The mean zonal wind speed according to observation hour was also computed, but, as expected, the larger variance of the wind speed prevents any significant observation of a diurnal variation in wind speed. The departure of the mean wind speed by observation hour from the mean wind speed for the season is shown in fig. 3. Error bars for two standard deviations of the mean have also been shown. A diurnal variation of the zonal wind of 1 m sec^{-1} is of course possible, but it is not demonstrated by these data.

The results of this study are summarized as follows:

(1) The relatively large intermediate scale variance of the summer stratospheric easterlies is not directly related to oscillations with solar or lunar tidal periods.

(2) A significant diurnal variation of the meridional component of the wind with an amplitude of the order of 1 m sec^{-1} has been detected at latitudes below 20N, and an equally large diurnal oscillation appears likely at 45N.

(3) The phase of the diurnal variation of the meridional velocity fluctuation at low latitudes appears to lead the wave at 45N by about 90 deg.

The dominance of the diurnal wind variation over the semidiurnal oscillation at 100,000 ft is not surprising. Not only does the reasonance theory predict a minimum semidiurnal oscillation in this region, but a deep layer just above the observation level is predicted to have a large diurnal radiative temperature change (London, 1957) which presumably could cause a diurnal pressure wave. It is interesting to speculate further on the diurnal pressure wave associated with the postulated wind variation. Stolov (1955) has deduced that the horizontal wind fields associated with large pressure systems of diurnal or semidiurnal period would be very similar to the relationship between pressure and wind fields in the travelling disturbances of the troposphere; *i.e.*, the wind is nearly parallel to the isobars at mid latitudes. The relatively large amplitude of the diurnal wind variation at low latitudes as well as the displacement of phase with latitude suggests that, unlike the semidiurnal pressure wave where the centers of the cells are at the equator, the centers of the cells of this diurnal pressure wave are located above the equator.

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STABILIZATION OF A HIGH-VOLTAGE DISCHARGE BY A VORTEX

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1. Introduction. Accounts of tornadoes, both ancient and modern, sometimes describe luminous electrical activity in the funnel, [1; 2]. The simple laboratory experiments reported here were carried out to determine what effects, if any, a vortex would have on a continuous high voltage discharge.

We have found that the vortex produces a stabilizing effect similar to that reported in early work on the arc fixation of nitrogen[3] and that it modifies the character of the discharge and the radio frequency noise that it produces.

2. Apparatus. The apparatus shown in figs. 1 and 2 consists of two steel rods mounted in the axis of a vertical pyrex tube. These rods are connected to a 60-cycle, AC high-voltage source, an ordinary oil-burner transformer. One of the rods is adjustable, and a continuous spark discharge can be produced when it is brought close to the other rod. Once initiated, the discharge can be lengthened by a readjustment of the movable rod. A small blower mounted on the top of the tube provides a gentle suction. When air is drawn into the lower opening of the tube through four tangential inlet holes, a weak vortex is formed. With this blower, the air within the tube is caused to rotate around the electrical discharge in the tube axis. When the vortex was formed in the experiments to be described, the pressure within the tube was 0.2 cm of water below that of the atmosphere, and the air flow was 100 cc per sec.

The apparatus shown in fig. 1 was constructed as a unit, and the transformer was housed in its base. The details of tube, electrode, and blower construction are shown in fig. 2.

3. Experimental. With this apparatus, we observed that the formation of a vortex caused a significant alteration in the character of the electric discharge.

