WINTER OPERATIONS BRIEF 2014/15

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ETIHAD
AIRWAYS
FLIGHT OPERATIONS

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PREFACE

Winter operations present additional challenges to aircraft operation as a result of low temperatures, contaminated runways, taxiways, and critical surfaces of the aircraft. It is the ultimate responsibility of the pilot in command to determine that the aircraft is in a safe condition for flight prior to take-off.

This Briefing is not meant to replace pilots' judgement and policies and procedures contained in operational documents and manuals. It shall be viewed as a quick reference to relevant content in controlled documents and manuals and to assist in clarifying any ambiguities that may exist.

DISPATCH CONSIDERATIONS

Along with all the normal dispatch considerations the below mentioned should be considered during winter operations.
Note: The OM-C should be consulted for specific Airfield procedures.

Departure airport

- Extra fuel may have to be loaded for gate holds, flow restrictions, taxi and deicing delays. Any anticipated delays should be communicated to Operations to enable the calculation of a realistic target block fuel.
- Winter Operations are often associated with Low Visibility, and as such this needs to be taken into consideration. For example a takeoff alternate may be required. Also note low visibility take off below 200 RVR (CAT C) and 250 RVR (CAT D) is prohibited if the runway is contaminated.
- Particular attention should be paid to MEL items impacting on braking, antiskid, reversers, ground spoilers etc. or any item that may adversely affect CAT II/III operations.
- Consider use of EY supplement found in the QRH (Contaminated Runway Operation and Runway Report decoding) to verify braking action and wind limits. Also MOTNE/OPMET decodes for contaminated runways can be found in this section.
- For Take-off performance, refer to LPCNG or the Boeing Performance Tool for the necessary calculations.

Enroute

- Flights with Anti-Ice on in the cruise will increase fuel consumption by approximately +2% to +5%.
- Refer to the applicable FCOM for guidance on when anti-ice should be used.

Destination Airport

- When dispatching to a contaminated runway that is also experiencing low visibility there are OMA/QRH restrictions that may be applicable. E.g. If the forecasted weather is below the destination applicable minima then a second destination alternate is required. (OMA 8.1)
- Forecast snowstorms may cover a huge area and the closest destination alternate may not always the best option.
- Auto rollout is not demonstrated on a contaminated runway (Airbus) therefore if the runway is contaminated, the aircraft is only Cat 3A capable (QRH EY SUPP 12)
- Consider landing distance calculations and cross wind limits (QRH EY SUPP) for a contaminated runway.
- Ensure that the runway is certified by Etihad for low visibility operations if low visibility is forecasted. (see 10-9EY Jeppesen charts).
- If no 10-9EY chart is published, as Etihad do not operate there on a regular basis but LVP have been approved by the Country/State. The charted minima shall be used for arrivals and departures at an airport where the State has granted a “blanket” LVP approval.

PRE-FLIGHT

In addition to the normal preflight duties there are additional duties when operating in winter conditions.
For Airbus these are found in - FCOM PRO-SUP-91-30
For Boeing these are found in - FCOM - Supplementary procedures - Adverse Weather - Cold Weather Operations (SP16)

The walk around

Etihad has a clean-wing concept. Take-off is prohibited if frost, ice or snow is adhering to the wings, control surfaces, engine inlets or other critical surfaces of the aircraft.
Exceptions to the above are a frost layer less than 3mm (1/8 inch) on the underside of the wings, in the area of fuel tanks. Thin hoarfrost is acceptable on the upper surface of the fuselage provided all vents and ports are clear. Thin hoarfrost is a uniform white deposit of fine crystalline texture, which usually occurs on exposed surfaces on a cold and cloudless night, and which is thin enough to distinguish surface features underneath, such as paint lines, markings or lettering.
During the walk around observe ramp area for suitability for pushback and engine start and in addition to the normal walk around items to be checked, particular attention should be paid to:

P – Pitot tubes, static ports, angle of attack sensors and areas adjacent. Ensure clear of frost, snow or ice. All protective covers must be removed.

R – Radome/Windshield. Ensure free of ice, snow, slush and frost.

E – Engine cowl, fan acoustic panels, inlets and N1 fan blades (Inspect behind the N1 fan blades as ice is often present here). Free of ice, and the N1 fan rotates freely. APU and air conditioning inlets free of snow and ice.

F – Fuel tank ventilation and drains. Ensure no leaking or ice observed from potable water drain panel, drain masts, fuel water drain valves or toilet service access doors. Ice accumulation on these areas may result in engine, fuselage or flight control FOD.

L – Landing gear and wheel wells. Free of ice and slush. Extreme cold may affect tire/oleo inflation. Contamination may affect landing gear retraction and proximity switches.

O - Outflow valve. Clear of all contamination.

W - Wings (critical surfaces, leading edges and upper surfaces), vertical and horizontal stabilizers and all control surfaces, (slats and flaps) shall be clear of snow, frost and ice for takeoff.

DE-ICING AND ANTI-ICING

The Decision

Once the walk around is complete the commander decides in conjunction with the co-pilot and ground crew if de-icing is required. As the final decision rests with the commander, his request will supersede the ground crew member's judgment not to de-ice. (OMA 8.2.7.5.4).

Actual De-icing Procedure

Airbus – FCOM pro-sup-91-30
Boeing – FCOM SP16

On completion of the procedure as a minimum the standardized notification performed by qualified personnel shall include:
The airplane critical parts are checked free of ice, frost, snow, and slush
The type of fluid e.g. Type IV or brand name if applicable
The fluid concentration e.g. 75/25 where the fluid proportion is always first
Local time when the procedure began
The statement "Post de-icing/anti-icing check completed"
This information enables flight crew to estimate the holdover time to be expected under the prevailing weather conditions.

Holdover Times

The holdover time is obtained by anti-icing fluids remaining on the airplane surfaces. With a one-step de-icing/anti-icing operation the holdover time begins at the start of the operation and with a two-step operation at the start of the final (anti-icing) step.
Holdover times for generic de-icing fluids e.g. Type II, IV etc can be found in OM-A Chapter 8.2. These are to be used where no brand name is given e.g. Russia
Holdover times for "brand Name" deicing fluids e.g. killfrost ABC-K PLUS can found In the Skybook/OM-C/RIM/General Information/Transport Canada HOT guidelines

Holdover Time Tables (HOT)

Below is an example of a hold over table that might be used during winter operations. Pilots are to enter the table with the actual OAT, the fluid concentration and the type of precipitation. In the corresponding box a time range will be extracted. Due to the many variables that can influence holdover time, these times should not be considered as absolute minimums or maximums because the actual time of protection may be extended or reduced, depending upon the particular conditions existing at the time. The lower limit of the published time range is used to indicate the estimated time of protection during moderate precipitation and the upper limit indicates the estimated time of protection during light precipitation. The responsibility for the application of this data remains with the user.

