NATIONAL BUREAU OF STANDARDS REPORT

2281

Cathode-Ray-Oscillograph Beam Intensification

By

John H. Park and H. N. Cones
Electricity Division
Electrical Instrument Section

Sponsored by
Office of Basic Instrumentation

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity. Resistance Measurements. Inductance and Capacitance. Electrical Instruments. Magnetic Measurements. Applied Electricity. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Gage.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Measurements. Infrared Spectroscopy. Nuclear Physics. Radioactivity. X-Rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. Atomic Energy Commission Instruments Branch.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Aerodynamics. Engineering Mechanics. Hydraulics. Mass. Capacity, Density, and Fluid Meters.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure. Chemistry of Mineral Products.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Machine Development.

Electronics. Engineering Electronics. Electron Tubes. Electronic Computers. Electronic Instrumentation.

Radio Propagation. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Frequency Utilization Research. Tropospheric Propagation Research. High Frequency Standards. Microwave Standards.

Ordnance Development.
Electromechanical Ordnance.
Ordnance Electronics.
These three divisions are engaged in a broad program of research and development in advanced ordnance. Activities include basic and applied research, engineering, pilot production, field testing, and evaluation of a wide variety of ordnance matériel. Special skills and facilities of other NBS divisions also contribute to this program. The activity is sponsored by the Department of Defense.

Missile Development. Missile research and development: engineering, dynamics, intelligence, instrumentation, evaluation. Combustion in jet engines. These activities are sponsored by the Department of Defense.

- Office of Basic Instrumentation
- Office of Weights and Measures.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT **NBS REPORT**

0103-23-2006 February 1953 2281

Cathode-Ray-Oscillograph Beam Intensification

By

John H. Park and H. N. Cones
Electricity Division
Electrical Instrument Section
National Bureau of Standards

Sponsored by
Office of Basic Instrumentation

NBS

FOREWORD

This work was conducted as part of the National Bureau of Standards Basic Instrumentation Program, jointly sponsored by the Office of Naval Research, the Air Research and Development Command, and the Atomic Energy Commission. Progress on all projects underway as part of the program is reported in Office of Basic Instrumentation Progress Reports.

This final report on this project describes the work done in an effort to obtain a better understanding of electron beam intensification phenomena, to obtain improved results, and to obtain optimum design of equipment. A description of the phenomena, and a method for applying it to a cathode-ray oscillograph have been reported in a previous paper. 1/

F. B. Silsbee, Chief
Electricity Division

A. V. Astin
Director

When the "starting switch" is closed the 0.15 µf capacitor discharges, putting a steeply rising pulse on both the cable going to the surge generator tripping circuit and the delay lines which control the time of firing of the 4C 35 hydrogen thyratron. Two adjustable delay lines as shown in figure 1 are used, one consisting of 10 sections of 1 microsecond delay each and the other consisting of 10 sections of 0.1 microsecond delay each. Control of timing in the range 0 to 0.1 microsecond is obtained by varying the adjustable resistor (0 to 10,000 ohms) in series with the 100 µµf capacitor used to connect the output of the delay lines to the grid of the hydrogen thyratron. When this tube fires the 1.5 and 0.05 µf capacitors discharge, producing pulses which (1) unblock the oscillograph beam by use of the Norinder Relay plates, (2) cause beam intensification (the method of applying the intensifying pulse to the CRO discharge tube circuit is shown in R.P. No. 2231), and (3) apply a sweep voltage to the CRO sweep plates after a 0.25 microsecond delay. By adjusting the delay lines any given part of the surge being measured can be displayed on the CRO sweep. In case there is very little or no delay in the surge generator trip circuit, it may be necessary to send the surge generator trip pulse through an additional delay line. The use of delay lines in the tripping circuits allows timing to be adjusted to within 0.01 microsecond or less.

The beam intensification permits higher sweep speeds to be easily and regularly used, thus a means must be provided for easily calibrating such sweeps. A seven megacycle crystal controlled oscillator with one stage of amplification was constructed which gives an output of several hundred volts across the deflection plates of the CRO. A frequency tripling circuit and another tuned amplifier were made so that a sweep calibrating frequency of 21 megacycles is available. This sweep calibrating equipment was built into one shielded box and permanently mounted on the CRO panel so that it would always be available for use with the CRO.

Another permanent addition to the CRO was the installation of two thermocouple vacuum gages, one in the exhaust port of the discharge tube, the other in the exhaust port of the main CRO deflection chamber. Heater supply meters and microammeters for indicating the output of the couples were mounted in a panel on the CRO. The thermocouple in the discharge tube port was used to furnish a record of the pressure in the discharge tube under various conditions. Both gages are valuable additions to the CRO since they give an exact indication of pressure in the CRO chambers and show when the pressures are correct for operation of the CRO. They have already proven very useful in detecting small leaks and indicating other non-operable conditions such as too much moisture in the film.

III. Experiments on Beam Intensification

In an effort to obtain a better understanding of the intensification phenomena several independent experiments were performed. These will now be described in approximately the order in which they were done.

1. Results with a Metal Discharge Tube

For the experiments described in Research Paper 2231 a CRO with a glass discharge tube was used as indicated in figure 1 of that paper. This glass tube has an outside diameter of 1 inch and is about 16 inches long. The end of the cathode is about 4 inches above the upper end of the metal anode tube which is inside the glass tube. Other experimenters[2] have used an all metal discharge tube in place of the glass tube. The cathode in that case is insulated from the metal tube by a glass or porcelain bushing, but extends below this insulation down into the metal tube. In order to determine whether or not the surface charges on the glass tube had any effect on the intensification phenomena it was decided to try the intensification technique with a metal rather than insulating tube surrounding the cathode.

Attempts were first made by using a longer anode tube inside the glass tube and putting an extension on the cathode so that the end of the cathode extended about 1 inch into the anode tube. However, since the anode tube is smaller (about 3/4 inch OD) than the glass tube, flashover between cathode and anode tube occurred before a steady beam could be established. In order to increase the spacing between the cathode and the grounded anode tube a combination metal and glass ("glass-metal") discharge tube was constructed as shown in figure 2. By carefully centering the cathode on the axis of the metal tube a discharge and electron beam along the tube axis could be obtained. The beam intensity could be regulated in the usual way by a fine control on the pressure in the discharge tube.

