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ARC DISCHARGE CONDITIONING TEST ON THE OAK RIDGE 25URC ACCELERATOR*

N. F. Ziegler, P. H. Stelson, C. M. Jones

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

J. E. Raatz

National Electrostatics Corporation
Middleton, Wisconsin 53562

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A hydrogen arc discharge has been run in the top five units (fifteen 20 cm tube sections) of the ORNL tandem accelerator to test the effectiveness of this method of cleaning the high voltage electrodes. The discharge was maintained in both the high- and low-energy tubes for a period of six hours. The arc current in each tube was 4.0 A and the hydrogen pressure was nominally 100 mTorr.

The arc discharge does not appear to have significantly affected the operating voltage of the top five units of the accelerator. However, the voltage conditioning behavior of the tested units is markedly different.

Introduction

In December 1984, a test of the hydrogen arc discharge cleaning technique was performed on the accelerating tubes of the top five units of the 25 URC accelerator in Oak Ridge. This test was motivated by our desire to evaluate this technique as a possible way to improve the performance of

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our present acceleration tubes and as a method which might be used in cleaning the compressed geometry tubes[1] which we plan to install in the accelerator in several years.

Arc discharge cleaning of accelerator tubes was first attempted by Isoya et al.[2] of Kyushu University, Japan, and has been tested in several other accelerators[3,4,5,6] with varying degrees of success. Results achieved in small accelerators have been encouraging, but in larger machines, the results have not been as conclusive.

The 25URC Accelerator

The 25URC accelerator[7] was constructed by National Electrostatics Corporation and installed in 1979. The column is composed of 27 active units with a modulus of 0.61 m and five dead sections. (Each active unit is composed of six 20 cm tube sections.) Two major dead sections divide the column into thirds while three minor dead sections are spaced four units above the column base and major dead sections. Every dead section contains two ion pumps and a CAMAC controller.

Arc Discharge Test

Prior to the arc discharge test, the top five units (Numbers 23 - 27) were conditioned to the highest possible gradient which could be achieved in a period of three days. Following this, the insulating gas was removed from the tank and the accelerating tubes were let up to dry nitrogen. Filaments for electron emission were then installed in the minor dead sections in both tubes. A source of electrons is required to reduce the

cathode drop in the first tube section and prevent tube damage.[3] After the filaments were installed, the tubes were evacuated and pumped for about ten days. During this time the tubes were checked for air leakage and a pressure of about 10^{-8} Torr achieved.

The arrangement of equipment for the arc discharge test is shown schematically in Figs. 1 and 2. Considerable effort was devoted to preventing air leakage into the system during the discharge. The hydrogen line up to the leak valve was maintained at a positive pressure, and the small volume between the leak valve and shut-off valve in D-4 was leak checked prior to opening the leak valve. Hydrogen gas was admitted to the tube, as indicated in Fig. 1, in the major dead section, D-4, which is located four units below the "ground" end of the discharge in minor dead section, D-5. During the discharge, the accelerator terminal potential was maintained at about 1000 volts relative to ground, thus an insulating transformer was required for operation of the turbo-pump and pressure indicators.

The electrical circuit for the arc discharge is shown in Fig. 2. The power supplies for the discharge (V_{23} through V_2, and V_B) were each rated 300 volts, DC, at 6 amperes. Operation in either constant voltage or constant current mode could be selected, but the constant current mode proved most stable for the test. Use of multiple power supplies rather than one 1500 volt, 6A, supply was originally dictated by the availability of the smaller units. An unexpected advantage may accrue from the use of multiple supplies, however, since the power available to the arc in any one accelerator unit is limited to that from a single supply. The disadvantage

measured. Most gaps measured greater than 10^{12} ohms. Seven gaps in Unit 23 exhibited resistance between 10^{11} and 10^{12} ohms and one gap in Unit 25 measured 1.3×10^{10} ohms, so apparently there was little, or no, sputtering during the discharge.

When the arc discharge was attempted in the high-energy tube, the filament failed after about an hour resulting in a delay of several days while the tube was let up to atmosphere, the filament replaced and the tube again evacuated. When the arc discharge was finally run in the high-energy tube, the operating conditions were essentially the same as used in the low-energy tube except that the hydrogen pressures were 260 mTorr inlet and 150 mTorr outlet. The voltage drop across individual tube sections was recorded at intervals during the discharge; and these data are presented graphically in Fig. 3.

