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20 KILOVOLT DELTA FUNCTION GENERATOR

Harry G. Heard

May 14, 1953

Berkeley, California

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Radiation Laboratory, Department of Physics
University of California, Berkeley, California

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ABSTRACT

An electronically triggered pulse generator is described which furnishes 20 kilovolt pulses having rise times of 0.6 millimicroseconds. Hydrogen thyratrons are used in a specially designed coaxial impulse generator which has a triggering time of the order of 100 millimicroseconds. The time jitter of the entire system depends on the speed of the incoming trigger signal and the statistical formation time of an atmospheric gap and is of the order of a few millimicroseconds. Triangular pulses having a width of 2.5 millimicroseconds and an amplitude greater than 20 kilovolts can be obtained.

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INTRODUCTION

Current investigations of the initiation mechanism of the d. c. vacuum spark called for an ultra-high speed impulse generator having millimicrosecond time jitter and capable of generating 20-30 kilovolt pulses of not greater than 3 millimicrosecond total width. A fast acting circuit was desired so that the selective attenuation and dispersion of delay cables could be reduced to a minimum.

Atmospheric gaps have been used for the generation of primary impulses having rise times of the order of 20 millimicroseconds[1] which with sufficient overvoltage can have a statistical formation time of less than a millimicrosecond.[2] Mercury and vacuum switches have been used for production of ultra-high speed impulses, but fail to meet the requirements either because of slow action and large time jitter of the mechanical circuit (1500 ± 200 microseconds) or because of limited voltage switching capacity.

It was found that the design requirements could be satisfied by the use of a coaxial impulse generator containing hydrogen thyratrons. This arrangement in combination with an atmospheric pulse sharpening gap is easily triggered and provides

1 R. C. Fletcher R. S. I. v. 20, p. 861, 1949
2 R. Strigel Elektrische Stossfestigkeit, Julius Springer, Berklin, 1939, p. 34

the desired needle impulse essentially free of spurious voltages.

THEORY

The technique for generating fast pulses consists simply of utilizing the short formative time lag of a highly overvoltaged air gap. The formative time lag of a pressurized spark gap decreases with overvoltage and increases with pressure. For sufficiently high voltages this time lag, which is less than electron transit time, but greater than photon transit time, can be lower than a millimicrosecond.

In order to utilize this characteristic, however, it is necessary to produce an impulse which will bring the electrodes to this high overvoltage in less than the statistical formation time of the gap. To generate impulses of the highest possible speed the atmospheric gap should have close spacing and the driving impulse should be as large in amplitude as possible. These two requirements can be satisfied if the driving pulse originates in a very low impedance generator which has a rise time less than the statistical formation time of the sharpening gap. Using equipment described below it was found possible to generate the desired impulse without resort to a pressurized gap.

APPARATUS

Coaxial Impulse Generator

The 5C22 hydrogen thyratron was chosen to generate the driving pulse because it is easily triggered and meets the voltage and time jitter requirements.

The impedance of the switch tubes was reduced to a minimum by enclosing them as the center conductor in a 50 ohm coaxial transmission line. Figures 1 and 2 illustrate the physical arrangement of parts.

High voltage insulation presented difficulties in this minimum space design. Continuous Teflon and polyethylene insulators were found to solve this problem.

The input and output of this generator were connected to RG-8U cable. Appropriate taper sections were designed to take care of the geometrical transformation at constant impedance.

This coaxial generator, when driven by 1 kv pulses of 5 millimicrosecond rise time, generated impulses from 5 to 25 kv with a rise time of 1.75 millimicroseconds. Approximately 40 feet of RG-8U cable was used to give a total pulse length of 80 millimicroseconds, see Figure 3.

It appears to be possible to produce pulses of arbitrarily large amplitude using this coaxial generator by simply adding more thyratrons in series. No change in rise time of the output pulse was detected when two tubes rather than one were used to generate the pulse.

The firing of the first tube in the chain, see Figure 4, places a sufficiently high voltage pulse the succeeding tubes that they fire in the order of a millimicrosecond.

Pulse amplitude was limited by spark-over of insulating transformers and transmission line connectors.

Both positive and negative impulses have been obtained from this driving generator by means of the simple modifications shown in Figures 5 and 6.

Delta Function Generator

Almost a factor of three increase in rise time results from the use of the pulse sharpening gap as can be seen by comparing Figure 3 with Figures 7 and 8. The leading edge of this pulse now has a rise time of slightly greater than 0.6 millimicroseconds. When differentiated by an appropriately chosen shorting stub, the delta function generator produces a pulse having a total width of less than 2.5 millimicroseconds (see Figure 9).

The flat-topped pulse from the coaxial impulse generator results in a differentiated pulse which is reasonably free from extraneous voltages.

In order to preserve the pulse waveform when driving a system of inherently high inductance and capacity, the delta function generator was made an integral part of the high voltage electrode (see Figures 10 and 11).

The needle pulse passes down approximately 18 inches of air and/or vacuum 50 ohm transmission line which is terminated at the 100 kv electrode by a distributed resistance equal to the characteristic impedance of the transmission line.

Measurements

Two problems arise in the measurement of ultra-high speed impulses, synchronization and oscilloscope bandwidth. Synchronization can be accomplished by triggering from the impulse and delaying this signal with high quality cable so that it appears after the sweep starts. The delay cable used in this standard low frequency technique causes pulse distortion by selective attenuation and dispersion of the high frequency components of the impulse. Because the above system is electronically triggered and has extremely small jitter, pulses can be observed by applying the impulse directly to the cathode ray tube deflection plates.

