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TESTS OF COMPRESSED GEOMETRY NEC ACCELERATION TUBES

James E. Raatz, Robert D. Rathmell

National Electrostatics Corporation
Middleton, Wisconsin 53562

Paul H. Stelson, Norval F. Ziegler

Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831

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Tests have been performed in the 3 MV Pelletron test machine at NEC on a compressed geometry tube which increases the insulating length of the tube by eliminating the heated electrode assemblies (~2.5 cm thick) at the end of each tube section. Some insert electrodes are changed to provide some trapping of secondary ions. The geometry tested provided an 18% increase in live ceramic in the tube. The compressed geometry tube allowed a terminal voltage of 3.55 MV on the 3 MV column at normal gradients of 30.3 kv/tube gap. The tube was also conditioned to more than 4 MV and remained stable in voltage with few sparks and with low x-ray levels for days at about 4 MV. This same performance could be achieved with or without arc discharge cleaning.

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Introduction

This report describes a joint effort between National Electrostatics Corp. and Oak Ridge National Laboratory to evaluate a new acceleration tube configuration with tests which began at NEC on April 15, 1984.

A proposed upgrading of the ORNL 25URC accelerator would be accomplished by removing the 2.5 cm thick heater plates between acceleration tube sections and installing a 12 gap tube section every two 1 MV column units to make up the proper tube length of 122 cm for 2 units. In sections of the column which are 5 units long between dead sections, a comparable increase in insulating length of the 5th (odd) unit could be obtained by adding a 6 gap tube section to make up the correct length. This tube geometry allows the tube to be connected to the column at each tube flange although the column connecting points are different than with the standard tube. This geometry would allow an 18% increase in live ceramic or 1.18 MV at normal gradients on a 1 MV unit. The essential features of this geometry could be tested by installing 11 tube sections in the NEC 3 MV test machine as shown in fig. 1. At normal tube gradients, these 11 tube sections would support 3.55 MV.

The compressed tube geometry has been previously tested by Assmann et al. at Munich. [1] The present tests were carried out to reproduce their results, to verify that this tube worked in the Pelletron column, and to investigate the need and effects of hydrogen arc discharge cleaning [2,3], of the tube in the absence of heated electrodes. The arc discharge cleaning procedure is described in another paper presented at this conference.[4]

The "compressed geometry" acceleration tube section required specially designed insert electrodes to provide the lens effect needed for trapping ions originating from aperture plates. The 2.5 cm diameter aperture plates in this accelerating tube were made of 1 mm thick Ti which is adequate to stop electrons with energies up to 1 MeV. The insert electrode configuration is compared for the standard and compressed geometry tubes in fig. 2. Ion trajectories for this electrode configuration have been studied by the Munich group. [1] They have shown that the standard configuration traps electrons originating at aperture plates within two tube sections while the compressed geometry allows such electrons to travel three tube sections.

Experiment

The acceleration tube sections were either new or recently reconditioned prior to the test. The acceleration tube was installed, evacuated for 60 hours to a level of 5.5×10^{-7} Torr, but was not baked. This tube showed conditioning in a pulsed x-ray mode without significant loading effects caused by intense steady x-ray levels, as detected by a sodium iodide detector which was set up to count x-rays between the energies of 30 keV and 600 keV. Steady x-ray levels during this period were generally less than 3000 cps. As shown in fig. 3, the voltage rose to 3.8 MV within 32 hours. Further conditioning was delayed while a sparking problem in the column was located.

After this problem was repaired the voltage on the tube was increased to 4.1 MV within a 48 hour period at which point the voltage may have been limited by the column insulation, but this was not verified. Voltage was turned off for 48 hours. When voltage was applied again it indicated no change in the conditioning state of the tube up to 4 MV. There were no sparks or change in x-ray levels.