Test Results

The arc discharge test was performed during a scheduled maintenance period for the 25URC accelerator. During this period the terminal gas stripper leak valve was repaired. Following the arc discharge the gas stripper system was tested. The leak valve, which was thought to be closed, flooded the vacuum system with nitrogen to a pressure of about 600 Torr. The rapid gas flow blew titanium dust from the sublimator pump into the foil changer just above the top of the low-energy tube and, very likely, into the tube itself. This possibility was initially viewed with consternation, but it now appears to have had little, if any, effect on accelerator performance. The vacuum accident has, however, cast doubt on the results achieved by the arc discharge.

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Following the scheduled maintenance period, the accelerator tank was pressurized in January 1985, and a preliminary check of tube conditioning was made. In February, a more detailed conditioning test was completed, and the results are compared with pre-discharge data in Fig. 4. In the post-discharge conditioning test, units were conditioned both singly and in adjacent pairs. Unfortunately, data for conditioning of single units was not obtained before the discharge, so a comparison cannot be made. Conditioning of unit pairs indicates that the arc discharge process did not improve the voltage limit of the tubes and, in fact, reduced the voltage limit slightly.

As shown in Fig. 5, a striking difference was noted in the pre- and post-discharge conditioning behavior of the acceleration tubes. Prior to the discharge, the tubes exhibited a typical conditioning pattern for the 25 URC accelerator. This pattern has two features. The first is a "continuous" X ray, thought to be associated with field emission, which is strongly but smoothly gradient dependent. At constant gradient, the continuous X rays may change abruptly in response to a spark. The second feature is characterized by pulsed X rays and vacuum bursts which have a sharp gradient threshold which increases with time, i.e. which "conditions" upward as the gradient is slowly increased. This feature is thought to be the familiar microdischarge phenomena resulting from positive-negative ion exchange.

The conditioning behavior of the acceleration tubes after arc-discharge cleaning has not been previously observed in the 25 URC accelerator. Both the continuous, time-independent X ray and pulsed X rays are absent. Instead, we observe continuous X ray production, with correspnding vacuum activity, which responds strongly to gradient increases and then quickly conditions away if gradient is held fixed. (The data shown in Fig. 5 were recorded for increasing gradient.)

The maximum stable indicated voltage for the top five units of the accelerator prior to the arc discharge test was 4.5 MV. After the test, this voltage was 4.45 MV or 1% less; hardly a conclusive result. Again, though, this could be a result of the vacuum accident. In light of this and the marked difference of conditioning behavior, another test of arc discharge cleaning is planned for the 25 URC accelerator in the near future.

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Figure Captions

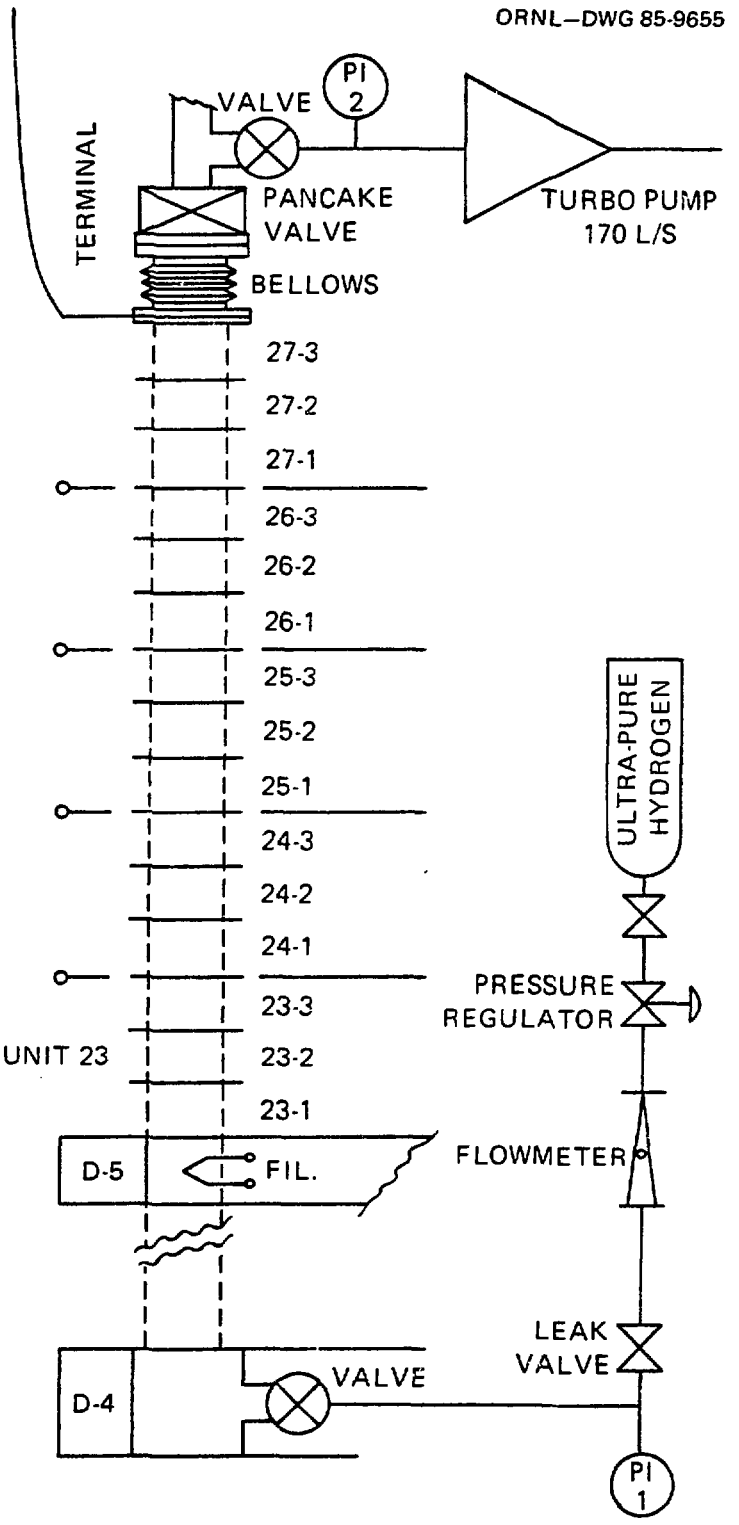
Fig. 1. Gas Flow Schematic for Arc Discharge Test.

