CDF Note No. 392
March 11, 1986

WIRE CHAMBER AGING

Muzaffer Atac, Fermi National Accelerator Laboratory[a]

Abstract

Wire chamber aging can be due to a variety of reasons. Some of the most commonly known reasons are discussed to some detail. Most chambers live fairly long when glow discharges, edge breakdowns, photoelectric feedback, and field emissions from cathodes are prevented. Polymerization and coating by impurities take substantial integrated charge, larger than 0.03 coulomb per wire per centimeter before observing substantial deterioration in chamber performance with most chamber gases. Test with 50/50 A-C_2H_6 with 0.5% or more ethanol vapor show that no appreciable damage is observed up to 1 coulomb charge per centimeter wire segment.

Introduction

Wire chamber aging especially if it is due to polymerization process may be very complicated to predict and understand. During the avalanche process large organic molecules break up several times by collisions with electrons and UV-photon absorption (quenching) processes. These products can be oil and paraffin like substances coat anode and cathode surfaces. Some of these products form a long chain of molecules, polymers, on the surfaces.

It was found by S. S. Friedland[1] that in a counter filled originally with Argon-Methane, the methane (mass 16) will decrease, but masses 27 and 28 were observed to increase, indicating polymerization and formation of such compounds as C_2H_4 and others. In general, it was found that gases in the methane series polymerized more than they dissociated, and that the reverse happened with such compounds as ethyl acetate and alcohols.

Polymerization is undesirable since as soon as the compound combines with more than 5 or 6 carbon atoms, it becomes a liquid or solid at room temperature and is deposited on the solid surfaces.

Contamination in chamber gases could slowly change anode and cathode surfaces. Oxidation can be accelerated during the avalanche process. Contamination of Si, S, Br, Cl, etc... compounds may coat surfaces and change surface characteristics,

---

[a]Operated by Universities Research Association under Contract with the United States Department of Energy.

Paper to be published in proceedings of Workshop on Radiation Damage to Wire Chambers, January 16-17, 1986, Lawrence Berkeley Laboratory, Berkeley, CA

therefore, gas purity is an important factor in the chamber aging process. For the same reasons dielectric films such as mylar, Kapton, etc. should not be used for covering chamber windows. They permit diffusions of gases into chambers and also slowly alter electric fields as they are charged up. Such windows should be covered with metallic materials on the inside.

Wire chamber aging can be accelerated with any of the following phenomena: Discharges (glow discharges or sparks), edge breakdowns, photoelectric feedback, and field emission from cathode surfaces. Discharges and edge breakdowns may leave scars on the surfaces.

In this paper some suggestions about the design and the operation of the drift chambers and proportional chambers are presented.

Edge Breakdowns

It is often found that with planer wire chambers that breakdowns at straight cut frame edges leave dark regions on both anode and cathode wires after some usage. Fig. 1a shows a typical frame that is commonly used for making planer wire chambers. Depending upon electric fields, thickness of the dielectric frame, and gas mixture substantial surface electric current flow may occur. The current may increase in time and result in surface corona discharge. A simple way of avoiding this problem is to make the frame as shown in Fig. 1b. With the addition of a ledge surface current path is doubled preventing surface corona.

Feedthrough Design

Cylindrical drift chambers have become very popular in recent years as colliding beam experiments have gained great importance. An injection molded small dielectric tube with the help of crimp tube having a very small inner diameter (as small as 75 μm) wires is precisely positioned under a required tension.

Figs. 2a and b show two different arrangements. Fig. 2a is a cross section view of a Delrin feedthrough. The main characteristics of this design is that the V-groove precisely positions the wire at the center of the Delrin tube at the innerface of the aluminum plate. The crimp tube stops somewhere within the aluminum plate, leaving the anode wire at a very high electric field since the dielectric surfaces are charged up as indicated in the figure. This may result in breakdown through the dielectric in a random way. Dark canals are found in the Delrin around the V-groove regions. Configuration shown in Fig.

2b would prevent the current punch-through by dropping the electric field within the aluminum plate since the crimp tube extends into the chamber volume. A 1 mm thick tube drops the field to much a lower value, and a 85 μm size hole in the tube precisely positions the wire[2]. Tests done with this feedthrough arrangement using Delrin materials (grades: 100, 500, 900, and 900s) showed considerable noise pulses even without the anode wire with a potential applied between the crimp tube and the aluminum plate. The noise pulses showed up around 2 kV and increased in amplitude as the voltage was increased. Fig. 3 shows such pulses. They are indistinguishable from typical proportional pulses. Magnified cross-sectional cuts showed voids in the injection molded Delrin samples. The most probable cause of the noise pulses is that the surface of the voids slowly charge up, polarize, and discharge producing random pulses which are shaped by the amplifier. The feedthroughs get noisier in time and show currents reaching 1 nA level. In this search of good injection molded dielectric materials polyethylene and Noryl N190 were found to be excellent; no noise pulse up to and beyond 3 kV and the leakage current was less than 10^{-12} A. This limit is due to insufficient sensitivity. Noryl is as rigid as Delrin and very stable, but polyethylene is not sufficiently rigid for the application.

Field Emission from Cathode Wires

Electrons can be emitted from a cathode wire surface when the electric field exceeds some critical value that is depended on the surface quality and type of material. The field may be as low as 30 kV/cm. Coated or plated Be-Cu wire surface found rather imperfect, full of dark spots. The study was done with a cylindrical tube of 1 cm diameter with a semitransparent window, In-Sn oxide coated mylar film. Photon emission from the region surrounding anode wire was observed when the wire was under a reversed high voltage, negative potential on the wire, and aluminum tube at ground. Conductive transparent window is also kept at ground potential.

Generally under normal operating conditions randomly emitted single electron pulses will not be seen in drift or proportional chambers unless the gas gain is set to be very high, above few 10^5, but these pulses can be there and accelerating the aging process. Fine finished stainless steel wires were found to be better for this effect. Good surface quality and rather thick wires, 150 μm or thicker, were advisable for the cathode or field wires for eliminating the field emission.

