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AERONAUTICAL INFORMATION CIRCULAR

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The following circular is hereby promulgated for information, guidance and necessary action.

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THE EFFECTS OF THUNDERSTOMS AND ASSOCIATED TUBULENCE ON AIRCRAFT OPERATIONS

The following information has been extracted from a CAA Aeronautical Information Circular United Kingdom.

1. Introduction:

1.1 This circular is issued to emphasize the hazards that thunderstorms and the turbulence associated with thunderstorms can present to flight operations and given guidance for flight through areas of thunderstorm activity where no alternative course of action is possible.

1.2 Since that time several fatal accident has occurred due to severe turbulence causing loss of control or structural failure. Two others were caused by power loss in turbine engines owing to water ingestion. There have also been several accidents involving serious injury due to severe turbulence. It is clear that cumulonimbus or thunderstorms continue to present a hazard to aircraft operation.

1.3 The purpose of this AIC is to repeat the warnings and advice contained in AIC 5/1979, amend as necessary to reflect the latest material on meteorological aspects of thunderstorms as well as giving information on the use of weather radar.

2 Thunderstorm Warnings

2.1 SIGMETS

2.1.1 The Meteorological office issue SIGMET Warnings of “Active Thunderstorms” when thunderstorms is, or are expected to be, sufficiently widespread to make their avoidance by aircraft difficult e.g. A line, extensive high level thunderstorms or thunderstorms embedded in cloud layers or concealed by haze. These warnings include information on the location, movement and development of active thunderstorm areas and associated turbulence and icing.

2.1.2 In addition, aircraft commanders are required to send a Special Aircraft Observation (AIREP SPECIAL) when conditions are encountered which are likely to affect the safety of aircraft. Such a report, of itself, cloud resulting the issue of a SIGMET warning.

2.1.3 Details of the SIGMET service and criteria for the special Aircraft Observations are given in the Tanzania Aeronautical Information Publication.

2.1.4 The Meteorological office does not issue SIGMET warnings in relation to isolated thunderstorms not embedded to cloud layers or concealed by haze (unless prompted by a special Aircraft Observation): the absence of SIGMET warnings does not therefore necessarily the absence of thunderstorms.

3 Aerodromes Warnings

3.1 The Meteorological office issues Aerodrome Warnings for thunderstorms for terminal area operations; these refer to the likelihood of thunderstorms in the immediate vicinity of an aerodrome**.**

3.2 Separate wind shear warnings may be issued at some aerodrome around the world where a nearby thunderstorm is one of the criteria for a wind shear warning. Elsewhere, the proximity of a thunderstorm will not necessarily result in such a warning.

4 Procedures and Flying Techniques

4.1 Thunderstorms should be avoided, either visually or by use of radar but if this is not possible, the following procedures and techniques, evolved from research and operational experience, are recommended:

a) Approaching the thunderstorms area

i) Ensure that crewmember's safety belts or harnesses are firmly fastened and secure any loose article. Switch on the seat belt notices and make sure that all passengers are securely strapped in and that loose equipment (e.g. cabin trolleys and galley containers) are firmly secured. Pilots should remember that the effect of turbu1ence is normally worse in the rear of the aircraft than on the flight deck.

ii) One pilot should control the aircraft other monitor the flight instrument continuously.

iii) Select an altitude for penetration bearing in mind the importance of ensuring adequate terrain clearance. Investigations have shown that although in some thunderstorms there is little turbulence at the lower levels, in other there is a great deal; altitude is not necessarily a guide to the degree of turbulence.

iv) Set the power to give the recommended speed for flight in turbulence, adjust the trim and note its position so that any excessive changes due auto-pilot or March trim can be quickly assessed. Turbulence penetration speeds quoted in flight or operations manuals provide will decrease the buffet owing to an increased angle of attack.

v) Check all flight instruments and electrical supplies

vi) Ensure that the pilot heaters are switched on.

vii) Check the operation of all ant-icing and de-icing equipment and operate all these systems in accordance with manufacturer or operator's instructions. The operation of leading edge, expanding boot type deicers should be delayed until some ice has formed, otherwise their effectiveness will be greatly reduced. In the absence of specific instructions, ensure that all ant-icing system is on.