The delay adjustment required for synchronization is thus placed in the oscilloscope trigger channel (where it logically should be to prevent pulse distortion).

Pulse measurements in the millimicrosecond range require cathode ray tubes having low transit time distortion and high writing speeds. The traveling wave[3] cathode ray tube was chosen over the more conventional tubes because of its low transit time distortion, (4 percent drop at 1000 mc) good impedance match at the deflection plates, higher beam power imput and sharper focus (0.15 mm spot

3 Smith, Talbot and Smith, Proc. IRE, v. 40, p. 297, 1952

diameter). With this cathode ray tube and a sweep generator similar to the coaxial impulse generator described above, sweep speeds of the order of 0.3 millimicroseconds per centimeter can easily be achieved. Faster sweeps can be produced, but photographic recording becomes difficult.

Further increases in rise time of high voltage impulses can be obtained if the sharpening gap is pressurized. This will allow the application of a higher driving voltage to the sharpening gap and a reduction in gap spacing. An upper limit on the rise to the peak voltage level is set by the breakdown mechanism of the pressurized gap. It thus appears possible to produce pulses having rise time of 10^{-10} seconds and less.

Fast rising pulses will find application in producing extremely high sweep speeds, removal of beams from cyclic accelerators, etc. The differentiated pulse will be invaluable in making cause and effect measurements and in producing short bursts of charged particles for interaction studies.

Acknowledgments

It is a pleasure for the author to acknowledge the work of Vernon Smith in the development, construction and testing of this instrument. R. M. Richter and H. L. Smith are thanked for their coordination of research facilities. D. C. Cook of the Naval Research Laboratory is thanked for making available the traveling wave oscilloscope.

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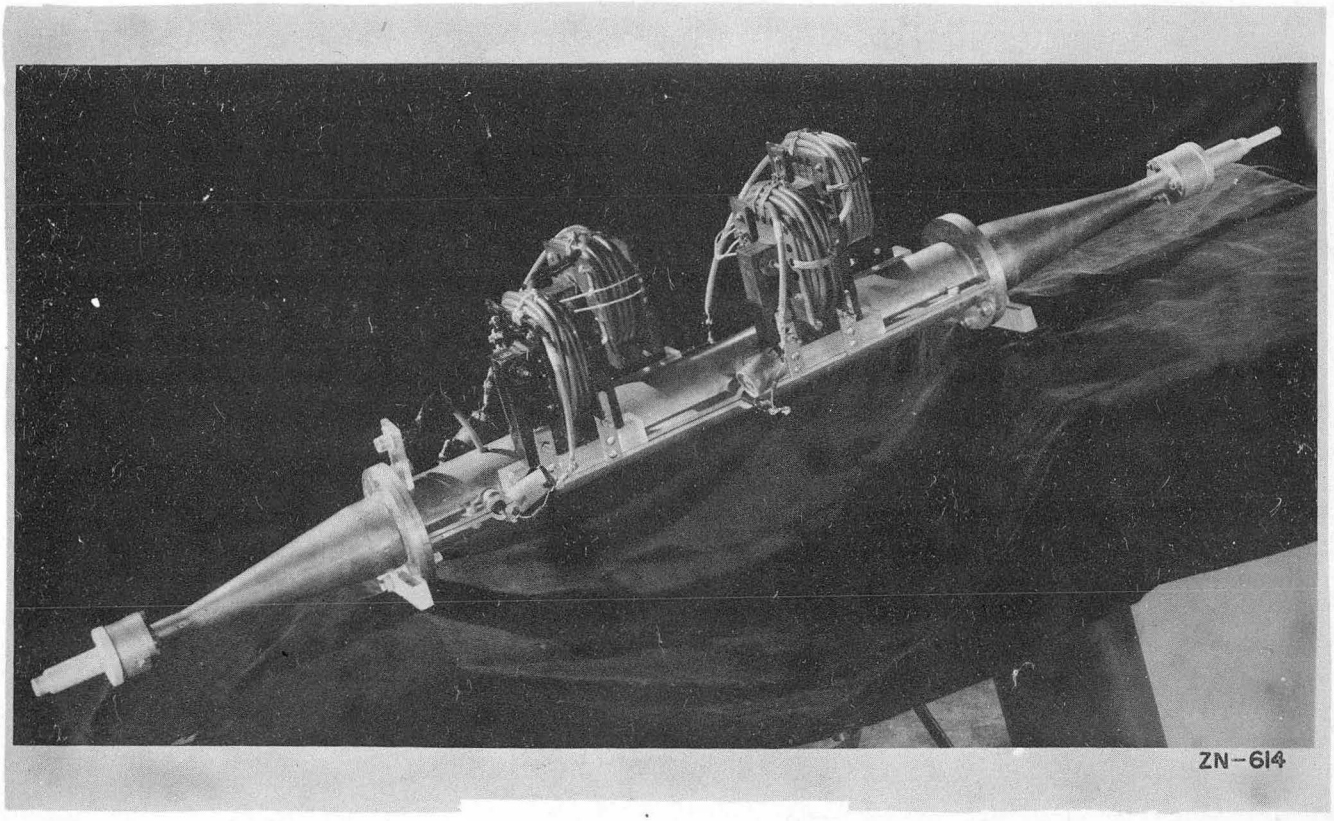


Fig. 1. Coaxial impulse generator showing externally mounted 30 kv isolation transformers.