Photo-Electrons and Discharges

Another very damaging phenomenon is glow discharge or spark discharge[3]. They occur at a critical gain for a given intensity in a gas mixture when ultraviolet photons are not fully quenched. The phenomenon manifests itself by a continuous current drawn from a high voltage power supply. It starts with an increase in current and after a brief hesitation current goes up again, and it reaches a steady value. The current may vary from a small fraction of a microampere to tens of microamperes.

It may be initiated with photon electron exchange process when UV quenching is insufficient. The most likely way this phenomenon may happen is to create a streamer condition which cannot quench itself and branch streamers. This then feeds itself through successive regeneration of electrons by photons continuously. Details can be found in Ref. 3.

The streamer condition may be reached at high rates with a sufficient gain when a track or tracks accidentally produced in the vicinity of a fully developed avalanche cone which provides electrons to be multiplied successively at the tip of the cone where the field is high.

The breakdown current was studied using tubes and a small drift chamber each having a semitransparent window (In-Sn oxide coated mylar film). Using an image intensifier video camera described earlier[4,5] photons emitted from the active area were observed while the average current drawn from the high voltage power supply was recorded. Pulses from the anode wires were also observed to detect streamer transitions when the applied voltage was sufficiently high.

Fig. 4 shows the experimental arrangement. A fairly intensive Sr^{90} β-Source of 2×10^5/sec cm^2 rate was used for the tests. The gas mixture was 50/50 C_2H_6/A flowing through ethyl alcohol at 0° C adding 1.4% vapor to the mixture. The flow rate was 200 cc per minute.

Fig. 5 shows the breakdown curve for 12 mm x 12 mm size aluminum tube having 50 μm thick gold plated tungsten seen in the figure that it is a well behaved smooth curve all the way to the full streamer operation. Thin aluminum absorbers were used to lower the source intensity. The breakdown occurred at a critical gain and intensity when the average current exceeded 0.5 μA. Without the ethyl alcohol vapor the breakdown current is below 0.02 μA.

For optical observation of the breakdown phenomenon the ethyl alcohol component of the gas mixture was removed, only 50% A/50% C_2H_6 was used. β-Source intensity was about 10^{-5} counts per wire per cm^2 for the small drift chamber shown in Fig. 6. The photon activity made the anode wires visible at 1.8 kV. Boiling like activity appeared on the TV monitor at 1.9 kV as shown in Figs. 7a and b. The activity stayed within circles of about 3.6 mm diameter at 2.1 kV. The circles remained when the source was removed as seen in Fig. 7b. The voltage had to be reduced below 1.8 kV for the circles to disappear.

1.4% ethanol vapor was added to the gas mixture, and the photon activity was observed. Figs. 8a, b, and c show that it takes considerably higher voltage for the wires to be visible, at 2.8 kV self quenching streamers are seen and at 3.1 kV full streamer operation. Branch streamers did not occur, and the breakdown condition was not met with the ethanol vapor in the drift chamber with the wire cathode configuration is a significant clue that breakdown is mediated by photoelectron conversion on the cathode surface. The breakdown occurs with 1.4% ethanol in the tube since it is a continuous coverage of cathode surface as compared to very small solid angle coverage with the wire cathode surface.

Ultraviolet photon transmission curves provided by Dr. Victor Ashford show that ethanol absorb the longer wavelength UV photons quite efficiently (Fig. 9). These are long ranged photons that are capable of knocking out electrons from cathode surfaces, and ethane molecules are very ineffective in quenching them.

Another independent experiment resulted in the attenuation length of $\lambda = 480$ μm for those photons capable of producing electrons in 50% A/50% C_2H_6 from the cathode wall of the 12 mm x 12 mm aluminum tube. The attenuation length is reduced to $\lambda = 160$ μm with the addition of 1.4 ethanol vapor. These numbers were not affected with the same tube after coating the inner wall with colloidal graphite.

No breakdown could be detectable up to 7 μA average current when 4.4% ethanol vapor was added to the gas mixture. Fig. 10 shows breakdown current as a function of ethanol concentration.

Aging

Argon-ethane gas mixture has been very popular because of good saturation property of electron drift velocity (Fig. 11) thus providing very good spacial resolutions. Long time studies of the gas mixture has shown that the lifetime of wire chambers can be very long since breakdown conditions are prevented with the addition of ethyl alcohol vapor. The table below shows integrated charge for different ethanol concentration. These are very direct measurements of currents drawn from the high voltage supply running steadily for five weeks or more keeping the current above 0.5 μA when the β-Source illuminating 6 mm length of one wire in the wire drift chamber. The gas gain was kept above 5×10^4 during the runs.

Gas Mixture	Collected Charge (Coulomb/cm^2 Wire)
50/50 A-C_2H_6 + 1.5% ethanol	1
50/50 A-C_2H_6 + 0.7% ethanol	2
50/50 A-C_2H_6 + 0.5% ethanol	1.5

During the runs an Fe^{55} source pulse height spectrum was taken periodically to see if resolution is changed. The most sensitive clue to aging is a reduction of 5.9 keV peak height to valley (between 3 keV argon escape peak and 5.9 keV line ratio. After the above runs there was slight darkening of the anode wire surface. This could be due to coating by impurities. Fig. 12 shows three pulse height spectra of the Fe^{55} source. Fig. 12b is on the aged spot, and Figs. 12a and c are taken on 6 mm distance on both sides of the aged spot. Slightly worse peak to valley ratio is seen in Fig. 12b. This picture was for the 0.5% ethanol case. There was no observable change on the cathode wires.

Acknowledgment

The author would like to express his appreciation to Ayfer Atac for her creative drawings.

References

1. S. S. Friedland, Phys. Rev. 74, 898 (1948).

2. M. Atac, T. Hessing, F. Feyzi, IEEE Trans. on Nucl. Sci., Vol. 33, No. 1 (1986) 189.

3. M. Atac, IEEE Trans. on Nucl. Sci., Vol. NS-31, No. 1 (Feb. 1984) 99.

4. M. Atac and A. Tollestrup, Fermilab Report FN-337 (1981).

5. M. Atac, A. Tollestrup, D. Potter, Nucl. Inst. and Meth. 200 (1982) 345-354.

Figure Captions

Fig. 1a Commonly used wire chamber frame with straight edge.