viii) Disregard any radio navigation indications subject to interference from static, e.g. ADF and OMEGA.

ix) Turn the cockpit lighting fully on and lower the crew seat to minimize the blinding effect of lighting flashes.

x) Follow the manufacturers or operator's recommendations on the use of the flight director, auto-pilot's and mano-metric locks. If these are not stated, height, mach, rate of climb or decent and airspeed locks should be operative. On many aircraft the auto-pilot, when engaged in a suitable mode (turbulence or basic attitude modes), is likely to produce lower structural loads than would result from manual flight: however, if major trim movements occur due to the auto-pilot's automatic trim the auto-pilot should be disengaged. Note that mach trim operation may also occur on some aircraft but the mach trim should remain engaged.

xi) Continue monitoring the weather radar in order to select the safest track for penetration, to minimize the time of exposure whilst avoiding areas of intense activity.

xii) Be prepared for turbulence, rain, hail, snow, icing, lighting, static discharge and wind shear. In turbine powered aircraft switch on the continuous ingestion system (to reduce the possibly of flameout due to water ingestion) ensuring that limitations, if any, on its use are not exceeded.

xiii) Avoid flying over the top of a thunderstorm whenever possible. Overlying small convective cells close to large storms should also be avoided, particularly if they are on the upwind side of the large storm, because they may grow very quickly. Similarly, do not contemplate flying beneath the cumulonimbus cloud. As well as the dangers associated with turbulence, rain, hail, snow or lightning, there may well be low cloud base, poor visibility, and possibly low-level wind shear.

b) Within the storm Area

(i) One pilot should control the aircraft regardless of all else.

(ii) Concentrate on maintaining a constant pitch attitude appropriate to climb, cruise or descent, by reference to the attitude indicators, carefully avoiding harsh or excessive control movements. Do not be misled by conflicting indications on other instruments. Do not allow large attitude excursions in the rolling plane to persist because these may result in nose down pitch changes.

(iii) Maintain the original heading- it is usually the quickest way out. Do not attempt any turns.

(iv) Do not correct for altitude gained or lost through up and down draughts unless absolutely necessary.

(v) Maintain the trim settings and avoid changing the power setting except when necessary to restore margins from stall warning or high-speed buffet. The target pitch attitude should not be changed unless the mean IAS differs significantly from the recommended penetration speed.

(vi) If trim variations due to the auto-pilot (auto-trim) are large the auto-pilot should be disengaged. Movement of the Mach trim, where it occurs, is however and desirable. Check that the yaw-damper remains engaged.

(vii) If negative “G” is experienced, temporary warnings low oil pressure (e.g. low oil pressure) may occur. These should be ignored.

(viii) On no account climb in an attempt to get over the top of the storm.

c) Air traffic Control Considerations.

(i) Modern ATC radar in general do not display weather which may constitute’ a hazard to aircrew ATC advice on weather avoidance will, thereof limited.

(ii) If a pilot intends to detour observed weather when in receipt of an Air, Traffic Service, which involved ATC responsibility for separation, he should first obtain clearance from ATC so that separation from other aircraft can be maintained. If for any reason the pilot is unable to contact ATC to inform the controller of his intended action, any manoeuvre should be limited to the extent necessary to avoid immediate danger and ATC must be informed as soon as possible.

(iiii) Because of the constraints on airspeed and flight path and the increased workload of the crew when flying in a TMA, pilots should consider making a diversion from, or delaying entry into, a TMA if a storm encounter seems probable.

(d) Take-off and Landing Problems

i) The take-off, initial climb, final approach and landing phases of flight present the pilot with additional problems because of the aircraft’s proximity to the ground and the maintenance of a safe flight path in these phases can be very difficult.

