Intermolecular bonding and the electric strengths of dielectric gases

In a recent report [1], it was shown that the relative electric strengths of simple dielectric gases and their mixtures are related to the strength and number of inter-atomic bonds in them; i.e. heat of atomization, which is a measure of intramolecular (i.e. inter-atomic) bonding, appears to be related to the electric strength for gases such as Ne, H_2, N_2, $N_2 + O_2$ (air), SO_2, SF_6, and SF_6 + air. It was noted [1] that the heat of atomization data needed to explore the effect of intramolecular bonding on the electric strengths of a wider range of dielectric gases, especially the fluorocarbons and fluoro-cyanocarbons, are not available. To pursue this line of thinking further for a very wide range of dielectric gases, it was decided to explore the effect of intermolecular bonding on their dielectric strength.

The measure of intermolecular bonding in gases is the boiling point (B.P.) and it turns out that the B.P. values for a very wide variety of dielectric gases are available in the literature.

In Table I the available data on the relative electric strengths and boiling points for various dielectric gases have been collected. A plot of B.P. versus the electric strengths (Fig. 1) shows a direct correlation, although the data show some rather pronounced scatter. It would thus appear that the high electric strength is related not only to the difficulty of overcoming intramolecular bonding in gases [1], but also to the difficulty of overcoming intermolecular bonding.

It has been suggested that high electric strength of a gas arises from its high electron capture capability [2]. The boiling point is an index of molecular agitation necessary to overcome the forces of van der Waals attraction between the molecules of a gases; also the electronic van der Waals attraction between molecules increases with the increase in the number of electrons per molecule [3]. In general, large molecules (containing many electrons) attract one another more strongly than smaller molecules (containing few electrons) [3]. It will follow, therefore, that substances with large molecular weight (and, in general, large molecular volumes) have high boiling points and those with small molecular weight (or small molecular volumes) have low boiling points [3]. Since high boiling substances tend to have high molecular weights and volumes, it would appear that they would also have high electron capture cross-sections and thence high electron capture capability; the latter would, of course, tend to be associated with high electric strength [2]. A qualitative basis for the correlation in Fig. 1 is thus clear from the foregoing comments. In any case, Fig. 1 can at least provide an empirical rough correlation between the electric strengths of a very wide range of dielectric gases and one of their fundamental physicochemical parameter, namely, the boiling point. The correlation in Fig. 1 is of particular interest in view of the fact that no general relationships con-

TABLE I Relative electric strengths and boiling points of dielectric gases

Number	Gas	Relative electric strength*	B.P.(°C)
1	Ne	0.25	−246
2	H_2	0.50	−253
3	N_2	1.0	−196
4	SO_2	1.3	−10
5	SF_6	2.5	−64
6	$CC1_2F$	2.42	−30
7	$CC1F_3$	1.43	−81
8	$CF_3{-}CF_2{-}CF_3$	2.19	−37
9	$F_3C{-}CF_3$	1.82	−78
10	C_4F_8	2.80	−6
11	C_4F_{10}	3.08	−2
12	C_5F_8	5.5	–
13	CF_2C1_2	2.4	−30
14	CF_3CN	3.5	−63
15	C_2F_5CN	4.5	−35
16	C_3F_7CN	5.5	1
17	CF_4	1.01	−182
18	$CC1_4$	6.33	76.7
19	He	0.15	−269

*Relative to air as 1.

Notes: (1) The electric strengths of H_2, N_2 and SF_6 are from Alston [4] (pp. 49 and 219); for Ne and SO_2, they were estimated from Fig. 3.15 (pp. 63) of Harrop [5]; the rest are from Table 12.7 of Saums and Pendleton [2]. For several cases such as SF_6, C_2F_6 and, to a slight extent, Ne, H_2 and N_2 the "relative electric strength" values as given in various references (e.g. [3–5]) are some what different even though they appear to have been determined under reasonably comparable condition *and normalized* to the electric strength of air as 1. The values given in Table I, however, are fairly good representative estimates.

(2) The B.P. values for gases are from Saums and Pendleton [2] (Table 12.8) or from Matheson Gas Data Book [6] or in some cases from other reliable sources [7]; B.P. value for C_5F_8 could not be found in the literature.

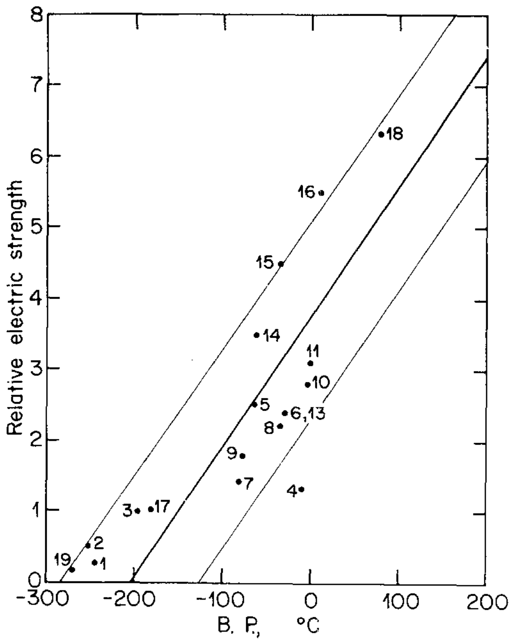

Figure 1 A plot of relative electric strengths against the boiling points for the various gaseous dielectrics listed in Table I; the numbers in this figure correspond to numbers identifying the various gases in Table I.

necting the electric strengths of a *very wide range* of dielectric gases with their fundamental physical, chemical, structural or compositional parameters seem to exist in the literature. Also such correlations as shown in Fig. 1 can perhaps provide a good starting point for the selection of new gaseous dielectric materials of use in power engineering, high voltage technology and industrial insulation.

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Physical characteristics of extruded carbon mixes

Carbon products are fabricated from a mixture of carbon filler and binder, such as coke and pitch respectively. This mixture is formed by moulding or extrusion and is then baked. The quality of the baked product is dependent upon the quality of the green carbon, which is considered as acceptable if free from surface cracks and containing an optimum amount of binder. Many investigations have been performed on the moulded carbon mixes [1–3], but little has appeared in the literature regarding the extruded carbon mixes [4–6]. A systematic study was made of the physical characteristics of extruded carbon mixes with regard to the processing conditions.

Fincle [4] reports some increase in viscosity of carbon mixes when extruded at high speeds, but no account of the extruded irregularities has been given. An explanation for the viscosity increase in the carbon mixes is proposed in this note. Suitable experiments were performed with carbon mixes to detect the presence of such extrudate irregularities and the results are reported below.

The carbon mixes in the present investigation consisted of calcined petroleum coke as filler and coal tar pitch as binder. The characteristics of these materials are given in Table I. Seven mixes were made using different proportions of binder. The filler in the seventh mixture consisted of a different particle size distribution. The above mixtures were roll-mixed at 120° C and then ground to pass through 60 B.S. mesh. Slugs, 12.5 cm diameter, were made from these mixtures which were extruded at speeds of either 2 to 4 m or 25 to 40 m