Wake Turbulence

In recent years it has been established that the turbulence which can be found behind all aircraft in flight is largely caused by two vortices, one of which trails from the tip of each wing. In simplified terms, this vortex is the result of a difference in the air pressure above and below the wing. The air moves from the higher pressure below the wing, round the wing tip towards the upper surface. This imparts a rolling motion in the airflow behind each wing tip and leads to the development of a pair of counter-rotating vortices which are left in the aircraft's wake. These vortices are a characteristic of the lift generated by a wing and appear as an aircraft rotates and leaves the ground during take-off and disappear again when the aircraft is firmly on the runway after landing.

The core of a vortex rotates much as a solid body does, ie the tangential velocities in it increase with increasing radius. Outside the core, however, tangential velocity decreases with increasing radius, so that the velocity reaches a peak at the edge of the core. The product of this peak velocity and the core radius associated with it offer a convenient way of describing the strength of a vortex and this depends mainly on the size, weight and air-speed of the aircraft generating it. Broadly speaking, the heavier the aircraft and the more slowly it flies the stronger are the vortices it generates, though changes of configuration generally modify the relationships involved. Vortex cores expand as they age and their peak peripheral velocities diminish correspondingly, so that vortex 'strength' remains much the same until other decay processes become important. It is during this phase, and particularly during its earlier stages, that the wakes of large aircraft constitute a hazard for smaller, following aircraft.

Flight tests have shown that wake vortices descend initially at rates determined by their distance apart,and then stabilise at heights between 500 ft and 1000 ft below the flight path of the generating aircraft. The initial rate of descent typical of large aircraft is about 400–500 ft/min, while the Argosy would produce about half that rate. A vortex pair tends to slow its rate of descent as it approaches the ground and eventually stabilises at a height equal to about one-half the span of the generating aircraft. At the same time each vortex develops an outward velocity that, in still air, eventually equals the magnitude of the original rate of descent. Experiments have shown that vortices can persist for about two minutes near the ground and for longer periods at higher altitudes.

A strong crosswind at an aerodrome will naturally blow both vortices from a generating aircraft away from the active runway. A light crosswind, however, may only be sufficient to cancel the outward movement near to the ground of the upwind vortex. In these conditions one of the vortices from an aircraft taking-off may remain stationary over the runway. Similarly a vortex from a landing aircraft may remain present along the final approach path. In calm atmospheric conditions the turbulence in these areas may be very persistent.

If all aircraft commence their take-off from the beginning of the runway then the smaller and lighter aircraft will generally get airborne in a shorter distance than that required by those which are larger and heavier. Since aircraft do not begin to generate wake vortices until they rotate and leave the runway, it follows that a light aircraft following a heavier one will take to the air in an area which is free from wake turbulence. Since vortices also descend in free air, the light aircraft's climb will tend to remain above the air affected by the preceding aircraft. In general, therefore, the light aircraft runs only a small risk of encountering wake turbulence if it starts its take-off from the runway threshold. However, if the light aircraft begins to roll from an intermediate point on the runway, it may not get airborne before it reaches the position where the preceding large aircraft has left the ground. It will now be flying in a region which has been affected by wake vortices. The dangers that an aircraft runs of encountering wake turbulence after it has made an 'intersection' take-off have long been recognised and warnings of this hazard may be seen in CAA Aeronautical Information Circulars (AIC) 52/1978 and 87/1979.

The behaviour of an aircraft which encounters wake turbulence will depend on the direction from which it enters the vortices. If it flies through them from the side then it will be most affected in pitch, being severely pitched either nose-up or nose-down successively. If the aircraft is flying parallel to the axis of the vortices and flies into the space between them then it will experience a down-draught. If it is flying parallel to the axis of the vortices and enters one of the vortex cores then it will suffer a severe rolling moment. The forces affecting the following aircraft will depend on the intensity and strength of the vortex which in turn will depend on the type of aircraft which is generating the vortices and also on the age of the vortex system. The control capability of the aircraft will determine just how much it will be affected by the forces of the turbulence. Evidence suggests that the vortex wake is most dangerous when the generating aircraft's wing span is more than double that of the follower. Apart from the strength of the 'downwash', which may exceed the climb performance of the following aircraft, a vortex core can produce a roll rate of up to 80 degrees per second which is about twice the roll rate capability of most light aircraft.