(ii) Some operators give advice on the airspeed adjustments to be made to allow for wind shear or turbulence (a speed increase – of up to 20 knots ‘according to the type of aircraft and the degree of turbulence, may be required) but the best advice that can be given to the pilot is that, when there are thunderstorms over or near the aerodrome, he should delay take-off or, when approaching to land, hold in an unaffected area or divert to a suitable alternate. For further information see AIC on ‘Low Altitude Wind shear.

APPENDIX A

Thunderstorms and their effect on aircraft operation are dealt with Appendix under the following headings:

Formation, development and Forecasting of Thunderstorm Flight Hazards;

Turbulence associated with Thunderstorms:

Thunderstorm Wind shear:

Tornadoes;

Hail;

Rain;

Icing;

Lighting;

Static Electricity;

Instrument Errors and Limitations;

Use of weather Radar.

APPENDIX B

FORMATION DEVELOPLENT AND FORECASTING OF THUNDERSTORMS

1. A thunderstorm, whether of the air mass or frontal type, usually consists of several self contained cells, each in a different state of development, but it must be stressed that the storm clouds are only the visible part of a turbulent system which extends over a much greater area. New and growing cells can be recognized by their cumuliform shape with ‘clear-cut outline and ‘cauliflower’ top while the tops of more mature cells will appear less clear-cut and will frequently be surrounded by fibrous cloud. It is Important, however, to remember that the development of cells, which can be very rapid, will not always be seen, even in daylight, since other clouds may obscure the view. In frontal or aerographic conditions, for instance, where forced ascent of air may give the impetus required for producing vigorous convection currents, extensive layer cloud structures

may obscure a view of the development of cumulonimbus or thunderstorm cells, Altocumulus Castellans is an indication of middle level instability, which often precedes or is associated with the development of thunderstorms. Mammatus clouds seen beneath cumulonimbus or their anvils are an indication of downward instability and associated turbulence.

2. Severe up and down draughts of comparable intensity, often in close proximity to each other, exist within the thunderstorm and frequently reach speeds in excess of 3 000 feet per minute. Sharp-edged gusts with vertical velocities of 10 000 feet per minute have been measured. The horizontal extent of these draughts may, occasionally, be more than a mile. The top of a developing cell has been observed to rise at more than 5 000 feet per minute. When thunderstorms are associated with frontal conditions, areas of 'line squall' activity can extend for more than 100 miles. The vertical extent of storms will vary considerably but it is not uncommon for them to penetrate the tropopause and exceed 40 000 feet in temperature latitudes and 60 000 feet in subtropical and tropical regions. Although an individual cell will usually last for less than an hour, a storm system, with new cells developing and old ones decaying, may persist for several hours.

3. Areas in which conditions will be favorable for the development of thunderstorms can usually be forecast successfully several hours in advance but it is not possible at present to determine the precise location and distribution of individual storms. Where up to-date ground radar information is available, however, useful information on the expected movement of an individual storm can be forecast for period. Of up to an hour or so ahead

4. Research has shown that, in general, movement is in the direction of the 10 000 foot (700 millibar) wind, though the tendency for large storm to distort wind fields and the development of new cells will cause variations in this general movement.

5. There are two facts that should be borne in mind. The first is that a severe storm can occur in practically any geographical area in which thunderstorms are known. The second is that no useful correlation exists between the external visual appearance of thunderstorms and the turbulence and hail within them. All thunderstorms are potentially dangerous.

APPENDIX C

1. Turbulence Associated with Thunderstorms

1.1 The air movement in thunderstorms generally referred to as turbulence and composed of draughts (sustained vertical or sloping currents) and gusts (irregular and local variations) can become violent, dangerous and even destructive, reaching a maximum intensity in developing and mature cells. High rates of roll, even with the application of full opposite aileron, and large pitching motions have been experienced in these storms, as have large vertical displacements of as much as 5000 feet. These extreme variations will, of course, only occur in the most severe conditions. Of equal importance is the fact that eddies which is left as gusts can occur some distance outside a thunderstorm cell. The regions around or between adjacent cell are therefore likely to be turbulent-severely so at times- and severe turbulence is often found 15 to 20 miles down wind of a severe storm core. Conditions at or near the surface in the vicinity of thunderstorms are often rough because, during the nature stage of the cells, the outflow from the base is of a turbulent nature and the air is colder than its environment, which produces a miniature cold front often accompanied by heavy precipitation and squally conditions. When this is associated with a line of thunderstorms its effects can be felt as much as 40 miles ahead of them. Take offs and landings in these circumstances are hazardous. Severe turbulence can also be encountered several thousand feet above the tops of actives

1.2 A thunderstorm cell must be well developed before lightning first occurs but it may continue in the
decaying cell. Lightning must not, therefore, be regarded as reliable guide to the degree of turbulence in a cloud.