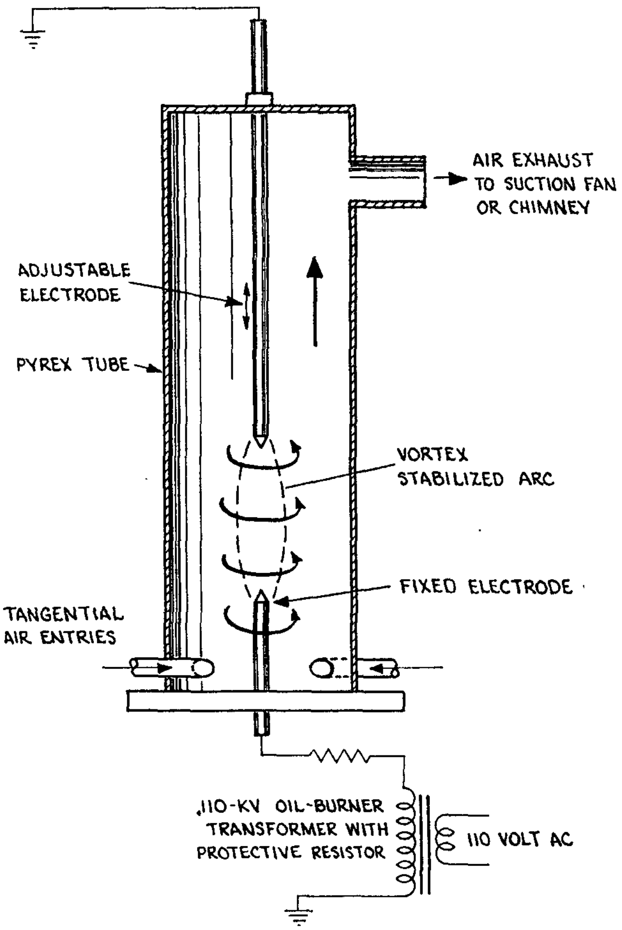

Fig. 1. Schematic drawing of arc and vortex arrangements.

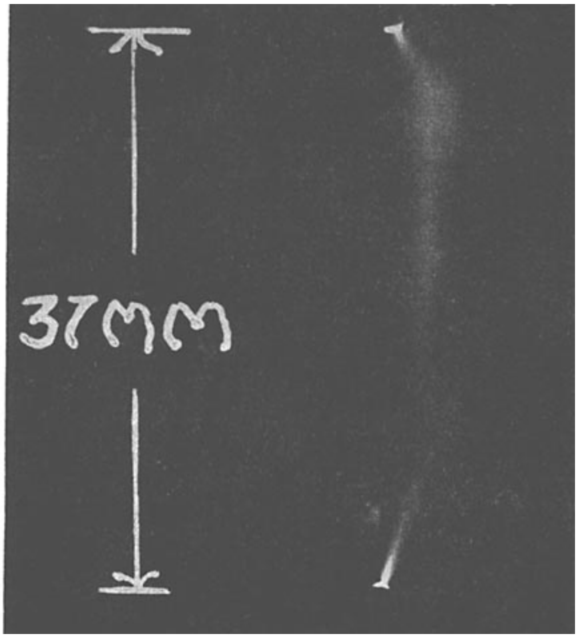

Fig. 3. Electric discharge at maximum stable length without vortex.

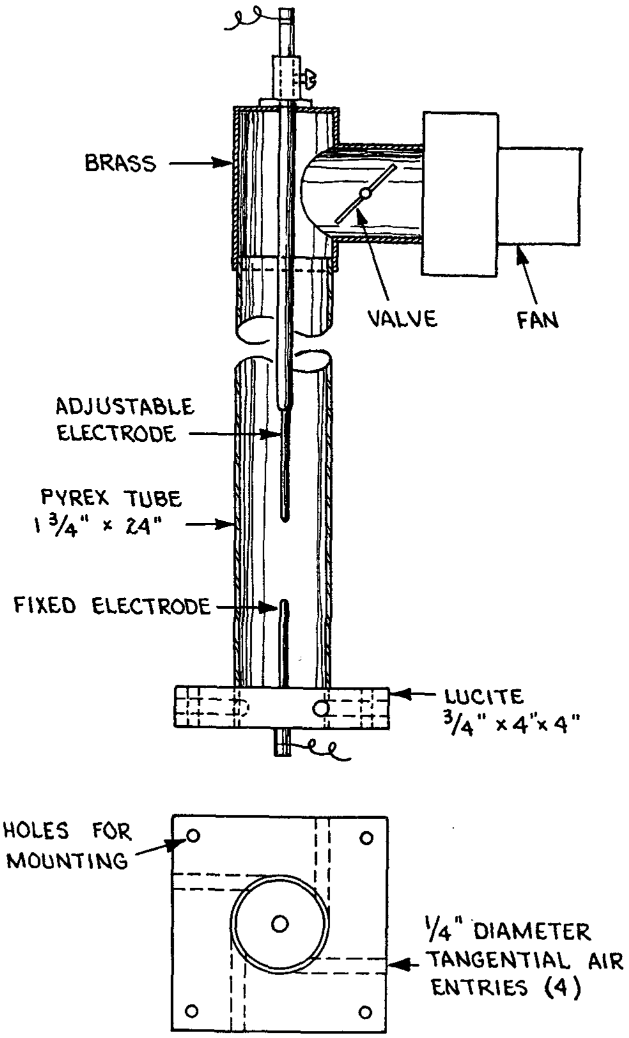

Fig. 2. Scale drawing of principal components of apparatus.

Without a vortex, a stable spark could not be maintained if the electrodes were more than 37 mm apart. A spark between electrodes having this separation is shown in fig. 3. When the blower was turned on and a vortex was created, we observed that the discharge between the electrodes became more steady, that its diameter increased, and that it appeared to assume the characteristics of a glow rather than a spark discharge. Fig. 4 shows the appearance of the discharge when the vortex is present. When the vortex was turned on, we found that the potential difference across the discharge dropped from 6.0 kv to 4.3 kv and that the current increased from about 17.5 to 19 milliamperes. It was also observed that, without the vortex, the discharge produced considerable radio-frequency noise in the broadcast band but that, when the vortex was turned on, this noise disappeared.

It was further observed that with the vortex it was possible to obtain a stable discharge even when the electrodes were as much as 68 mm apart. Such a dis-

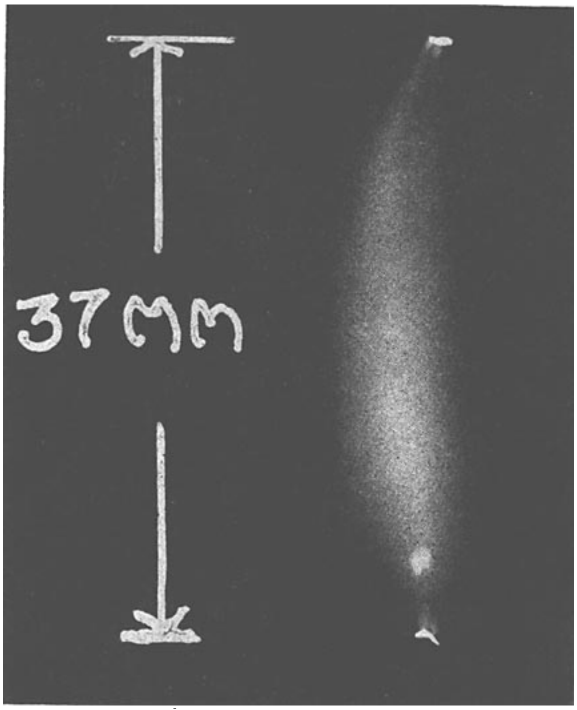

FIG. 4. Electric discharge with vortex.

charge is shown in fig. 5. The potential difference in this case is 7.3 kv, and the current is 14.5 milliamperes.

4. Conclusions. We believe that the effects the vortex produces on the discharge can be explained in terms of the centrifugal forces that it exerts. The rotation of the air in the tube produces a radial pressure gradient which is zero at the axis and which increases with the distance away from it. In a pressure gradient such as this, bouyant forces cause the hot gas in the electric discharge to move toward the region of lowest pressure at the axis. Thus, the centrifugal action automatically confines the discharge to the center of the vortex. This action stabilizes the discharge by forcing the hot ionized gases together in the axis and by preventing them from moving about and mixing with the cool surrounding air. This phenomenon is quite similar to the familiar climbing-spark demonstration in which buoyancy forces the hot gases of a horizontal high-voltage discharge between two vertical wires to climb in the normal vertical atmospheric pressure gradient. In the vortex experiment, the discharge moves radially toward the axis under the rotationally produced pressure gradient.

We conclude that the vortex produces the following effects on the high-voltage discharge:

(a) makes the discharge more stable,
(b) causes the character of the discharge to change from successive sparks to a continuous glow,
(c) increases the distance over which the discharge can be maintained,

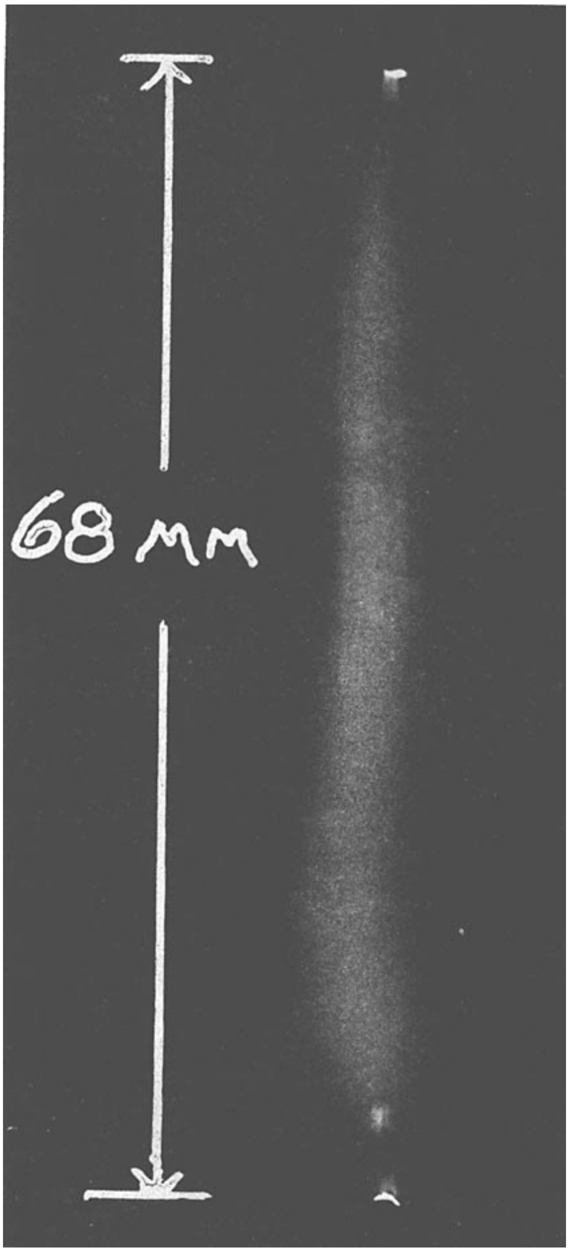

FIG. 5. Electric discharge with vortex at maximum stable length.

(d) decreases the electrical resistance of the discharge,
(e) decreases the noise of the discharge,
(*f*) decreases the production of the electromagnetic radiation in the broadcast band, and
(g) causes the discharge to center itself along the axis of rotation.

It is admittedly dangerous to attempt to extrapolate from these small laboratory experiments to the tornado funnel where conditions are vastly different. The results do suggest, however, that the tornado funnel might serve as a preferred path for lightning, as Peltier [4] has suggested, and that the vortex may stabilize and modify lightning discharges.

In these experiments, the pressure lowering in the vortex of only a fraction of a millibar is so small it has a negligible effect on the discharge. In actual tornadoes, pressure drops of 200 mb have been observed [5]. It is reasonable to suppose that here the pressure diminution may be large enough to produce effects not present in the laboratory model.

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A NOTE ON THE TWO-STREAM THEORY OF RADIATIONAL TRANSFER THROUGH CLOUDS[1]

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During the course of investigating infra-red radiational transfer through clouds, available literature on the subject was reviewed. Throughout the literature, one of the most popular methods of mathematically treating radiational transfer has been by means of the two-stream theory, first set up by Schuster (1905) and later by Mecke (1921). Subsequently, other workers in this field (Hewson, 1943; Neiburger, 1949) have used Mecke's equations for computation of such items as cloud albedo, absorption, and transmission through various hypothetical clouds. Various short-comings are inherent in the two-stream theory and have been discussed by the authors mentioned above, as well as by Gold and Whipple (Hewson, discussion, 1943). The method, at best, represents only an approximation to the actual physics of the radiational-transfer problem, and subsequent workers, notably Fritz (1954, 1958), have approached the problem from a physically more realistic viewpoint. Nevertheless, the two-stream method does permit one to make approximate calculations of the radiational transfer through clouds, and, as such, there is one further point worth noting which seems to have escaped the attention of previous workers in this field. Mecke and subsequent authors have defined the parameter β as the fraction of *incident* radiation scattered backwards by a drop. However, in setting up the differential equations for the upward and downward beams within the cloud, the scattered light is expressed as β multiplied by the difference between the total radiation intercepted by a drop and the amount absorbed by the drop. Thus, if we let the amount of radiation intercepted by a drop be given by I_0, and the amount absorbed by a drop be given by I_0x, then the scattered light, I_s, is given as

$$I_s = \beta I_0$$

and not as

$$I_s = \beta(I_0 - I_0x).$$

Since the absorption coefficient of liquid water in the visible and near infra-red regions of the spectrum is rather small, the parameter $(I_0 - I_0x)$ will not differ greatly from I_0. Therefore, for solar-energy transfer, the error resulting from the use of the incorrect expression for the scattered light will not be large. However, the error would be considerable when dealing with the infra-red transfer of terrestial radiation through clouds. Therefore, it was deemed advisable to set up the corrected form of the equations and solve them, following the method as originally pursued by Schuster.

The intensity of the forward component of radiation, A, and the backward component, B, may be expressed in the following differential form, as has been shown by Schuster:

$$dA = -x\alpha A dz - \alpha\beta(A - B)dz \qquad (1)$$

$$dB = x\alpha B dz - \alpha\beta(A - B)dz \qquad (2)$$

where α equals the total cross-sectional area per unit volume of the droplets which intercept parallel-beam

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