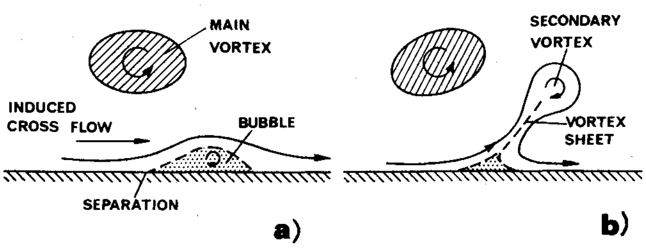

Fig. 4 Suggested interpretation of the total-head surveys: a) a section downstream of the initial separation, b) the subsequent development of the secondary vortex.

velocity, thus causing it to rise as seen in the flight tests. The paths of the main core are shown in Fig. 5 for the two examples depicted in Figs. 2 and 3 together with two different incidence cases. Values measured for circulation Reynolds number (Γ/ν) and the points where the floor separation was first detected are indicated. It is clear that the displacement effect of the bubble, and the influence of the reversed-sense vorticity within it, immediately effect the main core by checking its downward motion. The subsequent development of the secondary vortex causes the main core to rise. It also tends to arrest the trailing vortex's horizontal motion and in some configurations actually reverses its direction. The flight tests of Dee and Nicholas[1] show evidence to confirm this retardation but the dominating influence of cross winds coupled with experimental scatter preclude any positive confirmation. The reversal of the motion could be possibly attributed to tunnel wall interference but this is unlikely.

It is interesting to note the similarity between these observations and the flow over slender delta wings with leading edge separation[3,4] where the vortex sheet shed by each leading edge rolls up to form a concentrated core above the upper surface, inducing a secondary separation as in this experiment. There are, however, two significant differences between the two flows.

First, the secondary vortex formed above the ground is not confined by a vortex sheet feeding the main core. So it is free to rise and, under the influence of the stronger main vortex, would eventually spiral around it. In these experiments there was no indication of spiralling, and this may indicate that the secondary vortex quickly grows to a strength comparable with the main core. The rapid rate at which the main core rises (Fig. 5) would tend to confirm this, but the vortex sheet from the ground feeding the secondary vortex may be a contributory factor in preventing the spiralling.

Second, the surface boundary conditions are quite different in the two cases; one moving, the other fixed. Yet both flows exhibit the same qualitative features of secondary separation. This poses the question of whether the moving floor is essential for correct wind-tunnel simulation of trailing-vortex-ground interactions. Total-head surveys with the floor stationary clearly showed that, although the over all character of the flow remained unaltered, there were significant quantitative discrepancies. This presents a serious problem, as extending the limited scope of these tests, especially to higher Reynolds number, would demand an extremely

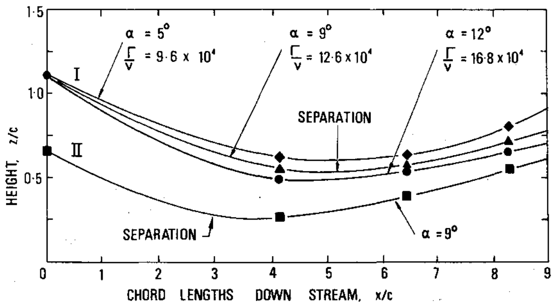

Fig. 5 Paths followed by the main vortex cores.

large moving floor. A series of careful full-scale flight tests made under still conditions and aimed at specifically investigating this phenomenon would be invaluable in verifying the relevance of these observations to actual aircraft wakes.

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Characteristics of a Magnetic Annular Arc Operating Continuously at Atmospheric Pressure

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In a recent paper[1] Garrison and Smith reported results from an arc operating continuously at atmospheric pressure, in which an apparently diffuse discharge filling the annular region between the electrodes was obtained.

Cathodes of copper and thoriated tungsten were used with a hemispherical tip 25 mm diam with a copper anode 34 mm i.d. An axial magnetic field of up to 2.5 Tesla and d.c. arc currents of from 700 amp to 2000 amp were used in nitrogen at atmospheric pressure.

The arc was photographed with a framing camera at 10,000 frames/sec with a shutter speed of 2 μsec. Examples of a spoke (constricted) discharge were shown at a magnetic flux density of 0.27 Tesla and an arc current of 760 amp, a transi-

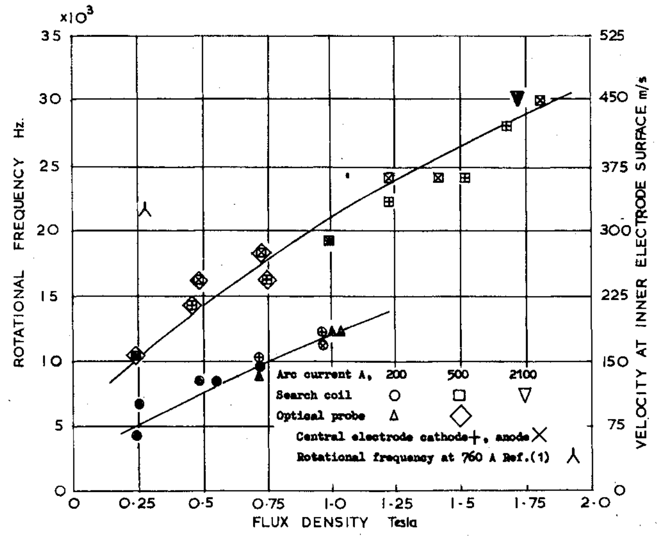

Fig. 1 Variation of arc velocity and rotational frequency with the magnetic flux density at various values of arc current.

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tional discharge at 1.5 Tesla and 745 amp and a diffuse discharge at 1.53 Tesla and 1580 amp. Results for similar conditions obtained with high-speed framing cameras have also indicated the existence of a diffuse discharge at around atmospheric pressure.[2]

The existence of diffuse discharges at atmospheric pressure has been specifically investigated[3] as part of a research programme on the development of high power plasma torches for industrial processes.[4] The experimental set up comprised two parallel copper co-axial electrodes with an outer electrode bore of 20.8 mm and a radial separation of 8 mm in an axial magnetic field of up to 1.75 Tesla. A pulsed d.c. supply of up to 2100 amp was used of sufficient duration for the arc to reach equilibrium conditions. Initial observations using a high-speed framing camera indicated that the annular gap was apparently filled with a diffuse discharge. Results obtained with an optical probe indicated that the discharge became diffuse at rotational frequencies of about 20,000 Hz.

It was decided that a conclusive test was to detect the magnetic field due to the discharge current using a coil probe. A uniform diffuse discharge would produce no output voltage, an unstable discharge fluctuating between a diffuse discharge and a constricted discharge would produce an irregular output. If the discharge remained constricted at all times a regularly fluctuating output consistent over the whole range including that over which optical methods indicated that the arc was constricted should be obtained. Accordingly a search coil with a ferrite core was constructed. The coil comprised 86 turns of 42 SWG wire on a ferrite core 1.8 mm diam and 2 mm long. The coil was mounted with its axis midway between the electrodes and insulated from the discharge by a thin sheet of mica and a boron nitride cap. The optical probe was also mounted on the same support. An oscilloscope with four separate input channels was used to measure simultaneously the output from the two probes, the arc voltage and the arc current.

The output from the search coil indicated that the discharge remained constricted over the entire operating range. The measurements of velocity and rotational frequency over the lower range of rotational frequency were consistent with those obtained with the optical probe. No evidence of a transition was obtained.

The variation of arc velocity and rotational frequency with the magnetic flux density at various values of arc current are shown in Fig. 1, together with the measured value of velocity obtained by Garrison and Smith. (The rotational frequency is different due to the variation in electrode geometry.) The variation of arc voltage with magnetic flux density was measured and the increase in arc voltage with arc current at high currents noted by Garrison and Smith was also observed. The results for the measured arc velocity using a magnetic probe and the arc voltage have been compared with values of arc velocity of discharges which were known to be constricted and were found to be consistent with them[3]; no discontinuity either in arc velocity or arc voltage, which might be expected to occur at the transition from a constricted arc to a diffuse arc occurred.

More recent results[5] using a camera with a framing rate of about 47,000 frames/sec and duration of exposure of 4 μsec with a similar co-axial electrode arrangement indicate that with a photographic system capable of high optical definition a constricted arc in air can be defined under similar conditions to those reported by the author and Garrison and Smith.

Various possible mechanisms for the persistence of luminescence of an arc exist. Acoustic measurements of the decrease in arc temperature after arc interruption for arc currents up to 25 amp in air at atmospheric pressure indicate that the temperature decreases from about 6000°K to 4000°K within 100 μsec after interruption of the arc current.[6] The effect of increase in arc current and electrode separation may be expected to result in an increase in duration of the luminosity. The luminosity of an arc due to ionisation below about 4000°K is negligible.

An alternative possible mechanism for the persistence of the luminosity of the discharge is the formation of active nitrogen.[3] Although the lifetime of active nitrogen can be in excess of $^1/_2$ hr at low pressures at atmospheric pressure its lifetime will be greatly reduced, nevertheless the lifetime is still sufficient to observe it as a jet when active nitrogen is discharged from a vessel into air.[7,8] The lifetime will, however, be further reduced by the presence of other gases and may account for the ability to discern a constricted arc in air with improved optical techniques, apparently not possible in nitrogen alone.

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Laminar Convective Heat-Transfer Rates on a Hemisphere Cylinder in Rarefied Hypersonic Flow

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Nomenclature

C_p = specific heat at constant pressure
C = linear viscosity relationship, $(T_\infty/\mu)(\mu^*/T^*)$
e = Davis' parameter $[\bar{\mu}/(\rho_\infty U_\infty r_n)]^{1/2}$
H_o = stagnation enthalpy
H_w = wall enthalpy
K^2 = Cheng's parameter, $p_\infty r_n/\mu_\infty U_\infty C$
M_∞ = freestream Mach number
p_0 = total pressure
p_∞ = freestream pressure
$\dot{Q}_o$ = stagnation point heat-transfer rate
$\dot{Q}_{1-4}$ = heat-transfer rate at various surface positions (Fig. 3)

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