With the combination "glass-metal" tube the metal tube was insulated from the anode electrode (with the small hole for letting the electron beam into the main CRO chamber) by rubber gaskets; thus the total current through the discharge could be measured as two parts - that coming from cathode to metal tube and that coming from cathode

---

[2] J. M. Dodds - "Metallentladungsrohr" Arch. f. Elektro. 29 p. 69 1935.
Burch and Whelpton - "The Technique of the High Speed CRO" JIEE (London) 71 p. 380 1932.

to anode. This was done for various values of discharge current and for the cathode at various distances from the anode. In all cases where the cathode extended down into the metal tube, about 60 percent of the total current to the cathode was collected at the anode, the remaining 40 percent being collected by the metal tube. With the end of the cathode about 3 inches above the end of the metal tube so that part of the discharge was enclosed by the glass tube, about 55 percent of the total current went to the anode and 45% to the metal tube. In all cases very little of the total cathode current (1 percent or less) passed through the small hole in the anode to be utilized as the electron beam for measuring purposes.

Intensifying pulses the same as those described in Research Paper 2231 and shown in figures 2 and 3 of that paper (these figures are reproduced in this report as figures 3 and 4) were applied in tests using the combination "glass metal" tube. With the cathode above the metal tube so that part of the discharge was in the glass tube, the discharge currents and beam intensification were almost exactly the same as with an all glass discharge tube (see figures 3 and 4). With the cathode extending into the metal tube (same as an all metal discharge tube) the results were quite different as indicated in figures 5 and 6. Beam intensification and second increase in discharge current did not occur, as seen by comparing figures 3A and 5A. Also, there was no reversal of discharge current as may be seen by comparing figures 4B and 6B.

2. Trial of Various Gases in Discharge Tube

Several gases, some with molecular weights quite different from the nitrogen and oxygen in air, which is normally used, were tried in the low-pressure discharge tube to determine whether there was a dependence of intensification on the molecular constitution of the gas used. This was accomplished by using the CRO film drying chamber (a heavy wall tube 5 inches in diameter and 10 inches long) as a storage tank for the gas to be used. This chamber was used because it was available on the CRO and could be evacuated by the CRO fore pump. Vacuum tight connections were made (1) from the film chamber to the intake of the CRO leak valve which regulated the flow of gas into the discharge tube and (2) from the film chamber (through a valve) to a regulating valve on a cylinder of the gas being used. A pressure gage was connected to the film chamber. The procedure was than (1) to evacuate the film chamber by opening a valve from it to the CRO fore pump, (2) to close this valve, (3) to allow gas to flow from the gas cylinder into the film chamber by opening the regulating valve first and then the valve on the line into the film chamber, allowing enough gas to flow into the film chamber to bring its pressure slightly above atmospheric, and (4) to close the valve on the intake line to the film chamber. When a gas cylinder was first connected to the system this procedure was repeated in order to flush out any gas left in the system from previous tests. The leak valve on the CRO discharge tube inlet was then adjusted in the usual manner to regulate pressure in the discharge tube. The volume of gas in the film chamber was sufficient for several hours operation of the CRO but when the pressure in the film chamber fell to atmospheric, more gas was let in from the cylinder. A tray of phosphorous pentoxide was kept in the film chamber to remove moisture from the gas being used.

For these experiments with various gases an all glass discharge tube and the regular cathode and anode tube were used. When hydrogen was used the pressure in the discharge tube had to be much higher than with air and since both the discharge tube and the deflection chamber of the CRO are evacuated by the same molecular pump, pressure in the deflection chamber was also higher. This at first resulted in flashover between sweep plates when sweep voltage was applied but by using a special sweep at reduced voltage, records with hydrogen were obtained under the same circuit conditions as used for figures 2 and 3 of RP 2231. The intensified discharge occurred for hydrogen essentially the same as it had for air. When helium was used the discharge pressure had to be much higher than for air but not as high as for hydrogen; no flashover between sweep plates was noted. Intensification occurred in the same manner but to a somewhat less degree than for air. When oxygen was used the pressure in the discharge tube was slightly lower than for air and the beam was very unsteady; however, records were obtained and the intensification was essentially the same as for air. When nitrogen was used the pressure in the discharge tube was also slightly lower than for air but the beam behaved normally and the intensification was the same as for air. Carbon tetrachloride ($C\ Cl_4$) gas was also tried by using a flask of liquid $C\ Cl_4$ in place of the cylinder of gas and allowing $C\ Cl_4$ to boil off into the film chamber after it had been evacuated. With $C\ Cl_4$ the beam behaved very well and the pressure in the discharge tube was about the same as for air; the intensification obtained was very nearly the same as for air.

The experiments with various gases showed slight differences in degree of intensification but the general nature of the intensification appears to be the same for all gases tried. Dry and moist air were also tried without observing significant differences.

3. Changes in Geometry of Cathode

The cathode of the discharge tube as normally used, consists of a 1/4 inch diameter aluminum rod, with the surface on its emitting-end polished, placed axially inside a steel shield as shown in figure 7. The small aluminum cylinder is held in place with a set screw and can be removed for re-polishing. The polished surface of the cathode is normally set at a distance d = 1.5 mm (see figure 7) inside the cathode shield. With this cathode setting the appearance of the discharge in the glass tube is about as shown in figure 7. The electron beam may be seen as a fine blue line starting at the center of the emitting-end of the cathode and following along the axis of the glass tube down into the metal anode tube. A blue fluorescent band appears on the inner surface of the glass tube at a distance "ℓ" below the cathode. Its upper edge is bright and sharply defined. When this edge appears tilted rather than perpendicular to the axis of the tube it is indicative of malcentering or malalignment of parts. (Inspection of this sharp edge of fluorescence offers a good guide for lining up the axis of the cathode). The distance ℓ from the lower edge of the cathode shield to this fluorescent line is always about 2 cm with the usual cathode setback in its shield.

It was found that a change in the cathode setback d caused a change in the distance ℓ, thus indicating a change in charge distribution inside the glass tube near the cathode. The effect of changing d on the intensification phenomena was therefore investigated. When d was made equal to zero (cathode and shield lined up) the distance ℓ was found to be reduced to about 1.1 cm and when d was changed to -1.55 mm (cathode below shield) became 0.8 cm. Under both conditions beam intensification still occurred in the same manner as with normal cathode setback but the degree of intensification was much less. When the cathode setback d was increased to 3 mm the distance ℓ was found to increase to 3.5 cm. Beam intensification still occurred in the same manner but somewhat increased in magnitude over that obtained with normal cathode setback.

4. Metal Bands Around the Discharge Tube

As indicated in the previous section a change in longitudinal position ℓ of the discharge sheath along the inside surface of the glass tube was accompanied by a change in magnitude of the intensification. This suggested that another kind of experiment be performed. That metal foil bands be wrapped around the outside of the glass tube and be either connected to ground or excited by a pulse with respect to ground. Trials were made with 1/2" and 1" wide bands placed tightly around the glass tube at various positions along its axis between the cathode and anode. Placing the band less than 3 cm from the cathode caused the beam to become unsteady. The effect of these bands on the intensification is quite spectacular and varied. Under most conditions they increase both the magnitude and duration of intensification but when the beam intensification is greatest it appears to come in "spurts" and does not yield a uniform trace.

