Dielectric Strength Notes
Note 15

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Pressure Dependency of the Pulse Breakdown of Gases

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The following measurements were rather preliminary, being undertaken in haste, and were performed by Dave Forster and Phil Champney. Following on some very preliminary measurements made by J. C. Martin, it was assumed that the positive point yielded a lower breakdown field for a given pulse length and so measurements were initially confined to this mode, since it was the minimum breakdown field that was required. Also following this early work, the power of the time on the breakdown pulse (t in microseconds) was taken as $1/6^{th}$. The pulse length applied by the test transformer was more or less of a constant duration and lay between 0.1 and 0.2 μsecond effective value.

In the early work (which was all at 15 p.s.i. absolute) the values given in Table I were obtained for k' where $k' = Ft^{1/6}d^{1/6}$ and t is in microseconds, d is in cms and is the distance between the point or small sphere and the plane and F is the breakdown voltage divided by this distance d in kV per cm.

TABLE I

Values of $k' = Ft^{1/6}d^{1/6}$

	Point -ve	+ve
AIR	28	24
FREON	65	37

Pressure 1 atmosphere

Analysis of the new data showed that a better fit for the power of d was one tenth. Thus the new data is expressed in terms of

$$k = F\ t^{1/6}d^{1/10}$$

The experiments were conducted in a perspex cylinder of I.D. 5 1/2 inches and the large radius electrode was a portion of a sphere of 8" O.D. which was cut so as to just fit in the bottom of the cylinder. The cylinder, which could be pressurised up to about two atmospheres, was placed under oil and was driven by a pulse transform. The needle point or small radius ball was located on the axis of the pressure-containing cylinder and could be set at various distances. The fact that the "plane" electrode was of distinctly limited extent and the presence of the oil do not appear to have affected the results obtained at one atmosphere, when these are compared with those obtained previously in a setup of much better geometrical conditions. However, some effect of the experimental set-up cannot be excluded and it should again be emphasised that the variation of k with time was not investigated to any significant extent.

Table II gives the results of the point to plane experiment and also gives values of k where the point was replaced by a sphere of 1 inch diameter. As was found previously, in the case of air, this actually reduces the breakdown voltage. The values given are the average of k for distances ranging from 2 cms to 15 cms and the individual values of k were usually within 10% of the mean. Small systematic variations are apparent in the original data but for approximate predictions of the pulse breakdown voltage of a given set-up, answers good to 10% should be obtained.

TABLE II

Values of $k = Ft^{1/6}d^{1/10}$ for positive point or small sphere

p absolute p.s.i.		15	25	35
AIR	Point	24	33	37
	Small Sphere	20	28	33
FREON	Point	40	43	46
	Small Sphere	45	51	55
SF_6	Point	48	45	59
	Small Sphere	60	66	69

As an example of the meaning of the data, a pair of points or a point plane to which a positive pulse of 1 million volts of 1 microsecond is applied will spark over for air, freon and sulphur hexafluoride at atmospheric pressure for approximate distances of 63, 36 and 29 cms respectively.

Subsequent to these measurements with positive points, another set were performed which repeated them with negative points. The point results fitted the new relation very well but the fit for the data for small spheres was considerably less satisfactory, the data suggesting a slightly stronger dependency on d . However the data for the small spheres are included in Table III but the fit of the data over the full range of d (2 to 15 cms) was not better than 20% for spheres.

At one pressure of Freon, the time dependency was looked at and fitted the one-sixth power well. One set of data for the highest pressure longest gap in Freon did not agree with the relation, but the pressure vessel after these measurements showed tracks down its inner wall, so this set of data was ignored.

Table III gives the values for k- and it shows that now in all cases the small sphere breakdown voltage is lower than that for a sharp needle. In addition, for pressures over one atmosphere absolute the negative point breakdown voltage was higher than that for positive points, in some cases considerably so. For a negative pulse of 1 million volts of duration 1 microsecond, the breakdown distance in the gases at atmospheric pressure would be approximately 60, 20 and 16 cms.

TABLE III

Values for k- for negative point and small sphere

p absolute p.s.i		15	25	35
AIR	Point	25	38	49
	Small sphere	17	-	28
FREON	Point	67	84	100
	Small sphere	47	-	77
SF_6	Point	79	-	116
	Small sphere	49	-	93