PART 2 : SECTION 4

CHAPTER 7

FLYING IN TURBULENCE AND PRECIPITATION

Significance of Turbulence

1. The importance of using the correct technique when flying through turbulence becomes greater as aircraft speeds increase. At low speeds turbulence means no more than physical discomfort or, in cloud, a challenge to the instrument-flying ability of the pilot, but at high speeds turbulence may impose severe structural stresses on the aircraft.

Effect of Speed

2. The T.A.S. is the most important factor when flying in turbulence. When an up-draught is entered, the loading on the wings is suddenly increased until the upward motion of the aircraft is adjusted to that of the surrounding air. At low speeds the momentary increase in the angle of attack caused by the rising air may be sufficient to stall the aircraft. At high speeds it may impose excessive loading with the consequent risk of structural damage or even failure. The best speed must take into account the A.U.W., strength, and wing loading of each particular aircraft, as well as the gust velocities likely to be encountered ; the best speed is therefore one which gives the greatest margin of safety with regard to controllability and structural limitations.

3. It has been found difficult to specify the optimum speed that should be used when in turbulent conditions. Pilot's Notes for some aircraft recommend the best speed, but this cannot always be done owing to lack of knowledge of all the implications. The following generalizations can be used in the absence of guidance from Pilot's Notes ; it should be noted that the speeds apply to particular classes of aircraft.

4. For turbo-jet fighters and light bombers the best I.A.S. up to about 20,000 feet is about 300 knots. If strong turbulence is encountered on the climb, the speed should be adjusted and the climb maintained until the turbulence is cleared. During a descent the same speed should be set and adhered to as far as possible until clear of the turbulence.

5. For piston-engined aircraft of all types for which Pilot's Notes do not give an optimum speed, the best speed is about 1·6 to 1·65 times the power-off stalling speed (flaps up) at the appropriate weight. However, on lightly loaded types such as elementary trainers and light communications aircraft a speed of about twice the stalling speed should be maintained.

Use of the Controls

6. The main requirement is to keep the aircraft on a fairly even keel, *i.e.* constant attitude, by moderate, never extreme, movements of the controls. The aim should be to allow the aircraft to ride the bumps rather than to fight them with the controls. Rough handling aggravates the stresses already imposed by the turbulence. Normally any variation of height and fluctuation in speed that results from flying the aircraft in a constant attitude must be accepted.

7. The danger of turbulence can be assessed only by reference to an accelerometer and/or the experience of the pilot.

Types of Turbulence

8. The three main types of turbulence are :—

(*a*) *Clear Air Turbulence.* Marked turbulence is sometimes suddenly encountered when flying in completely clear and otherwise smooth conditions at heights above 20,000 feet. This is usually due to the presence of a jet stream. Turbulence is localized and may usually be avoided by climbing or descending out of the narrow height band normally occupied by the jet stream. This type of turbulence is often characterized by a cobblestone effect, *i.e.* a fairly steady, high-frequency bumpiness.

(*b*) *Air-Mass Turbulence.* In an unstable air mass, turbulence is likely to be particularly severe from ground level to the tops of any heap-type clouds. The most violent air-mass turbulence is encountered in thunderstorms (cumulonimbus clouds) and these are considered in more detail in para. 9 *et seq*. Dependent on the amount of vertical development of the cumulus clouds, flying conditions in or below them vary in the degree of turbulence encountered, and when a speed for flying in turbulence is given in Pilot's Notes this should be set before entering the area. Above the cloud tops the air is generally quite smooth.

In tropical countries, however, where intense surface heating occurs, the lower air becomes extremely turbulent by midday although cloud may not form. This point should be borne in mind when descending from smooth air at high altitude, and the aircraft prepared for possible turbulence. The upper limit of this type of turbulence is usually about 10,000 feet. As the sun sinks lower, the air gradually becomes less turbulent until in the evenings it is generally quite smooth. The smoothest conditions for flying are in early morning or the evening.

(*c*) *Ground Turbulence*. On a windy day turbulence is experienced close to the ground and is especially noticeable in the lee of hills, woods, and large buildings. Not only may this turbulence be severe, but strong down draughts may endanger an aircraft if it is flying very close to the ground. Such down draughts may considerably reduce the climbing performance and may prevent low-powered aircraft from clearing hill tops. A climb to clear a range of hills should therefore be started in ample time to allow sufficient height to be gained. This type of turbulence frequently produces a thin layer of stratocumulus cloud above which smooth conditions may be found. Aircraft approaching to land are also affected by this type of turbulence and its associated wind gradient, which is liable to cause a sudden drop in airspeed. The remedy is to approach at 10 to 15 knots above the recommended speed for the particular configuration, when these conditions are prevailing.