Placing the metal bands around the glass discharge tube undoubtedly causes changes in potential distribution and thus charge density inside the tube. The observed effects on intensification were quite large but results were not always repeatable. Refinements in the techniques for applying bands to the glass tube will need to be made before proper control can be obtained for CRO applications.

5. Full Voltage Suddenly Applied to Discharge Tube

The intensification reported above was caused by a suddenly applied change in the total voltage across the discharge tubes of only about 2 to 5 percent of the voltage. In normal operation of the CRO the discharge tube voltage is gradually increased to its normal operating value and a steady state equilibrium condition in the discharge is always maintained. A small sudden change in voltage as has been explained gives momentary beam intensification. The question arose as to what would happen if the full voltage were suddenly applied to the glass discharge tube.

Several designs of quick acting mechanical switches, operating both in air and under oil were tried for suddenly applying the voltage. In all cases it was found that connection was made by a spark in the insulating medium of the switch prior to metallic contact of the switch. The characteristics of this spark determine how quickly the voltage is applied and whether the initial connection is stable. Therefore a three-ball sphere gap was used to suddenly apply the voltage, the time of application being controlled by a steep voltage pulse to the middle ball. It was found that the impedance of the spark between the spheres does not reach a low and definite value unless the current in the spark exceeded 10 ma. The circuit for suddenly applying voltage consisted of a high voltage capacitor (charged to 50 KV) that was discharged through a high resistance by the three ball gap. The CRO discharge tube was connected across this resistor so that the voltage applied to it was determined by the current building up through the resistor at gap breakdown. The value of this resistance was kept high so that adequate voltage was maintained across the discharge tube for a long time, but it had to be low enough to insure a minimum current above 10 ma. A value of 2×10^6 ohms was found to be satisfactory. Measurements were made of the rise time of this voltage by disconnecting it from the discharge tube, supplying the tube with a steady 50 KV, and using either a capacitance or resistance divider to connect a small fraction of the voltage to the CRO deflecting plate. With this circuit arrangement the voltage rises from zero to full value in about 3 microseconds and maintains nearly full value for several hundred microseconds. When this voltage was used to supply the discharge tube a very intense electron beam was established at about the time full voltage was established across the tube. The beam intensity was even greater than that obtained with a low voltage pulse as applied above under steady discharge conditions of the tube, and the intensification lasted much longer - up to at least 50 μs.

An attempt was made to measure the current through the discharge tube while the beam was being established but charging currents caused by the small stray capacitance of the cathode, anode and its shield, masked the current being measured. An accurate measurement of the voltage applied to the discharge tube could not be obtained because of the uncertain characteristics of resistors used in the divider circuit. The need to keep its inductance low required that the divider be made of globar or carbon units. All such available resistors were found to have a very high voltage coefficient (5 percent per KV per cm).

Efforts to find high resistance units of minimum inductance that did not have too high a voltage coefficient were unsuccessful. A Wheatstone bridge was set up - using a high voltage pulse in place of a battery and the CRO deflecting plates for a detector. Wire wound non-inductive resistors (zero voltage coefficient) were used in three arms of the bridge with the resistor being tested in the fourth arm. As many different types and makes of resistors as could be obtained were tested to determine their voltage coefficients but none were found with a low enough coefficient to be suitable for a divider. Thus measurement difficulties encountered when using this high-resistance surge-voltage divider limited the usefulness of further data that might have been taken with it.

However, the results described above, when full voltage was suddenly applied to the discharge tube indicated that further work along this line should be done. Detailed information was needed as to what happens in the discharge tube as the voltage across it is quickly raised from zero to full value (50 KV). The beam appeared to be established within a few microseconds and the phenomena of interest would probably not last more than about 100 microseconds. Thus the voltage applied should rise quickly to maximum value and remain nearly constant for about 100 microseconds. Such a voltage can be obtained by using the two lower capacitance units of a high-voltage surge generator discharging through a resistance of about 1000 ohms. Thus it was apparent that a voltage divider for measuring purposes could be made up of low resistance non-inductive wire wound units that would eliminate the difficulties encountered with the high resistance divider. A schematic wiring diagram of the setup that was devised for further studies is shown in figure 8. An overhead line was used to bring the 50 KV from the surge generator to the CRO. Some resistance is placed in series with the line at the surge generator and a capacitance to ground at this point was used to adjust the rate of voltage rise. At the CRO, the overhead line was connected to ground through a resistance divider with a high side of 1000 ohms and a low side of 25 ohms, giving a voltage of correct magnitude for the CRO deflecting plates. The high side of the divider was connected to the cathode of the discharge tube through a 10,000 ohm resistance for suddenly applying voltage. The applied voltage could be easily synchronized with the CRO sweep by using the regular trip circuits of the CRO and surge generator.

A considerable amount of data was taken with this setup under various conditions in the discharge tube. Under some conditions a beam is established as soon as the tube voltage reaches its maximum value. The beam builds up to an extremely high intensity in a few hundredths of a microsecond and stays high for a few microseconds and then gradually dies out. Under other conditions either no beam is established or it is delayed an erratic amount (up to 30 microseconds) after voltage is applied. All the factors which might be thought to affect build-up of the beam were changed but the erratic behavior still persisted and could not be pinned down to any of the variables tried.

The most easily controlled variable in the discharge tube is gas pressure and effects of changes in gas pressure were thoroughly investigated. Under steady state conditions the discharge is extremely sensitive to changes in gas pressure, a satisfactory beam is attained only over a range in pressure of the order of a fraction of a micron at a pressure of about 15 microns. At lower pressures no visible discharge is obtained and at higher pressures the discharge current becomes high and unstable. With suddenly applied voltage a very intense beam is obtained at the pressure yielding a good steady state beam. For small increases in pressure a more intense beam is obtained which lasts longer, but when pressure is increased a little more the discharge lights up the whole tube and apparently draws a very large current which reduces the voltage applied to the tube and no beam is obtained. If the pressure is reduced below the normal steady state value, a momentary beam can still be established but the intensity and duration of the beam decrease markedly with pressure. In some cases a very short duration (less than 1 microsecond) beam was obtained at even the lowest pressure obtainable (about 1 micron). The erratic behavior of the beam did not appear to depend solely on the gas pressure although at times when a beam could not be obtained at one pressure, changing the pressure caused the beam to appear.

Another variable which at times appeared to affect the erratic behavior is the distance between the cathode and the anode tube inside the discharge tube. Changing this distance at times appeared to make the beam disappear entirely but no definite repeatable effect of changing this distance could be established.

Another factor considered was the effect of the brown coating of metal oxide which appears on the inside of the glass tube after it has been in operation over a fairly long period. No direct correlation between the density of this coating and erratic beam behavior could be established.