Accidents involving loss of control of the aircraft have been caused by flying in and around thunderstorms, in some instances there was structural failure, which probably occurred in the attempt to regain control.

Stress requirements for modern transport aircraft set at a level which experience has shown will rarely be reached, nevertheless, flight research has indicated that if, in the extreme conditions which may exist within thunderstorms abnormal pilot induced load are added to already high gust-loads the stress limits may be exceeded.

In some instances the correct flying technique is difficult to achieve and the indications are that loss control which may follow incorrect techniques is a more serious hazard than the risk of structural failure due to directly to an encounter with turbulence. This is because the pilot is then faced not only with the problem of recovery but also the risk that recovery manoeuvers are likely to subject the aircraft to great stress that may lead to structural failure or serious deformation.

2. Thunderstorm Wind shear

2.1 Accidents have occurred during the take-off, initial final approach phases of flight, which were probably due in part, if not entirely, to the effect of rapid variation in wind velocity known as wind shear. Unlike the erratic fluctuations caused by gusts, winds rise to airspeed fluctuations caused by gust wind shear gives rise to airspeed fluctuations of more sustained nature and is therefore likely to be more dangerous. Gusts are likely to accompany wind shear conditions. of a more nature and is therefore likely to be more Gusts are likely to accompany wind shear.

Thunderstorms frequently produce wind shear, and although it is hazardous at all levels, it is in the lower level that wind shear may have more drastic consequences. Winds caused by the outflow of cold air from the base of a thunderstorm cell have been known to change in shallow layers of a few hundred much as 80 knots in speed and 90,degrees direction. Due to the effect of inertia in flight will tend to maintain its ground wind shear will therefore produce airspeed and wind shear will tend to maintain its ground speed and wind shear will therefore produce airspeed variations which can be large enough. For further information see AIC on “Low

Altitude wind shear".

3. Tornadoes

3.1 Tornadoes present a very serious threat to aircraft. A Fokker F-28 flying in cloud at 3,000 ft shortly after takeoff from Rotterdam was destroyed by a tornado on 6th October 1981. Tornadoes are generally associated with organized severe local storms. They occur frequently in the United State but can also arise the UK and Europe although they are less common and seldom as violent. There is evidence tornado circulation may extend through the depth the storm and constitute a hazard to aircraft at all heights.

3.2 The most violent thunderstorms draw air into their cloud base with great vigor. If the incoming air has any concentrated vortex from the surface well into the cloud. Meteorologists have estimated that wind velocities in such a vortex can exceed 200 knots. Pressure inside the vortex being quite low, the strong winds gather dust and debris and the low pressure generates a funnel-shaped cloud extending downward from the cumulonimbus base. If the cloud does not reach the land surface, it is a tornado.

3.3 Tornadoes occur with both isolated and squall line thunderstorms. An aircraft entering a tornado is almost certain to suffer structural damage. Since the vortex extends well into the cloud, any pilot flying on instruments in a severe thunderstorm could encounter a hidden vortex.

3.4 Families of tornadoes have been observed as appendages of the main cloud extending several miles outward from the area of lightning and precipitation. Thus any cloud connected to severe thunderstorm carries a threat of violence

4. Hail

4.1 Notwithstanding all the work that has been done in the field of thunderstorm forecasting or fully reliable method has yet been evolved for recognizing or forecasting a storm that will produce hail. It is safest to assume that exist in one part or other of every thunderstorms at some stage in its life. The higher the lapse rate and the greater the moisture content of the air mass, the stronger will be the convective activity which increases the likelihood of the formation of damaging hail. Stability in the upper atmosphere results in the characteristic anvil or spreading-out of the top of the cumulonimbus cloud and strong upper winds will often cause hail to fall from the overhang. Flight beneath the overhang should be avoided.