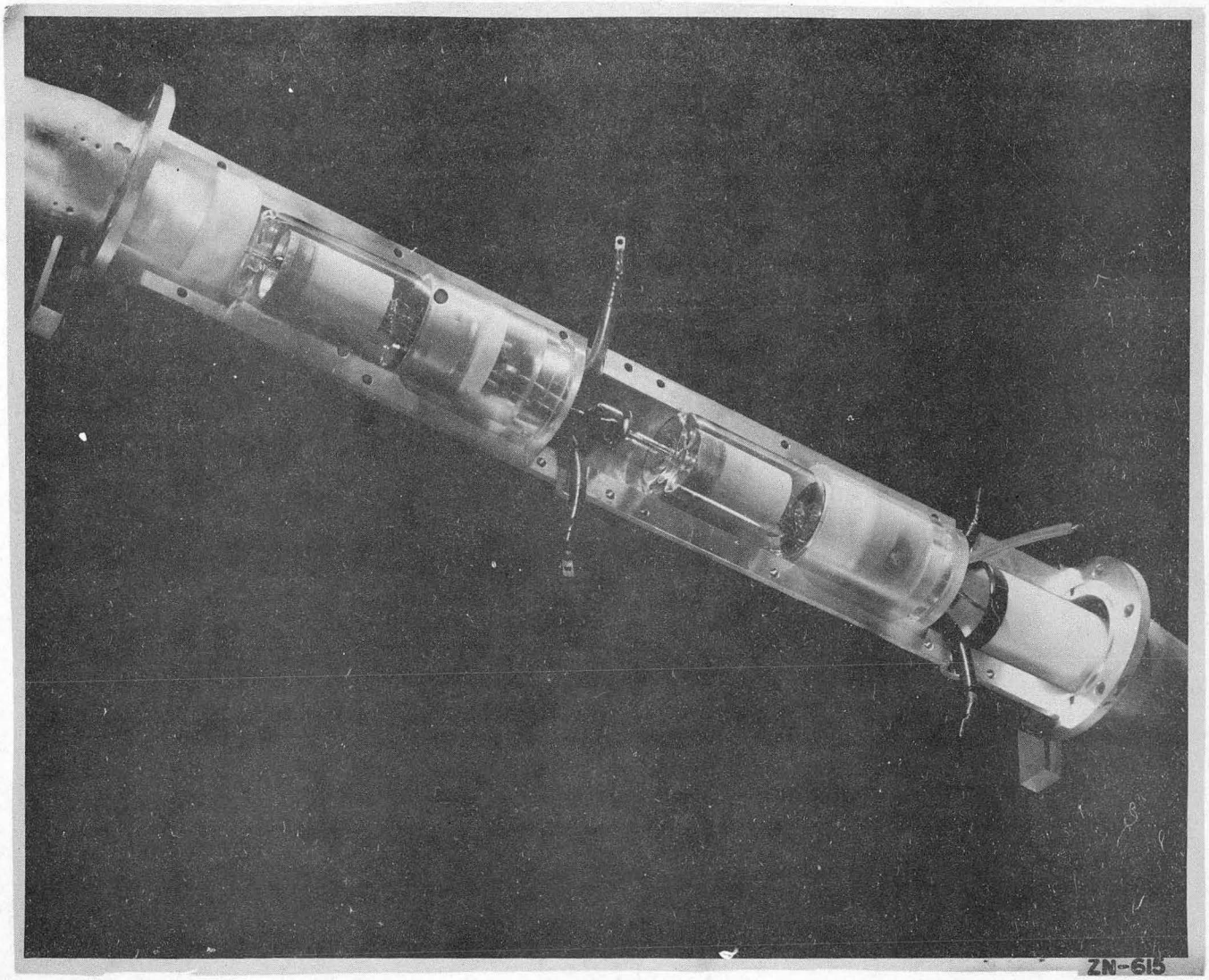


Fig. 2. Open view of coaxial impulse generator showing location of 5C22 thyratrons.

