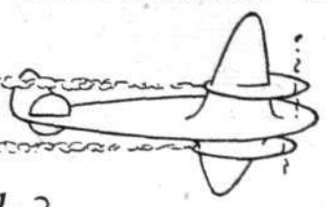
EVEN I CAN UNDERSTAND—4.



Q. *What are exhaust and wing-tip trails?*

A. 1. Exhaust trails

The fuel used in aero engines contains carbon and hydrogen. The products of combustion from the carbon are a colourless gas and from the hydrogen plain water vapour or water. A modern aero engine at cruising power might be putting out about 400 lb. of water per hour. This comes out of the exhaust as an invisible vapour and in general remains invisible, water vapour being an invisible gas. There are occasions, however, when long enduring trails are visible after the passage of an aeroplane which finally look like ordinary clouds.

Visible clouds are formed when there is more invisible water vapour about than can be accommodated. The excess vapour then condenses into a cloud of water droplets or ice particles which are visible. The amount of invisible vapour that a cubic foot of space will hold depends only on the temperature. On an ordinary day (+ 15°C.) this would be about 6 grains, while in a temperature of – 50°C. it is less than 1/70th of a grain, and any excess must condense as a visible cloud, so there is good reason why these exhaust trails should sometimes be visible in the low temperatures which exist at high altitudes. Very broadly speaking, these trails either form very close to the exhaust or not at all so that they would not seem to depend on a thorough mixing with the cold air but rather on the conditions they meet as soon as they issue. It will be appreciated that very variable degrees of moisture content may be met with at high altitudes and when cirrus cloud is about it has condensed because the vapour content is around 100 per cent. In these conditions the additional vapour put out by the exhaust cannot very well be accepted without condensation notwithstanding the addition of exhaust heat.

2. Wing-tip trails

The pressure of air is high near the middle of the span on the under surface of the wing and lower at the wing tip. On the upper surface the converse is the case. The air in passing across the wing chord tends to seek a low pressure region. It therefore tends to slide out towards the wing tip on the under surface and in towards the centre on the upper surface. These movements combine and form a vortex at the wing tip. The vortex will be stronger the greater the work done by the aeroplane; in other words, the higher the loading or the combination of normal loading and the addition to it due to manœuvring. A rapidly rotating vortex has considerable centrifugal force. This causes a rarefaction and therefore expansion of the air in the middle of the vortex. Air cannot be suddenly expanded without declining in temperature. If the vortex is strong enough and the humidity of the air high enough, the "dew point" will be reached, condensation will take place and wing-tip trails appear. These generally disappear almost at once at low altitudes as the decay of the vortex allows the trail to evaporate.

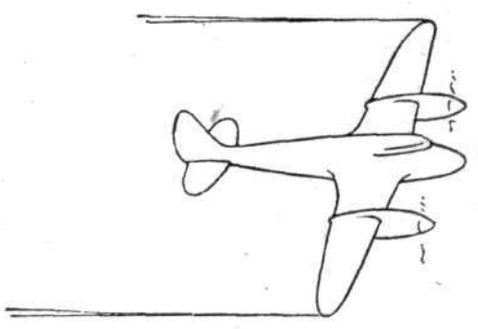
Observation has recently shown that wing-tip vortices can be audible as well as visible. When a highly loaded aeroplane is doing tight turns or "pull outs" fairly near spectators it has several times been noted that as the aeroplane is receding into the distance with diminishing noise, a new noise suddenly begins and may persist for a few seconds. This noise has been likened to the whistle of a falling object and has actually caused some alarm. The conditions make it certain that this noise has its own source away from the aeroplane and it is reasonable to suppose that a vortex of sufficient strength to cause condensation in summer weather will whistle as it rotates. It has then only to come close enough, by drifting on the wind or otherwise, to be heard before it decays. The close physical similarity of these wing-tip trails to water-spouts forces itself on the attention.

3. Conclusion

There is a clear difference between the exhaust and wing-tip trails. The exhaust adds water vapour to what is there already, and if the air is saturated or nearly so, will leave an enduring cloud. The wing-tip trail adds nothing, but by locally lowering the temperature causes condensation which re-evaporates when the vortex decays and the atmosphere returns to its former condition. This is the general rule. It is, however, possible to have supersaturated air in which there has been nothing to start the condensation. In this case there is nothing to prevent the wing-tip vortex acting as a trigger to start the overdue condensation which may then be of the enduring type.

Everyday illustrations of the phenomena can be seen—lowering of temperature (causing condensation) by expansion in the exhaust of the pneumatic drill—suppression of visible "steam" from the locomotive on a hot day when the air will accept much water vapour uncondensed, and the fact that the motor-car exhaust, generally invisible even in very cold weather, produces a visible cloud when the atmosphere is cold and a cold engine abstracts heat before the exhaust comes out.

The locomotive provides a case where the trail-making mechanism is kept constant while the external atmosphere is varied from a no-trail to a full-trail condition, while the motor-car example shows that with constant atmospheric conditions the thermal state of the issuing exhaust determines whether or not a trail shall be formed.



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