4.2 The maximum size of hailstones which have been found on ground is around five and half inches in diameter. It is known that hail stones of four inches in diameter can be uncounted at 10,000 feet and damaging hail up to 45 000 feet.

4.3 Although hail encounters are usually of short duration, damage to aircraft can be severe. Hail may damage the leading edges and hence reduce the efficiency of the wing. Windscreens or other transparencies may be shattered. In an encounter in the Middle East, hail severely damaged the airframe of a VC 10, which encountered a thunderstorm shortly after take-off. The radome was torn away, denting and damage to the skin occurred in many areas but there was no evidence of a lightning strike.

4.4 Although no fatal accidents to civil aircraft are known to have been attributable entirely to hail damage, hails can be serious hazard at all altitudes at which civil aircraft operate. Evidence for this comes from a study of military aircraft accidents in the USA, in which aircraft were damaged or destroyed by the combined effect of hail and turbulence, and from experience gained through the United States National Severe Storms Project together with individual reports of encounters with hail in normal operations.

5.0 Rain

5.1 Water ingestion by turbine engines

5.2 Turbine engines have a limit on the amount of water they can ingest. Up draughts are present in many thunderstorms, particu1arly those in the developing stages. If the up draught velocity in the thunderstorm approaches or exceeds the terminal velocity of the falling raindrops, very high concentrations of water may occur. It is possible that these concentrations can be in excess of the quantity of water turbine engines are designed to ingest, which could result in flameout and/or structural failure of one or more engines.

5.3 At the present time, there is no known operational procedure that can completely eliminate the possibility of engine damage/flameout during massive water ingestion but although the exact mechanism of these water induced engine has not been determined, it is believed that thrust changes may have an effect on engine stall margins.

5.4 To eliminate the risk of engine damage or flameout by heavy rain, it is essential to avoid severe storms.
During an unavoidable encounter with extreme precipitation, the best known recommendation is to follow the severe turbulence penetration procedure contained in, the approved aircraft flight manual, with special emphasis on avoiding thrust changes unless excessive airspeed variations occur. Flight research has revealed that water can exist in large quantities at high altitudes even where the ambient temperature low as -30 deg C. Rain, sometime heavy, may therefore encountered and give rise to ice accretion and a possibility of the malfunctioning of pressure instruments.

5.5 Heavy precipitation, which occurs in cumulonimbus, may often be seen as shafts of rain below the cloud base. Where precipitation does not reach the surface, the streaks appear as virga .The evaporation cooling associated with virga may intensify existing downdraughts.

6.0 Icing

6.1 Flight must not be initiated or continued into areas where the forecast icing conditions will exceed the icing limitations of the aircraft.

6.2 Formation of ice on the airframe must always be considered likely when flight take place through cloud or rain at a temperature below 0 deg C .The temperature range favorable for ice accretion in thunderstorms is from 0 deg C down to the –45 deg C, ie where water droplets can exist in a super cooled state. Below about –30 deg C, however, a large part of the free water content of the atmosphere normally consists of ice particles or crystals and snowflakes and chances of severe icing at these low temperatures are, therefore, greatly reduced.

6.3 In piston engines loss of power can occur over a wide range of temperatures as a result of the formation of ice in the induction system. Careful use of carburetor heat or other induction anti icing equipment is therefore essential to prevent or minimize this loss of power. Furthermore, in clear air of high humid (i.e. of the order of 60% of more), which might exist in areas of thunderstorms activity, carburetor ice can easily form.

6.4 Where turbine engines are concerned, the danger of flameout must be recognized where never icing conditions are met. Igniters must therefore be switched on remain on provided they are cleared for continues operation. In all circumstances operators of manufacturer's instructions must be strictly followed to achieve maximum protection.