Guidelines for holdover times anticipated for Type III fluid mixtures as a function of weather conditions and OAT (Valid for metallic and composite surfaces)

OAT (1)		Type III Fluid Concentration Neat-Fluid/Water (Vol%/Vol%)	Approximate Holdover Time under various weather conditions (hours:minutes)					
ºC	ºF		Freezing fog	Snow/ Snow Grains/ Snow Pellets(2)	Freezing Drizzle(3)	Light Freezing Rain	Rain on Cold Soaked Wing	Other (4) (5)
-3 and above	27 and above	100/0	0:20 – 0:40	0:10 – 0:20	0:10 – 0:20	0:8 – 0:10	0:06 – 0:20	
		75/25	0:15 – 0:30	0:08 – 0:10	0:08 – 0:10	0:06 – 0:10	0:02 – 0:10	
		50/50	0:10 – 0:10	0:04 – 0:08	0:05 – 0:09	0:04 – 0:06		
below -3 to -14	below 27 to 7	100/0	0:20 – 0:40	0:09 – 0:15	0:10 – 0:20	0:08 – 0:10	**CAUTION:** NO Holdover Time Guidelines exist	
		75/25	0:15 – 0:30	0:07 – 0:10	0:09 – 0:12	0:06 – 0:09		
below -10	below 14	100/0	0:20 – 0:40	0:08 – 0:15				

(1) Ensure that the lowest operational use temperature (LOUT) is respected. Consider the use of Type I fluid when Type III fluid cannot be used.
(2) In light "Rain and Snow" conditions use "Light Freezing Rain" holdover times
(3) If positive identification of "Freezing Drizzle" is not possible use "Light Freezing Rain" holdover times
(4) Other conditions are: Heavy snow, ice pellets, moderate and heavy freezing rain, hail
(5) For holdover times under active frost conditions see the separate frost table (Table 3)

CAUTION: The time of protection will be shortened in heavy precipitation conditions. Heavy precipitation rates or high moisture content, high wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when the aircraft skin temperature is lower than the OAT. Therefore, the indicated times should be used only in conjunction with a pre-takeoff check.

De-icing/anti-icing fluids used during ground de-icing/anti-icing are not intended for and do not provide protection during flight.

N.B. If the fuel temp is below the OAT, the Lowest Operational Use Temperature (LOUT) should be verified with the de-icing service provider to ensure that it is at or below the fuel temperature
N.B. NO holdover guidelines exist for heavy precipitation

Ice Pellets

Research has shown that the behavior of anti-ice fluids in ice pellet precipitation is very different from other types of precipitation. Ice pellet allowance times and the associated operational guidelines can be found in Skybook/OM-C/RIM/General Information/Transport Canada HOT guidelines/pg 58

Holdover Time Range Application

Once the pilot has extracted the holdover time, it's validity will begin at the "deicing commencement time" given to the pilot by the deicing personnel at the end of the procedure. The time to be used will depend on if the precipitation is light or moderate.
It is important to note that once the HOT time clock has been started it must not be stopped for intermittent precipitation. There is no practical way to determine how much residual anti-icing fluid is on the wing under these circumstances. HOT values under these conditions have not been assessed.

Determining Snow Fall Rates

The VISIBILITY IN SNOW Vs. SNOWFALL INTENSITY CHART is used to assist the pilot in determining the rate of snowfall only. It's found in:
skybook/omc/general information/Holdover time guidelines/pg 49

VISIBILITY IN SNOW Vs. SNOWFALL INTENSITY CHART

Lighting	Temperature Range		Visibility in Snow in Statute Miles (Meters)			
	ºC	ºF	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1 (≤1600)	>1 to 2 1/2 (>1600 to 4000)	>2 1/2 to 4 (>4000 to 6400)	>4 (>6400)
	Below -1	Below 30	≤3/4 (≤1200)	>3/4 to 1 1/2 (>1200 to 2400)	>1 1/2 to 3 (>2400 to 4800)	>3 (>4800)
Daylight	-1 and above	30 and above	≤1/2 (≤800)	>1/2 to 1 1/2 (>800 to 2400)	>1/2 to 3 (>2400 to 4800)	>3 (>4800)
	Below -1	Below 30	≤3/8 (≤600)	>3/8 to 7/8 (>600 to 1400)	>7/8 to 2 (>1400 to 3200)	>2 (>3200)

This table applies to all Type I, II, III and IV fluids. The visibility to be used is the one stated in the ATIS. Assuming that the ATIS states in the daytime a visibility in snowfall of 1800m and a temperature of -5 C then the snowfall intensity is light. The upper limit (higher time) of the time span extracted from the holdover tables would then be applicable.

Determining Precipitation Rates Other than Snowfall

For precipitation rates other than snow, meteorological reports for the airport of operation may be the best source of information. The pilot alone has no way to measure or otherwise reasonably judge what the precipitation rate is other than to receive information about the measurements taken by qualified meteorological persons. This measurement report will imply a rather wide range of possible precipitation rates. The worst-case rate must be assumed. That is, the highest precipitation rate must therefore be assumed, and hence the lowest holdover time for the conditions should be used.

Elapsed time is less than the lowest time in the time band

Based on new Transport Canada recommendations, Etihad recommends that even if the lowest time in the time band has NOT been exceeded for conditions covered by the HOT tables, a pre take-off inspection is to be conducted prior to take off.

Elapsed time within the range of HOT for the conditions

Etihad strongly recommends that even when the time that has expired since anti-icing is within the range of time chosen by the Commander for the conditions present and covered by the Guidelines, a pre take-off inspection is to be conducted prior to take off.

Holdover Time Exceeded

A take-off shall not be commenced when holdover times have been exceeded especially if any precipitation has fallen since the time anti-icing began unless a pre-take-off inspection has been conducted and the wings are verified as being “clean”.

Pre Take–off Inspection

The Pre Take-off inspection is used to determine if the anti icing fluid has failed.

The inspection shall be conducted within five minutes prior to beginning the take-off roll, except for Type I fluids. Type I fluids have very short HOT performance and fluid failure occurs suddenly. If, after conducting the pre-take-off inspection, it is not possible to take-off within five minutes, the aircraft must return for deicing/anti-icing.

