Dielectric Strength Notes
Note 6

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Breakdown Strength of "Tedlar" Polyvinyl Fluoride Film as a Function of Volume Stressed

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In these experiments the single shot impulse breakdown strength of samples of Tedlar film 0.002" thick (the greatest thickness available) was measured for four different areas between 1 and 1000 cm^2. For each area the mean and standard deviation of the breakdown voltage were obtained from about ten firings. As in the case of other plastics tested previously (mylar, polyethylene, lucite, polypropylene) the samples were clamped between electrodes of copper foil or brass block immersed in water, conduction and dielectric constant effects preventing stress concentration near edges, and voltages were applied in about 1 microsecond from a condenser discharge or a pulse transformer.

The results are tabulated in table I and plotted in figure 1 which shows that log E (electric field, MV/cm) falls off linearly with increasing log v (volume stressed; in this case, since the thickness was constant this is effectively the area stressed) the slope being the same as for the latter three of the plastics mentioned above, and greater than for mylar. The breakdown field falls by a factor of 1.33 for each increase of volume by a factor of 10; or alternatively one can write $E \propto v^{-1/8}$. This relationship is consistent with the average standard deviation of 14% for any given volume.

Table I also shows the effect of putting two sheets together with water in between, the area being 20 cm^2. Here the field remains almost as high as in the single sheet, whereas one would expect a small drop (9%) because of the volume being doubled.

The relative strengths of Tedlar and the other plastics may be seen in figure 2. Assuming that at high frequency the dielectric constant of Tedlar is 7 and that of mylar 2.8, the energy density in Tedlar falls below that in the same volume of mylar when the volume exceeds about 10 cc.

Attempts were made to measure the D.C. Breakdown strength at the two intermediate volumes 0.1 cc and 1 cc. This had previously been done in the case of mylar using the two following techniques to combat sparking at the electrode edges.

(1) In air, two circular copper foil electrodes of the required area were stuck on rigid flat blocks of lucite, and surrounded by close fitting annuli of paper 1/2" wide. These sandwiched the Tedlar film, which overlapped the paper by at least 1". The whole was pressed tightly together by weights exerting about 1/2 lb/cm^2.

(2) A similar assembly used no adhesive or paper, but instead the pressure smeared out a drop of oil (transformer oil or castor oil) placed centrally so that it sealed the edges of the metal electrodes with little or no bubbles. This oil also formed a thin film between Tedlar and electrode.

In both (1) and (2) the voltage was raised on the electrodes in 5 - 10 seconds until breakdown occurred. For the smaller area, the two techniques gave definitely different results (table (2)), those in air being higher; the pulse value is probably accurate to five percent only, and the D.C. in air figure is not really significantly higher. However, there is a real difference between the D.C. values in air and oil and this is probably due to discharges in the oil rather than failure of the thin air film to transmit the voltage completely to the Tedlar. A similar pattern was obtained with .002" Mylar of this area, the voltages being; pulse, 17.2kV; DC air 17.8, DC oil 16.6.

The application of technique (2) to the larger volume (1 cc) again yielded answers a little lower than the pulse value. Attempts to use technique (1) showed another effect; here, the increased circumference led to leakage corona currents on the Tedlar surface limiting the rate of charge, so that approximately one minute was required to breakdown the samples instead of 5 - 10 seconds. This corona current is spectacularly bigger than for (say) mylar, no doubt owing to the large dielectric constant which helps to maintain high fields in the air. A circumference of 50 cm leaked 1 milliampere at about 5 or 6 kV, and this died away very slowly, allowing the voltage to be raised only very gradually as the charging unit could not deliver more current. The breakdown voltage was then found lower than the pulse value and subsequently experiment showed that increased charging time leads to lower breakdown voltage. A sample left at 80% of the mean breakdown voltage broke after approximately one minute on average; this was repeated with oil as the ambient medium, with similar results, and is therefore likely to be intrinsic to the Tedlar. Similar experiments in which the same area of mylar was broken with D.C. rising in 10 seconds and then in stages, from 0 - 75% in 5 seconds and 75 upwards at 10% per minute give mean breakdown values of 16.2 kV and 16.1 kV respectively, showing the time dependence observed with Tedlar to be absent. This was repeated with polyethylene, and again no time dependence observed.

Even where the voltage was applied in 5 - 10 seconds a residual, but small, degradation in breakdown voltage probably exists, so that for short times of application (say 1 second) the D.C. strength may well be higher than the pulse; however this is of little value where serious degradation may occur in the times required to charge large condenser banks.

