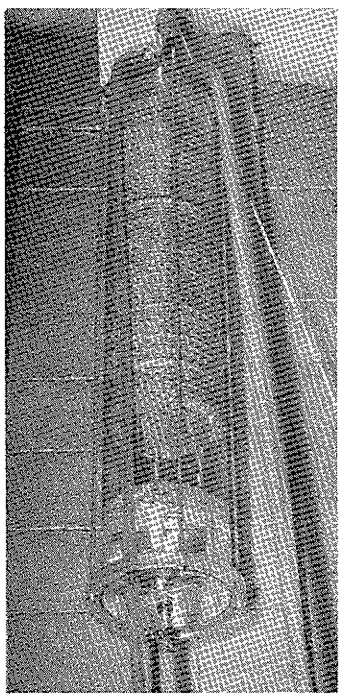
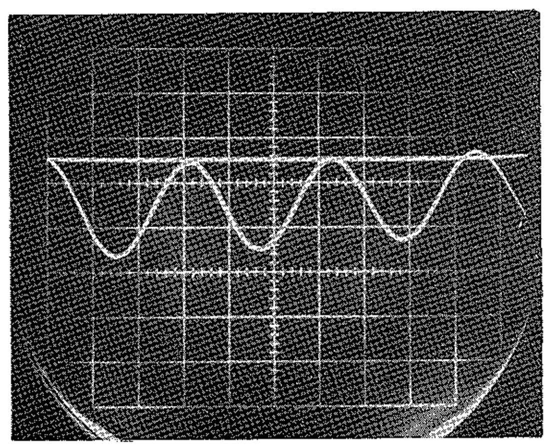
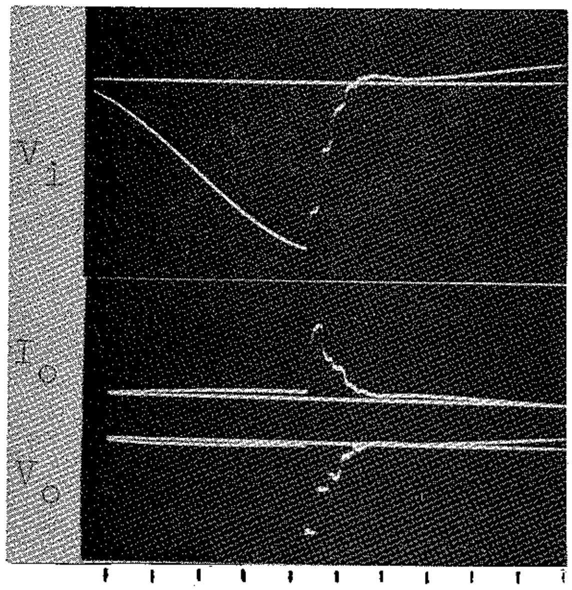


Figure 6 Deaerator for the 7 ohm water dielectric generator



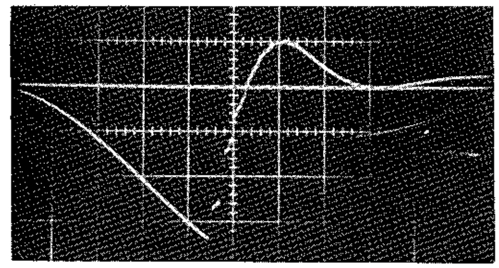
1 μsec/cm

Figure 7 Resonance charging voltage waveform on intermediate pipe of 7 Ω water dielectric generator during calibration of voltmeter. (~12M Ω cm water).

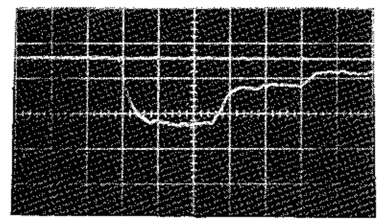


200 ns/cm

Figure 8 Voltage and current waveforms in the 7 Ω water dielectric generator with a matched load.