It is preferred that a ground crew member, if available, do the inspection from the outside however if this is not possible then it is expected that one of the pilots will step back to the cabin and inspect the wings. If it is dark outside then use of the wing lights and a flashlight offer good assistance. If it cannot be determined if there is contamination on the wings then the aircraft shall return to the gate for another deice anti ice treatment.
It is very important that if one deicing truck was used for the deice/anti ice procedure, then the pilots find out which wing was treated first as under normal conditions this wing would be the one exposed to precipitation the longest and thus must be inspected as a minimum.

The anti ice fluid has failed if it has lost its sheen or if contamination is seen on the top of the wing and is adhering.

Operational Responsibility

The general transfer of operational responsibility for the de-ice/anti-ice treatment from the ground crew to the Commander takes place at the moment the aircraft starts moving under its own power.

Localized De-Icing

When no precipitation is falling or expected, a “local area” de-icing may be carried out under the below mentioned or similar conditions. In some cases a full or complete de-icing is not necessary. When the presence of frost and/or ice is limited to localized areas on the surfaces of the airplane and no holdover time is likely to be required, only the contaminated areas will require treatment. This type of contamination will generally be found on the wing and/or stabilizer leading edges or in patches on the wing and/or stabilizer upper surfaces.

Spray the affected area(s) with a heated fluid/water mixture suitable for a One-Step Procedure. Then spray the same area(s) on the other side of the airplane.

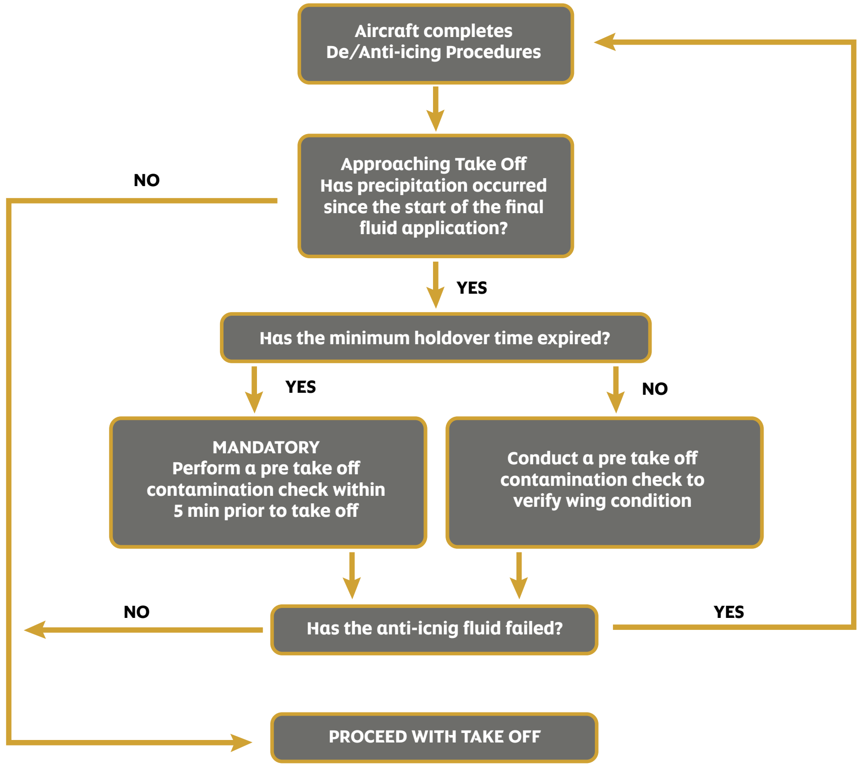
Both sides of the airplane must be treated identically (same areas, same amount and type of fluid, same mixture strength), even if the contamination is only present on one side. A trained and qualified person must check the treatment was performed symmetrically and that all contamination has been removed.

After this check has confirmed that the treated areas are clean, the following statement shall be given to the Commander: “Local Area De-icing only. Airplane is clean. Holdover times do not apply”.

Note: For more information please refer to the GOM.

Consideration should also be given to situations where no precipitation is falling but where actual freezing conditions exist.

De/Anti-icing Decision Tree



PRIOR TO TAXI

- Perform the normal engine start procedures but note that oil temperature may be slow to rise and initial oil pressure may be higher than normal. Displays may require additional warm-up time before engine indications accurately show changing values. Displays may appear less bright than normal.
- It is highly recommended to avoid engine start during pushback with slippery ramp conditions.
- Icing conditions may be expected when the OAT (on the ground and for Take off), or the TAT (in Flight) is 10°C or below, and there is visible moisture in the air (such as clouds, fog with low visibility of one mile or less, rain snow sleet, ice crystals), or when standing water, slush, ice or snow is present on the taxiways or runways.
- Engine anti-ice must be selected ON immediately after all engines are started and it must remain on during all ground and take-off operations when icing conditions exist or are anticipated. If there is any appreciable delay in starting the remaining engines during the start sequence, select engine anti-ice ON for running engines. e.g. if one engine is started and then ECAM or other procedures are required which delay subsequent engine (s) start, do not delay in selecting engine anti- ice ON for running engine (s). Do not rely on airframe visual icing cues before activating engine anti-ice. Use the temperature and visible moisture criteria.
- Wing anti-ice
    i) Airbus - should be selected on if it is believed that airframe icing may occur after take-off. (e.g. ATIS may report icing conditions on departure). Ensure that this is taken into account in the aircraft take-off performance calculations.

    ii) Boeing - The primary method is to use the automatic ice detection system to activate wing anti-ice, which acts as a de–icer by allowing ice to accumulate before turning wing anti–ice on.
- Operate the APU only when necessary during de-icing/anti-icing treatment. Consider briefing the cabin crew on the possibility of fluid-ingestion post de-icing.
- Delay flight control checks until de-icing has been completed. If the taxiways are covered by ice, snow, slush or standing water, or if precipitation is falling, with temperatures below freezing, taxi out with the flaps retracted. Taxiing with the flaps extended subjects flaps and flap-drive mechanism to contamination. Delay the before takeoff checks until just prior to line up.

DURING TAXI

This guidance is applicable for normal operations using all engines during taxi.

