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DESIGN AND CHARACTERISTICS OF A 100 KILOVOLT HYDROGEN THYRATRON TUBE

by

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The peak forward voltage capability and other characteristics of hydrogen thyratron tubes made with a plurality of grids were investigated under operating conditions prescribed by Specification No. SCL-7001/80. The tubes which were of ceramic-metal design had to meet the following test requirements:

Peak forward anode voltage:	100 kilovolts
Peak anode current:	200 amperes
Test repetition rate:	1000 cps
Pulse width (70 percent):	1 microsecond
Average anode current:	0.2 ampere
P_b-Factor (epy x i_b x prr):	20×10^9

Principal objectives of this development were the practical feasibility of multi-grid tubes with adequate characteristics, and an understanding of the factors which basically determine their performance and possible limitations.

The requirement of a very high voltage capability made it mandatory to think of a periodic or "iterative" design which would permit in a strictly additive manner the use of as many gradient grids as needed for reliable operation. A grid structure following this principle was designed for this investigation. It was made with "short" gradient grids; that is, grids whose axial dimensions are small as compared to their diameter. With a sufficiently flat, or "planar" type grid, favorable anode take-over characteristics could be obtained which, in the first place, would depend on baffling and aperture geometry. Furthermore, good deionization and sparking voltage characteristics were expected as a consequence of small gap volume.

In a short grid structure of this kind, the seals with the ceramic envelope of the closely spaced grids are at a small distance from each other which is determined by the length of the grid and the size of the gap. Voltage breakdown between adjacent seals, both inside and outside the tube, through which high voltage operation would be greatly limited, was overcome with the design illustrated by Figure 1. As it provided an effective protection of gaps and seals, it was used without change on 30 tubes of this type which were made with three, four and six gaps and served as experimental vehicle for this investigation.

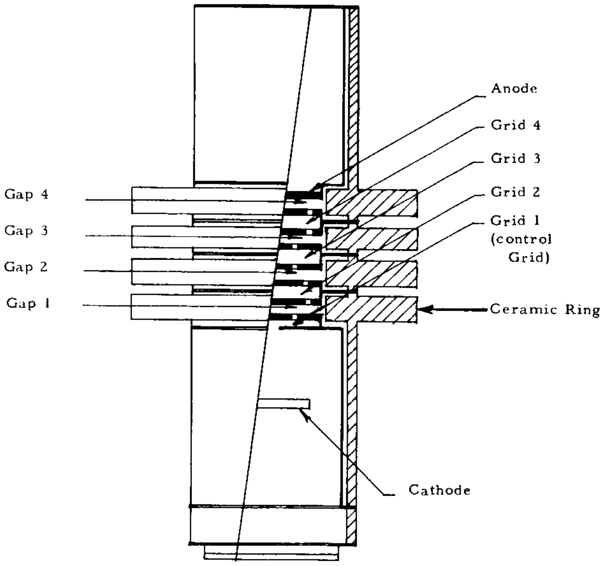

Figure 1: 100 KV - 10 KW Hydrogen Thyratron Tube. Basic design of a four-gap Tube.

The grid-envelope structure of a four-grid* tube with four gaps consists of three planar gradient grids and four ceramic envelope rings which are brazed to the grid flanges. Voltage breakdown between seals is inhibited by internal and external extensions of the rings which internally follow the grid outlines with a small clearance. Metallic deposits originating in the gaps are formed on the cylindrical surface of the extension and are prevented from forming a continuous conducting layer between seals.

For testing and evaluation of the tubes, a line-type modulator was constructed which produced the specified operating condition and had the following characteristics:

L_N = 138 microhenry

C_N = .001816 microfarad

R_N = 250 ohm

L_C = 56 henry

R_L - 220 ohm

*The control grid is included in this number which is equal to the number of gaps.

The instrumentation included a pulse transformer for viewing the current pulse, and two capacitance dividers of 1.9 uuF for the measurement of grid voltages. All components of the test set were contained in one large oil filled steel tank. A circuit diagram is shown in Figure 2. A resistance divider of 10 megohms per gap was used for stabilizing grid potentials.

The high voltage capability of this multi-grid design became immediately evident when the first three-gap tubes were tested. They aged and operated with great facility, and anode take-over characteristics were satisfactory. One of these tubes (No. 4) was life tested for 348 hours and had an uninterrupted run of 123 hours at 90 KV. However, these tests were made with a pulse repetition rate of 320 pps, and the P_b-Factor of 7.2 x 10^9 was rather low.