THUNDERSTORMS

Considerations

9. Flight through a thunderstorm may be accompanied by almost all the meteorological hazards. When a thunderstorm has to be penetrated, it is as well to assume beforehand that a "rough ride" lies ahead and to take suitable precautions.

10. A typical well-developed cumulonimbus cloud is generally regarded as having three distinct parts :—

(*a*) The base, which is usually dark in colour, extending upwards for about 2,000 feet in the form of a roll.

(*b*) The main body, consisting of a greyish-white column in which vertical draughts may be considerable.

(*c*) The anvil-top, consisting of ice crystals, growing out of the main body and extending ahead in the direction of travel of the upper wind.

Detection by Radar

11. It is sometimes possible to detect thunderstorms by airborne radar, and thus obtain advance warning of impending turbulence. The range and clarity of the radar response depends largely on the amount of solid or liquid in the cloud ; thus an active thunderstorm containing large quantities of hail and rain provides a strong return, whilst an inactive or diminishing storm may not show up at all. Warning is thereby given of the more dangerous type of storm.

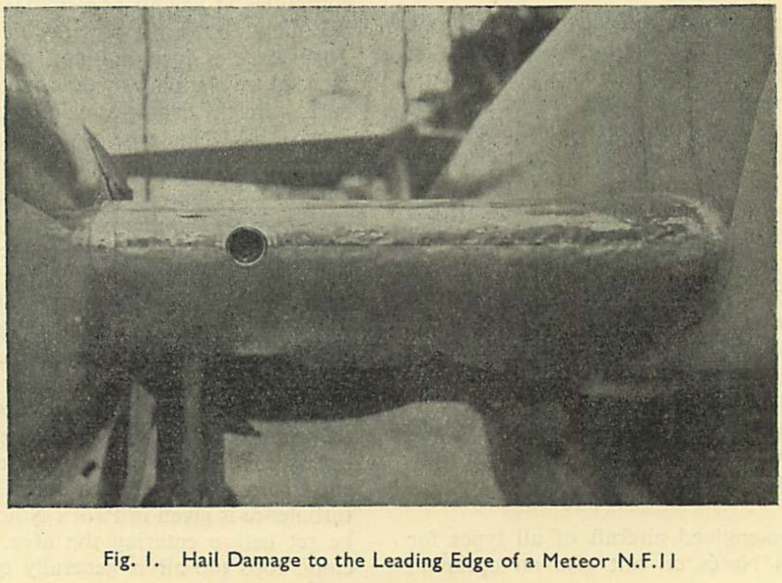


Fig. 1. Hail Damage to the Leading Edge of a Meteor N.F.11

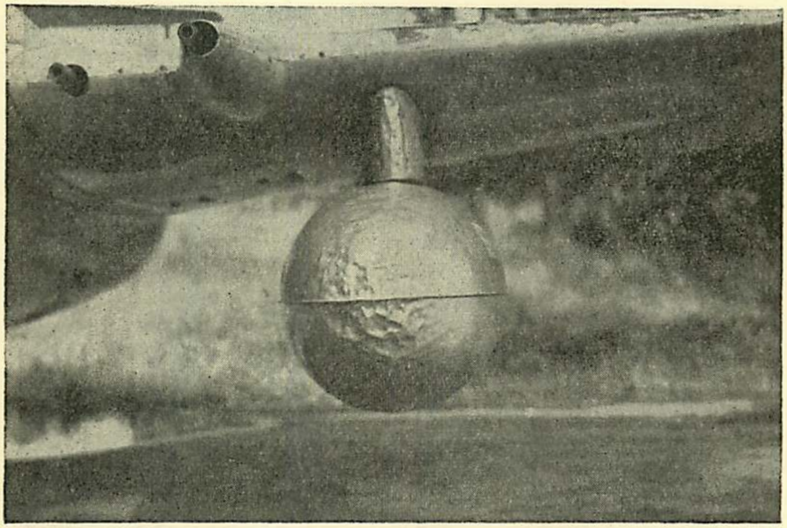


Fig. 2. Drop Tank Damaged by Hail

Hail

12. Hail may cause damage to both the airframe and engine of an aircraft. Hailstones vary considerably in size ranging from small particles to pieces the size of golf balls, depending on how long they have been supported within the cloud by the strong vertical currents. There is no method of foretelling when and where hail is to be encountered in a storm ; but by flying as far below the freezing level as possible or alternatively at heights of 25,000 feet or more the chances of encountering hail are minimized. Figs. 1 and 2 show examples of hail damage.

Icing

13. Thunderstorms usually contain large supercooled water droplets and are therefore likely to produce clear ice. Unless the storms are extensive the amount of ice accumulated is generally small, as individual storms are of small horizontal area, but the rate of accretion may be high.

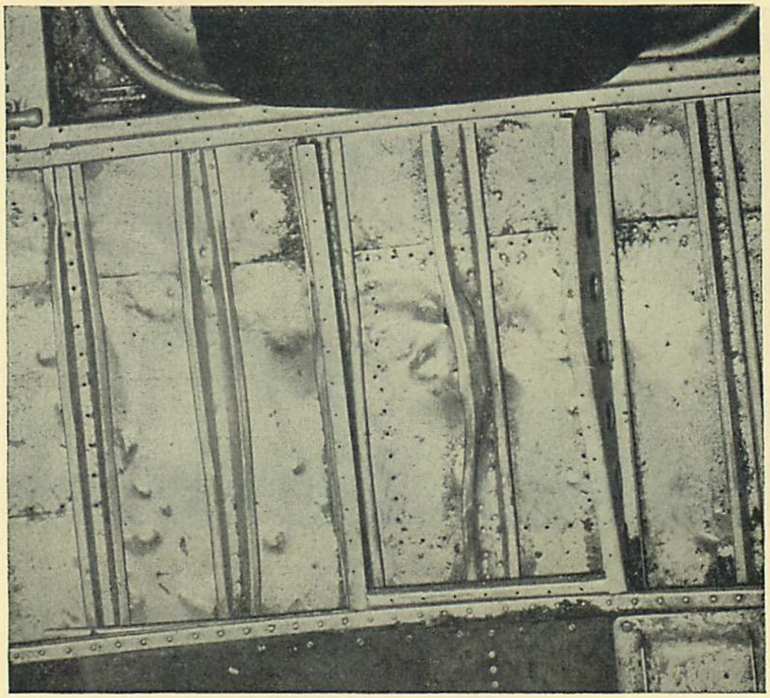
Lightning

14. The most spectacular and probably the least significant feature of a thunderstorm is lightning. The brilliant flash of a close discharge, the smell of ozone, and the noise are startling, but much of the effect can be reduced by turning on all cockpit lighting to reduce the contrast and dazzle when flashes occur ; this is particularly important at night.

15. **Bonding.** All conducting parts of an aircraft are bonded together by metal connections. Bonding metal has a low resistance and allows an electrical discharge to be distributed throughout the airframe. Lightning strikes therefore cause no serious damage or harm to the aircraft and crew.

16. **Lightning Damage.** Since trailing aerials or towed cables make ideal conductors for lightning and may be burned through by a discharge, these items should always be earthed and retracted before entering a storm. Lightning strikes (Fig. 3) usually cause no more damage than the burning of a few small holes in wing tips, rudders, or elevators, but if the discharge happens to strike a radio antenna or pressure head it may weaken or bend it. Magnetic compasses are usually unreliable after a lightning strike and should be checked by astronomical or radio means if possible. A ground swing should be carried out before the next flight and the details of the incident should be reported.

17. **St. Elmo's Fire.** Another phenomenon akin to lightning is known as St. Elmo's fire, corona, or brush discharge. Large potential differences occur in the atmosphere and are often intensified in or near thunderstorms. Since an aircraft in flight assumes the potential of the atmosphere around it, when it moves into an area of different potential, a visible discharge takes place. This



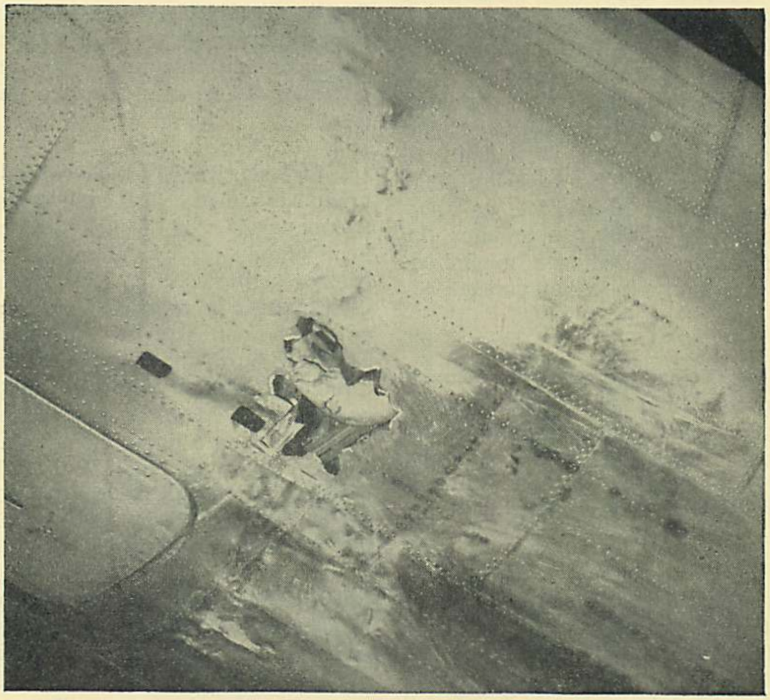


Fig. 3. Lightning Damage

The top picture shows internal damage to the underside of the fuselage.
The bottom picture shows external damage ; the blackened area is a scorch mark.

often manifests itself at night, or in dense cloud by day, as a blue flickering flame or halo about the propellers or other projections on the aircraft. Sometimes it takes the form of minute but bright discharges from moisture globules on the windscreen. These discharges are harmless as the amount of heat generated is small.

Flight Planning

18. When planning a flight that may pass through a turbulent area the following points should be borne in mind :—

(*a*) Isolated storms can usually be avoided ; at night the lightning flashes reveal the cloud structure.

(*b*) Thunderstorms associated with a frontal system are more difficult to detect, since they may be masked by layer cloud often extending down to the surface. Flight through frontal systems should be made below 6,000 feet or as high as practicable.

19. If a line of frontal thunderstorms lies across the flight path it is sometimes possible to select a point of entry where the vertical development is least pronounced, as this implies less vertical movement of the air. At night lightning flashes, or their absence, may reveal the best point at which to penetrate. The following is a summary of the main precautions to be observed :—

(*a*) *Height to Fly*. To avoid the worst turbulence it is generally advisable to fly below 8,000 feet or above the cloud tops. If it is decided to fly beneath the storm itself, remember that strong down draughts and precipitation may be encountered just under the cloud base.

(*b*) *Preparation*. Prepare the aircraft well in advance. All safety harnesses should be tight, otherwise there is a distinct possibility of injury in severe turbulence. All loose equipment should be secured. All available de-icing equipment should be switched on. The aircraft should be trimmed for straight and level flight at the best I.A.S. for turbulence. It may be desirable to disengage the autopilot.

(*c*) *Unreliability of Instruments*. All instruments which are sensitive to atmospheric pressure may fluctuate considerably and even freeze or give totally unreliable indications. The turn and slip indicator oscillates from side to side of the datum, making accurate interpretation difficult.

(*d*) *Maintaining a Constant Attitude*. **Concentrate on maintaining a constant attitude** by watching the artificial horizon ; the A.S.I. and altimeter readings should be allowed to vary with the effects of the turbulence, but if altitude is reduced to or below safety height the aircraft must be climbed.

(*e*) *Maintaining Original Heading*. The quickest way through is often straight ahead and turns should be restricted to small alterations designed to achieve the smoothest path through the storm.

PRECIPITATION

General

20. There are four different types of precipitation which may be encountered : rain, hail, snow, and sleet. Sleet is a mixture of wet snow and rain. Although snow and sleet are comparatively rare, rain and hail are quite common. The pilot must therefore know what to expect when handling an aircraft either on the ground or in the air under these conditions.

Rain

21. The main effect of rain is a general reduction of forward visibility which in extreme cases may fall to zero. Rain also causes damage to the paint finish on all leading edges. Windscreen wipers should be switched on, if fitted.

22. **Taxying.** Speed should be low to avoid any tendency to skid on corners or when stopping, particularly on parking aprons where the surface may be greasy or oily. Similar care should be taken when running up against either brakes or chocks ; on wet surfaces the chocks or locked wheels may slide. Aircraft fitted with high-pressure tyres having a comparatively small contact area with the ground are very prone to this effect. Braking effectiveness is always reduced and distances to a stop are increased.

23. **Take-Off.**

(*a*) *Reduced Forward Vision*. Vision is quickly reduced by the wall of water which builds up as the aircraft accelerates. The pilot should be prepared to complete an instrument take-off when taking off in heavy rain, rather than persist with visual flight under worsening conditions.

(*b*) *Risk of Ice*. If icing is likely after take-off the windscreen de-icer should be operated beforehand. This sprays a film of de-icer fluid on the screen before the climb into an icing layer, and also ensures that the pump is working.

24. **High-Speed Flight.** The highly polished paint or dope finish on many aircraft tends to be stripped by rain, causing flaking of the paint, especially on the leading edges. The resulting roughened surfaces can cause considerable drag and loss in performance at high mach numbers. Radomes in particular are liable to damage through rain. The speed should be reduced to "turbulence" speed before flying in rain for an appreciable period.

25. **Descending from High Altitude into Rain—Use of Windscreen Wipers.** When descending quickly from high altitude it takes some time for the airframe to warm up to the temperature of the air at the lower level. If rain is falling at this lower level, there is a definite risk of ice forming on the aircraft. Where possible de-icers should be used in anticipation of this occurrence; windscreen wipers, however, must not be used on a dry windscreen as damage is quickly caused to the wiping element. Windscreen wipers should be turned on, and the operating rate adjusted to suit conditions, only when rain is encountered.

26. **Approaching an Airfield.** The speed should be adjusted to ensure the least loss of vision—this means the lowest safe cruising speed. Clear vision panels can be opened.

27. **Landing.**

(*a*) *Navigational Aids.* Heavy rain affects radio navigational aids, particularly G.C.A. equipment. The G.C.A. precision tube may be blotted out by returns from heavy rain, but some assistance can still be given by using the search system to guide the aircraft to the runway approach lights. High-intensity approach and runway lighting reduces the strain of landing in heavy rain, and, even in very poor conditions, a safe landing can be made by use of the runway lights and the flight instruments.

(*b*) *Damage to Flaps.* The flaps may be damaged by water thrown up while landing on wet or slush-covered runways. When these conditions are suspected, it may be advisable to use full flap only after the aircraft has slowed down some 20 to 30 knots after landing, or even to complete the landing using only partial flap.

(*c*) A wet runway can cause a considerable increase in the landing run owing to the decreased brake effectiveness.

(i) Braking efficiency is reduced on a wet runway, as the lubricating effect of the water causes the wheels to lock more easily for a given braking effort; the smoother the runway surface the worse the effect. (See Part 4, Sect. 3, Chap. 2, paras. 67 to 70.)

(ii) The brakes cannot always be relied on in these conditions, especially when high landing speeds are used. The effects are very noticeable on aircraft with high-pressure tyres which have only a small contact area with the ground; on such aircraft, if the runway is wet the degree of braking available is seriously reduced. Even when Maxaret anti-skid units are fitted, although the wheels cannot skid, the braking efficiency is low and the landing run unavoidably extended. If the runway is wet, aircraft fitted with high-pressure tyres and having high landing speeds should be diverted if the runway length available is at all marginal.

28. Other effects of flying in rain may be summarized as causing :—

(*a*) Lower cylinder-head temperatures.

(*b*) Risk of carburettor icing.

(*c*) If the fuselage leaks, saturation of electrical equipment, particularly intercommunication wiring and sockets.

Hail

29. Hail can cause substantial damage to both the airframe and engine of an aircraft, and forward visibility is considerably reduced. Otherwise hail has little effect on performance and may even prove of assistance in helping to break off existing airframe icing (see para. 12).

30. **Effect of Speed.** When the aircraft is flown through hail either in or under heap-type cloud, damage can be caused to the canopy and the forward-facing parts of the airframe. The greater the speed the greater the amount of damage. To minimize damage to the airframe, speed should be reduced to "turbulence" speed when flying in hail.

31. **Flight Planning.** There is no method of foretelling whether or not hail is present in or under cloud, though radar responses may indicate the regions of maximum activity which may contain hail, thus enabling them to be avoided. By flying as far below or above the freezing level as possible the chances of encountering hail are minimized.

Snow and Sleet

32. Snow and sleet cause reduced visibility both in the air and on the ground. Owing to the slippery surface, directional control and braking can be seriously reduced. There is also some risk of impact icing from sleet. The effects are as follows :—

(*a*) *Taxying.* Pilots should exercise extreme caution when taxying in snow owing to the reduced braking effectiveness. This is particularly important when taxying near other aircraft and obstructions. The possibility of entering concealed drifts should be borne in mind, as the aircraft may be damaged if the speed is high.

(*b*) *Take-Off.* In uncompressed snow of any depth the aircraft takes longer to accelerate, and may be difficult to keep straight initially owing to poor braking. The longest run into wind should therefore be used. Compressed snow does not retard the aircraft but is generally fairly slippery. Slush will add to the drag on take-off.

(*c*) *Landing.* In loose snow or slush there is a risk of damage to flaps owing to the snow thrown up by the wheels ; if possible not more than half flap should be used and the touch-down made at the lowest safe speed. All the effects detailed in para. 27(*c*) can be encountered in snow and the same precautions should be taken.