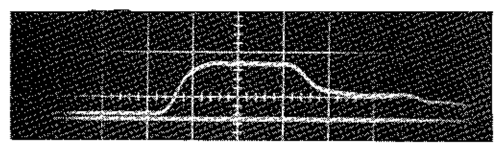


V_i 200 ns/cm



V_o 20 ns/cm

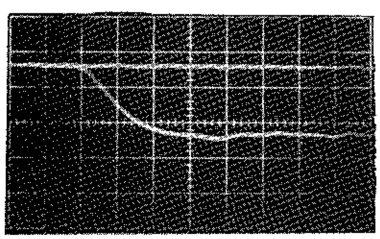
(2.5 ns risetime oscilloscope)



I_o 20 ns/cm

(7 ns risetime oscilloscope)

Figure 9 Voltage and current waveforms in the 7 Ω water dielectric generator with a matched load



5 ns/cm

Figure 10 Leading edge of the voltage pulse from the 7 Ω water dielectric generator with a matched load. 10% to 90% risetime is about 8.5 ns.

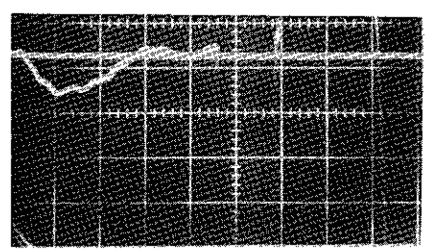
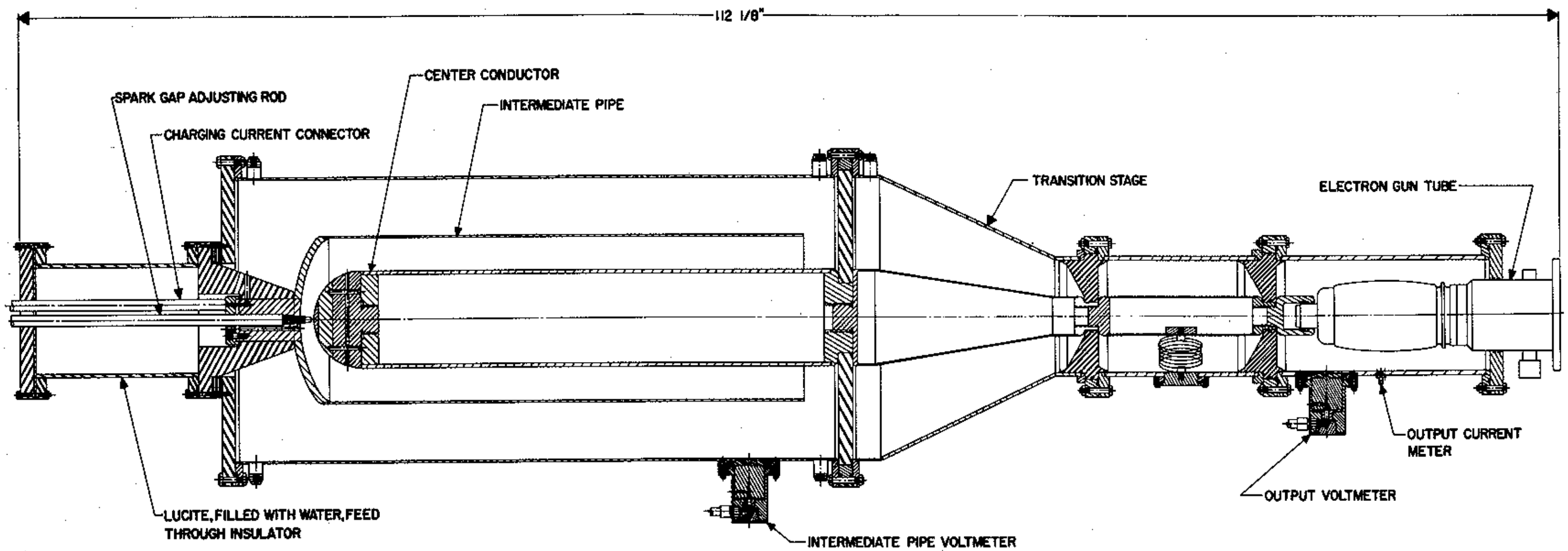


Figure 11 Output voltage prepulse on the 7 Ω water dielectric generator with an open circuit load (21 kV peak for 500 kV main pulse into a matched load).



7 OHM BALANCED BLUMLEIN GENERATOR

FIG. 12