FIG 1

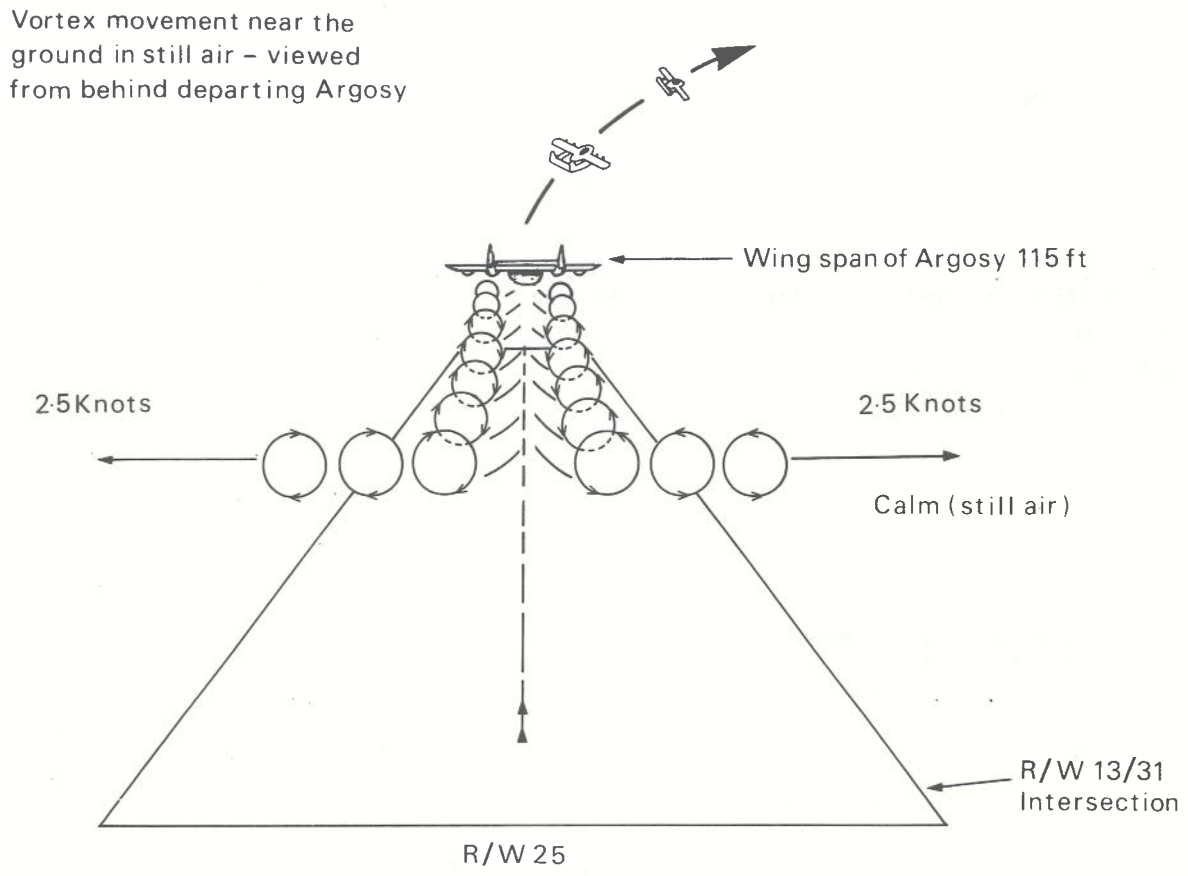