An attempt was made to correlate erratic behavior with moisture content of the gas in the discharge tube. Both very dry and very wet air were tried without successful correlation. Neither could correlation be obtained with the general weather conditions or humidity of the laboratory air.

A factor which at first seemed to affect the erratic behavior was the condition of the cathode. On some trials a cathode which had been used for a long period and had an appreciable crater at its center where the beam originates appeared to always give repeatable results. A new cathode appeared to give erratic behavior. However, these tests could not always be repeated with the same results.

Since condition of the cathode appeared to have an effect, a trial with a cathode of a different metal was made. A piece of pure silver was soldered on the end of a cathode rod and then turned down and polished. With the silver as the cathode no erratic behavior was noted. The beam always started within a microsecond after the attainment of full voltage and built up to very high intensity within a few hundredths of a microsecond. The intensification lasted longer with the silver cathode, up to 60 microseconds, but both the intensity and duration were found to decrease as the pressure was decreased. The metal oxide coating on the inside of the glass tube builds up very rapidly in use with a silver cathode and one trial was made by replacing the silver cathode with the usual type of aluminum cathode after a heavy coating on the glass had been built up, using the silver cathode. For this trial the aluminum cathode also gave a good repeatable intensified beam.

The experiments described above, with full voltage suddenly applied, were carried out using a glass discharge tube. To see if the glass was in any way responsible for the beam intensification obtained, similar experiments were carried out using the glass-metal discharge tube shown in figure 2, with the cathode projecting down into the metal tube. With this simulated "metal" tube and an aluminum cathode, a beam could not be established by suddenly applying the voltage. With a silver cathode, repeatable beams were established but they differed from those obtained with a glass discharge tube. Although the initial stages of the developing beam repeated quite well there was a delay of about 10 microseconds after full voltage was applied before the beam started. The buildup of beam intensity was much slower, requiring several microseconds. However, the intensity and duration were about the same once the beam was established. The changes in beam intensification and its duration with changes in pressure were about the same as those already described when a glass tube was used. These results indicate that the mechanism for establishing the discharge is quite different for a metal tube than for a glass tube. No satisfactory explanation was deduced for the erratic results obtained when full voltage is suddenly applied to the discharge tube.

IV. Summary of Results

1. A method has been developed for momentarily intensifying the electron beam obtained from a cold-cathode discharge tube. This momentary intensification is about fifty times its steady state value. The utilization of this method of beam intensification for obtaining very high writing speeds with a CRO has been described in R.P. No. 2231.

2. This intensification phenomena is not dependent to any very great extent on the gas used in the discharge tube.

3. The material surrounding the discharge at and near the cathode must be a dielectric such as glass and not a conductor if intensification by superposed small pulses is to be obtained.

4. When full voltage is suddenly applied to the discharge tube an intensified beam is obtained at times, but results are usually not repeatable.

5. A satisfactory theoretical explanation for this beam intensification phenomena was not obtained. Such an explanation will probably not be attained until the steady state mechanism of the discharge in a high-voltage cold-cathode tube is completely understood. Although such discharge tubes have been in use for over thirty years there is still no experimentally verified theory for explaining their behavior. Continued studies of exactly what happens when full voltage is suddenly applied to the electrodes might eventually yield a satisfactory theory.

6. The most important objective of this work which was to learn enough about the intensification phenomena so that it could be used to obtain very high writing speeds with the CRO has been achieved. The CRO, with intensification, has already been used in an investigation of insulator puncture using surges with rates of voltage rise up to 11,000 KV per microsecond. It is now being used to study front of wave measurements on rapidly rising voltage surges.

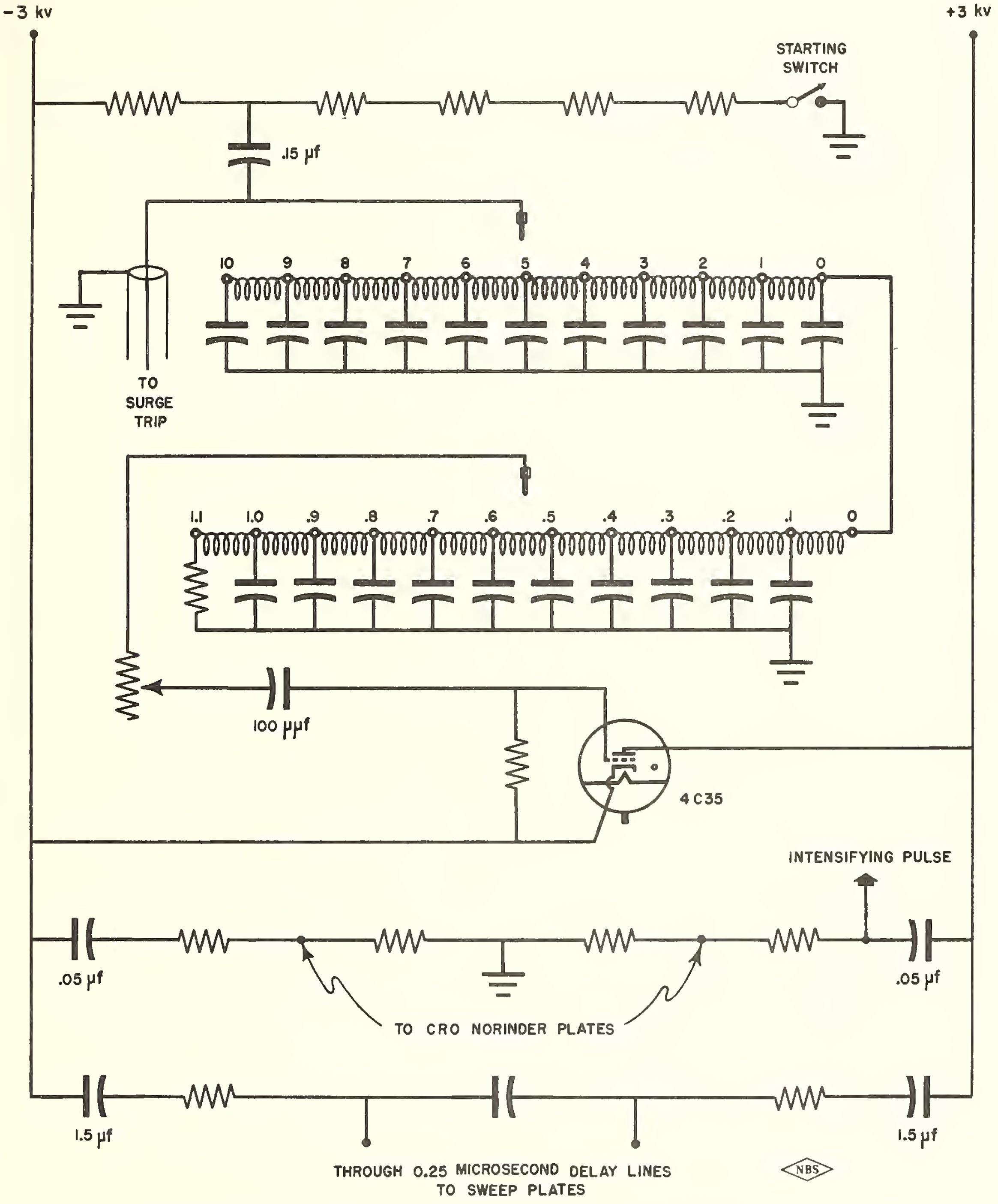

Figure 1. Wiring diagram showing delay lines used to synchronize CRO sweep with surge generator