At this time it was decided to proceed with the hydrogen discharge. The arc discharge power supply connections to the column are shown in fig. 4. The tube was let up to atmospheric pressure for installation of a new cathode filament. The arc discharge was then carried out with 4 amps current at 50 volts per tube section for 2 hours at 7.6 Pa H_2 pressure. Voltage conditioning was started about 3 hours after the arc discharge was completed. After 3 hours of conditioning and less than 10 sparks to zero a voltage of 3.65 MV was reached. The radiation level between 2.8 and 3.65 MV ranged from 8000 to 70,000 cps. After a total of 20 hours (sitting at 3.6 MV overnight) voltage was increased to 4.15 MV and radiation had dropped to ~1.5 k cps at 3.9 MV and the x-rays were pulsed rather than continuous.

A second discharge was run at 50 Volts per tube section at 4.5 Amp for 4 hours at 10 Pa H_2 pressure. Voltage was applied 15 hours later. As shown in fig. 3, the voltage rose to 4 MV after 5 hours and 75 sparks with radiation levels of 3 - 50 k cps.

The tube was allowed to condition at or near 4 MV for an additional 18 hours and radiation had dropped to 300 cps. Voltage held 4.0 MV for 4 days with a total of 10 discharges. The x-ray level remained at a few hundred counts per second over this period.

All accelerator tubes were removed from the accelerator and disassembled. All tubes were measured for resistance and found to have greater than 500,000 megohms across 12 mm insulating gaps. Visual observation indicated that there was sputtering onto the ceramic as evidenced by a very light gray shading spread uniformly over the ceramics. There were numerous spark marks near the aluminum bond fillet, but no corresponding dark tracks of material sputtered across the ceramic. There was no discoloration of the tube electrodes; however, the 2.5 cm aperture plates in some cases bowed as much as 1.5 mm from the plane presumably because thermal expansion was confined at each end of the plate where it was supported by an annular ring. This will be corrected by allowing for expansion in future designs.

Conclusion

These tests and those at Munich [1] confirm that the compressed geometry tube causes no apparent degradation of the gradient which individual ceramics can support so that one can hope to see the ultimate accelerator voltage increase in proportion to the increase in live ceramic. In the case tested here, an 18% increase in live ceramic was obtained. At the normal gradient of 30.3 kV/gap on NEC tubes this allows the average column gradient to be increased from 1.64 MV/m to 1.94 MV/m. Gradients as high as 2.3 MV/m were sustained in these tests.

The upper voltage limit was the same with arc discharge cleaning as it was without it. It may be that conditioning time is shortened by arc discharge cleaning, but this experiment was not a good test of that hypothesis since the tube had been conditioned to full gradient once before the arc discharge process was used. In contrast to the Munich results, we observed that some conditioning was required after the arc cleaning was performed. This conditioning was manifested by continuous x-ray activity which decreased in time at a given voltage level and by sparks. There was little or no pulsed x-ray or vacuum activity during conditioning.

Although the trapping of particles originating from tube apertures is less efficient than the standard design, the trapping appears to be adequate. There is no evidence of ion or electron loading in the tube and it sits stably at high gradient with no radiation after conditioning.

References

1) W. Assmann, G. Korschinek, H. Munzer, Nuclear Instruments and Methods, 220 (1984) 86.

2) A. Isoya et al., Proc. 3rd International Conference on Electrostatics Accelerator Technology, Oak Ridge (IEEE Press. New York 1981) 98

3) G. Korschinek et al., Nuclear Instruments and Methods, 220 (1984) 82

4) P. H. Stelson, J. E. Raatz, R. D. Rathmell, Proc. of 4th International Conference of Electrostatic Accelerator Technology and Associated Boosters, Buenos Aires (1985).