6.5 It must be emphasized that, when flying in thunderstorms, anything more than very light ice accretion adds to the problems related to turbulence because of the increased weight of the aircraft, the disturbance of the normal airflow and the reduced effectiveness of the control surfaces.

6.6 Experience has shown that, provided the normal precautions are taken (ie using the anti-icing or de-icing equipment correctly) icing conditions need not be a grave hazard if penetration of a thunderstorm area cannot be avoided. However, failure to recognize or anticipate icing conditions, failure to use the equipment properly, equipment un-serviceability or extended flight through a storm area will all considerably increase the risk involved.

7.0 Lightning

7.1 Lightning can occur in cloud between two clouds or between a cloud and the ground. Investigations have shown that most recorded lightning strikes occur at levels where the temperature is between +10 deg C and -10 deg C, i.e. within about 5 000 feet above or below the freezing level. Some risk also exists outside this band, particularly in the higher levels.

7.2 The brilliant flash, the small of burning and the accompanying explosive noise may be alarming and distracting to the pilots of an aircraft struck by lightning. The report on a serious accident, in which a large transport aircraft was destroyed, stated that it was due to a lightning strike causing ignition of vapour in the region of fuel tank vents but fatal accidents due to lightning strikes have fortunately been very few and most aircraft receive only superficial damage when struck.

7.3 The effect of lightning strikes upon both direct reading magnetic compasses and magnetically slaved compasses is mentioned in a later section.

8.0 Static Electricity

8.1 This phenomenon will generally first be noticed as noise on the High and Medium frequency radio bands and also, to -a lesser extent, on VHF receivers. As the static electricity increases in severity, the noise will increase and in extreme cases a visible discharge, known as St Elmo's fire, will be seen on some part of the aircraft, particularly around the edges of windscreens. Static electricity is not associated only with thunderstorms but such conditions are particularly favorable to its creation. Although it is not normally dangerous, there have been rare incidents when a static discharge across a windscreen or plastic panel caused it to break.

8.2 An understanding of the effect of static electricity on radio equipment is important. it is detrimental to the performance of MF (e.g. ADF) and HF equipment but has little or no effect upon VHF and UHF. On HF, static may cause the signal-to-noise to be such that communications are impossible. In these conditions navigation aids such as ADF and OMEGA must be used with extreme caution due to the fluctuating or erroneous indications that may occur.

9.0 Instrumental Errors and Limitations

9.1 Altimeters and Vertical Speed Indicators

9.1.1 Local pressure field variations can occur in or very close to a thunderstorm at all height and this, heights, together with local gusts, may give rise to errors in the indications of altimeters and vertical speed indicators. There is some doubt as to the magnitude of altitude errors but there is evidence that they can be as much as + or - 1 000 feet.

It is essential, for ground clearance purposes, that due allowance is made for such errors when flying in or near thunderstorm areas. Near the surface periods of heavy rain are an indication of the likelihood of pressure variations and gusts.

9.2 Airspeed Indicators

9.2.1 Despite the precautions taken in the design of pilot heads, there is still a possibility that very heavy rain may cause an airspeed indicator to give a false indication even when the pilot head heaters are used. If the power, which gives the safest speed for penetration, has been selected before a storm is entered, no action should be taken to correct for violent or short period airspeed indicator oscillations, provided a reasonably level attitude is maintained.

9.3 Attitude Indicators

9.3.1 Attitude is indicated by instruments presenting pitch and rolls information alone or by other more complex flight directors containing attitude indication amongst other elements.

9.3.2 The simple artificial. Horizons fitted to most aircraft, either as the main attitude indicator or as a standby instrument when remote reading indicators are installed, provide indications of freedom in the rolling plane. Except in rare circumstances these instruments give an adequate range of indication but may lack referencing, which would enable the pilot to assess attitude accurately at large angles of pitch or be given maximum assistance in recovery from any unusual attitudes.