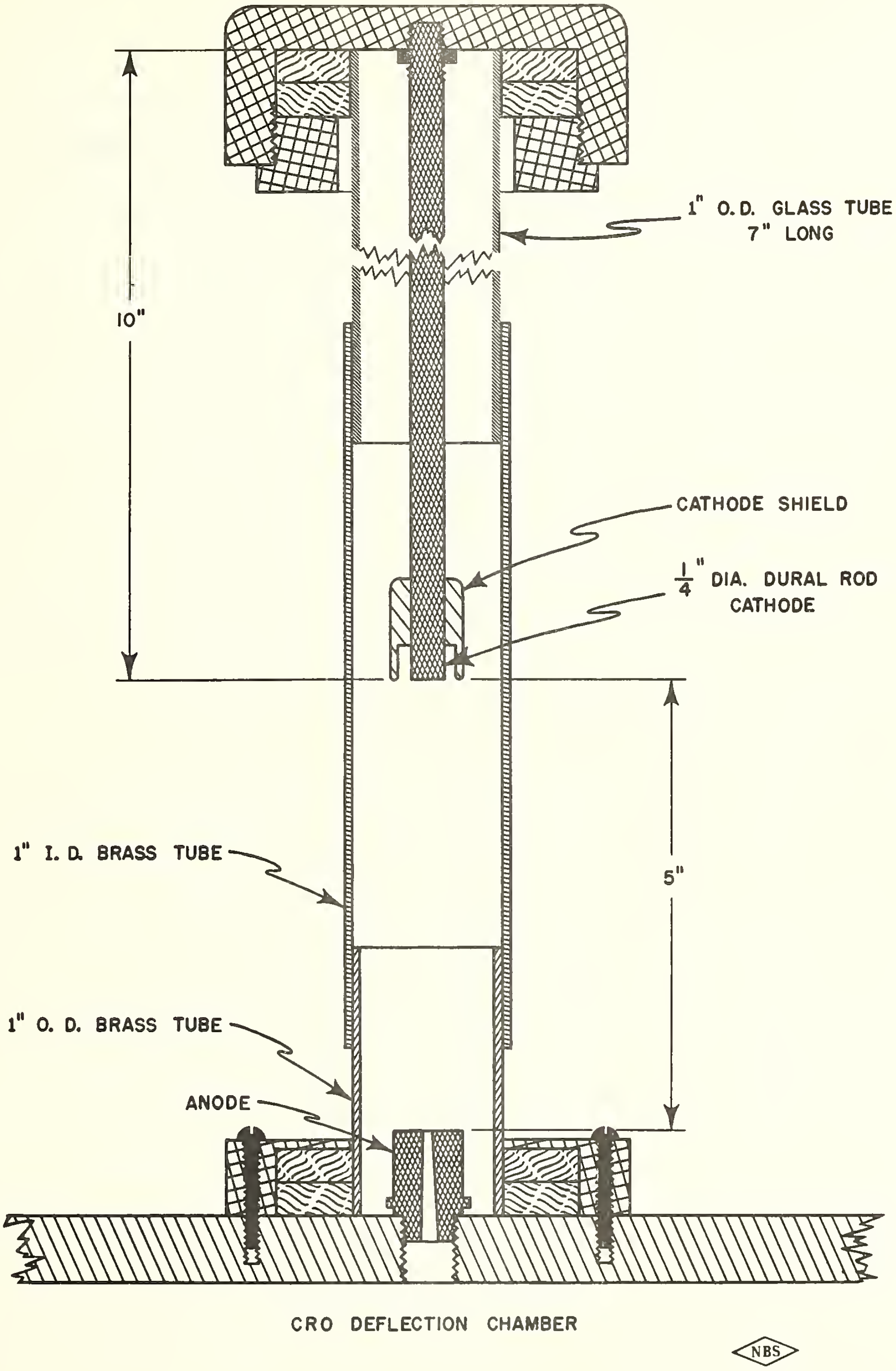

Figure 2. Modified discharge tube for producing electron beam

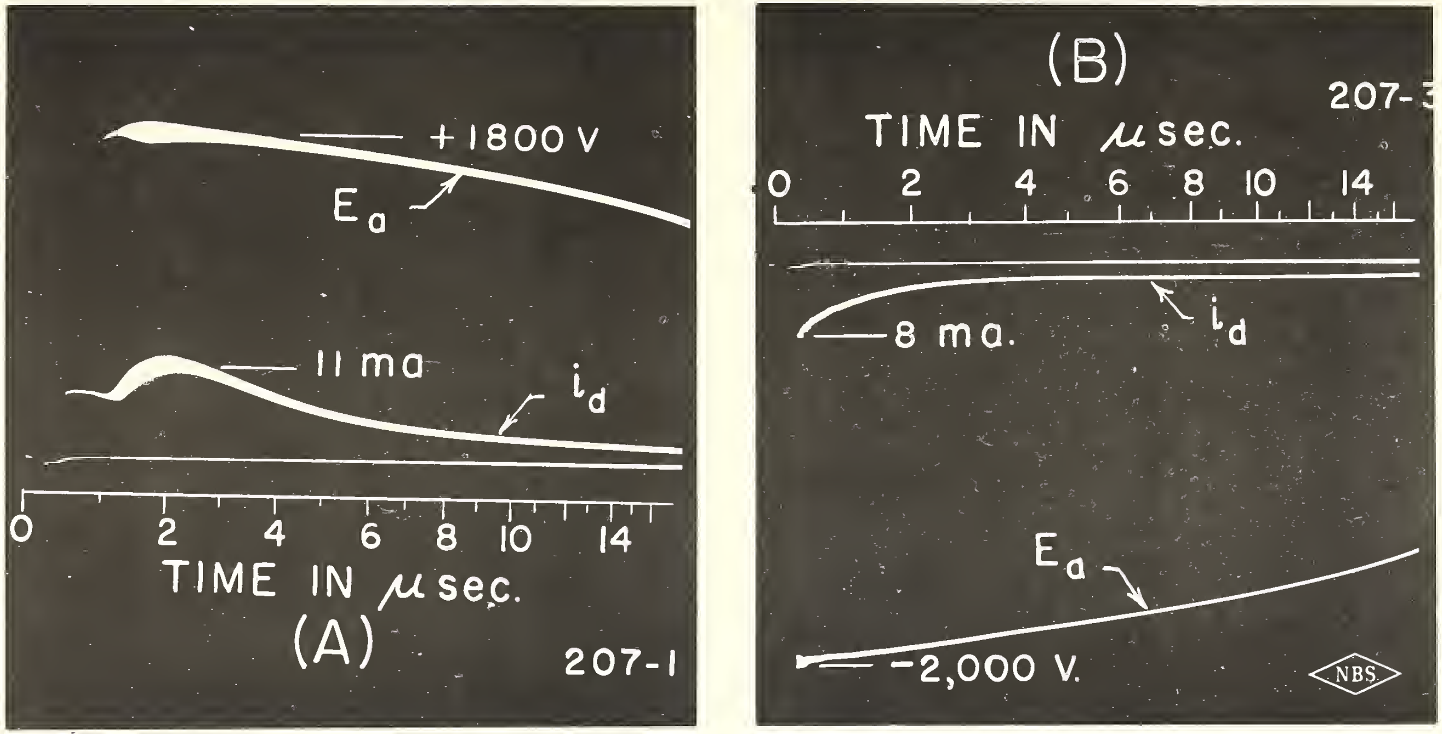

Figure 3. Oscillograms of intensification pulses using an all-glass discharge tube. E_a is voltage pulse applied to anode. i_d is the corresponding change in current through the discharge tube.

(A) is for positive polarity voltage pulse, and