1b Wire chamber frame with ledge.

Fig. 2a Feedthrough arrangement with V-groove which positions wire precisely. The arrangement may cause breakdowns.

2b Feedthrough arrangement with crimp tube positioning wire precisely. Large enough diameter lowers the electric field.

Fig. 3 Noise pulses produced in Delrin material.

Fig. 4 Experimental arrangement with image intensifier camera for observing photon activity.

Fig. 5 Breakdown curve for 12 mm x 12 mm size aluminum tube. Gas mixture 50% A/50% C_2H_6 bubbling through ethyl alcohol at 0°C adding 1.4% vapor.

Fig. 6 Cross section view of the small drift chamber for optical observation of breakdown phenomenon.

Fig. 7a Photon activity showing normal operating regions along the anode wires together with breakdown regions with the Sr^{90} β-Source without ethyl alcohol vapor in the gas.

7b Breakdown regions are continuously active even after removing the source.

Fig. 8a Ethyl alcohol is added to the chamber gas. Chamber operating in saturated avalanche mode.

8b Chamber operating in a mixed mode; self quenching streamers appear.

8c Full streamer operation. Up to full streamer operation with no breakdown activity with the help of ethyl alcohol vapor.

Fig. 9 UV transmission curves through the given gas mixtures (provided by V. Ashford).

Fig. 10 Breakdown current as a function of ethyl alcohol concentration.

Fig. 11 Electron drift velocity as a function of high voltage for different ethyl alcohol vapor concentration in 50% A/50% C_2H_6 gas mixture.

Fig. 12 a and c Fe^{55} pulse height spectra taken after 1.5 coulomb integrated charge on one wire of 6 mm segment. The spectra taken 6 mm away from the exposed section on either side.

12b Fe^{55} spectrum taken on the exposed section of the wire showing slightly worse peak to valley ratio.

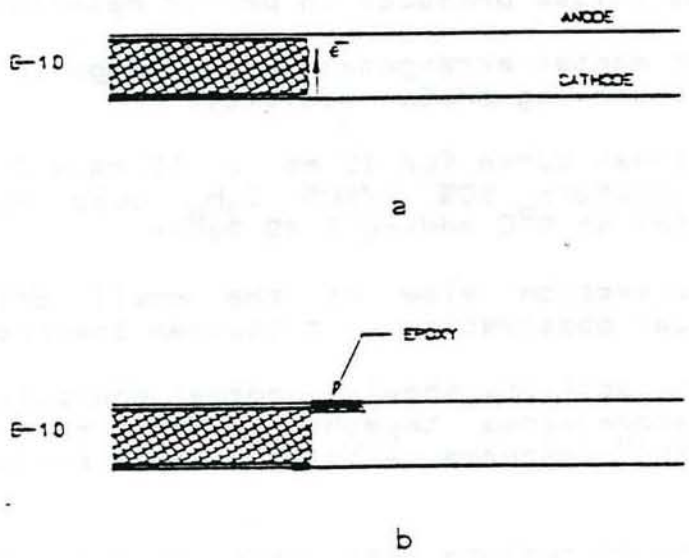
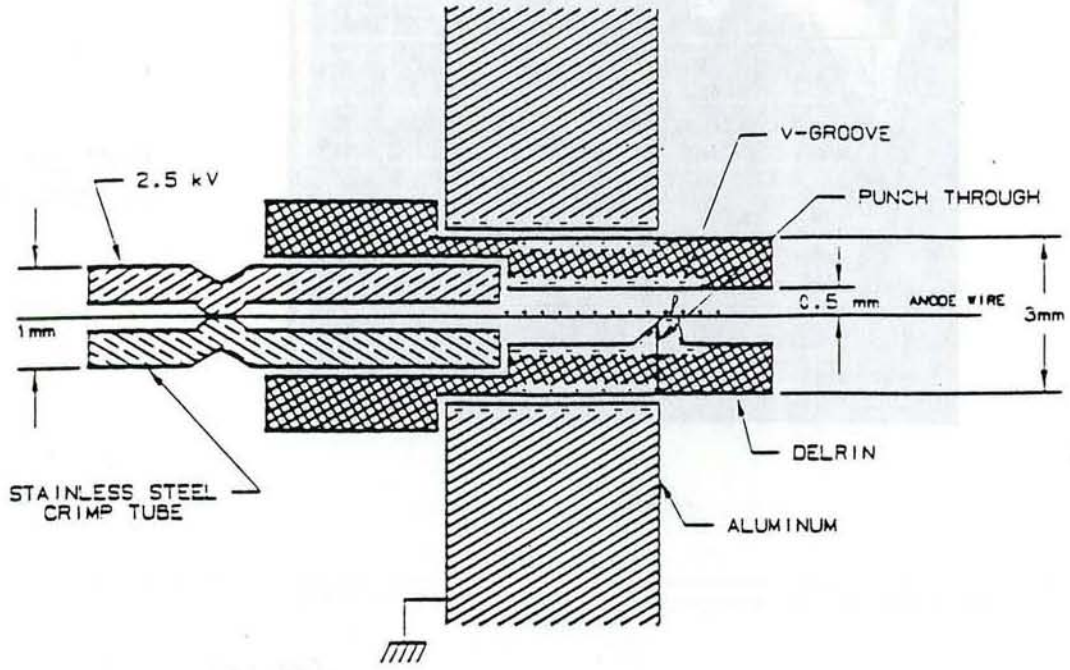
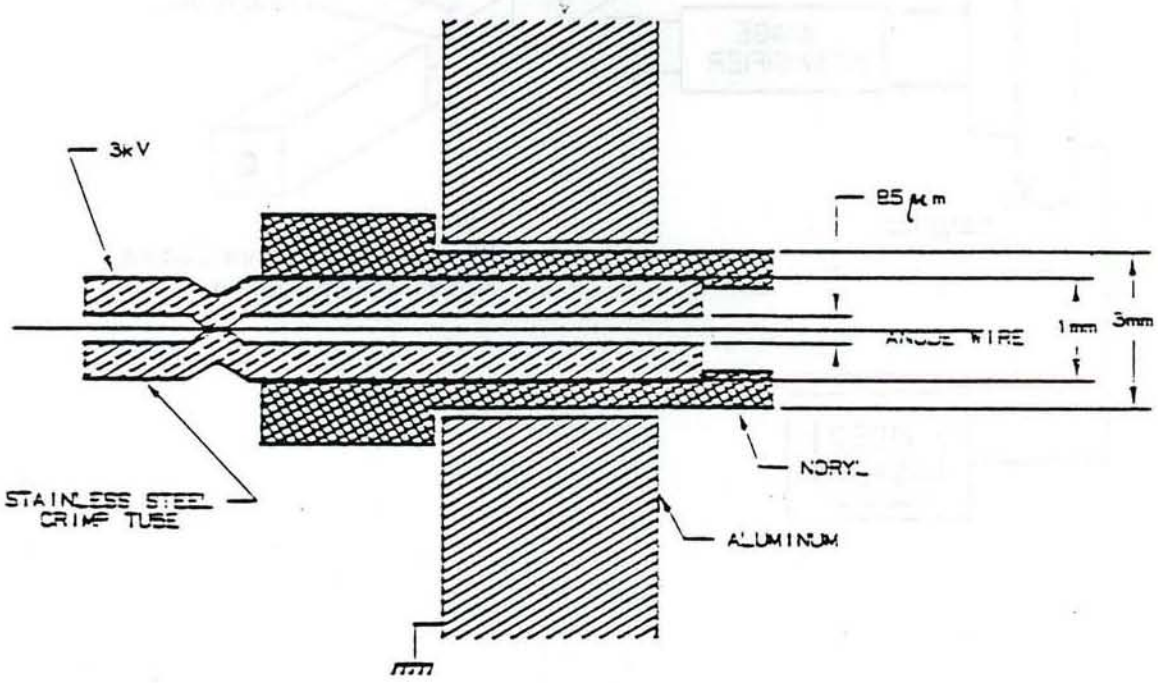