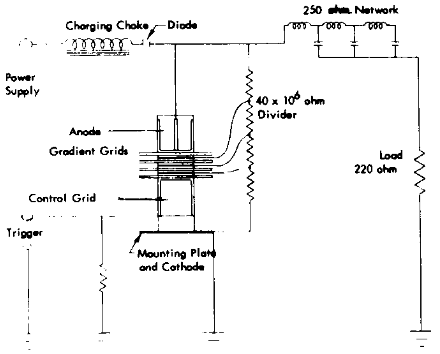

Figure 2: Circuit Diagram of the Test Modulator.

Unexpectedly short lives were experienced in the beginning when operation at the specified ratings of 100 KV, 10 KW, 1000 pps and a P_b-Factor of 20 x 10^9 was attempted. The anode plate was found to be strongly eroded at the impact areas of the discharge, and high voltage breakdown through the ceramic envelope extension at the anode gap became a typical cause of failure. These defects are illustrated by the photographs in Figures 3 and 4.

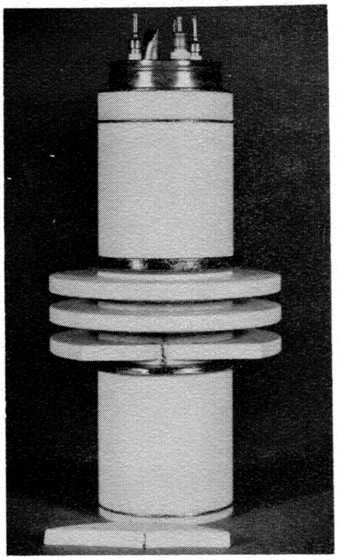

Figure 3: Three-Gap Tube damaged by voltage breakdown through the envelope ring.

Figure 4: Anode of the same tube showing deep holes at the impact areas of the discharge. Gradient grids have eight .104" dia. holes.

Anode erosion was reduced by operating the tubes under a sufficiently high gas pressure. This was not a problem as reservoir ranges were always wide and had fairly high upper limits. Range stability during life was provided by a titanium hydride reservoir containing 2.5 grams of hydride and approximately 30 liter x millimeter of hydrogen. Tube life was greatly improved in this way since the danger of voltage breakdown across the anode gap insulation was reduced at the same time. Tube lives of several hundred hours were attained.

Defocusing of the discharge at the anode plate; that is, a reduction of current density in the impact areas, was effected by substituting two slots for the eight holes normally used in the gradient grids. Erosion in the linear marks produced with this type of grid aperture was less, and a similar result was obtained by substituting tungsten for molybdenum which was commonly used.

In spite of these measures, tube life still was terminated by voltage breakdown through the ceramic envelope ring, which resulted in a leak. In most tubes this defect was caused at the external ceramic extension of the anode gap, in one tube internally, and in two other cases the gap next to the anode gap was involved or the only one affected. Improvement of this condition was attempted by avoiding high electrical field strength at the seals, and by increasing the thickness of the external extension of the envelope ring.

The voltage breakdown at the anode gap, the erosion of the anode plate, and the apparent applicability of the epy-parameter in the P_b-Factor defining dissipation at the anode, suggest that high voltage drops are formed in the anode gap during commutation. A condition of this kind is possibly indicated by the potential level of the gradient grid which is next to the anode.

Gradient grid potentials in a four gap tube made with slot type grids are shown in Figure 5. As a general rule, all grid potentials were found to be below the voltage levels established by the resistance divider. At epy = 100 KV, the voltage drop across the anode gap thus amounted to some 30 KV for slot type grids, and was still larger for the other grid type. The potentials which are determined from the scope traces are attained by the grids between pulses as the network charges up. When they break down during anode take-over, commutation voltage drops of short duration must appear in the gaps which depend on the nature and timing of the anode take-over process.

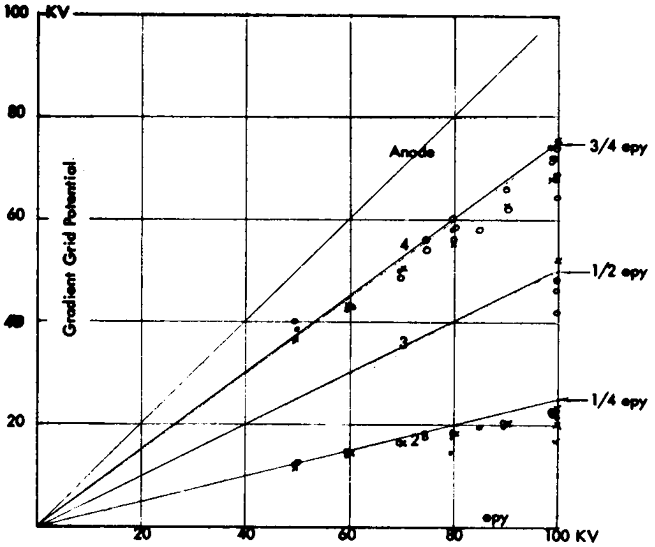

Figure 5: Gradient Grid Potentials in a Four-Gap Tube.