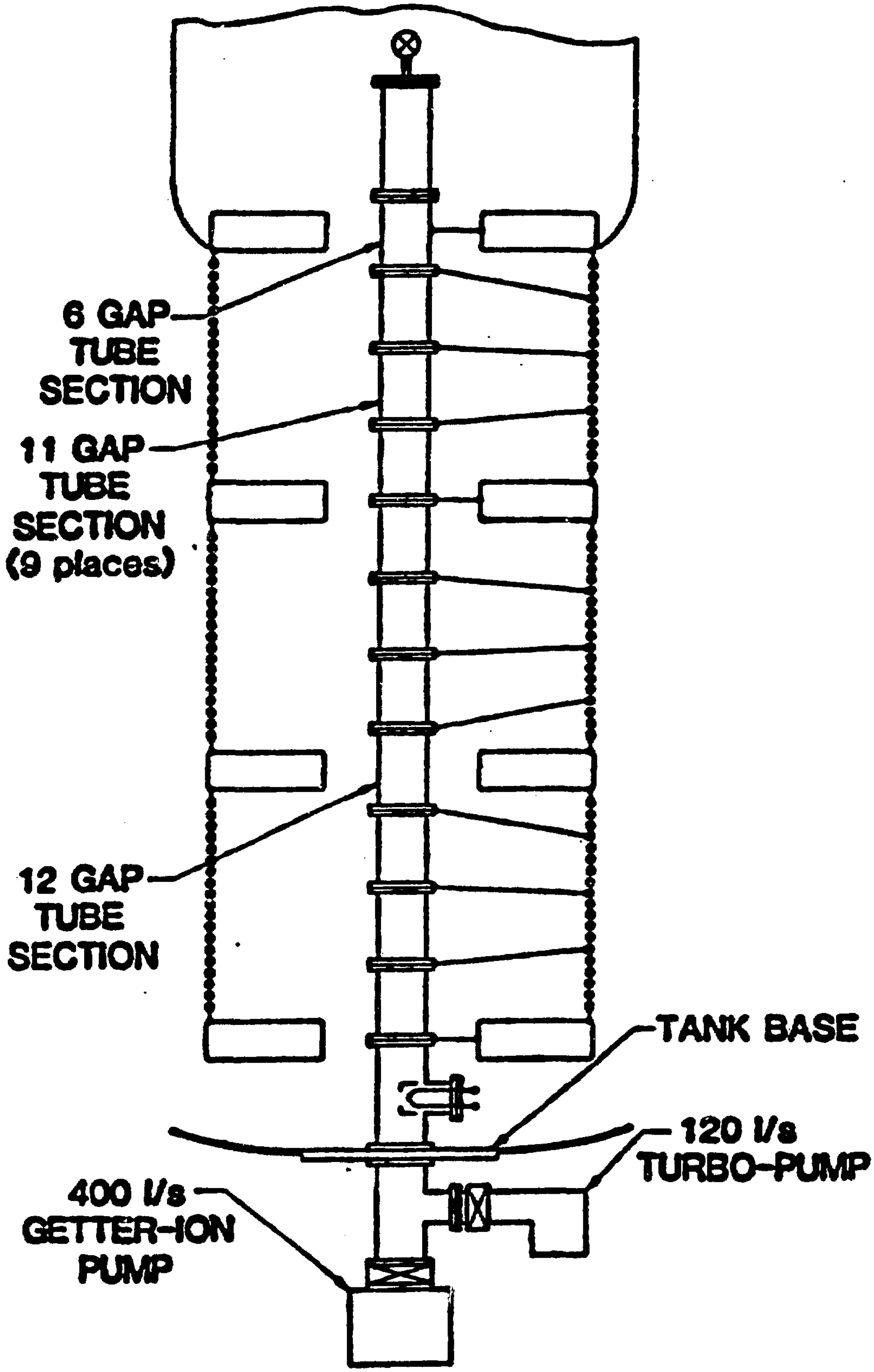
Figure Captions

Figure 1: The compressed geometry tube installed in the 3 MV column of the NEC test machine.

Figure 2: A comparison of internal electrode configurations for the standard tube with heated electrode assemblies (a) to the compressed geometry tube (b).