9.3.3 Pitch referencing is also lacking on the attitude indicators of some flight director presentations. More over, their range of indication is much less than 85 degrees up and down, in some cases less than 30 'degrees. The presentation of information on these earlier instruments does not give an indication to the pilot of the point at which the aircraft's pitch attitude exceeds the limit of indication of the instrument. These instruments therefore give no guidance as to the progress of recovery from attitudes outside their normal range of indication.

9.3.4 The variety-of instruments which may be encountered makes it essential that pilots are fully aware of the limitations of the particular attitude indicator (2) fitted in the aircraft they fly.

9.4 Magnetic Compasses

9.4.1 Magnetic compasses are likely to be seriously affected by a lightning strike. They should not be relied upon after an aircraft has been struck and should be checked as soon as possible in accordance with Civil Aircraft Inspection Procedures (CAIP) AL/IO-5 or 6.

10. Use of Weather Radar

10.1 Pilot should be in doubt about the function of airborne weather radar. It is provided to enable them to avoid thunderstorms and not to assist them in penetrating areas of storms activity. Airborne radar are of either G (formerly C) or I (formerly X) band type; of radar in their aircraft and its limitations. G Band Radar are designed to detect areas of heavy precipitation and their displays will require a different interpretation from those of I band equipment. Operators should ensure that their crews are given adequate instruction, in respect of the adjustment and interpretation of the display, on the relevant radar type in its various modes.

10.2 It should be noted that, with weather radar of both types, the significance of the radar return given intensity usually increases with altitude. The strengths of the echo is not necessarily an indication of the strength of the associated turbulence.

10.3 Radar return Intensities may also be misleading because attention resulting intervening heavy rain. This may lead to serious underestimation of the severity of the rainfall in a large storm and an incorrect assumption of where the heaviest rainfall is likely to be encountered. The echo will be relatively weaker and the actual position of the further away than indicated on the radar display, sometimes beyond may be completely masked. This effect is more marked on I-band than G-band radar.

10.4 It should also be noted that, notwithstanding recent research and operational experience, it still seems impossible to use radar to detect with certainty areas where large hail stones exist, because cloud containing rain or hail can produce identical radar pictures. Some operators have claimed success in avoiding hail by keeping well clear of the cloud echoes, which have scalloped edges or pointed or hooked finger attached but the best advice is to give radar echoes wide berth, as when detouring storms visually.

10.5 The high rate growth of thunderstorms and the danger of flying over or near to the tops both of the main storm and small convective cells close to it must also be remembered when using weather radar for storm avoidance.

10.5.1 some guidance on the distances by which thunderstorms should be avoided is given in table at the end of this Appendix.

APPENDIX - D

USE OF WEATHER RADAR-GUIDENCE TO PILOTS

Flight Altitude (1000s of Ft)	Echo Characteristics			
	SHAPE	**INTENSITTY**	**GRADIENTOF INTENSITY**	**RATE OF CHANGE**
0-20	Avoid by 10 Miles echoes With hooks, fingers, scalloped edges or other protrusions	Avoid by 5 miles With echoes with Sharp edges or strong intensities	Avoid by 5 miles Echoes with strong gradients of intensity	Avoid by 10 Miles echoes showing rapid change of shape, height, or intensity
20-25	Avoid all echoes by 10 miles			
25-30	Avoid all echoes by 15 miles			
Above 30	Avoid all echoes by 20 miles			

Applicable to sets with Iso-Echo or colour display. Iso-Echo produces a hole in a strong echo when the returned signal is above a pre-set value.

Note:

1. If flight is over storm clouds, always maintain at 5000 ft vertical separation from cloud tops. It is difficult to estimate this separation but information on the altitude of the tops may be available for guidance.

2. If aircraft is not equipped with the radar or radar is inoperative, avoid by 10 miles any that by visual inspection is tall, growing rapidly or has an anvil top.

3. Intermittently monitor long ranges on radar to avoid getting into situations where no alternative

remains but the penetration of hazard areas.

4. Avoid flying under a cumulonimbus overhang. If such flight cannot be avoided, tilt antenna full up occasionally to determine, if possible, whether precipitation (which may be hail) exists in or is falling from the overhang.

Cancel AIC 5/1989