Fig. 1

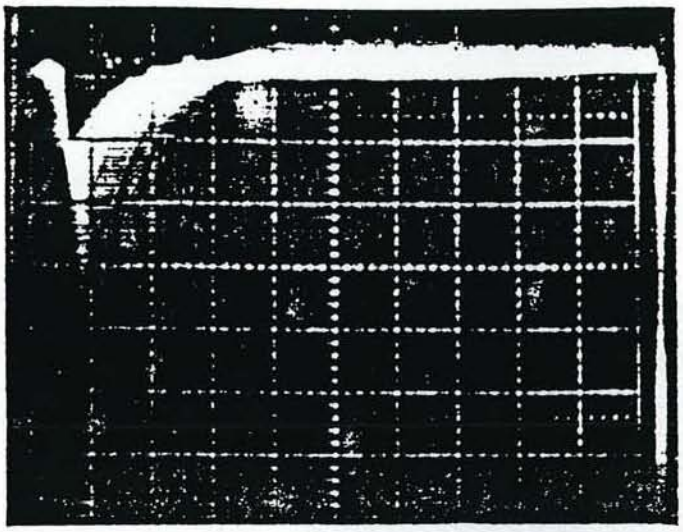

V-GROOVE
2.5 kV
PUNCH THROUGH
0.5 mm
ANODE WIRE
3mm
1mm
DELRIN
STAINLESS STEEL
CRIMP TUBE
ALUMINUM

(a)


3kV
85 μm
1mm
3mm
ANODE WIRE
NORYL
STAINLESS STEEL
CRIMP TUBE
ALUMINUM

(b)