Anode take-over characteristics were satisfactory as take-over time was in the range of 0.2 to 0.5 microseconds and depended on epy, repetion rate, and gas pressure in the same way as in one gap tubes. Take-over change was .020 to .050 microseconds. Minimum anode take-over voltage was very low for hole type grids, and between 5 and 15 KVdc for the other type. Time jitter was somewhat above the specified maximum value, and erratic. The anode to cathode voltage drop during conduction was 150 to 175 volts in four gap tubes, and the voltage drop per gap from 20 to 25 volts.

The outstanding voltage capability demonstrated by all tubes points to good sparking voltage characteristics of the gaps which were extensively investigated. Characteristics for a three and a four gap tube are shown in Figures 6 and 7. Both tubes had identical hole type grids and had been exposed to a peak forward voltage of 100 KV for about the same length of time. Sparking potentials in three gap tubes were found to be typically higher than in four gap tubes. Since comparable gaps are identical by design, and the gaps in the three gap type are exposed to higher voltage during operation, a causative relation between sparking potential levels and gap voltage drops produced by operating the tubes seems to exist.

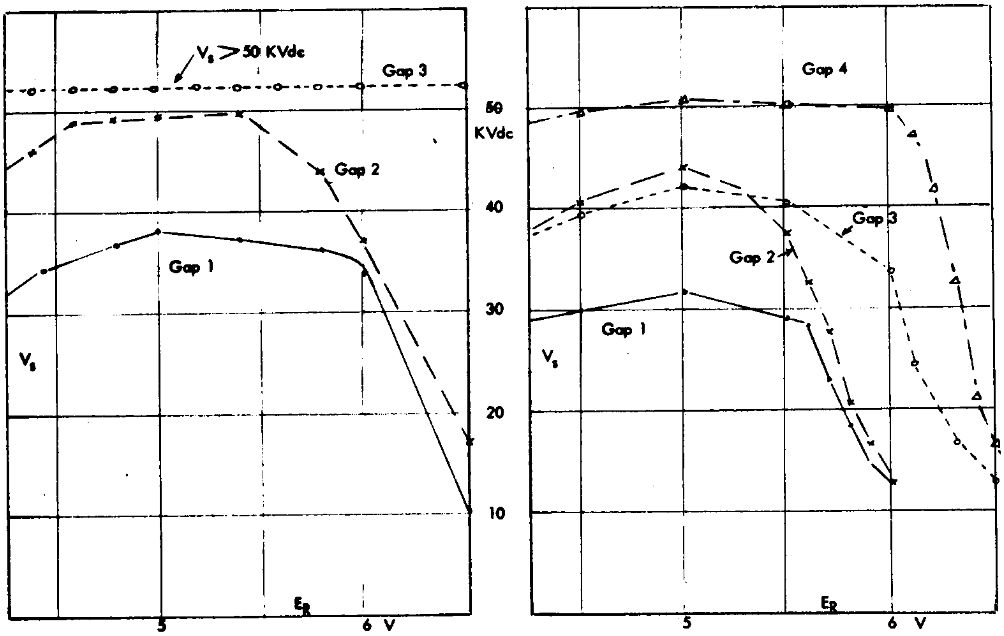

Figure 6: 3-Gap Tube.

Figure 7: 4-Gap Tube.

Sparking Voltages V_S in Three and Four Gap Tubes.

The data obtained through this investigation, incomplete as they are, lead to some conclusions regarding the factors which determine the characteristics of multi-gap tubes made with short baffled grids. The ability to operate at high voltages may be explained by the fact that the grids are connected to the voltage source through the high resistance elements of the divider, so that sparking currents in the gaps are mostly too small to affect the entire tube. Depressed gradient grid potentials are due to some conductivity existing in the gaps between pulses which can be caused by conducting deposits between seals, grid emission, or a high impedance discharge condition stemming from incomplete deionization or insufficient baffling of the grids. This condition seems to be the most likely cause since deposits and grid emission can be ruled out. Breakdown of the ceramic ring at the anode gap points to voltage drops which are higher than those existing between pulses. They are associated with the commutation process and a consequence of a successive breakdown of the gaps. Such voltage drops of short duration may also offer an explanation for the erosion of the anode plate which is at least partly due to high velocity electrons.

A peak forward voltage capability above 100 KV is indicated by this investigation. It is expected that a development beyond this voltage level will have to deal with the problems of the anode gap in the first place. Requirements on the dielectric strength of ceramic materials and on anode plate materials and design will be very high.

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