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Interpretation of High Pressure Arc Data

In the high pressure arc the dependence of electric gradient E (volts cm^{-1}) and current density I (amp. cm^{-2}) on the nature of the gas and its pressure p has now been studied for A, N_2, He, and H_2 over a portion of the pressure range up to 1200 atmospheres.[1] We find that the body of experimental results can be correlated by means of convective heat loss from solid cylinders, leading to an explanation of the variation of E and I with i and p which is in good agreement with the experiments.

For this purpose, we neglect radiation and use an equation of the Nusselt[2] type

$$y=f(x) \tag{1}$$

between the dimensionless variables y and x where

$$y=W/k\Delta T\pi, \quad x=D^3\rho^2 g\Delta T\beta/\eta^2, \tag{2}$$

W = loss (in calories) per unit length of axis; k = conductivity; D = diameter; ρ = density; β = coefficient of expansion; η = viscosity. In the range of interest in arcs,

$$f(x)=\text{const } x^n \tag{1'}$$

with $n=0.1$ provides a satisfactory approximation.

In the usual applications of (1) ΔT is not large, and the fluid constants ρ, β, η, k are evaluated at the mean temperature. For this case a large body of experimental data confirms the essential correctness of the relationships. An indication of how to evaluate them for large ΔT was obtained by studying ways of bringing Langmuir's data on heat losses from wires in air at high temperatures into agreement with (1). This is done by taking k, ρ, η at the arc temperature and β at the ambient temperature.

When the method is applied to arcs, we find that the calculated thermal loss agrees satisfactorily with the observed energy input in A and He. In arcs in air, the calculated heat loss is approximately one-third of the observed. This discrepancy we ascribe to dissociation, and when k is increased by Langmuir's diffusion term, good agreement is obtained.

As an application of (1) one can account correctly for the arc characteristics. Assuming constant T and applying Saha's equation, one finds

$$E\sim i^{-a}, \quad \text{where} \quad a=\frac{2-3n}{2+3n}, \tag{3}$$

where n is as in (1′). Thus the Steinmetz equation of the arc is obtained from thermal data. The exponent a has the value 0.74 from the above theory and lies between 0.45 and 1 in experiments.

When pressure p varies, it is necessary to take account of the variation of T with p. From arc data which yield the dependence of T on p,[1] and Saha's equation, we find the variation of the electron density with p. Using this and the previous relations, we find that E varies as $p^{0.3}$ and D as $p^{-0.33}$. At $p=100$ atmospheres, $E_{\text{calc}}/E_{\text{obs}}=1.32$, while $D_{\text{calc}}/D_{\text{obs}}=1.14$.

Measurements of D, E, I, and i for several gases up to 100 atmospheres pressure are being made by a new method of improved accuracy. The new measurements, it is believed, will not change the trends in the variation of these quantities, which are well enough established by data already in hand, but only serve to define the approximations involved.

Thus, by applying conduction and convection heat transfer data to the arc column, and determining the temperature variation experimentally, a simple formulation of the electrical characteristics of the arc and their variation with pressure is obtained.

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Ionic Recombination in the Ionosphere—A Correction

In my recent letter to the Editor, Phys. Rev. **51**, 1110 (1937), I gave a value for the coefficient of recombination α for $(O_2)_2$ ions in the E layer of the ionosphere computed from the Thomson theory as $\alpha=1.61\times10^{-8}$. Professor N. E. Bradbury in a letter wrote me that he was unable to check this value. Calculation shows that the value of the coefficient ϵ in Thomson's equation is critically dependent on the value of e^{-x} for small values of x. In my computation I had used only two members of the series expansion. Using three terms I now check Bradbury's value and wish to correct my previous value. The value of α on this calculation is $\alpha=1.68\times10^{-10}$. This is of the same order of magnitude as α_r, the value given for a recombination process in which recombination takes place for *all* impacts where the distance of ionic approach r_0 is 4×10^{-8} cm or less. These calculations thus show that the Thomson mechanism already ceases to be dominant in the E layer of the ionosphere. Professor Bradbury also points out that the auroral spectrum shows no O_2 or O_2+ lines so that the oxygen must be atomic. It is doubtful whether this will change the conclusions in the previous letter since O certainly has an electron affinity so that free electrons will probably not exist for any length of time in the E layer.

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