Dielectric Strength Notes
Note 8

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D.C. and Pulse Breakdown of Thin Plastic Films

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Attempts were made to determine a D.C. breakdown strength for relatively small areas (20 - 180 cm^2) of polythene, mylar and Tedlar film of thickness .002" - .0025" by a number of techniques. In one method, the film was clamped in air between circular copper electrodes stuck onto perspex sheets and surrounded by a close fitting annulus of paper. In a second, the electrodes were .002" Aluminium applied to the plastic with a central drop of oil, which, when the whole was squeezed between perspex blocks, spread out and sealed the edges. Transformer oil and castor oil were both tried, and the technique was also tried using distilled water. The high voltage supply could only deliver 1 milliampere and with water this current was reached below 10kV, and no results were therefore obtained. However, with thinner or weaker plastics, a smaller circumference, purer water, or a more powerful power charging supply this method should prove possible.

The use of castor oil had been successful in the past, but now led to consistent breakdown at the edges of the aluminium. For example, with 20cm^2 Tedlar this occurred at 11.5kV on average. When transformer oil was used the breakdown no longer occurred at the edge and a value of 15.1kV was obtained. However, in air this area withstood on average 19.1kV and since it is not expected that the air film between electrode and plastic will withhold any significant voltage, this difference must be due to discharges occurring in the oil.

A corresponding experiment with 180 cm^2 of melinex gave 17.8kV in air and 14.2kV immersed in transformer oil. The method in air was therefore adopted.

The effect of prolonged exposure to the DC voltage was then investigated. Using 180cm^2 tedlar, the breakdown strength was determined when charging as fast as possible. This process took 30 - 45 seconds, because above 7kV the charging current rose to a milliamp and fell very slowly, permitting only a very gradual raising of voltage. This current was being passed as a corona discharge across the surface, a phenomenon comparatively unnoticeable with melinex or polythene and attributed to the high dielectric constant of Tedlar (7). In this case, the breakdown voltage was 12.7kV, no higher than the 12.9 observed in oil, where no significant edge current flowed and charging time was 5 - 10 seconds. Suspicion that the increased charging time led to a lower observed breakdown voltages was confirmed by applying 9kV to a similar piece of Tedlar and maintaining it, whereupon breakdown occurred after 1 minute. At 8kV about 2 minutes was required.

Measurements were then made on polythene and melinex to see if a dependence on charging rate existed. The breakdown voltages (13.4kV and 17.8kV) were found when the voltage was applied in 5 - 10 seconds, and then another series was done in which the voltage was raised rapidly to 75% of the mean breakdown strength and then raised in steps of 0.5kV every half minute. The results (13.2 and 17.7kV) were essentially the same, indicating that no effect of charging time existed.

Thus it was impossible to measure a definite strength for Tedlar D.C. in air. However, with 18cm^2 the voltage with reasonably fast charging (19.1kV) probably is little affected and already exceeds the measured pulse value 180kV for this area, though the difference is hardly significant. In the case of melinex the D.C. value (17.8kV) is close to the pulse value 17.2kV, but the latter is a trifle low compared with the mylar volume versus field plot and with the 23.2kV observed for 20cm^2 (pulsed). With polythene the pulse value is considerably higher (17.2kV) than for D.C. (13.4kV) but in performing the D.C. experiments a substantial proportion of samples were rejected because they gave answers less than 3kV (and some less than 500V). No such observation was ever made with the pulse and therefore one suspects the presence of defects which cannot cause breakdown in 1 usec but which may affect even the apparently normal results with D.C. As an experiment, two layers of polythene were tested; the results, pulse 34.0 D.C. 32.7 were in good agreement; the D.C. strength was 2.4 times that for one sheet, since (presumably) the chance of two defects lining up is small.

Since the pulse strength for two sheets had not fallen because of the increase of volume, four sheets of polythene were next tested, the mean voltage again doubled (68.3). The original 17.2 for one sheet is 2.73mV/cm which already exceeds the value from previous experiments for this volume slightly (none used such thin sheet) i.e. 2.60 and with four sheets the discrepancy is marked. It appears that either the breakdown is delayed by travelling through water interfaces between plastic layers or that one sheet (presumably that near the anode) alone is determining the breakdown strength. The former explanation is rendered less likely by the result of testing with air between sheets (except outside the electrodes where water was allowed to enter), which gave 66.2kV, nearly the same. A repeat with tedlar gave; 1 sheet 18.0kV, 2 sheets 35.6kV with 20 cm^2, 1 sheet 13.6kV, 4 sheets 57.4kV with 180cm^2, indicating the same result.

In the case of polythene, material in single sheet form equivalent to four layers was available, and this held only 46.5kV, slightly below the volume plot (8%) but 30% below the value for 4 sheets.

To test the possibility that only the sheet near the anode can cause a discharge to propagate through the pile, a sheet of tedlar and one of polythene were broken together. When the polythene, which must always break first, was on the positive side the voltage was 23.0kV, of which 18.4 should have been on the polythene which normally breaks at 17.2, while with the polythene negative the voltage was 27.4kV. Thus a polarity effect was observed, but it was not large enough to indicate that the proposed explanation is correct.

An uncomplete experiment with melinex seemed to be indicating that 5 sheets of 2 thou material withstood the same gradient as one sheet of 10^x (there is known to be little or no polarity effect with this material) but this gradient seemed to be even higher than one 2 thou sheet would withstand in this area ($180cm^2$). The 10 thou mylar seemed to exceed its expected voltage, and the higher voltages of the set were regularly accompanied by 4 - 6 breakdown channels.

It therefore appears that the use of multiple thin sheets is advantageous, both for pulse and D.C. application, but more experiment is required to elucidate the processes involved.

The table gives the results obtained. The standard deviations were as follows on average:

Pulse (single layer)	15%
Pulse (multiple layer)	12%
D.C.	14%

Breakdown Voltages (kV)

Melinex (a) Pulse (.0021")

20cm^2	180cm^2 (1 layer)	(5 layers 10.6 thou)	Single 10.1 thou	
23.2	17.2	102	96	3.7MV/cm Vol.2cc
4.4MV/cm Vol.0.22cc				

(b) D.C. 180cm^2

Oil 14.2kV
Air 17.8 (fast)
17.7 (slow)

Polythene (a) Pulse (.0025")

180cm^2	1 layer	2 layers	4 layers (water between)	4 layers (air between)
	17.2	34.0	68.3 (9.6 thou)	66.2

1 single 9.6 thou

46.5

(b) D.C. 180cm^2 in air

1 layer 13.4

2 layers 32.7

Tedlar (a) Pulse (.00205")

	1 layer	2 layers (water between)
20cm^2	18.0	35.6

	1 layer	4 layers (water between)
180cm^2	13.6	57.4

(b) D.C.

20cm^2 Oil 15.1 (fast)
Air 19.1 (fast)

180cm^2 Oil 12.9 (fast)
Air 12.7 (slow)

Polythene and Tedlar

(Pulse) Polythene positive 23.0
" negative 27.4