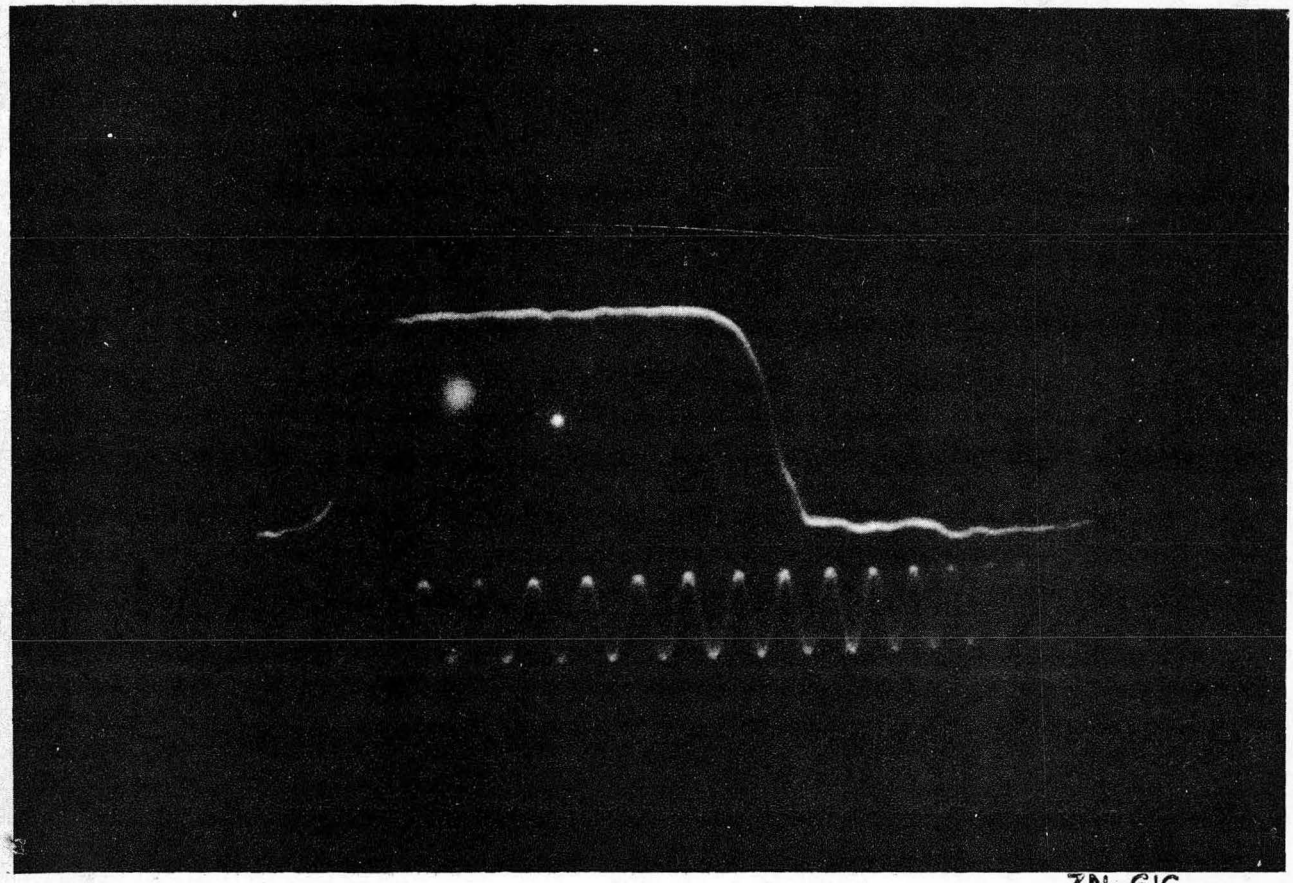
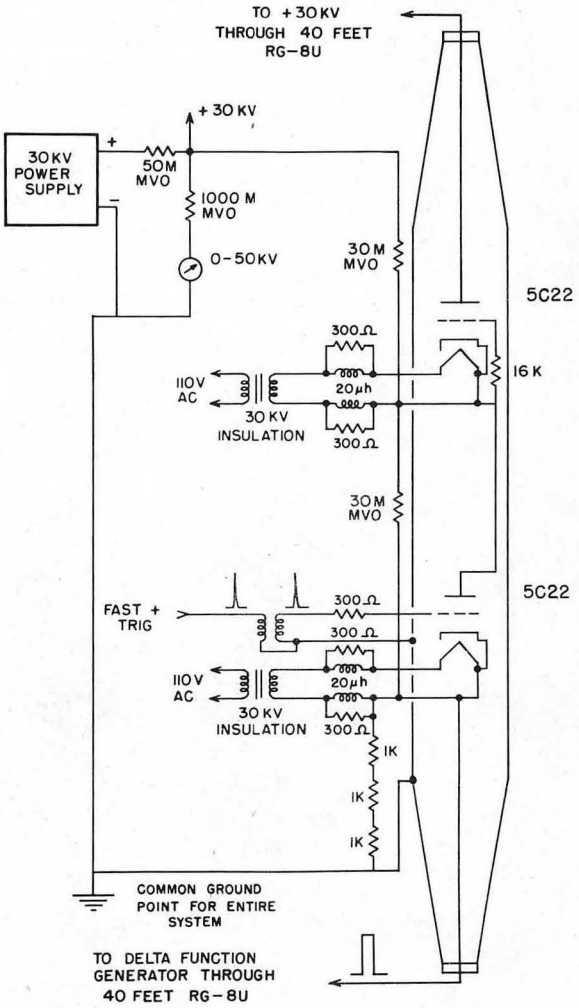


Fig. 3. Direct output of coaxial impulse generator before sharpening. Rise time 1.75×10^{-9} sec 107.2 ± .1 mc timing wave.