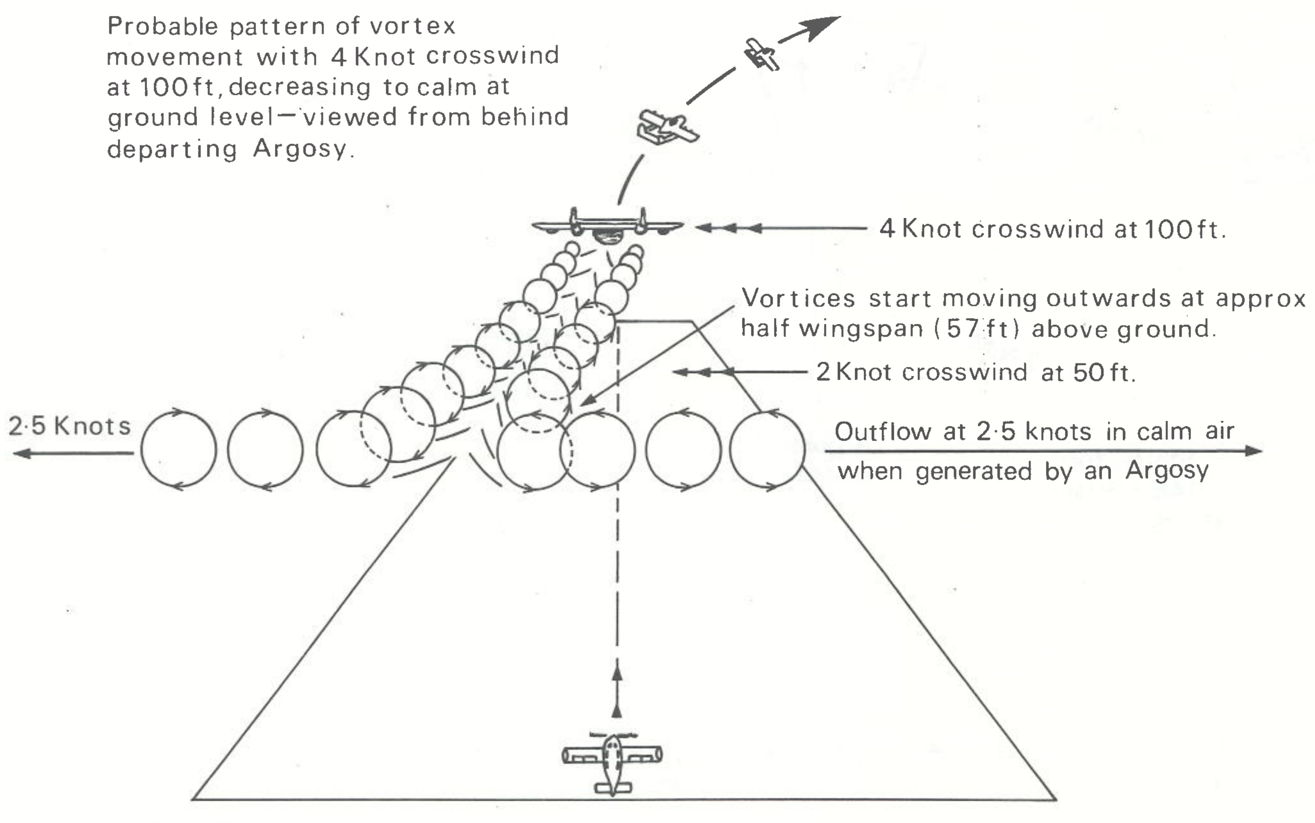

Vortex movement near the
ground in still air – viewed
from behind departing Argosy
Wing span of Argosy 115 ft
2·5 Knots
2·5 Knots
Calm (still air)
R/W 13/31
Intersection
R/W 25

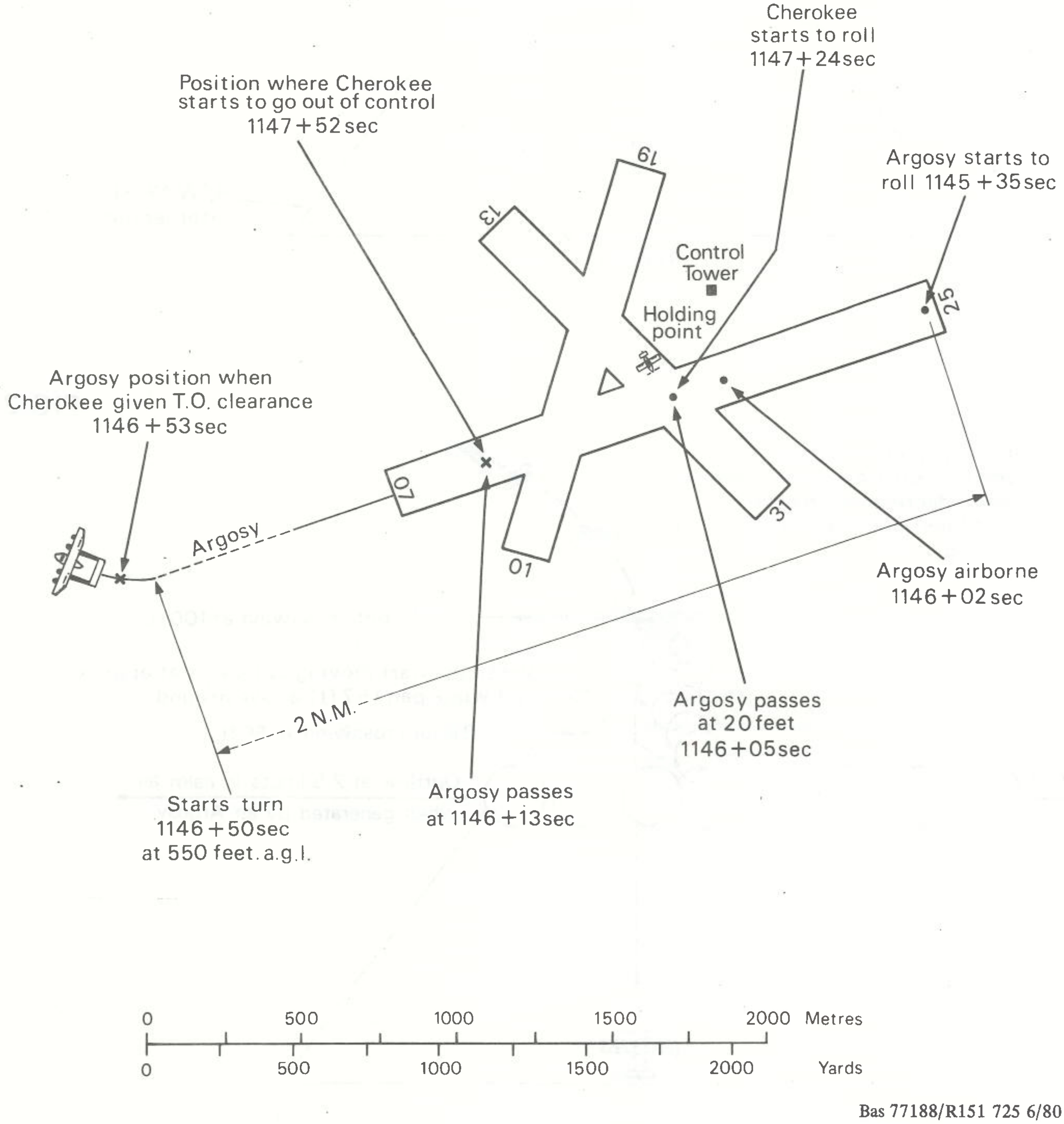
FIG 2


Probable pattern of vortex
movement with 4 Knot crosswind
at 100 ft, decreasing to calm at
ground level—viewed from behind
departing Argosy.
4 Knot crosswind at 100 ft.
Vortices start moving outwards at approx
half wingspan (57 ft) above ground.
2 Knot crosswind at 50 ft.
2·5 Knots
Outflow at 2·5 knots in calm air
when generated by an Argosy

Calculated times for the sequence of events leading to the accident to G-AYMJ

RUNWAY 25 DIMENSIONS

Elevation:	182 feet
Length:	1827 Metres
Width:	46 Metres
Distance from 25 end to 13/31 intersection:	880 Metres
Distance from 13/31 intersection to 07 end:	945 Metres
Take off run — Argosy:	700 Metres
Cherokee Take off distance to 50 feet:	445 Metres



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