- Allowing greater than normal distances between airplanes while taxiing will aid in stopping and turning in slippery conditions. This will also reduce the potential for snow and slush being blown and adhering onto the airplane or engine inlets.
- Taxi at a reduced speed (Maximum 10Kts in a straight line and 5Kts while in a turn). Taxiing on slippery taxiways or runways at excessive speed or with strong crosswinds may cause the airplane to skid. Use smaller nose-wheel steering and rudder inputs. Limit thrust to the minimum required. Use of differential engine thrust assists in maintaining airplane momentum through a turn.
- When nearing turn completion, placing both engines at idle thrust reduces the potential for nose-wheel skidding. Differential braking may be more effective than nose-wheel steering on slippery or contaminated surfaces.
- Be aware that when taxiing on contaminated surfaces, if the aircraft is brought to a complete stop there may be a build up of slush/ice in front of the wheels resulting in a condition similar to the aircraft being chocked.
- During prolonged ground operations, periodic engine run-ups should be performed per the Boeing/Airbus FCOM to shed the accreted ice.
- Crew should be aware of the possibility of snow banks existing along the taxiway edges. The crew should be aware of the height of the snow banks and ensure sufficient clearance between the snow banks and the engines.
- On contaminated runways and taxiways, the radio altitude indications may fluctuate and auto call outs or GPWS warnings may be activated.
- Be aware of additional thrust with ENG ANTI-ICE ON while maneuvering.
- There have been incidents where certain chemical agents used for treating runways and taxiways have caused a non-toxic mist in the aircraft cabin that has been misidentified as smoke. It may therefore be prudent under these circumstances for pilots to brief the cabin crew accordingly.

BEFORE/DURING TAKEOFF

- Keep in mind the following company rules on contaminated runways
- Take off and Landing on runways for which the braking action is reported as “POOR” or the coefficient friction ≤0.25 is NOT permitted.
- For Airbus fleet, take-off on a runway covered with more than 101.6mm (4inches) of dry snow or 25.4mm (1 inch) of wet snow is NOT permitted.
- For Boeing fleet, take-off on a runway covered with more than 101.6mm (4inches) of dry snow or 12.7mm (0.5 inch) of wet snow is NOT permitted.
- The use of ATM/FLEX is not authorized for take-off from a contaminated runway (fixed de-rate is acceptable on Boeing).
- If a runway has been cleared of contaminants, it must be cleared such that there must be at least 45m of cleared width for the entire length of the take off or landing distance required. This maybe reduced to 30m for narrow body aircraft with approval from the fleet office.
- For airplane performance purposes a runway is considered contaminated when more than 25% of the runway surface area within the reported length and width being used is covered by more than 3mm of water or by slush, ice, snow (dry or wet), or frost equivalent to more than 3 mm (0·125 in) of water.
- Do the normal Before Take-off Procedure. Extend the flaps to the take-off setting at this time if they have not been extended because of slush, standing water, icing conditions or because of de-icing/anti-icing. The flaps must be extended before completing the Before Take-Off Checklist. Use maximum runway distance available.
- An intersection may be utilized if this avoids a section of runway, which has an unusable braking action.
- Verify that airplane surfaces are free of ice, snow and frost before moving into position for takeoff. If in doubt return to the ramp for De/Anti-Icing.
- In icing conditions, refer to the Boeing/Airbus FCOM for guidance regarding static engine run-up before take-off.
- Before brake release, check for stable engine operation. After setting take-off engine pressure ratio (EPR), or N1, check that engine indications are normal, in agreement and in the expected range. Check that other flight deck indications are also normal.
- Rotate smoothly and normally at VR.
- Do not lift the nose wheel before VR in an attempt to avoid splashing slush on the aircraft, because this produces additional aerodynamic drag.
- Retract flaps at the normal flap retraction altitude and on the normal speed.
- If you have to abort takeoff, maintain directional control with the rudder pedals. If necessary, use differential braking to regain the centerline when stopping distance permits.

CRUISE

- Icing conditions generally occur from +10°C down to -40°C and are most likely around FL100. Severe icing rarely occurs below -12°C, but icing conditions can be encountered at any FL.
- ENGINE ANTI ICE must be ON/AUTO (as applicable) during all ground and flight operations, when icing conditions exist, or are anticipated, except during climb and cruise when the SAT is below -40°C.
- WING ANTI ICE may either be used to prevent ice formation, or to remove ice accumulation from the wing leading edges in flight.
- WING ANTI ICE should be selected ON/AUTO (as applicable), whenever there is an indication that airframe icing exists. This can be evidenced by ice accumulation on the visual ice indicator (located between the two cockpit windshields – Airbus), or on the windshield wipers. On the Boeing the primary method is to use the automatic ice detection system to activate wing anti-ice which acts as a de–icer by allowing ice to accumulate before turning wing anti–ice on.
- Fuel tank transfer may be applicable as per aircraft FCOM procedure if the fuel temperature becomes too low. If necessary raise TAT by descending to warmer air mass below the tropopause where the TAT increases approximately 2°C/1000 feet.
- A mach 0.01 M increase increases the TAT by approximately 0.5°C - 0.7°C

DESCENT

- ENGINE ANTI ICE must be ON/AUTO (as applicable) before and during a descent in icing conditions, even if the SAT is below -40 deg C. The engine anti icing is selected on in accordance with relevant FCOM, before penetration of even thin cloud layers to avoid the possibility of failure. There have been many cases worldwide in recent years where jet engine failure has occurred due to failure to select engine anti ice protection on in icing conditions.
- WING ANTI ICE should be selected ON, whenever there is an indication that airframe icing exists.
- Extended flight, in icing conditions with the slats and/or flaps extended, should be avoided.
- Apply altitude temperature corrections if required. Altitudes assigned by ATC during radar-vectored approaches are temperature corrected and require no further adjustment by the crew. All intermediate and final approach altitudes need to be adjusted when flying a procedural approach. Likewise any MDA/DA or acceleration altitudes need to be adjusted. Altitude adjustments can be made using the tables in OMA 8.1 Crews must inform ATC whenever they make temperature corrections.

In-flight Landing Re-assessment

Based on a Norwegian Accident Investigation Board report on Winter Operations, Friction Measurements and Conditions for Friction Predictions, at air temperatures of +3°C and below, with a dew point spread of 3°C or less, the runway surface condition may be more slippery than anticipated on snow and ice. Thus when these conditions exist it may be appropriate to factor the landing distance further.

- Before commencing an approach, the Commander should ensure that a safe approach and landing can be made given the updated meteorological and runway surface condition.
- Carefully workout runway performance calculations particularly if there is a crosswind. Consider use of EY supplement found in the QRH (Contaminated Runway Operation and Runway Report decoding).
- Consider any restrictions that are applicable if low visibility conditions are also present. (OMA 8.4)
- Non-Decelerated Approach is recommended using the maximum landing flap selection in order to minimize landing speed and landing distance.