(B) is for negative polarity voltage pulse.

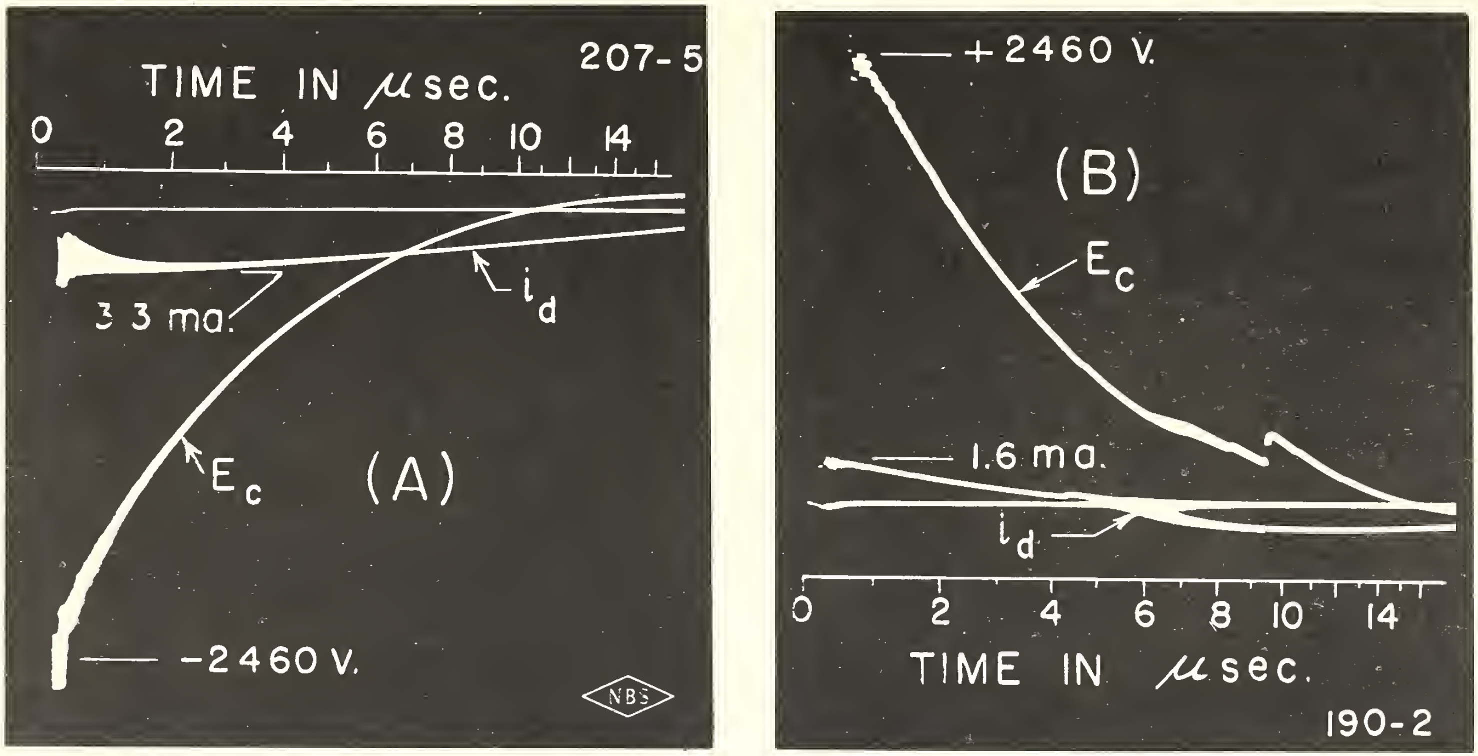

Figure 4. Oscillograms of intensification pulses using an all-glass discharge tube. E_c is voltage pulse applied to cathode. i_d is the corresponding change in current through the discharge tube.

(A) is for negative polarity voltage pulse, and

(B) is for positive polarity voltage pulse.