Fig. 2. Electrical Circuit for Arc Discharge Test.

Fig. 3. Arc Voltage Across High-Energy Tube Sections.

Fig. 4. Comparison of Conditioned Units.

Fig. 5. Tube Conditioning Activity.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UNIT 23
D-5
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PRESSURE REGULATOR
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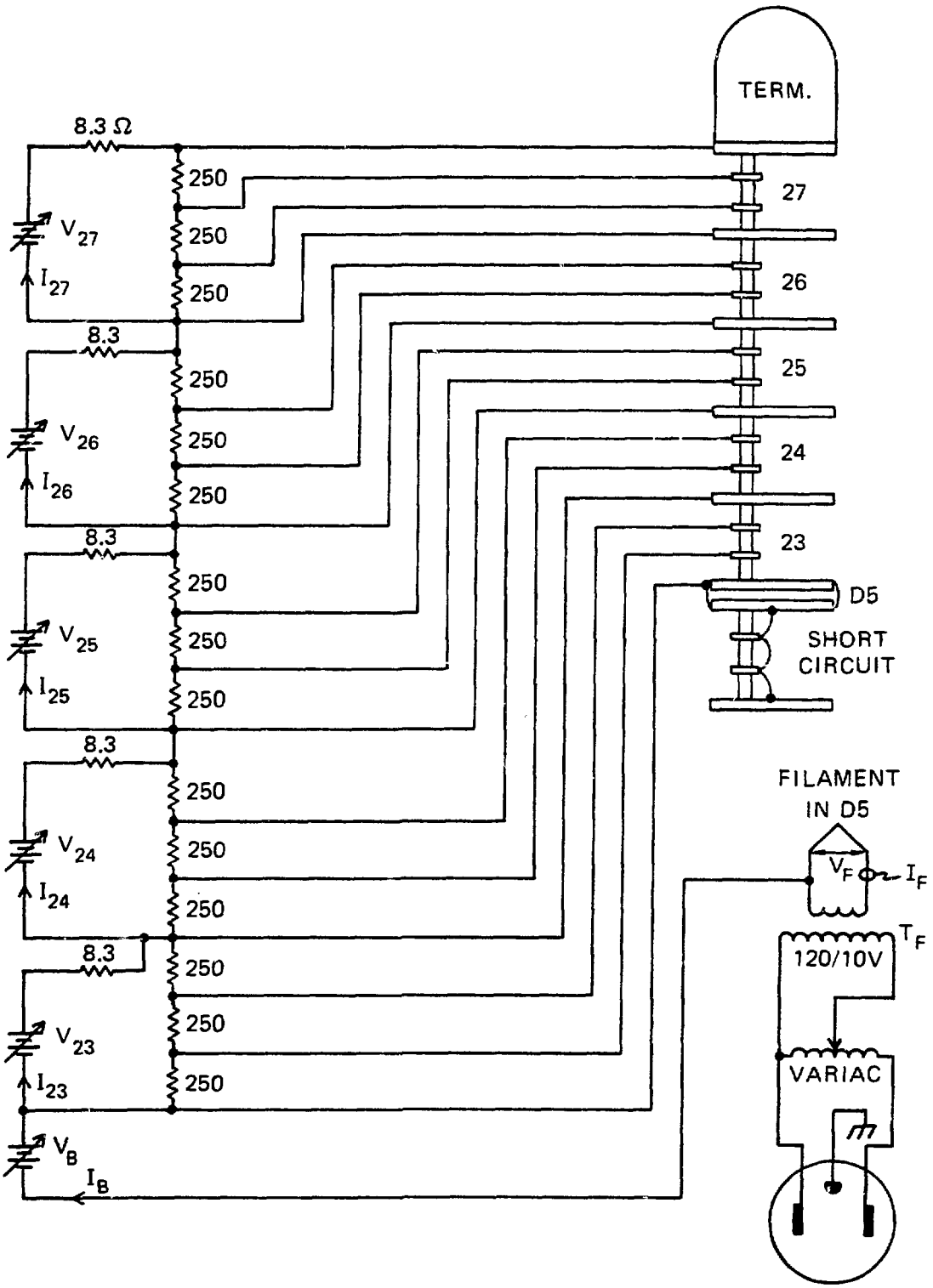

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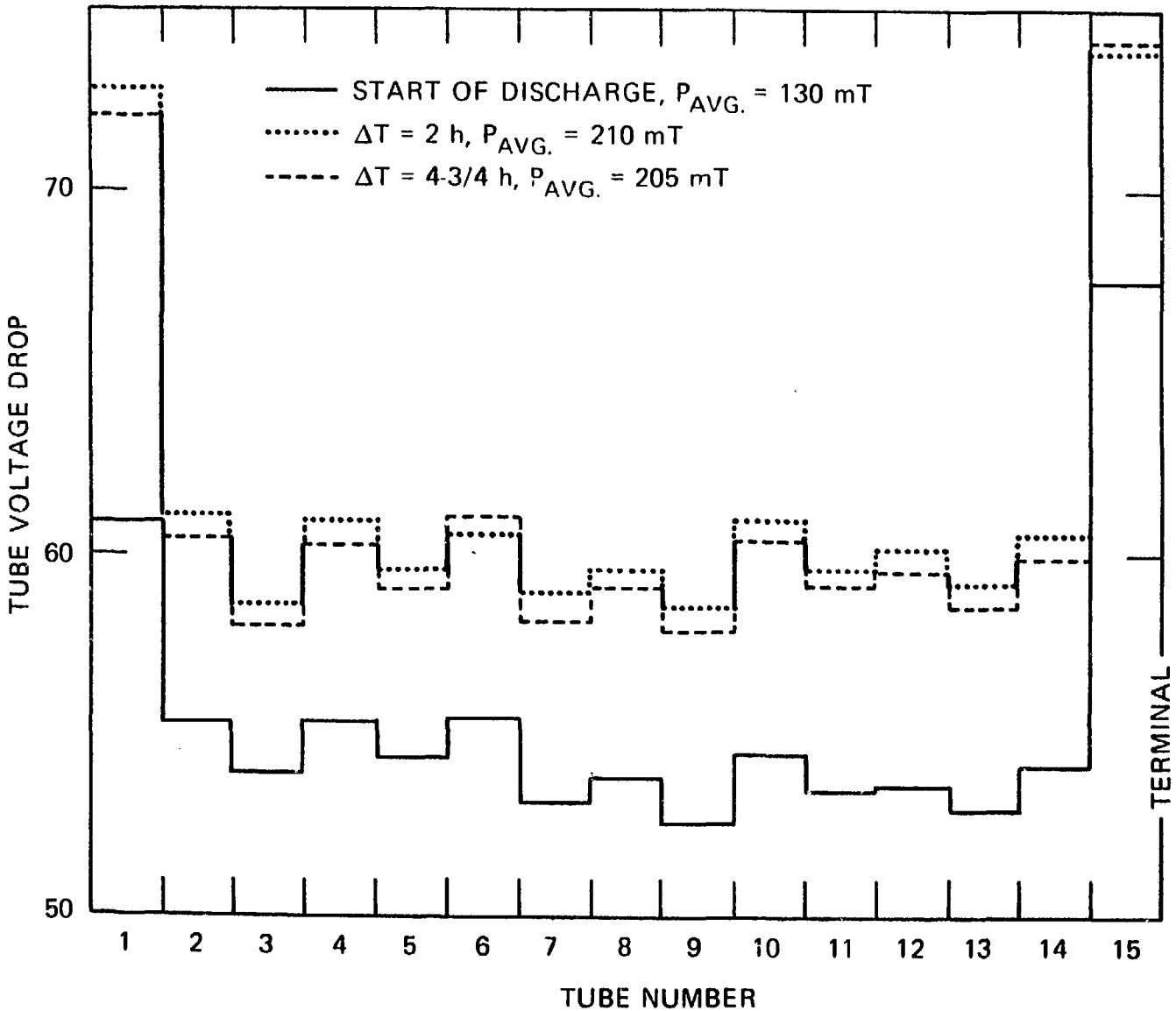