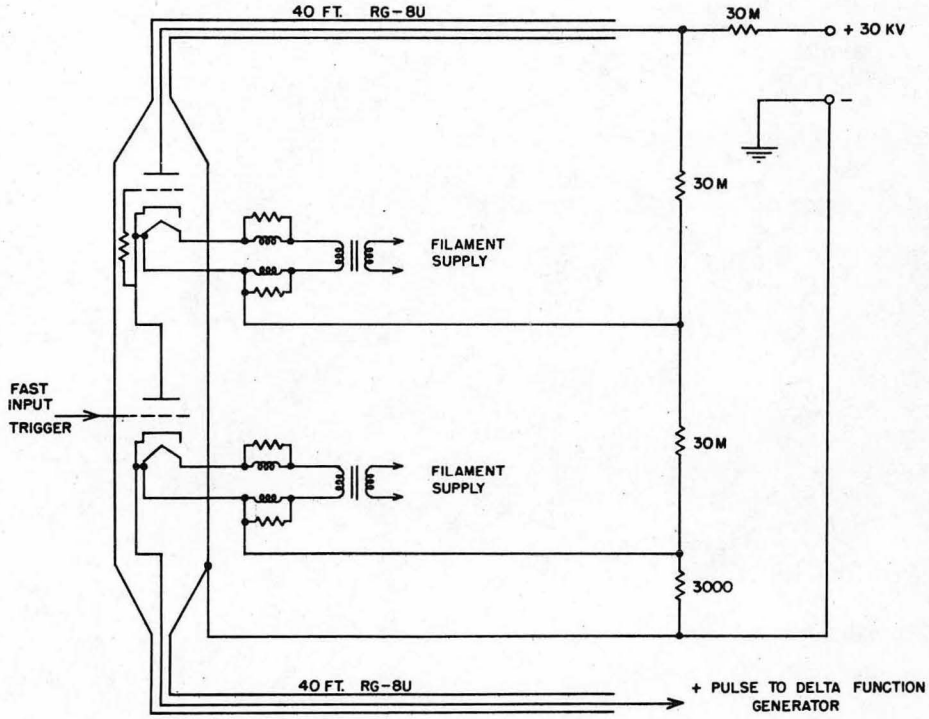


25 KV COAXIAL IMPULSE GENERATOR

(CONNECTED FOR PLUS PULSE OUTPUT)

MU-5506

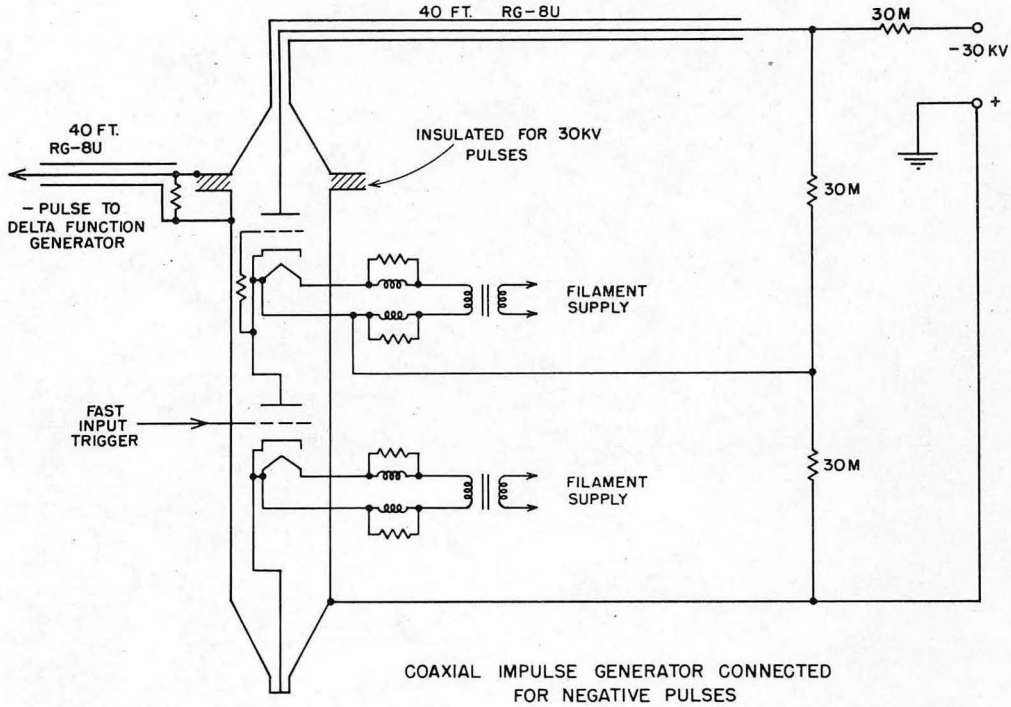
FIG. 4



COAXIAL IMPULSE GENERATOR CONNECTED FOR POSITIVE PULSES

FIG. 5

MU-5507



COAXIAL IMPULSE GENERATOR CONNECTED
FOR NEGATIVE PULSES

FIG. 6

MU-5508

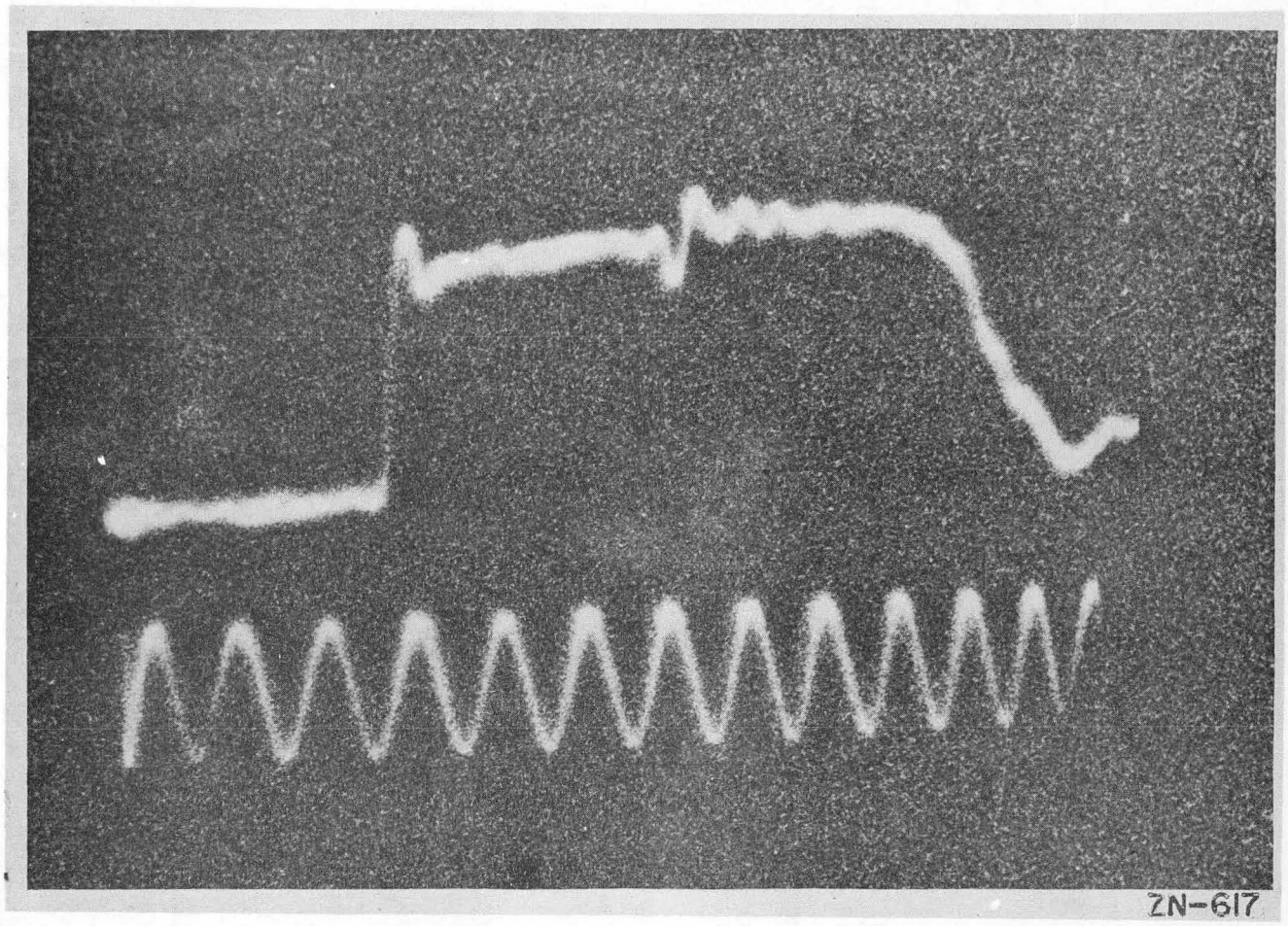


Fig. 7. Sharpened output of coaxial impulse generator before differentiation. Pulse length of 6.3 x 10^{-8} sec. 108.0 ± .1 mc timing wave.

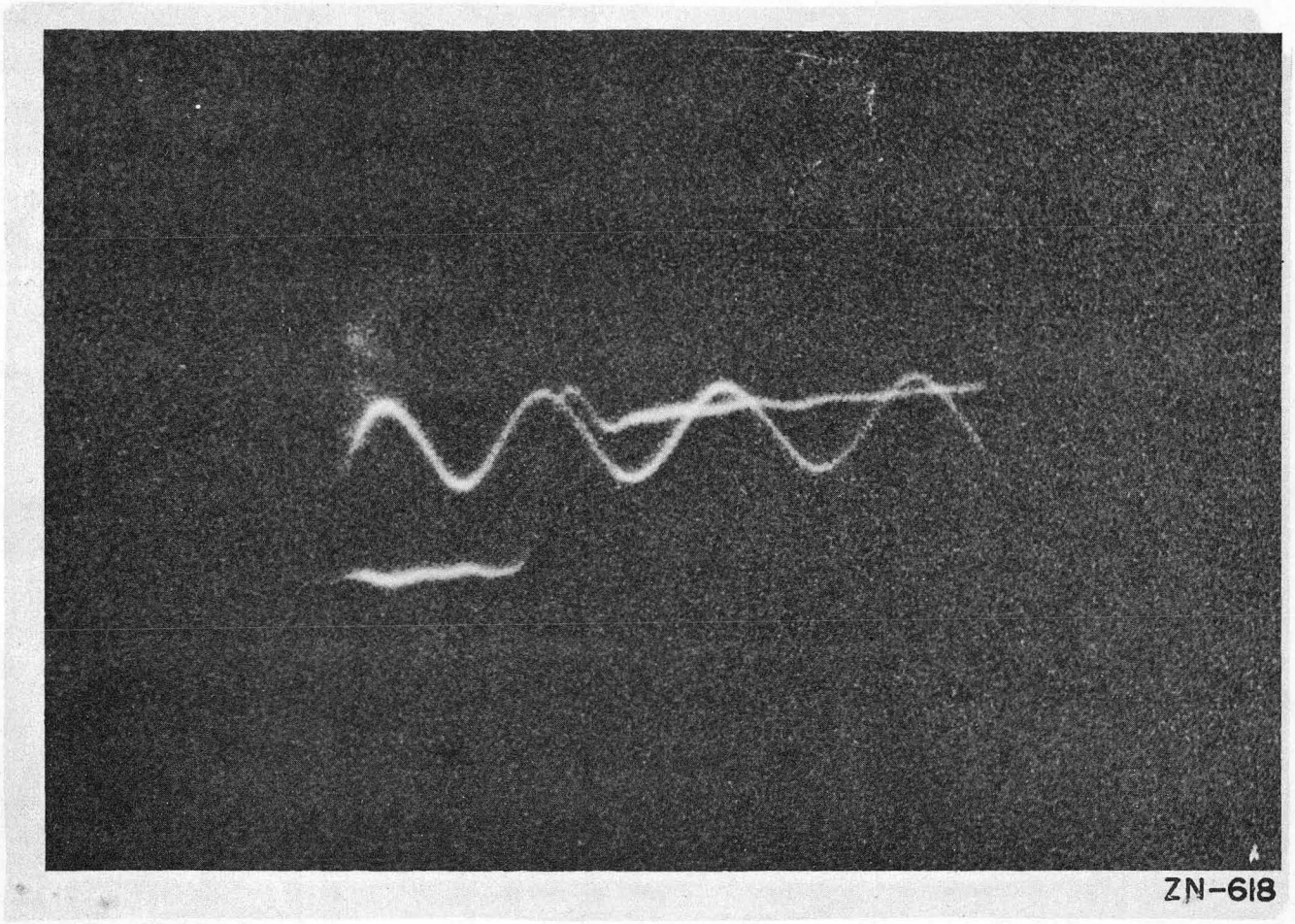


Fig. 8. Sharpened output of coaxial impulse generator rise time 0.6×10^{-9} sec. 108 ± .1 mc timing wave.

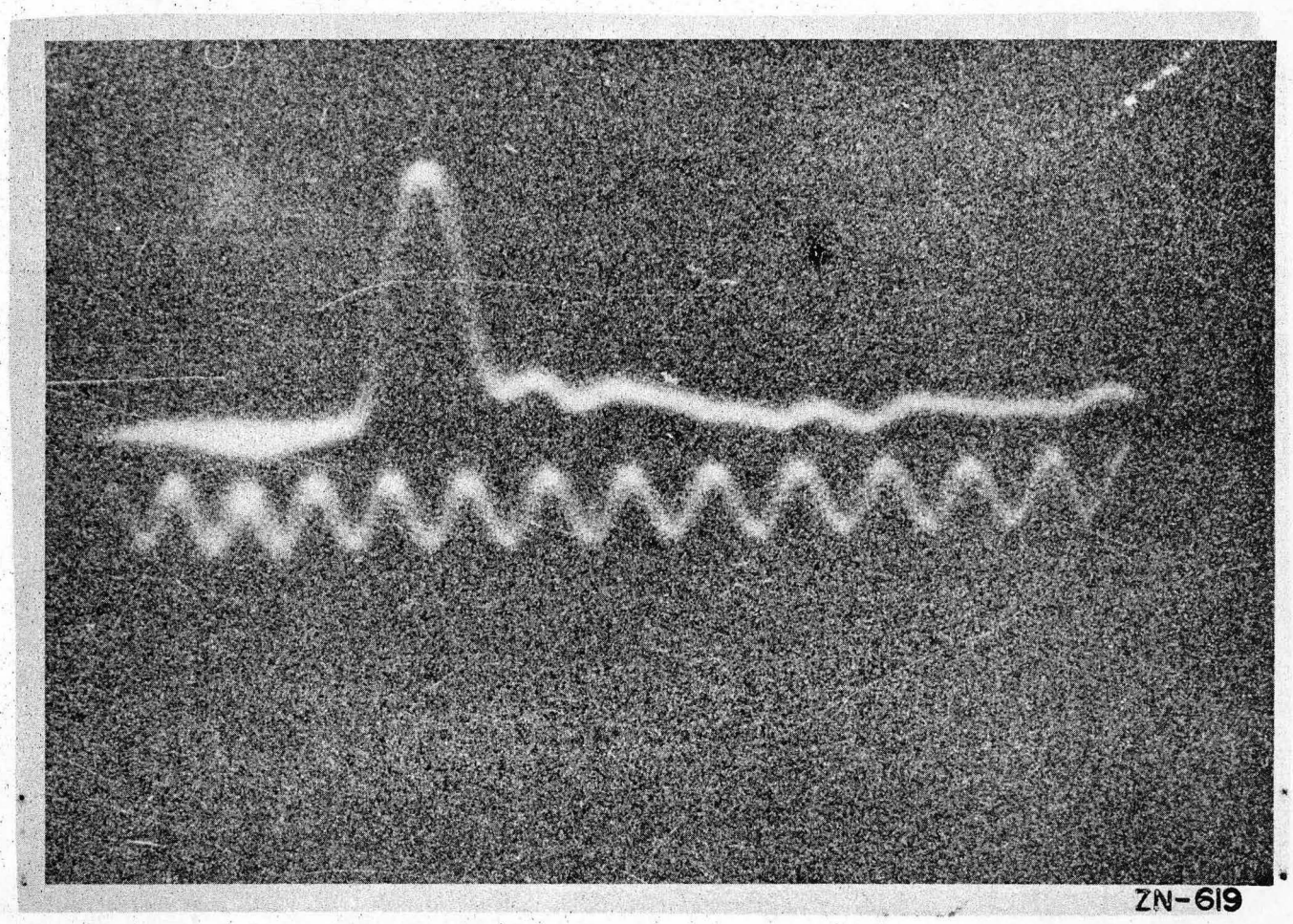


Fig. 9. Differentiated output of delta function generator. Pulse width 2.5×10^{-9} sec. 402.1 ± 0.4 mc timing wave.