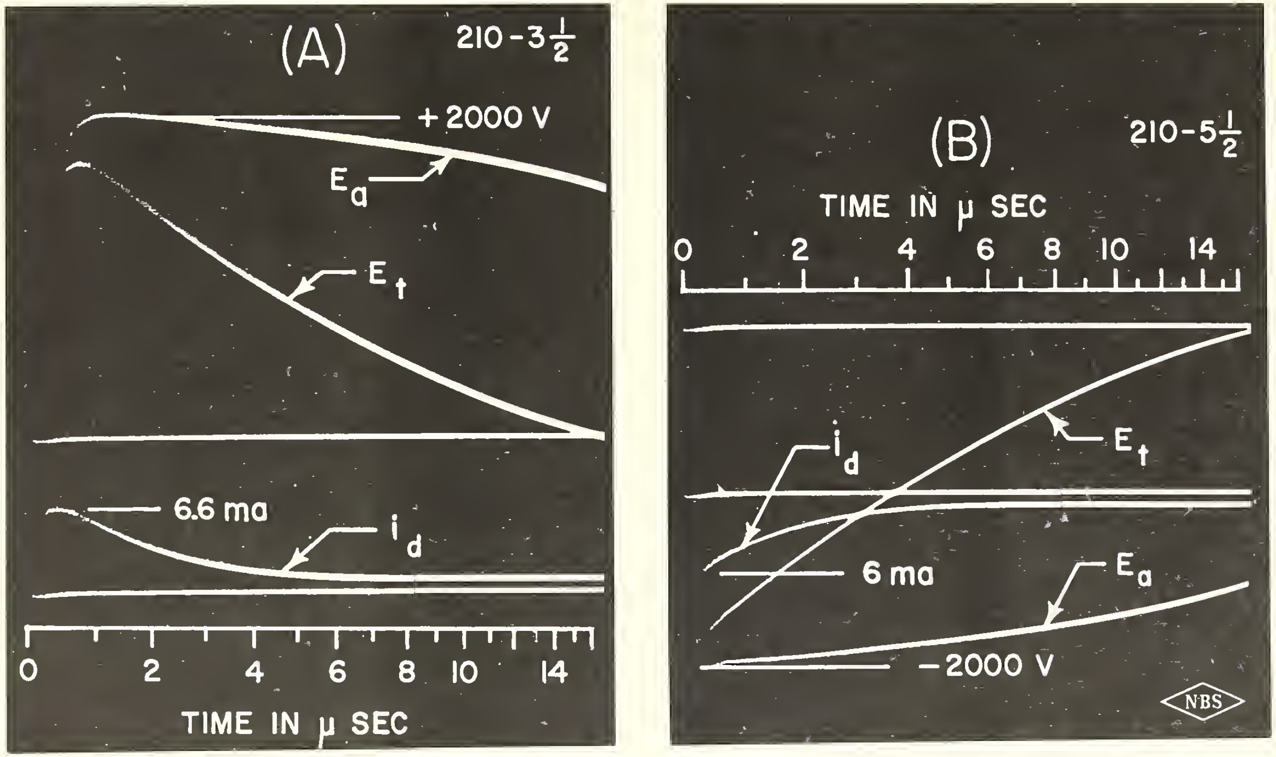

Figure 5. Oscillograms of intensification pulses using the modified discharge tube shown in figure 2, with the cathode extending inside the anode tube. E_a is voltage pulse applied to anode. E_t is the resulting voltage of the anode tube. i_d is the corresponding change in current through the discharge tube.

(A) is for positive polarity voltage pulse, and

(B) is for negative polarity voltage pulse.

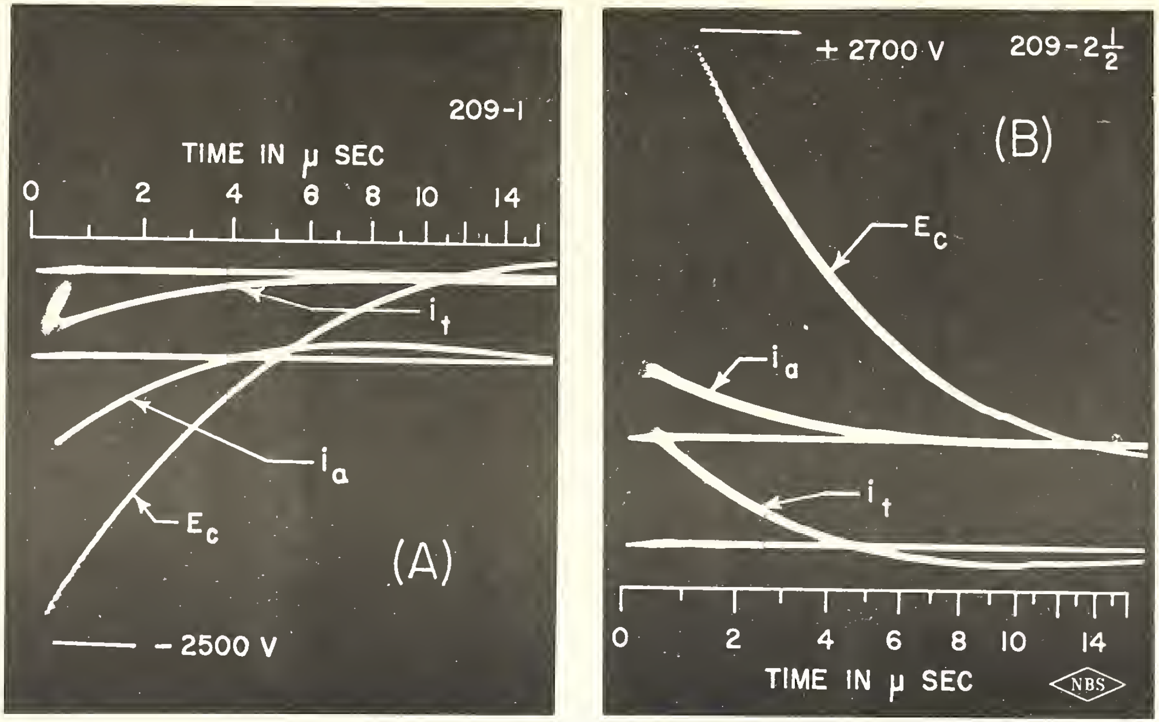

Figure 6. Oscillograms of intensification pulses using the modified discharge tube shown in figure 2, with the cathode extending inside the anode tube. E_c is voltage pulse applied to cathode. i_a is the corresponding change in current to the anode (maximum value = 2.6 ma). i_t is the corresponding change in current to the anode tube (maximum value = 4.7 ma).

(A) is for negative polarity voltage pulse, and

(B) is for positive polarity voltage pulse.