Fig. 2



5 mV/div
50 ns/div

Fig. 3

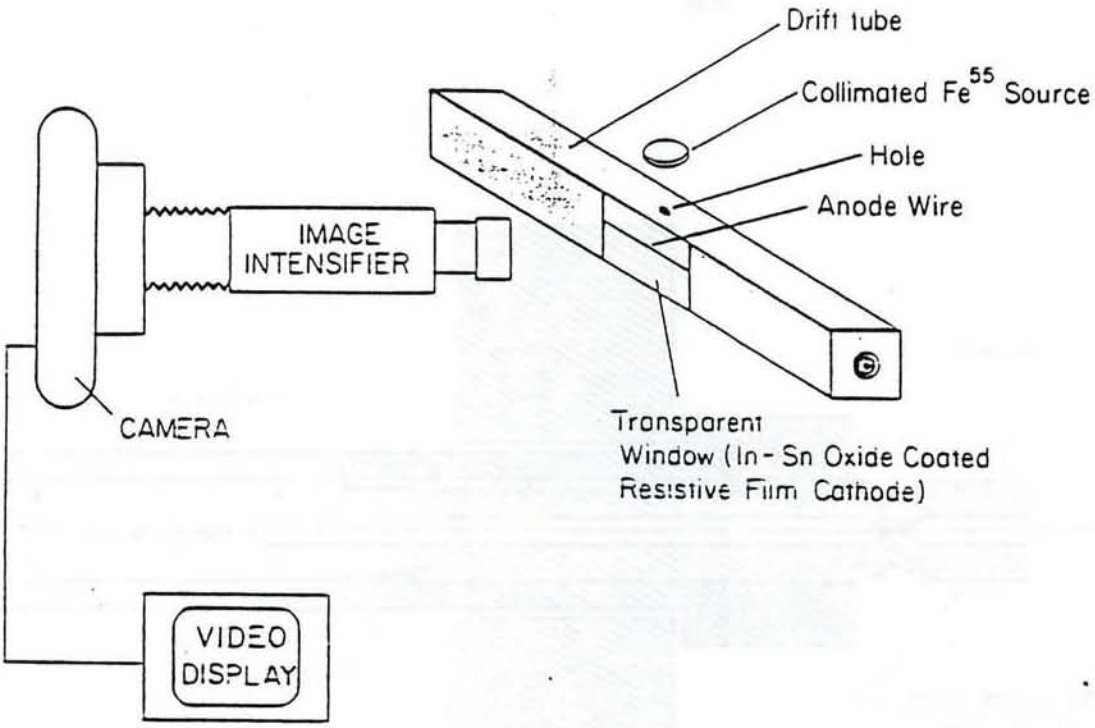


Fig. 4

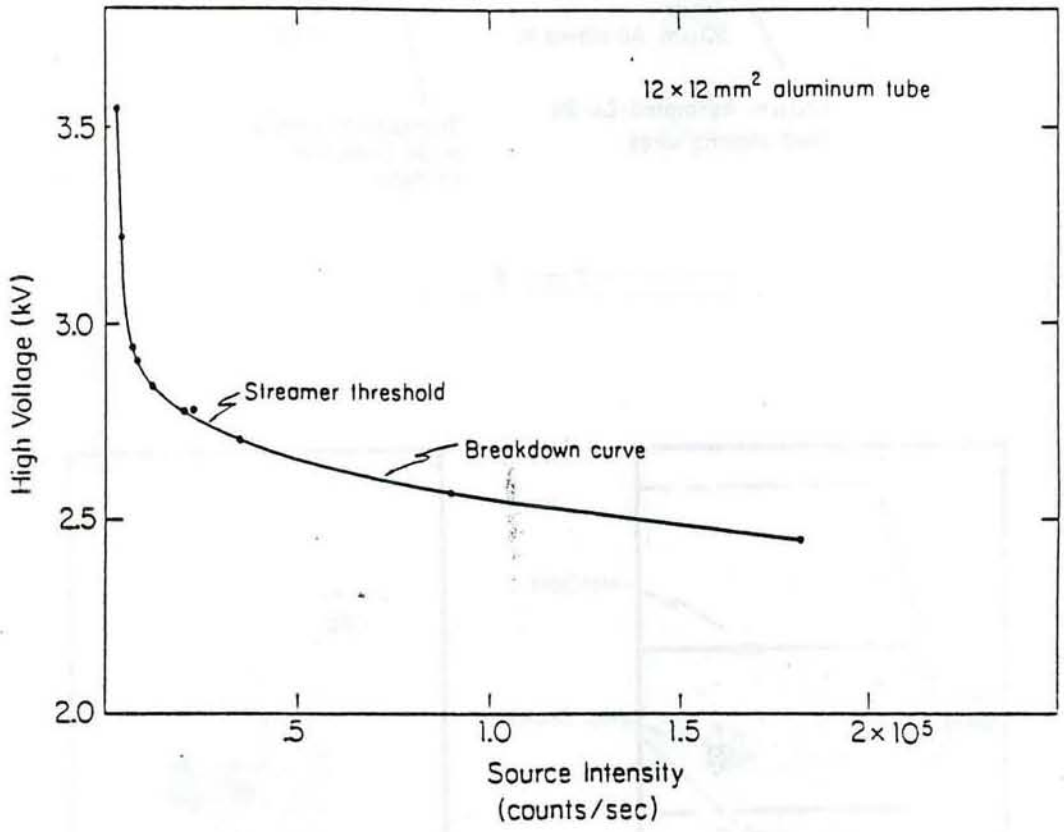

12 × 12 mm² aluminum tube
3.5
3.0
2.5
2.0
High Voltage (kV)
Streamer threshold
Breakdown curve
.5
1.0
1.5
2×10⁵
Source Intensity
(counts/sec)

Fig. 5

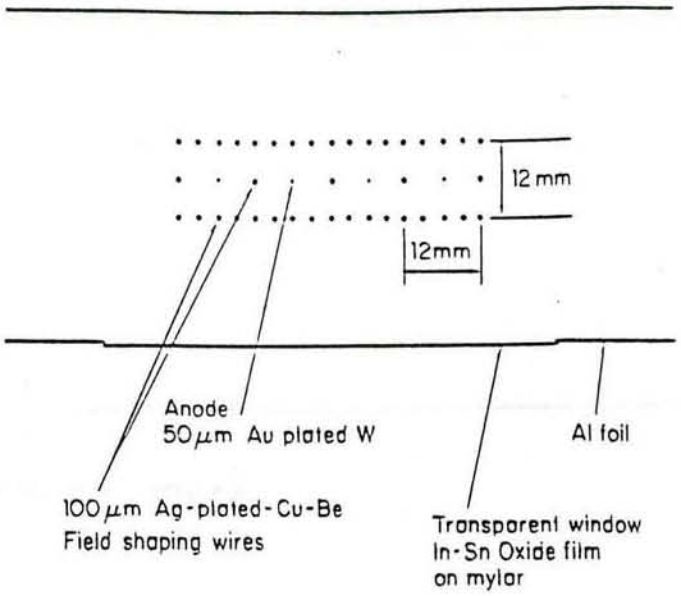

12 mm
12mm
Anode
50 μm Au plated W
Al foil
100 μm Ag-plated-Cu-Be
Field shaping wires
Transparent window
In-Sn Oxide film
on mylar

Fig. 6

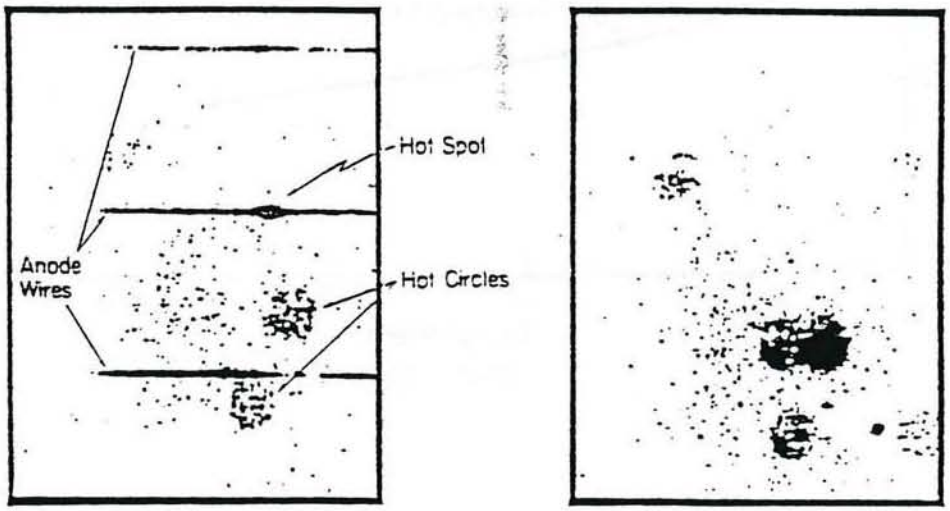

Hot Spot
Anode
Wires
Hot Circles
(a)
(b)