DELTA FUNCTION GENERATOR CROSS-SECTION SHOWING PULSE SHARPENING GAP, DIFFERENTIATING STUB AND INTEGRAL TRANSMISSION LINE TERMINATED AT THE 100 KV ELECTRODE

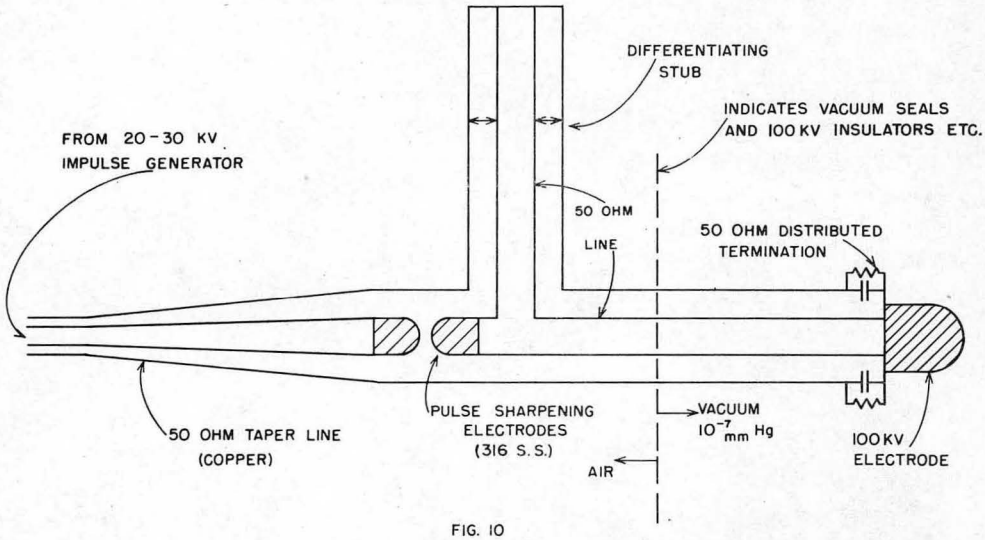


FIG. 10

MU-5509

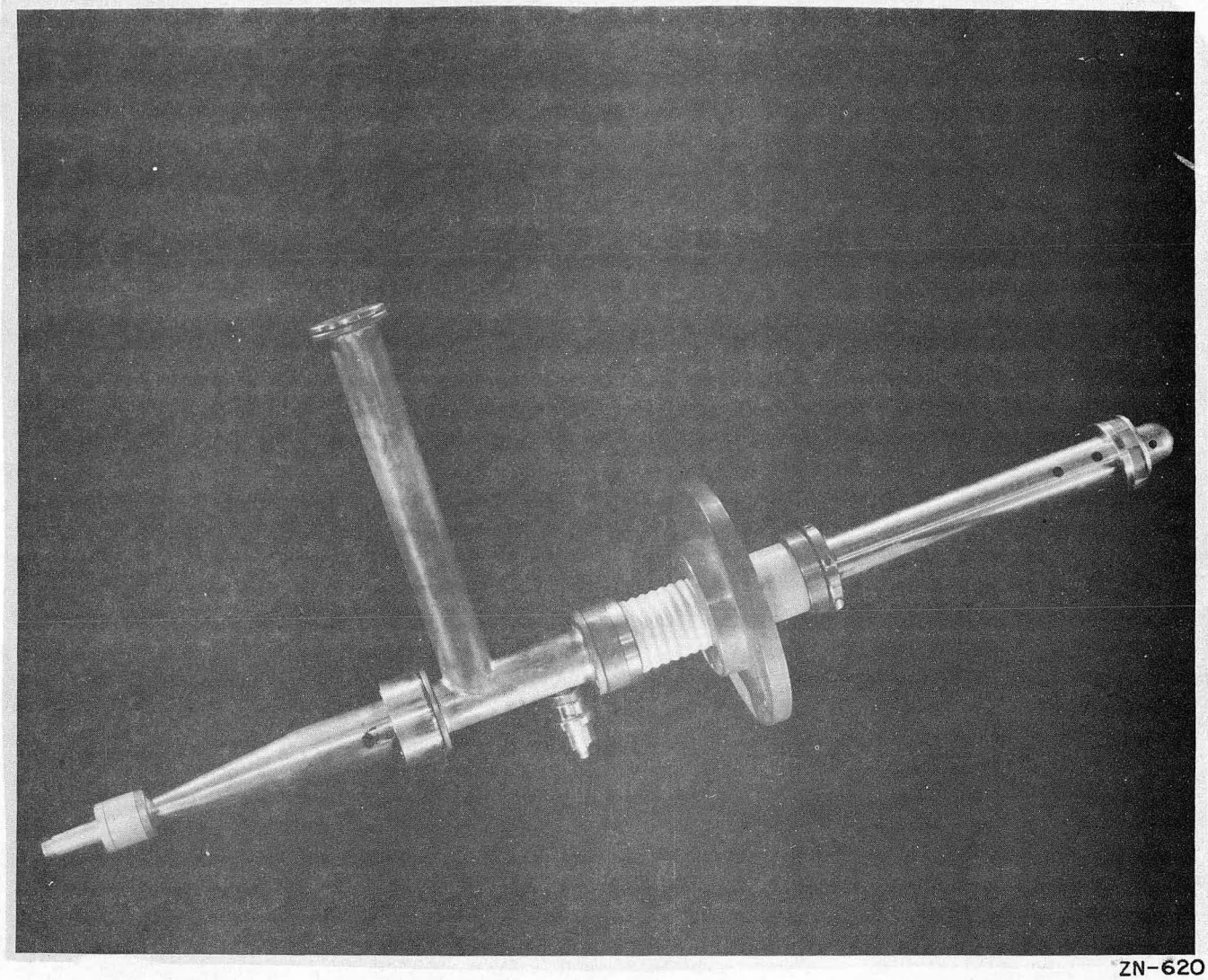


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Fig. 11. Complete delta function generator 100 kv electrode.