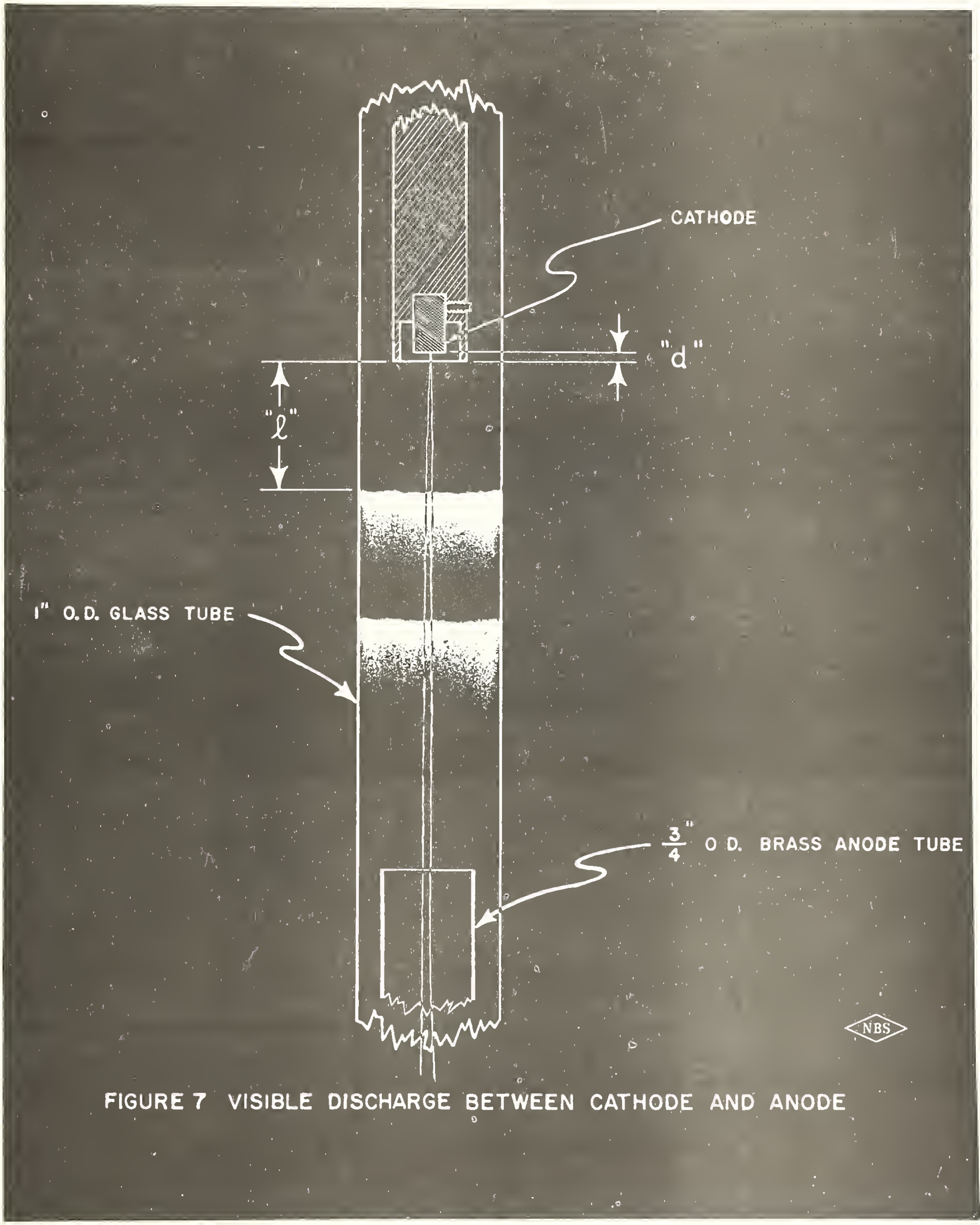

FIGURE 7 VISIBLE DISCHARGE BETWEEN CATHODE AND ANODE

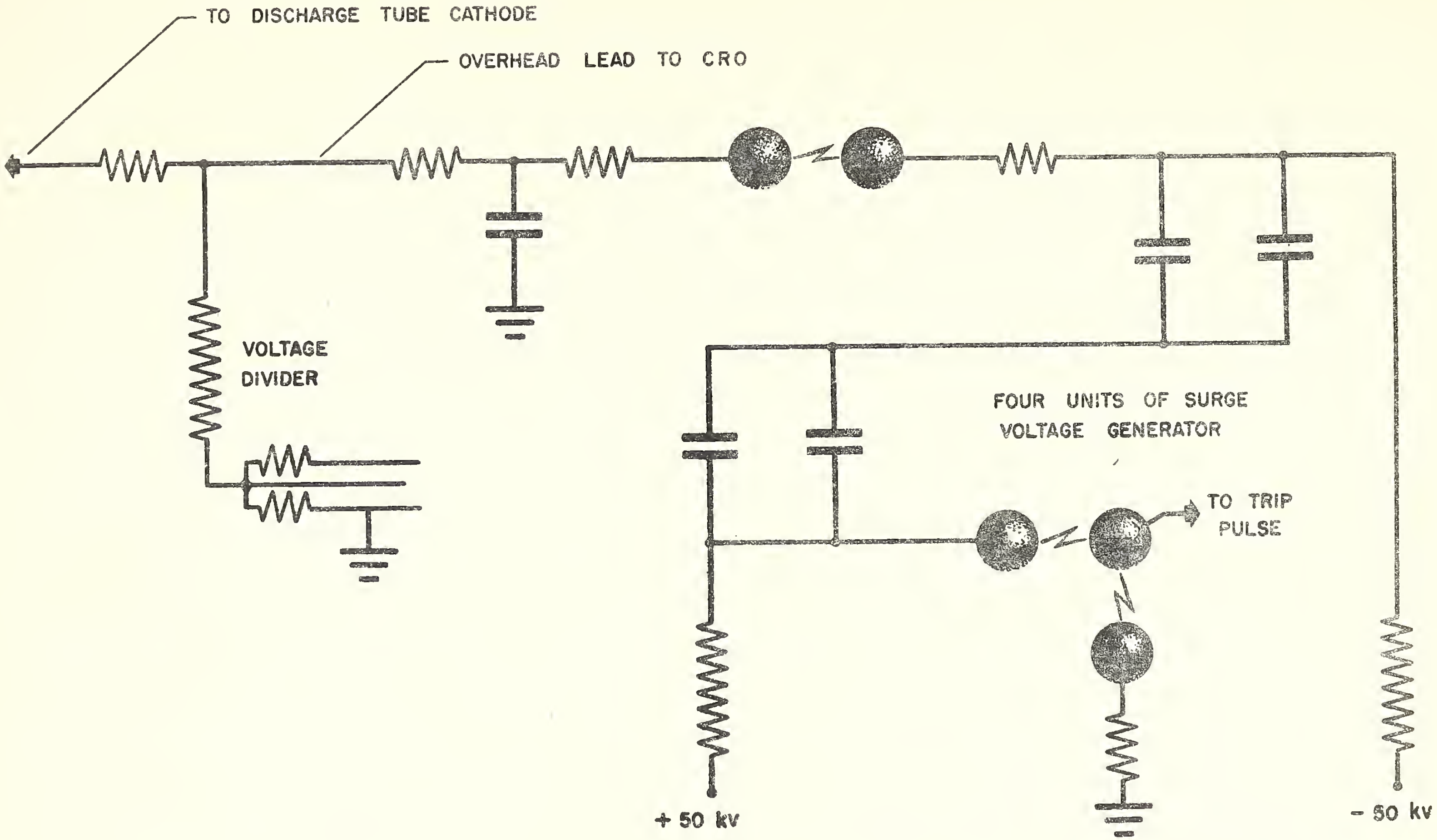

FIGURE 8 CIRCUIT USED FOR SUDDENLY APPLYING VOLTAGE TO DISCHARGE TUBE

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS