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Publication Date
1968-04-30

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April 30, 1968

Berkeley, California

To be presented at
Third International Symposium
on Discharges and Electrical
Insulation in Vacuum
Paris, September 16-18, 1968

UCRL-18218
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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ABSTRACT

Four glass cathode parallel-plate velocity spectrometers have been used in secondary beam particle research since 1965. Two of these units have 10-foot-long and two have 15-foot-long electrodes. All units have 12-inch-wide electrodes. One additional unit of each length has just been completed and will be in use by the date of this publication. These units operate at up to 625 kV for many months without appreciable maintenance. On occasion the same unit has been used in several experiments with a total "in use" time of 6 to 8 months. Initial voltage conditioning is at $\sim 5 \times 10^{-6}$ torr. Above about 350 kV the vacuum is reduced to about 1 micron by a controlled argon leak into the chamber. Total conditioning time is usually less than 24 hours. About every 3 months a high-vacuum ($\sim 5 \times 10^{-6}$ torr) low-voltage reconditioning of about 6 hours is required.

Current consumption, including power supply, is approximately < 150 μA on each electrode (<300 μA total). The units are not gap sensitive. The operating conditions are the same for electrode gaps between 2 and 4 inches.

Glass temperatures are maintained at about 105°C, thereby reducing volume resistivity to between 4×10^{8} and 1.5×10^{10} Ω cm. This elevated temperature appears to retard the collection of hydrocarbons that can cause breakdown.

Introduction

The Lawrence Radiation Laboratory spectrometers consist of long narrow electrodes that are charged oppositely with respect to ground. A low-order magnetic field is used across the plates throughout the length of the electrodes. A secondary beam of charged particles passes lengthwise between the plates. Adjustment of the cross electric and magnetic fields is used to select, by null deflection, charged particles of the desired velocity.

Two models of spectrometers are in use at LRL (3 remodeled in 1961 and 6 built since 1964). Both models use channel-shaped glass cathodes and stainless steel anodes. The principal differences in the two models are in the clearance, shape, and location of components and in the electrode support insulators. The earlier models (2-10 feet and 1-20 feet) are voltage limited at about 425-450 kV. The later design units (2-10 feet and 2-15 feet) have been operating at 600-625 kV for the past 3 years (duty factor 50-75%). (Two additional units of identical design have just been fabricated and are being put into service.)

*Work sponsored by the U. S. Atomic Energy Commission.

The following primarily concerns operation of the four higher-voltage units.

Description

The six spectrometers now in use at LRL are briefly described below. More detailed information on the first two units of this type (MKV) is published in IEEE Transactions.[1]

The electrodes are mounted parallel inside a vacuum tank, 2.5 feet square by 10 or 15 feet long (Figs. 1 and 2). The magnet coils are wound on the aluminum vacuum tank. The steel magnet pole pieces on the sides of the tank also serve as cover plates for the large rectangular access openings. Return-path steel plates cover the coils on the top and bottom of the tank. The cathode and anode are 10 or 15 feet long by 1 foot wide on the flat. The electrode mountings are designed to permit cathode and anode position to be reversed from that shown in Fig. 2. Electrode gap is adjustable, with a maximum of 4 inches. Stainless steel, diverging electrode extensions are mounted on each end of the electrodes; the high-voltage lead-in connects to these extensions at one end of the electrodes. The extensions are duplicated at the opposite end to reduce aberrations. A polished stainless steel liner between the electrodes and the vacuum tank wall serves the dual purpose of a ground plane and a heat shield. Input to the heaters is about 1250 W. The vacuum system consists of a 6-inch oil diffusion pump with an optically dense chevron-type LN trap.

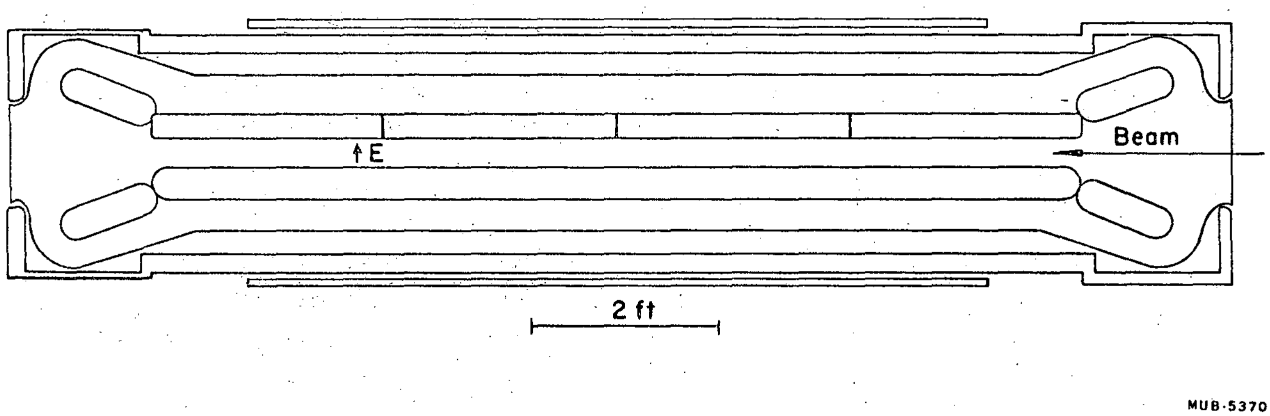

Fig. 1. Elevation view of vacuum tank.

Operation

The operating technique is basically the same for the two types of separators in use. The earlier models require more care in conditioning and operating.

Briefly the initial high voltage conditioning is as follows:

1. During the evacuation of the vacuum chamber (to ~ 5×10^{-6} torr) the glass cathode plates are heated to ~ 105°C.[2,3]

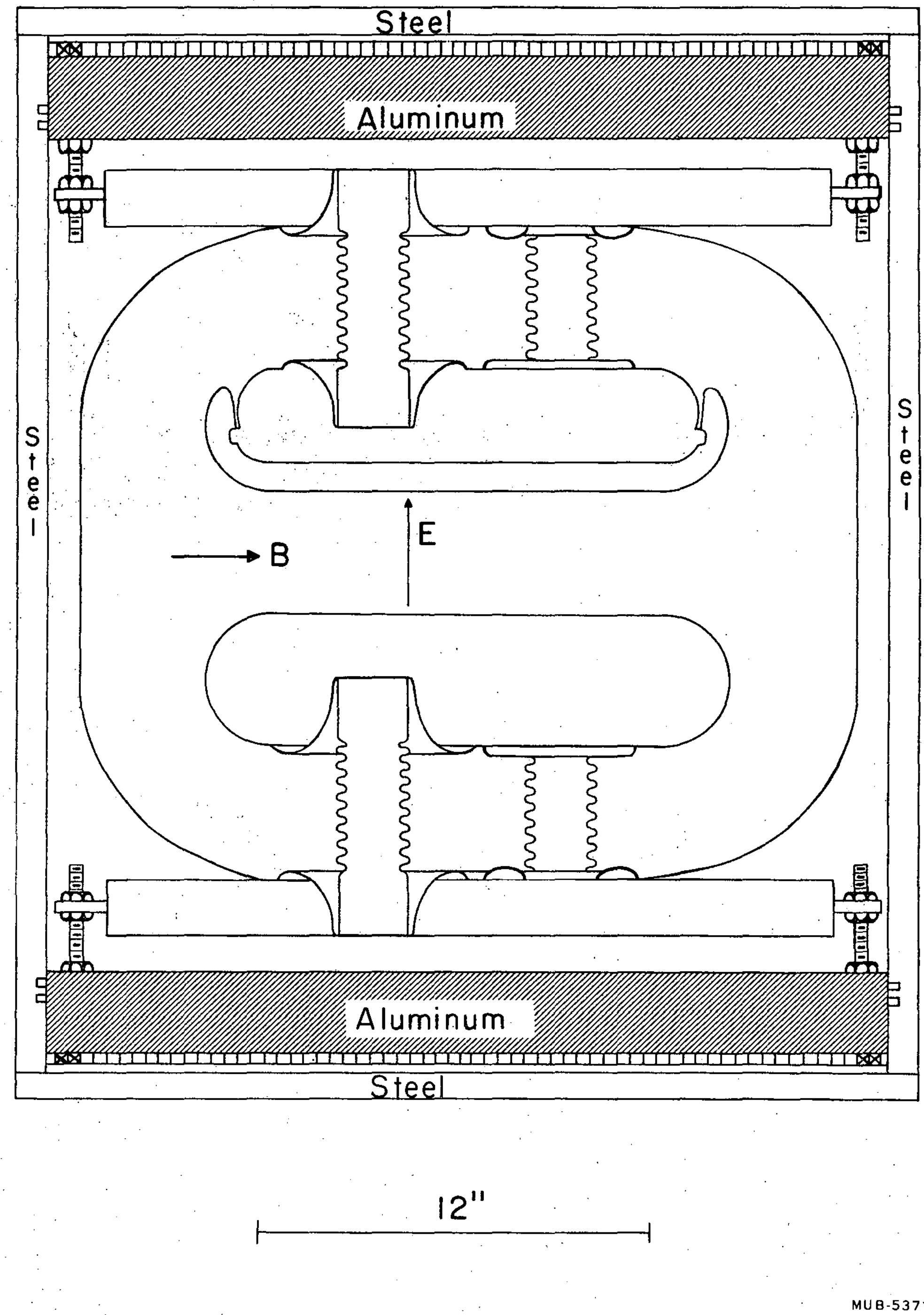

Fig. 2. Cross section of separator.

2. High voltage is applied to each electrode separately. When the current is stabilized and the voltage reaches 170 kV the voltage is reduced to 25 kV. The opposite polarity plate is then conditioned in the same manner. Current drain is 200 μA or less on a plate in a clean system.

3. The current is never allowed to exceed 300 μA on the electrode during conditioning. About 110 μA of the drain is due to the meter stick readout in the power supply.

4. The vacuum is never allowed to fall below ~ 4 x 10^{-5} torr during initial conditioning.

5. After both plates have been individually conditioned, the voltage is then applied to both simultaneously up to 170 kV on each plate. When the drain is steady at < 150 μA on each plate this phase of conditioning is complete.

6. A micro-leak of argon is then bled into the tank, reducing the vacuum to ~ 1 micron.

7. Each plate is then brought up to half of the maximum operating voltage. Current drain will drop to between 110 and 140 μA per electrode.

8. Voltage is then applied simultaneously to both electrodes up to full operating voltage.

9. After the physics research experimenters have been instructed in the operating procedure[4] they take over the operation of the spectrometer during the course of their experiment. If trouble arises or the experiment is interrupted for an extended period, the Bevatron operator takes over.

Observations

Several factors appear to contribute significantly to the operation, namely:

1. Four inch diameters are used extensively in the units. The edges of the electrodes are basically 4 inches in diameter. The high-voltage connector between the high-voltage feed-through and the electrodes consists of a 4-inch diameter stainless steel tube with a spherical end where it connects to the electrode.

2. A 4-inch clearance is used wherever possible between parts carrying high voltage and the ground plane. This clearance is maintained in the high-voltage feed-through. Coved corners are used on the stainless steel liner surrounding the electrodes in the main vacuum tank. Sharp edges of the liner are avoided. One-eighth-inch radii are used on the edges of the liner sheets wherever they are exposed to the high-voltage electrodes.

3. Electrode support insulators (Fig. 3) with copper ends, hard-soldered to them, have proven maintenance free. After 3 years of operation, only one or two individual insulators have been replaced because of failure. They are made of 99% alumina. The intimate electrical connection between the ceramic and the metal ends definitely appears to be an advantage as it distributes the electrical stress uniformly around the periphery of the insulator. Earlier model spectrometers used insulators that had

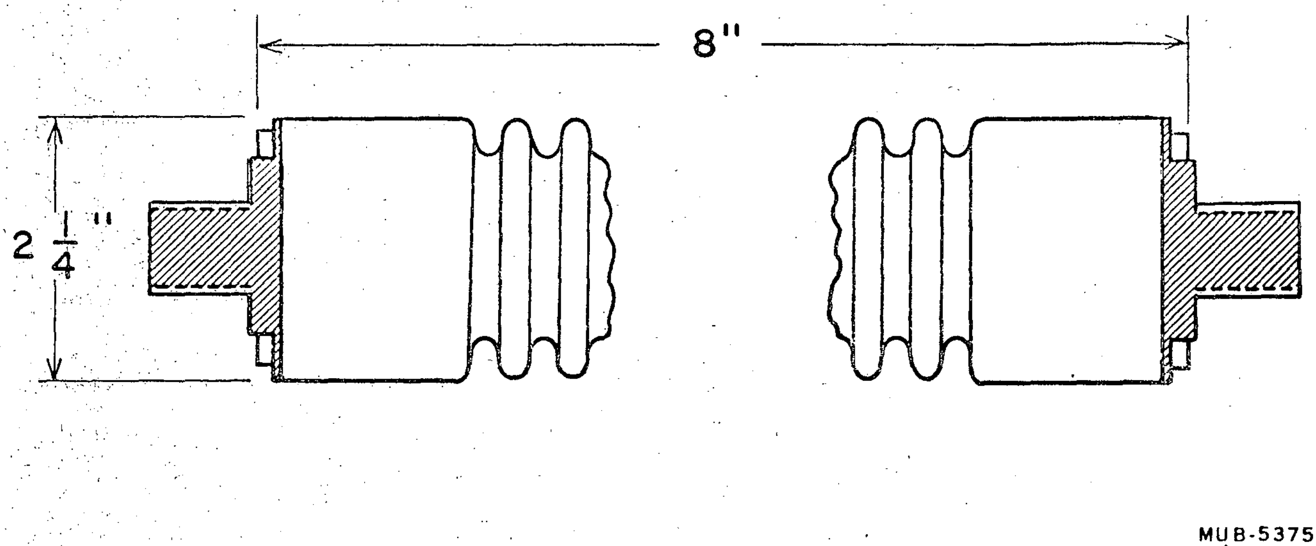

Fig. 3. Electrode support insulator.

bolt-on type of connection. Evidence was observed many times where the point contact and thus high electrical stress concentration had caused the breakdown of the insulator.

4. High-voltage feed-through assemblies are located in the low-magnetic fringe field rather than in a high field region. The spectrometer field has little effect on the operation of the high voltage. On occasion it has been necessary to locate the high-voltage feed-through portion of the separator very close to one of the "H" magnets having a high fringe field. The separator is voltage limited at ~ 500 kV with the "H" magnet turned on. To alleviate this condition, it is necessary to add a magnetic shield to reduce the disturbance in the separator high-voltage feed-through area.

5. Several screen barriers are used in the vacuum system. First, it is necessary to put an 8-mesh stainless steel screen in the port between the vacuum system and the main vacuum chamber. Second, it is desirable to use a fine-mesh stainless steel cup around the ion gauge in the vacuum system. During argon operation the ion gauge is only turned on long enough to take a reading of the pressure.

6. It is most desirable to always have the glass cathode on top. Minute chips of glass can and are blasted out of the glass. They fall onto the anode but frequently they can be blasted off of the anode. Small glass (or metallic) fragments on the cathode often lead to glass breakage. On occasion the separators continue to operate satisfactorily with craters produced by hard sparks.

7. The use of soda lime glass as a cathode material has proven very acceptable. It is, however, mandatory that over-current limiting circuitry be used in the control system. Runaway hard-sparking will blast craters and can even break an expensive (~$1500) piece of glass. Small craters can be blended-out by localized polishing. Resistance measurement[3] of soda lime glass indicates a ρv of 4×10^8 to 1.5×10^{10} Ω cm at ~ 105°C is acceptable; however, the operating temperature is not known precisely under operating conditions. The optimum temperature can only be determined by close observation of the operating conditions.

8. Heat and adequate pumping speed within the vacuum chamber greatly reduce the harmful accumulation of volatile products. These products if allowed to accumulate greatly enhance glow discharges leading to sparking.

Cost

The first four of the latest type units cost $8100 per foot excluding the high-voltage power supplies. This included engineering cost and 100% spares of the glass cathode plates.

The two units just completed cost about $5750 per foot. No engineering cost is included as they are identical to the first four built. No glass fabrication costs are included as spares from the previous units were used.

Operation and Maintenance Cost

One technician full time is required to condition, install, etc. an average of four spectrometers in use at any one time. Engineering assistance requires less than 20% of one man's time.

Component breakdown cost has been practically nil on the four newer units during 3 years of operation. Repairs due to human errors (vacuum system mishandling, etc.) have not been too frequent (approximately every 3 months).

Whenever an electrode gap change is required for a new experiment the spectrometer is usually completely dismantled and all parts thoroughly cleaned. On occasion a spectrometer has been used in several experiments over a period of about a year with only an occasional high-vacuum reconditioning.

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