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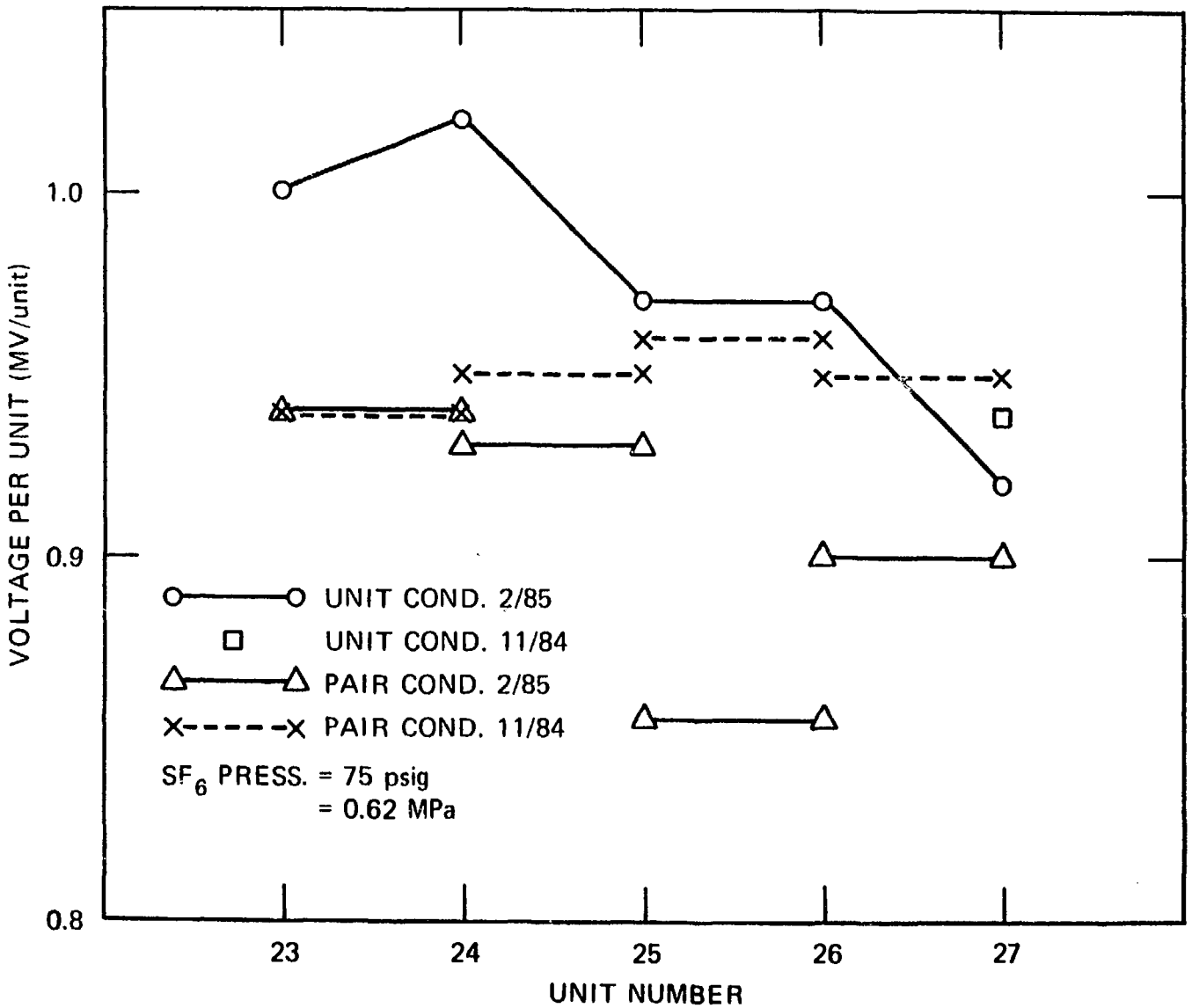

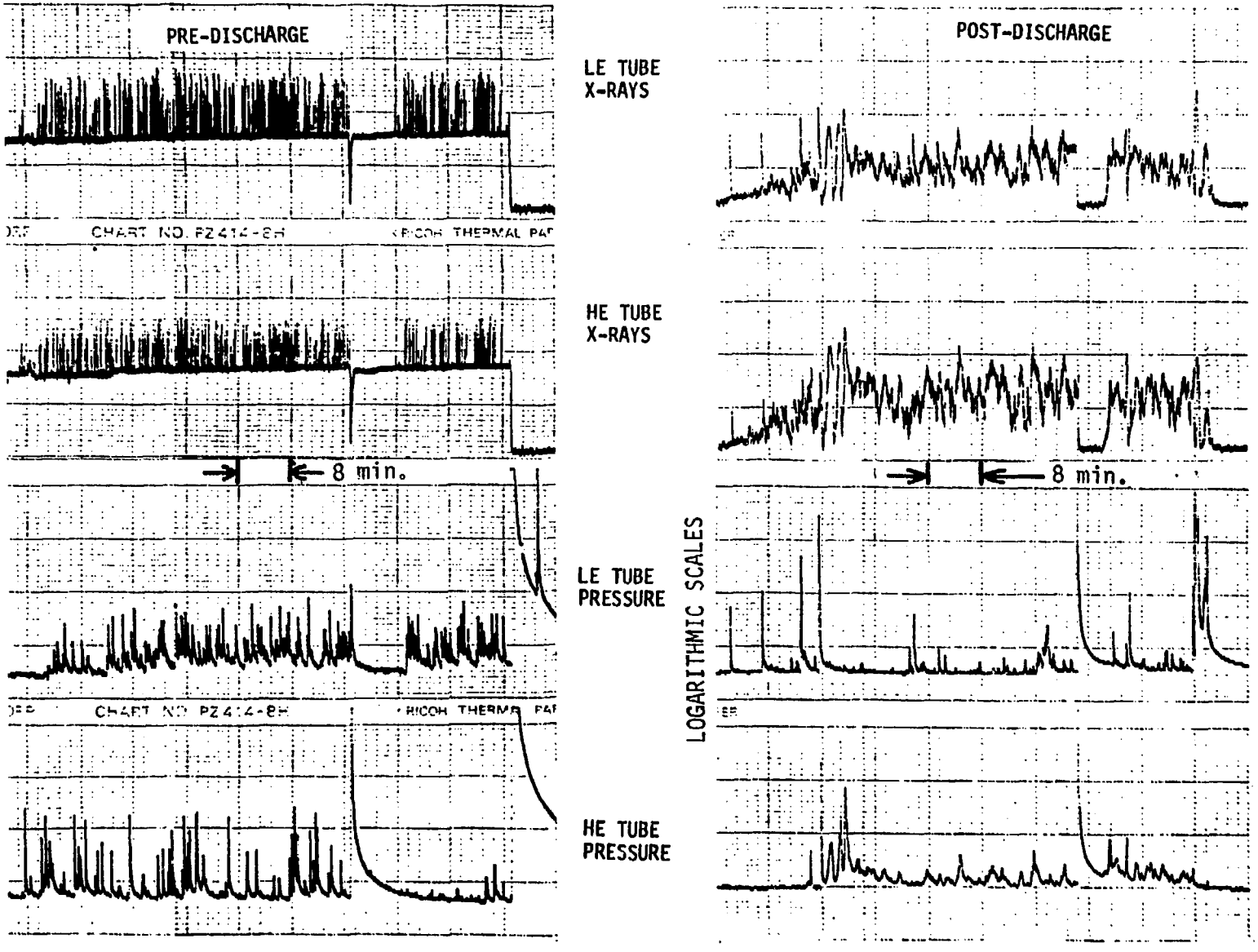
PRE-DISCHARGE
POST-DISCHARGE
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