LANDING

- Follow the normal procedures for approach and landing. Use the normal reference speeds unless otherwise directed by the Boeing/Airbus FCOM. The appropriate speed increments shall be added for flight in icing conditions.
- Arm the autobrake and spoiler systems, if available, before landing.
- The airplane should be firmly flown onto the runway at the aiming point.
- Immediately after main-gear contact with the runway, deploy the speed brakes if not already deployed by the automatic system.
- Without delay, lower the nose-wheel to the runway to gain nose-wheel directional control. Do not hold the nose gear off the runway.
- Use of autobrakes is recommended, <u>provided the contamination is evenly distributed</u>. This will allow the pilot to better concentrate on directional control of the airplane. If manual braking is used, apply moderate to firm steady pedal pressure symmetrically until a safe stop is assured.
- Let the anti-skid system do its work. Do not pump the brake pedals.
- Do not use asymmetric reverse thrust on an icy or slippery runway unless necessary to arrest lateral skid.
- When using reverse thrust, be prepared for a possible downwind drift on a slippery runway with a crosswind.
- Be aware of aircraft's tendency to "weathercock" due to crosswinds on slippery runways and the impact of the lateral reverse thrust vector. Consider the use of idle reverse thrust until directional control can be assured, if conditions permit.
- The use of more than idle reverse thrust below 70 kts may cause blowback of snow or ice onto the wings and into the slats. Ensure reversers are stowed by 40kts on contaminated runways unless an emergency stop is required. This will prevent ingestion of snow or ice, which can cause fan damage and/or engine flameout. If there is snow, visibility may be reduced by snow blowing forward at low speeds if reversers are not cancelled.
- During winter operations, it is even more important than usual that the flight crew do not attempt to turn off the runway until the airplane has slowed to a reasonable taxi speed.
- Taxi at a reduced speed. Taxiing on slippery taxiways or runways at excessive speed or with strong crosswinds may cause the airplane to skid.
- Use the engine anti-ice system during all ground operations when icing conditions exist or are anticipated.
- Use caution on ramp areas due to obscured taxi and parking lines. Ramp and gate areas contaminated with glycol from de-icing operations may be extremely slippery.
- Leave FLAPS extended for inspection if contamination is suspected.
- Carefully analyze the condition of taxiways and ramp areas before considering reduced engine taxi procedure.
- Be aware of additional thrust with ENG ANTI-ICE ON while maneuvering and approaching the ramp.

PARKING AND SECURING

- Keep parking brake set if the gate parking area is contaminated and/or slippery even after chocks are installed. De-icing fluid on the ramp may prevent the chocks from holding the aircraft in place. This supersedes the requirement to release the parking brake if brake temperatures exceed 500°C.
- Ensure an entry is made into the ATL if airframe icing is encountered on descent/ approach and that inspection is required on extended flaps.
- Secure the aircraft for cold soak if required according to the applicable FCOM.

Appendix 1

Low Visibility Operations

OVERVIEW

The purpose of this appendix is to highlight some of the operational issues which may be encountered because of low visibility operations which may occur in conjunction with cold weather operations.

Aircraft specific Low Visibility Procedures are detailed in the applicable Flight Manuals and Quick Reference Handbooks. OM-A contains company procedures which pilots must also be familiar with, Chapter **8.4, All Weather Operations.**

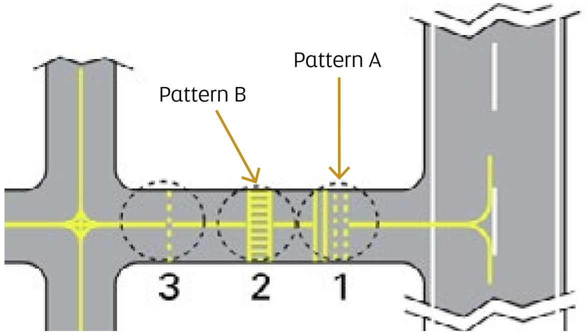
Low Visibility procedures are recommended by ICAO to be implemented by the Airport Authorities when weather conditions fall below or expected to fall below 800 meters RVR or 200 feet cloud base, to ensure a sterile localizer sensitive area. If "Low Visibility Procedures in Force" is transmitted on the airfield ATIS, then runway and ILS protection procedures appropriate to the weather conditions have been applied (i.e. RVR between 300m-600m CAT 2, and RVR below 300m CAT 3). When the RVR is close to or below minimums, crew should bear in mind that the RVR quoted is the reading taken at the time of the observation, which may not be representative of the current conditions. When the crew workload permits, it is advisable to contact ATC and note the most up-to-date RVR readings.

PUSHBACK AND ENGINE START

- It is highly recommended to avoid engine start during pushback with slippery ramp conditions, which may be present in cold weather with LVP's in force
- Icing conditions may be expected when the OAT (on the ground and for Take-off), or the TAT (in Flight) is 10°C or below, and there is visible moisture in the air (such as clouds, fog with low visibility of one mile or less, rain snow sleet, ice crystals), or when standing water, slush, ice or snow is present on the taxiways or runways.
- Engine anti-ice must be selected ON immediately after all engines are started and it must remain on during all ground and take-off operations when icing conditions exist or are anticipated. If there is any appreciable delay in starting the remaining engines during the start sequence, select engine anti-ice ON for running engines. e.g. if one engine is started and then ECAM or other procedures are required which delay subsequent engine (s) start, do not delay in selecting engine anti- ice ON for running engine (s). Do not rely on airframe visual icing cues before activating engine anti-ice. Use the temperature and visible moisture criteria.
- The use of engine anti-ice on the ground will increase the minimum ground idle power output from the engines, this increase in thrust must be taken into consideration when taxiing to ensure adherence to the maximum taxi speed of 10kts and to make crew aware of brake temperatures during taxi.
- When taxiing in LVP conditions, especially when they coincide with cold weather operations, crew should be aware of the possibility of ice build-up on the fan blades of the engines. The appropriate ice-shedding/engine run-up procedures as detailed in flight manuals should be applied.

BEFORE TAXI

The commander will brief the taxi route to the CAT II/III holding points for the runway in use and any special taxiway routings that should or should not be used. The crew should also be aware of any special taxi lighting systems that may be available at the airfield of departure, such as SMGCS. During taxi the F/O should concentrate on the orientation of the aircraft in relation to the airport chart. If pilots are unable to verify their position, stop the aircraft and ask for assistance.



