The forced convection heat transfer rate per unit area is given by

$$q = \frac{d\rho c}{4\alpha_i} \frac{1}{IR_i} \frac{dE}{Dt}. \qquad (4)$$

Hence the heat transfer per unit area is directly proportional to the time rate of change of voltage across the wire. The heat transfer to the wire decreases exponentially with time. The wire never actually reaches equilibrium because of the short duration of flow time and hence the heating stops after the hot flow ceases. The heat transfer rate that is most significant occurs at $t = 0$ (i.e., just after the arrival of the shock wave). There are two reasons for this: (1) The temperature of the wire is known at this time ($T_w = T_i$) and does not need to be calculated. (2) There is no heat lost to the wire supports at $t = 0$ and therefore no end loss corrections are necessary.

Preliminary heat transfer results of several runs are shown in Fig. 2. For the pressures and Mach numbers shown the heat transfer rate is proportional to $(p/d)^{\frac{1}{2}}$ as one would expect from hot-wire results. The results are quite consistent and repeatable. The wire should prove to be a valuable flow instrument in many short-duration flow problems with a gas of high stagnation enthalpy. Further investigations of this are being carried out. A more detailed report including calibration technique, construction of the wire, end loss corrections, and operating technique may be found in reference 4.

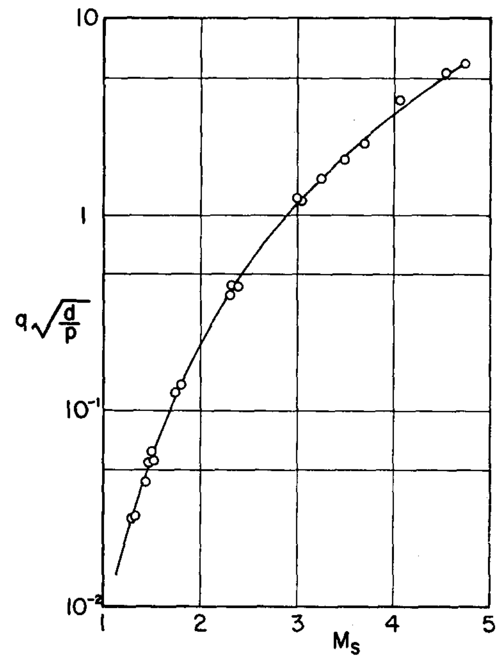

FIG. 2. Heat transfer rate versus shock Mach number. Nominal diameter of wires used in the experiment: 0.0025, 0.00125, 0.0005 cm. Initial pressures of the shock tube: 5, 50, 500 mm Hg. Dimensions of heat transfer rate parameter: (cal/cm^2 sec) (cm/mm Hg)$^{\frac{1}{2}}$.

This work was carried out under the sponsorship and with financial assistance of the office, Chief of Ordnance, and Office of Ordnance Research, U. S. Army.

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Electrical Discharges in Hypersonic Flows

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IN order to study the interaction between an electrical current and a high-speed flow, experiments are being conducted with low-current electrical discharges in the 5×5-in. test section of the GALCIT hypersonic tunnel, in which continuous uniform flows are produced at $M = 5.8$ and total temperatures $= 150°C$.

One of the very first problems investigated was the dielectric breakdown of air between two electrodes immersed in the hypersonic stream. Studies were made with several pairs of copper and tungsten electrodes, with their electric field aligned either parallel with or transverse to the stream. Figure 1 shows breakdown voltages obtained with uncooled copper electrodes designed in the "Rogowski"[1] fashion, for the case where the electric field vector was transverse to the airstream. Contrary to initial expectation the breakdown voltages are seen to lie *below* those obtained statically (without flow) with the same geometry. A more important observation is that the Paschen similarity criterion, which states that the breakdown voltage is solely a function of the product of the gas density and the interelectrode distance, is not borne out here.

An apparent explanation of the data lies in the choice of the density in the product $\rho\ d$. High-speed flows can support large density differences across shock waves and boundary layers continuously, and therefore the assumption of uniform density inherent in the static breakdown analysis is no longer true. In the present case one has to take into account the local Mach number and laminar boundary-layer thickness over the electrode; in other words, the Paschen similarity should now be extended to include aerodynamic similarity.

A simple analysis was carried out, resulting in the computation of breakdown voltages for uniform electric field but nonuniform density field between the electrodes.

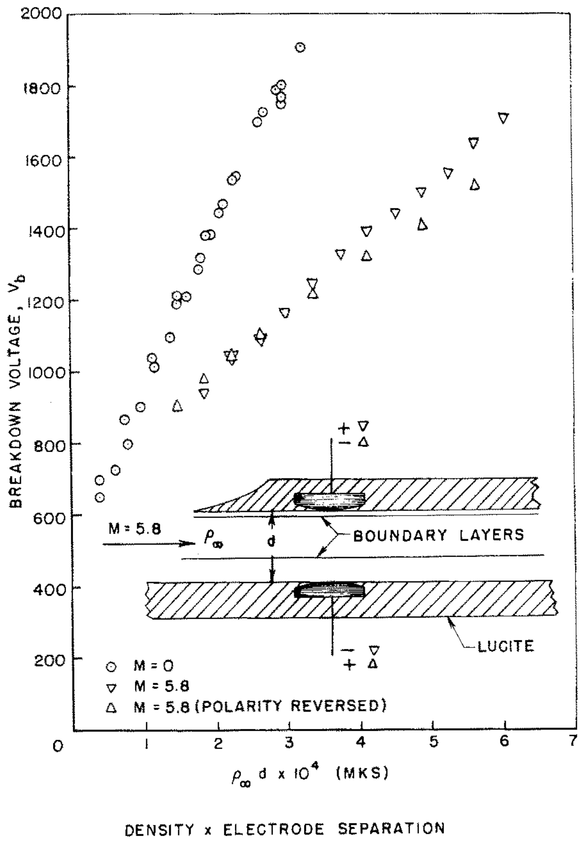

FIG. 1. Comparison of breakdown voltages with and without flow.

The Townsend breakdown criterion[2] was used, and the density variation in the boundary layer was approximated alternately by a "step" and a linear function. The ratio of interelectrode distance to the boundary-layer thickness emerged as the important parameter from this analysis, and satisfactory agreement with the experiment was demonstrated. Furthermore, the effect of the stream velocity (3000 fps in the present case) does not seem to be important for the electrode dimensions and prebreakdown electric fields used, which is to be expected since the ionic mobilities are so high [order of 200 to 300 (cm/sec)/(v/cm)] that the ionic drift velocities due to the prebreakdown field are larger than the flow velocity.

Such arguments lead to the conclusion that regions of intense viscous dissipation, such as boundary layers, free shear layers, and wakes form good electrical conductors when contrasted to the external (unperturbed) flow, at least within the range of parameters investigated.

As an illustration, it was decided to attempt the confinement of an electrical discharge in the axisymmetric wake behind a body. For this purpose a cone-cylinder body was built of insulating material and a copper anode was inserted into it, with its tip protruding from the blunt base of the cylinder. The anode body was aligned with the stream at zero incidence and a copper cathode was placed some distance downstream in the wake. The discharge was studied with the aid of photography with ordinary emulsions, and its voltage-current characteristics. Glow and arc discharges in excess of 10 cm in length and of a few millimeters in diameter were obtained. The voltages necessary for discharge maintenance ranged from 300 to 1500 v and the currents from 50 μa to 0.5 amp/cm^2. The discharge range covered with the available power supply was from the subnormal glow to the low-current arc, with the glow-arc transition observable in many instances.

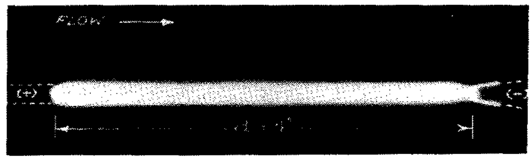

FIG. 2. Steady-state confinement of an electrical arc discharge in the hypersonic wake. In the dark region external to the glow, $T = 50°$K and flow velocity $\doteq$ 3000 fps. Discharge voltage = 1250 v dc, current = 0.05 amp.

Figure 2 shows a typical continuous discharge in the wake. The discharge boundary is well defined and the discharge does not seem to be influenced by the nonuniformities known to exist in parts of the wake, e.g., near the anode body base. The wake thus seems to act as a good confinement channel for electrical current flow, and offers an alternative to confining and stabilizing discharges by the vortex method.[3] Since the dimensions of such a discharge are influenced primarily by the anode body base diameter and the range of the power supply, this method holds promise as a tool for studying diffusion, recombination and the relative influence of the fluid flow, and the electric field on the current column.

This work was carried out under the sponsorship of the Office, Chief of Ordnance, Army Ballistic Missile Agency and the Office of Ordnance Research, U. S. Army.

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Attenuation of a Moving Magnetic Field in a Shock Tube

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THIS letter describes measurements of the magnetic field associated with a circulating current traveling in an electrically driven shock tube. As a means of obtaining higher velocity gas flow, an axial magnetic