Fig. 7

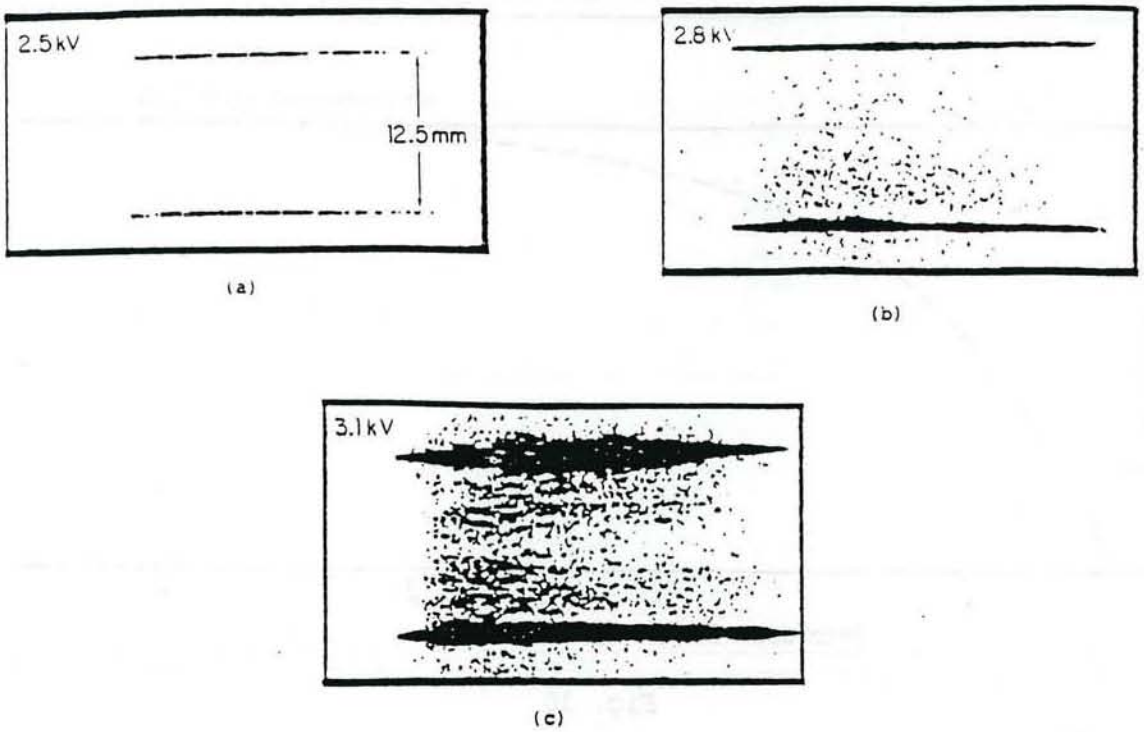

2.5kV
12.5mm
(a)
2.8kV
(b)
3.1kV
(c)

Fig. 8

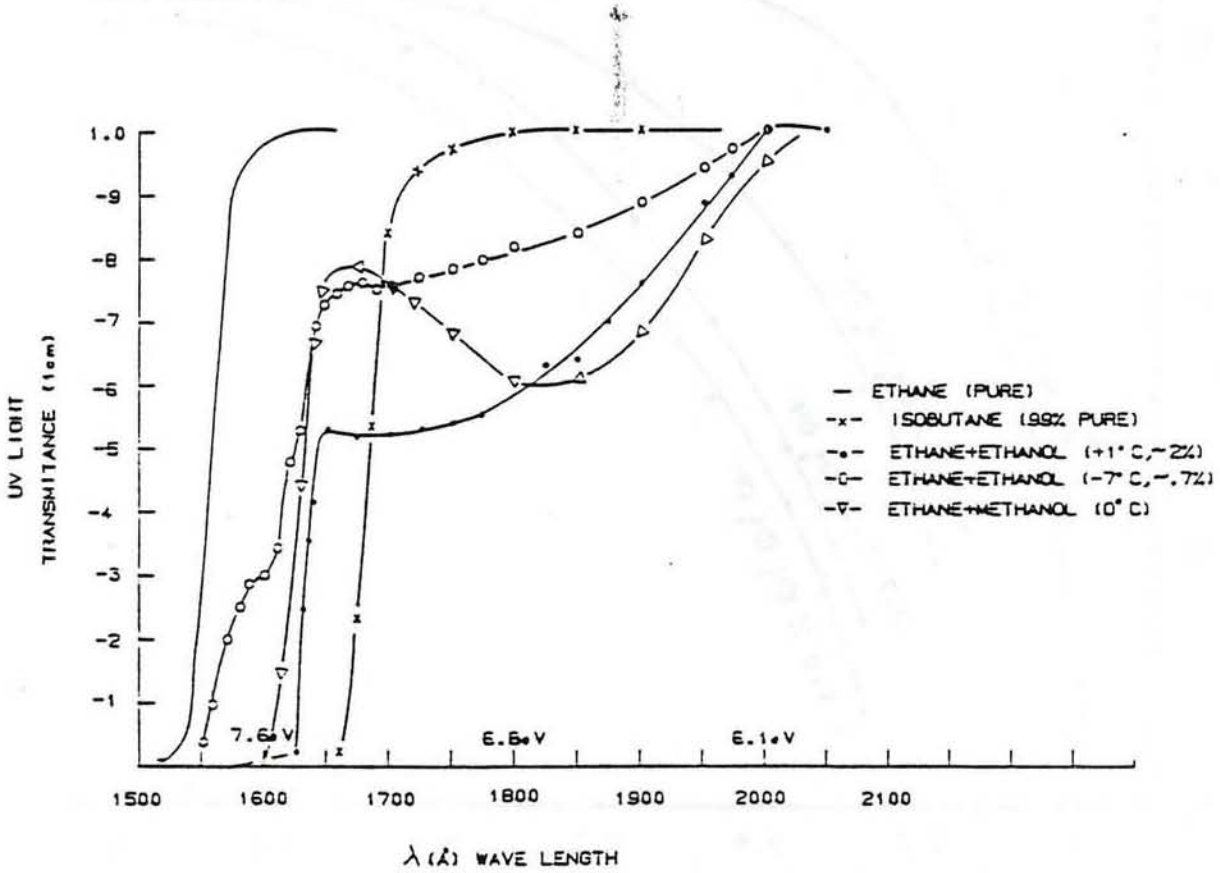

UV LIGHT TRANSMITTANCE (1cm)
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
7.6eV
6.8eV
6.1eV
1500
1600
1700
1800
1900
2000
2100
λ (Å) WAVE LENGTH
— ETHANE (PURE)
-x- ISOBUTANE (99% PURE)
-•- ETHANE+ETHANOL (+1° C, -2%)
-□- ETHANE+ETHANOL (-7° C, -.7%)
-▽- ETHANE+METHANOL (0° C)

Fig. 9

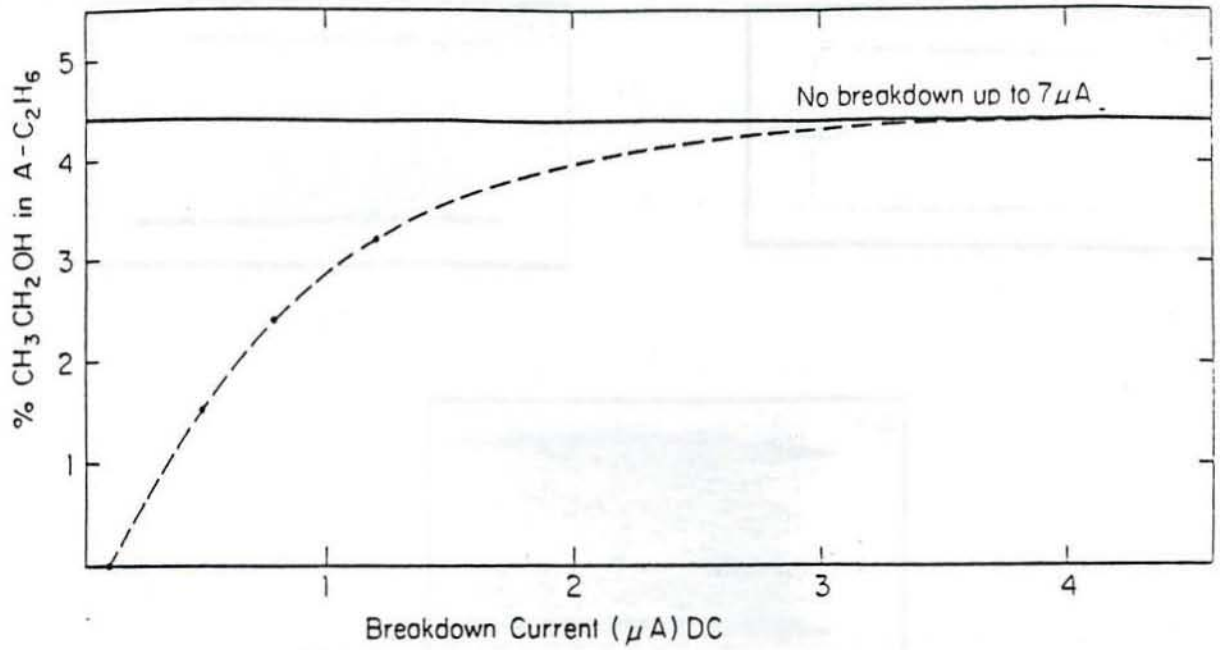

No breakdown up to 7 μA
% CH_3CH_2OH in A-C_2H_6
Breakdown Current (μA) DC

Fig. 10

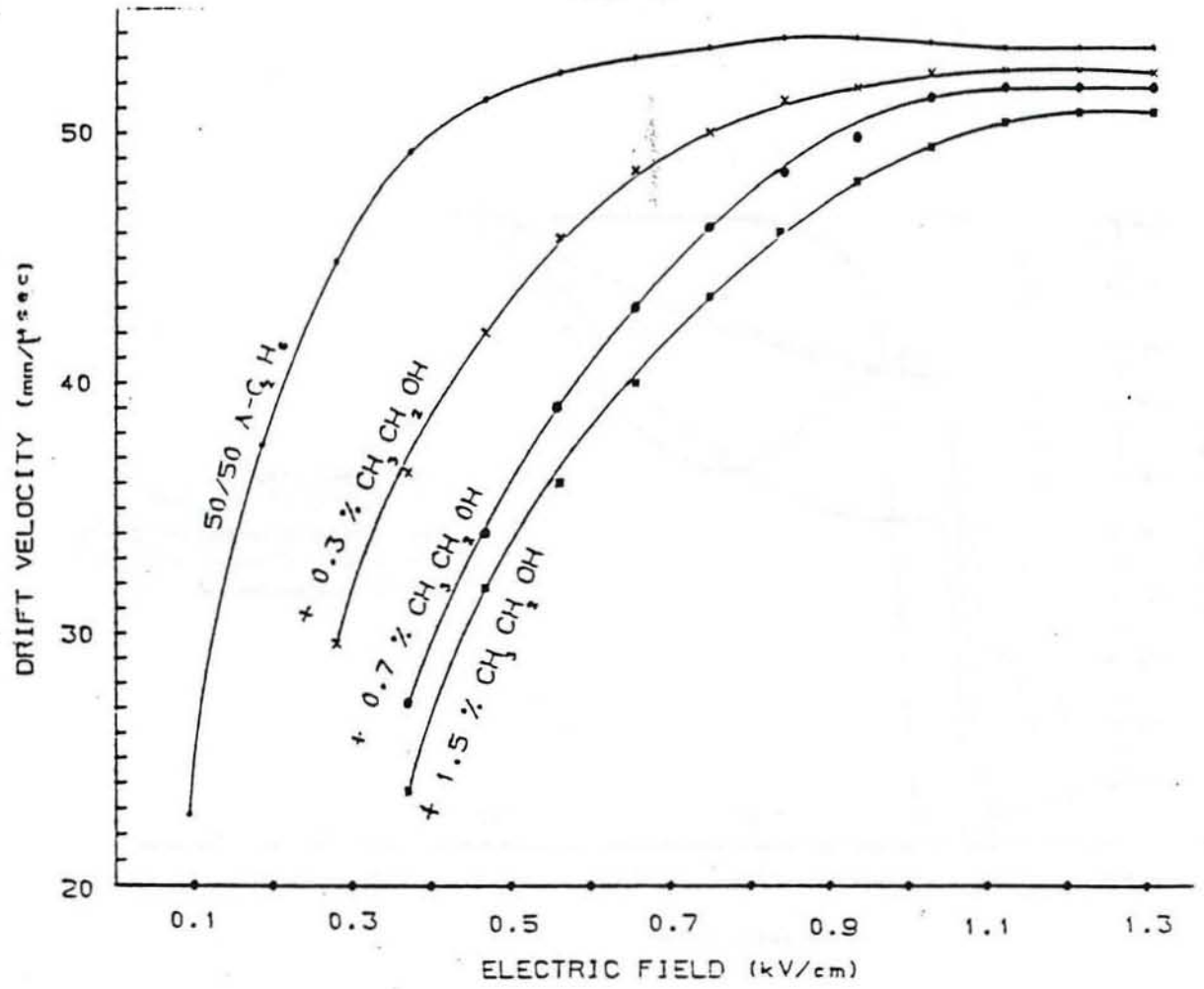
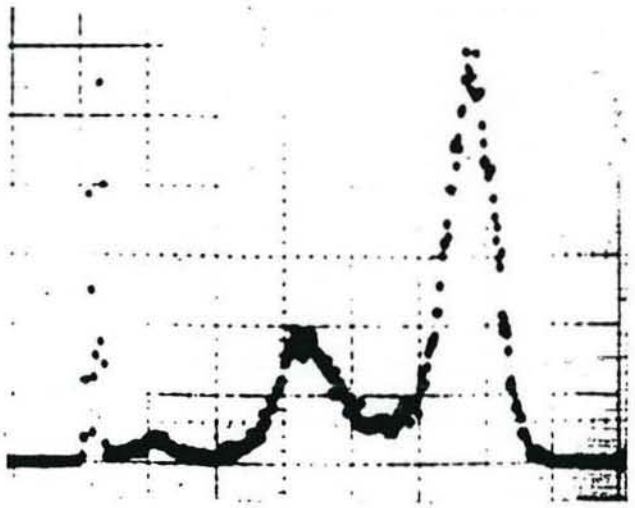
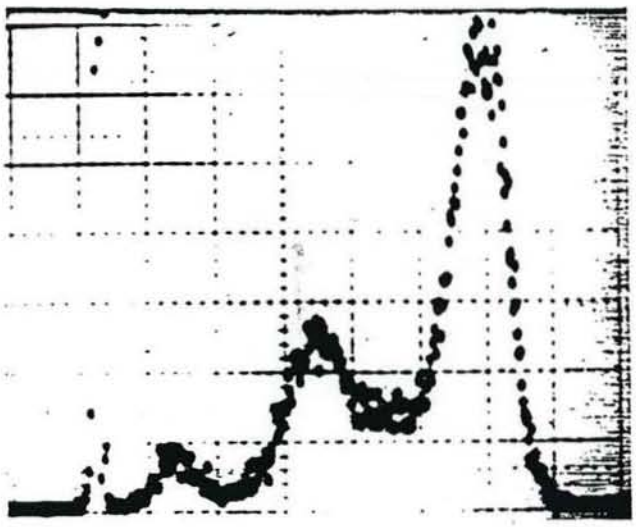

50/50 A-C2H6
+ 0.3 % CH3CH2OH
+ 0.7 % CH3CH2OH
+ 1.5 % CH3CH2OH
DRIFT VELOCITY (mm/μsec)
ELECTRIC FIELD (kV/cm)

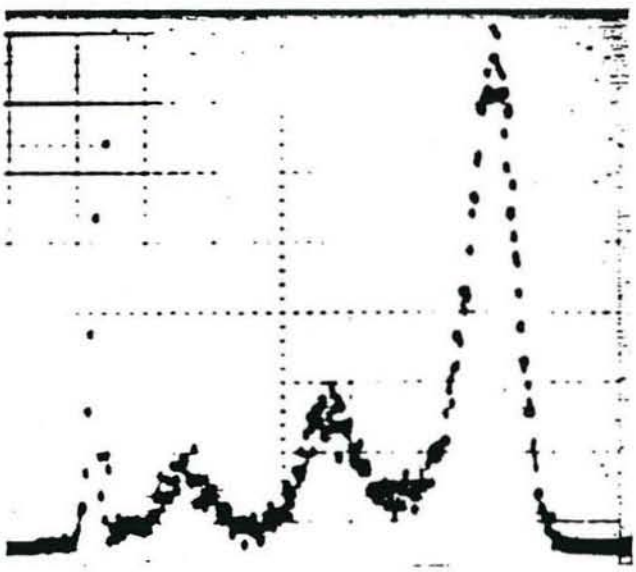
Fig. 11



(a)



(b)



(c)

Fig. 12