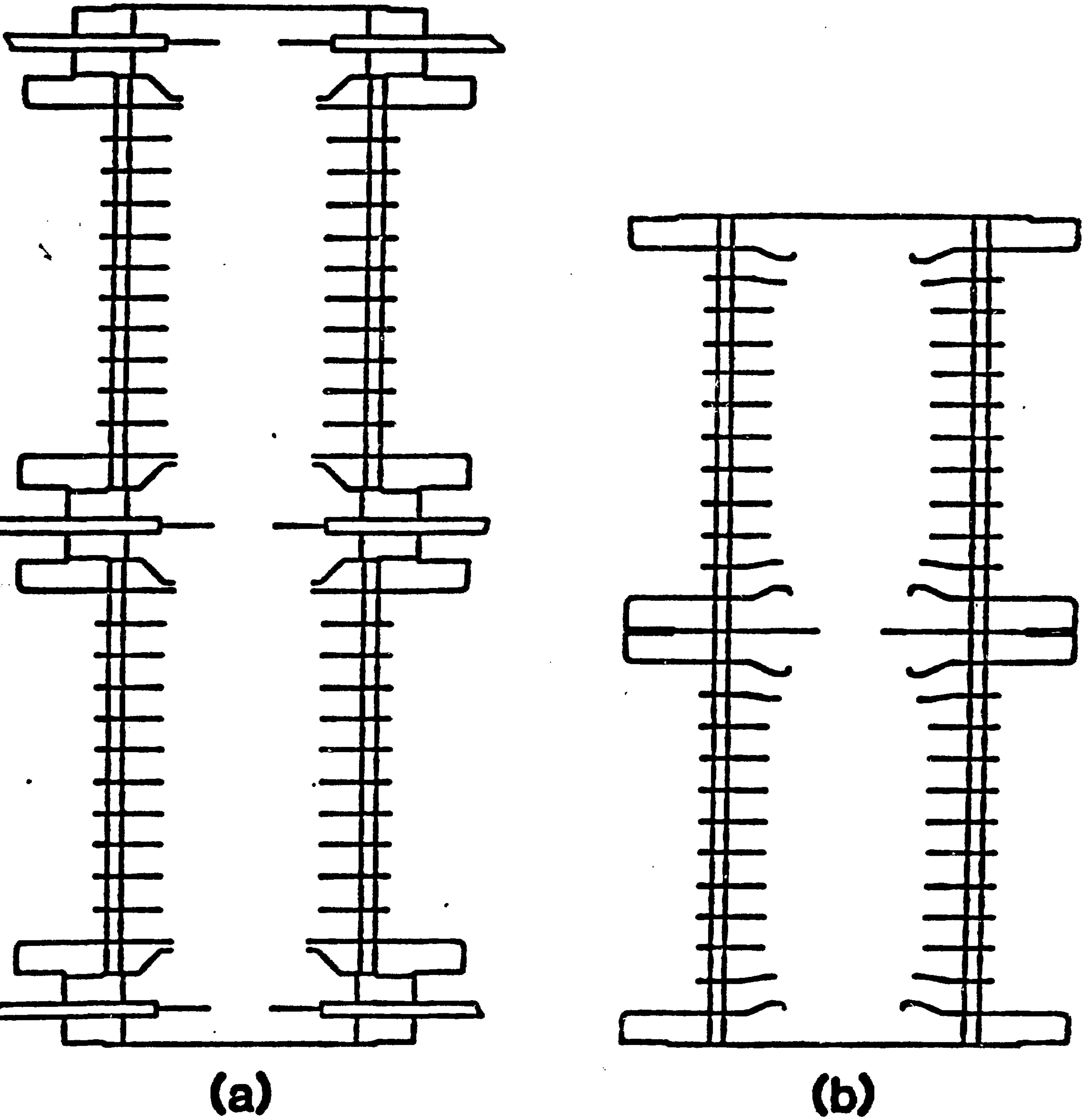
Figure 3: Conditioning voltage versus time for the initial conditioning before the arc discharge and that after the second arc discharge procedure.

Figure 4: Power supply and resistor connections to the column during hydrogen arc cleaning. The power supplies were current regulated supplies from Electronic Measurements Inc. rated at 5A, 250VDC.