TABLE I Impulse Breakdown in Water

Thickness d (cm)	Mean Voltage V(kV)	Field E (MV/cm)	Area A (cm^2)	Volume v (cc)	No. of Shots N	Standard Deviation σ (%)
.0052	25.9	4.98	1	.005	11	19
"	18.0	3.45	20	.10	21	11
"	13.6	2.60	180	.94	10	19
"	10.6	2.04	1150	6	10	14
.0104 (2 layers)	35.6	3.41	20	.20	14	11

Mean Standard Deviation 14%
(Using weighting factor $\sqrt{\bar{N}}$)

TABLE II D.C. in Air and Oil

D	V	E	A	v	N	σ	Rise Time (sec)	Medium
.0052	19.1	3.67	20	.10	9	7	5 - 10	Air
"	15.1	2.90	20	.10	7	7	5 - 10	Oil
"	12.7	2.45	180	.94	12	13	60	Air
"	12.9	2.47	180	.94	6	8	5 - 10	Oil

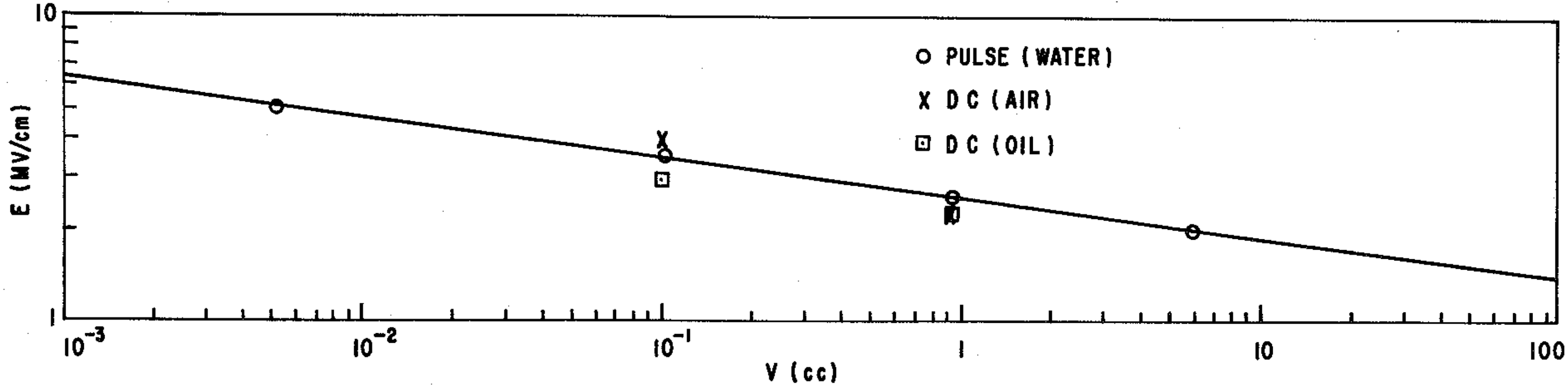

FIG 1. TEDLAR STRENGTH VS VOLUME

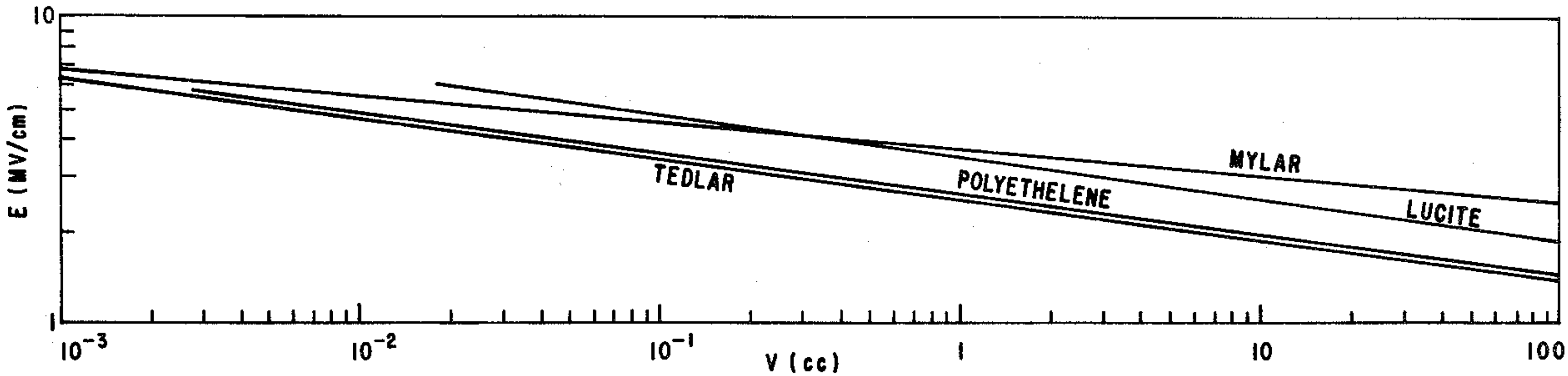

FIG 2. STRENGTH OF MYLAR LUCITE