1. Runway Taxi-Holding Position marking pattern 'A'. identifying last holding position prior to entering runway. Marks visual/CAT I & CAT II/III Taxi-Holding Positions where only one Taxi-Holding Position is provided.
2. Runway Taxi-Holding Position marking pattern 'B' identifying CAT I, II or III where a closer visual/CAT I Taxi-Holding Position is provided.
3. Intermediate Taxi-Holding Position.

TAXIING

Bear in mind that in poor visibility, bright lights in the vicinity may be visible, but not unlit or poorly lit obstacles such as aircraft wingtips or tails. Taxi as slowly as necessary and remember taxi speed is limited to 10kts. CM2 should monitor taxi speed and airfield position, using compass information in conjunction with airfield charts to assess the aircraft position.
Prior to line-up, Captains should consider runway state and braking action particularly when carrying out a take-off when the RVR is below 200m. Refer to QRH information to cross-check the minimum required RVR's for departure when the runway is reported as contaminated.

TAKE OFF

- The following should be considered when planning for a low visibility take off:
- Confirm Low Visibility Procedures are in effect for the departure runway.
- Centerline lights spaced not more that 15m apart are required.
- Check reported braking action.
- Check maximum cross-wind limits.
- Ensure relevant RVR values have been achieved as necessary for the departure.
- All take offs with a RVR of less than 400m shall be performed by the captain.

As the aircraft is lined up on the runway, confirm the aircraft is lined up on the runway centerline lights (white, maximum 15m spacing), not the edge lights (white, normally 60m spacing). Select the ILS and use it as a centerline check, along with aircraft alignment on the Navigation Display. During the take-off roll, use the centerline lights for directional control, remember as the speed increases, the streaming effect of the centerline lights improves and directional control becomes easier.

Finally, there are no obligated power settings for low visibility take offs, here are 2 points to consider:
- Full T/O thrust reduces the take-off run.
- Reduced T/O thrust reduces the yaw moment in case of an engine failure.

REJECTED TAKE-OFF

If it is necessary to abandon the take-off during low visibility operations, directional control with reference to the centerline may become relatively less easy as speed is reduced. The use of auto-brake should ensure the aircraft comes to a stop before the end of the runway. As soon as the centerline lights change to alternate red and white, 900m of runway is left. When the centerline lights change to constant red, only 300m of runway remains.

EN-ROUTE

Check the latest RVR, wind and runway condition for destination and alternates. An approach should not be commenced if the controlling RVR is less than the specified minimum for landing unless RVR reports indicate that minimum RVR for landing will be achieved before the airplane passes the approach ban point (outer marker or equivalent, normally 1000ft AAL).

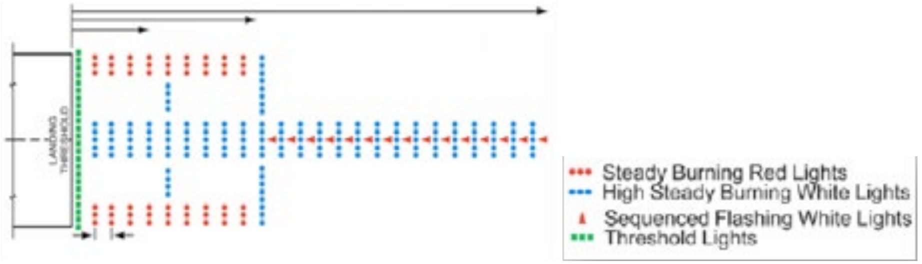
Consider the type of approach to be flown, CAT II, CAT IIIA or CAT IIIB.

Consult the applicable destination Jeppesen chart to confirm type of approach available and applicable Etihad minima.

DESCENT, APPROACH PREPARATION

- Captain briefs the F/O according to aircraft type standard operating procedures.
- Aircraft status and crew qualification are checked.
- Weather requirements are checked, for example wind limits, braking action, RVR and cloud base.
- Reported braking action should be checked and verified to meet aircraft limits.
- Auto-brake usage should be considered.
- DH should be verified and entered in FMS/MCDU.

- Missed approach procedures should be reviewed.
- Failure cases during approach should be reviewed.
- After landing and taxi routings should be reviewed.



In summary, the Captain should give a thorough briefing of the planned approach. Special emphasis should be placed on the fact that the crew must be able to consider a Go-Round at the first sign of an abnormal situation developing. A CAT II/II approach should not be commenced or continued under pressure or with any doubt with respect to aircraft position or status.

APPROACH SEQUENCE OF EVENTS

As per aircraft type. For a more complete review of Low Visibility Operations please refer to FCOM and Skybook, Training section.

Appendix 2

Boeing Weather Radar Operational Brief

Airplane Affectivity: All Airplanes
Subject: MultiScan Weather Radar (WXR) Operation
Reason: Several recent occurrences of flying through, or near the high-altitude convective weather were reported. It has become apparent that the information provided to the flight crew regarding the use of Weather Radar is somewhat inadequate.

The information provided in this Bulletin may facilitate the improved situational awareness and thus enhance the decision making when flying through the area with potential build-ups. In the event of conflict with the FAA approved Airplane Flight Manual (AFM), the AFM shall supersede. Etihad Airways regards the information or procedures described herein as having a direct or indirect bearing on the safe operation of this model airplane.

THE FOLLOWING PROCEDURE AND/OR INFORMATION IS EFFECTIVE UPON RECEIPT

BACKGROUND INFORMATION

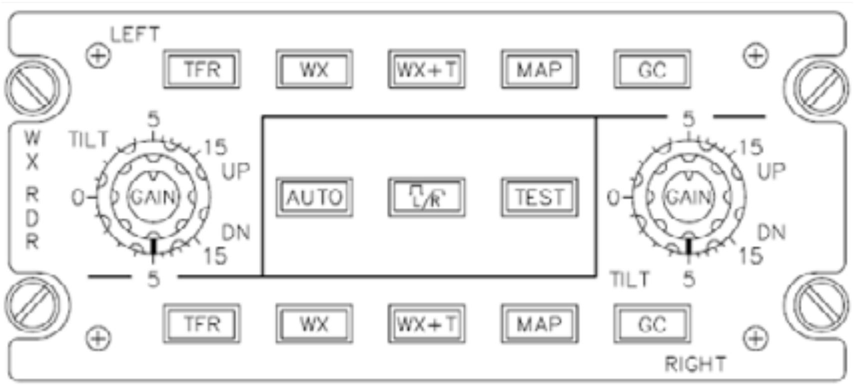
Storm reflectivity can be divided into three parts:

The bottom third of the storm, below the freezing level, is composed entirely of water and is the most reflective part of the storm. Thus, the weather radar returns of the bottom of the storm are the strongest.