6 GAP
TUBE
SECTION
11 GAP
TUBE
SECTION
(9 places)
12 GAP
TUBE
SECTION
TANK BASE
120 l/s
TURBO-PUMP
400 l/s
GETTER-ION
PUMP

Fig. 1



(a) (b)

Fig.2

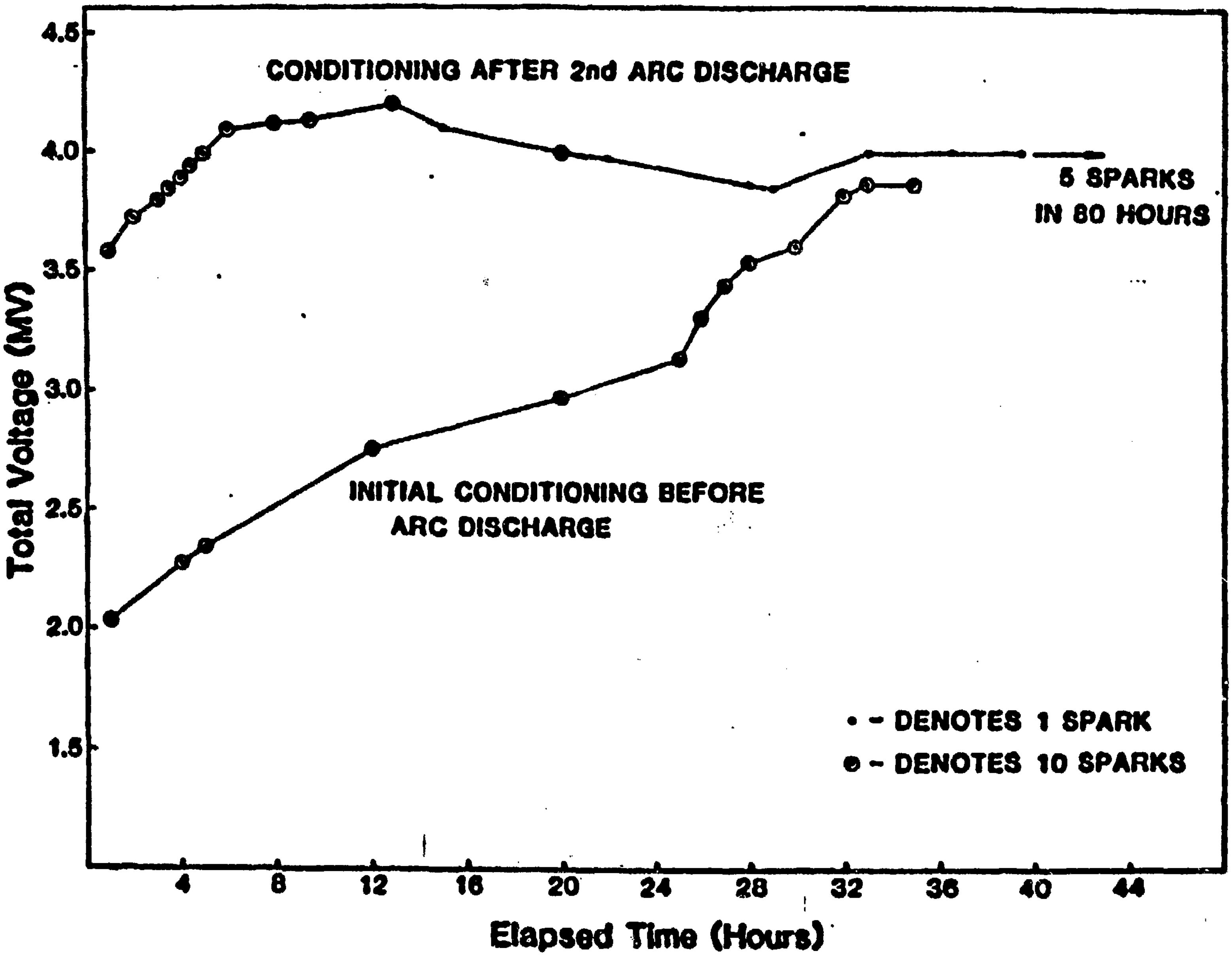
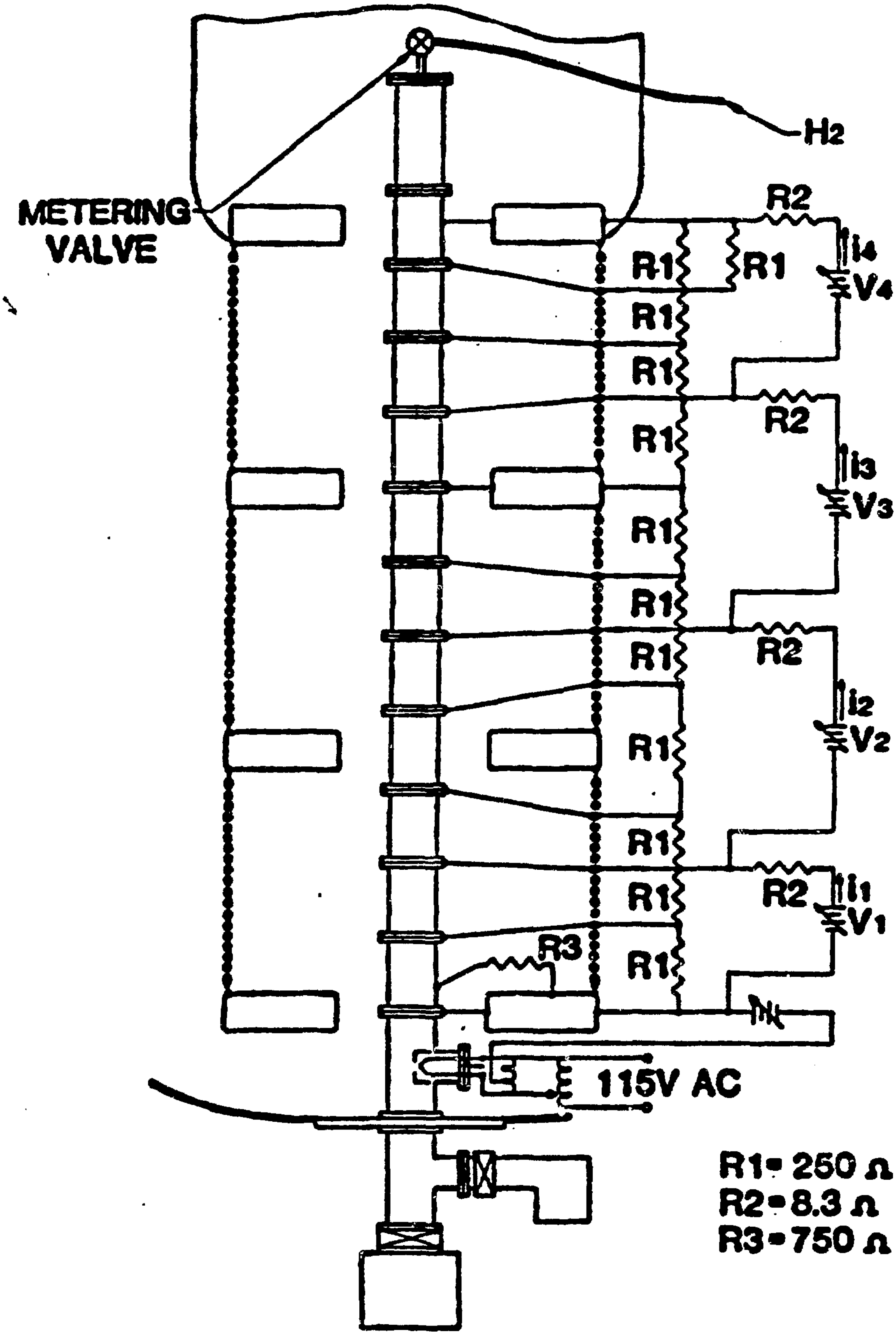

CONDITIONING AFTER 2nd ARC DISCHARGE
5 SPARKS
IN 80 HOURS
INITIAL CONDITIONING BEFORE
ARC DISCHARGE
• - DENOTES 1 SPARK
⊙ - DENOTES 10 SPARKS
Total Voltage (MV)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
4
8
12
16
20
24
28
32
36
40
44
Elapsed Time (Hours)

Fig. 3



METERING VALVE
H2
R2
R1
R1
i4
V4
i3
V3
i2
V2
i1
V1
R3
115V AC
R1= 250 Ω
R2= 8.3 Ω
R3= 750 Ω

Fig. 4