The middle third of the storm is composed of a combination of supercooled water and ice crystals. Reflectivity in this part of the storm is less because ice crystals are very poor radar reflectors.

The top third of the storm is composed entirely of ice crystals (very poor radar reflector) and is almost invisible to radar. At temperatures below freezing near convective weather, the airplane can encounter visible moisture made up of high concentrations of small ice crystals. In addition, a growing storm will have a turbulence bow wave above the visible portion of the storm.

Weather Radar System Information



Weather Radar Panel (Typical)

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Mode of Operation

The MultiScan WXR can operate in Manual or Auto modes.

In Manual mode, the MultiScan WXR operates like traditional weather radar with full operator control over tilt and gain settings.

In AUTO mode, the MultiScan WXR is designed to depict weather as far as 320 NM away while removing ground clutter returns. The MultiScan WXR shows weather along the aircraft flight path only. Weather approximately 6,000 ft. below the aircraft and determined by the system to not be a threat is not displayed to prevent unnecessary deviations.

Gain Control

Placing the GAIN control in the 12 o'clock position sets receiver sensitivity at a preset calibration level. Gain can be adjusted in both Manual (MAN) and AUTO modes.

In AUTO mode, the radar uses a temperature-based gain to compensate for poor storm reflectivity in the upper two thirds of the storm and, thus, lessens the possibility of inadvertent storm top penetration. As temperature decreases, the gain is automatically increased. As a result, at cruise altitudes, operating in AUTO mode with gain in the 12 o'clock position is roughly equivalent to operating in manual mode with the maximum gain setting.

Tilt Control

Tilt control can only be adjusted in Manual mode.

The MultiScan WXR complies with new FAA turbulence certification. The threshold is dependent on airplane vertical acceleration, airspeed, altitude, and the presence of sufficient precipitation. This new turbulence display represents a moderate to severe turbulence condition. Turbulence that is less than the new industry guidance threshold is not displayed.

Note: Turbulence detection requires the presence of precipitation. Clear air turbulence cannot be detected.
When encountering stratiform (i.e. non-convective) clouds with rain at altitudes between 10,000 and 20,000 feet, a magenta turbulence display may show, even though the airplane is experiencing little or no turbulence.

Operational Recommendations

Ground Clutter
The MultiScan WXR contains an automatic alignment feature that refines antenna alignment and improves antenna pointing accuracy. Automatic alignment requires a few minutes to complete. Prior to completion of the first automatic alignment, if the ground clutter returns are undesirable, Manual mode may be used.

Ice Crystal Icing (ICI) Conditions
High concentrations of ice crystals can sometimes be found above and near regions of heavy convective precipitation. Ice crystals are difficult to detect because they do not cause significant weather radar returns. Use of Manual Tilt mode is recommended, to allow for tilting the antenna down to determine if convective weather is present below the airplane path.
CAUTION: In AUTO mode, weather approximately 6,000 ft. below the aircraft and determined by the system to not be a threat is not displayed.

CAUTION: As the temperature-based gain compensation is only available in AUTO Tilt mode, it might be necessary to adjust the gain to improve the detection capability. Avoid flying directly over significant amber or red radar returns indicating moderate to heavy convective precipitation, even if there are no returns at the airplane altitude.

Top of Descent

Since the weather below the airplane flight path is not shown, before top of descent, select Manual mode, adjust the gain and tilt the antenna down to determine if convective weather is present below the airplane flight path. Once the descent is established and the situation is sufficiently analyzed, reselect AUTO mode and the preset gain (GAIN control at the 12 o'clock position).

Low Altitude Weather Detection

At lower altitudes, i.e., below 20,000 feet, convective weather with low altitude tops may not be shown on the ND. Increasing the gain will display these low reflectivity cells on the ND. When flying around areas of highly reflective weather, e.g., monsoons, significant convection, etc., increasing the gain may show higher intensity weather returns than actual. Use the preset gain (GAIN control at the 12 o'clock position) for these situations.

CONCLUSION

Technologically advanced equipment has greatly improved humans' capacity to deal with the challenges of flight. This is particularly true when considering the reliability of the equipment, the amount of data available and the way the information is presented to pilot. It must be noted though that one of the effects of this advance is pilots' over-reliance and increasing dependence on technology.

The analysis of some of the recent accidents revealed that pilots' skills, situational awareness and decision-making may have been somewhat degraded due to this phenomenon.

It must be emphasized that the technology is not meant to replace the common sense, experience and airmanship. Thorough understanding of the system and its limitations is absolutely essential as well. Real flight safety can be achieved only when all of these elements supplement each other.

Appendix 3

Airbus Weather Radar Operational Brief

REASON FOR ISSUE

There have been several recent occurrences of flight through, or near high-altitude convective weather. An analysis of these events indicates that the information provided to Flight Crew regarding the use of Weather Radar is somewhat inadequate. The information provided in this Bulletin is intended to improve flight crew systems knowledge and procedural application in the use of the weather radar. This increased situational awareness should facilitate improved decision making when flying in an area of convective weather.

This bulletin must be read in conjunction with the Etihad Airways policy on thunderstorms in OMA 8.3.8.1.

BACKGROUND INFORMATION

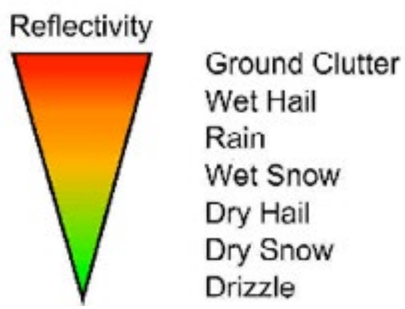
Storm reflectivity can be divided into three parts:

- The bottom third of the storm, below the freezing level, is composed entirely of water and is the most reflective part of the storm. Thus, the weather radar returns of the bottom of the storm are the strongest.
- The middle third of the storm is composed of a combination of supercooled water and ice crystals. Reflectivity in this part of the storm is less because ice crystals are very poor radar reflectors.
- At high altitude (top third of the storm), a cell may have ice particles. Reflection of ice particles is weak. An incorrect tilt/gain combination may lead to only scan the upper (less reflective) part of a cell. As a consequence, a cell may not be detected or may be underestimated.

At temperatures below freezing near convective weather, the airplane can encounter visible moisture made up of high concentrations of small ice crystals. In addition, a growing storm will have a turbulence bow wave above the visible portion of the storm.

WEATHER DETECTION

Weather detection is based on the reflectivity of the water droplets.
The intensity of the weather echo is linked to the droplet size, composition and quantity (e.g. the reflection of water particles is five times greater than ice particles of the same size).



Flight Crew must be aware that the weather radar does not detect weather that has small droplets (e.g. clouds or fog), or that does not have droplets (e.g. clear air turbulence).

GROUND MAPPING

Ground mapping is a secondary function of the weather radar.
In MAP mode, the ND displays ground echoes in various colours depending on their altitude and intensity.

WEATHER RADAR SYSTEM INFORMATION

Several types of Weather Radar Control panels can be found on the Airbus fleet but essentially manual modes of operation are common to all types.

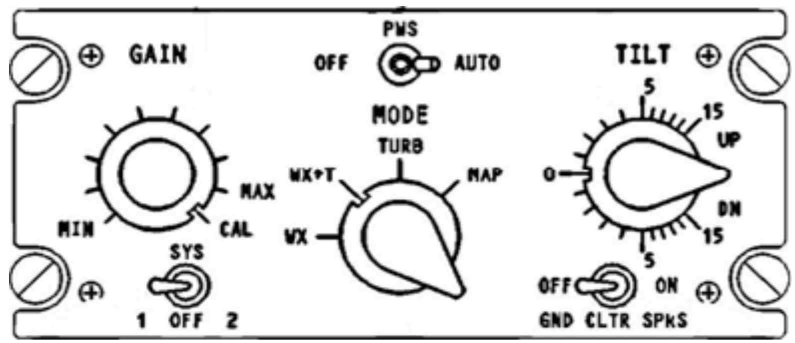


Figure 1: Manual Radar with Ground Clutter Suppression (A320/330/340)

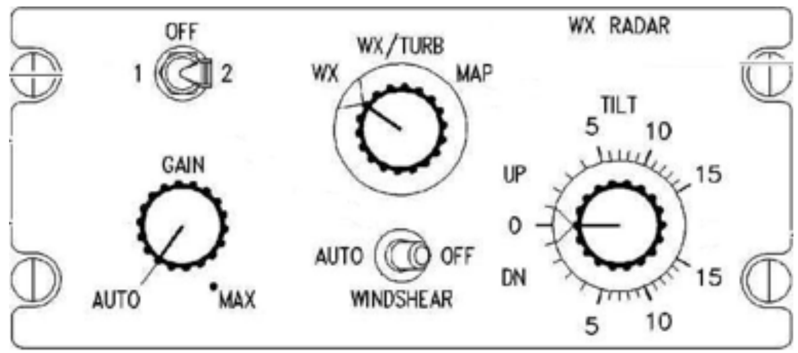


Figure 2: Manual Weather Radar without Ground Clutter Suppression (A320/330/340)

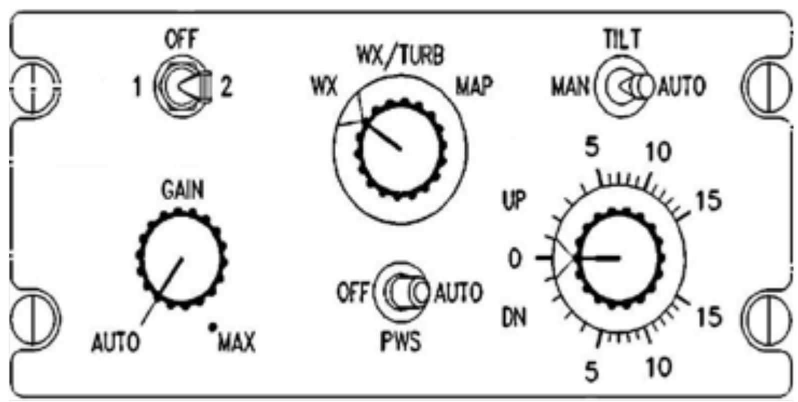


Figure 3: Honeywell: Auto Tilt Radar (A320/330/340)

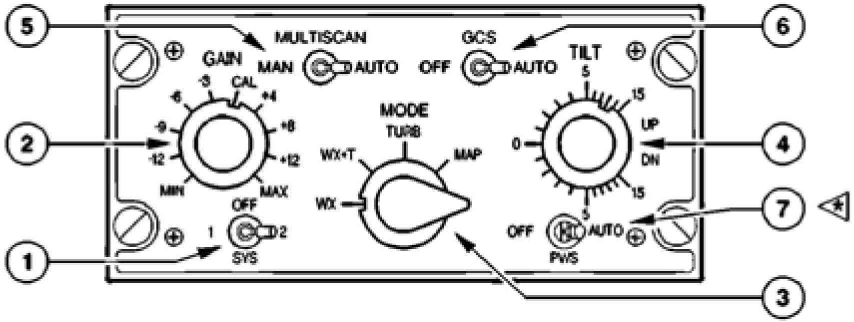


Figure 4: Rockwell Collins: Multi Scan Radar (A320 only)

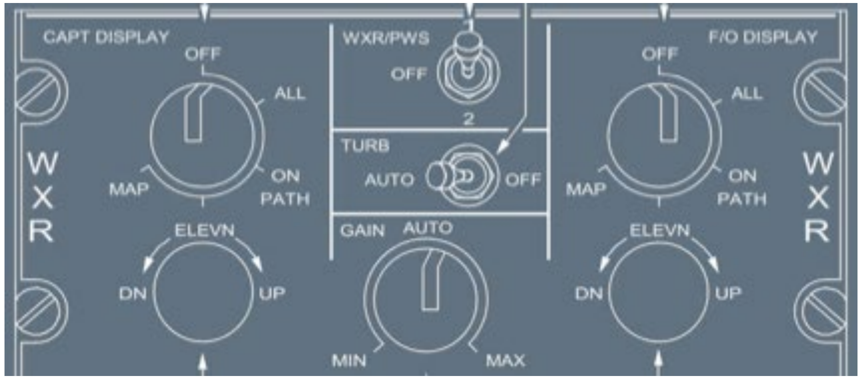


Figure 5: Honeywell: Fully Automatic Radar (A320 only)

TILT CONTROL

To ensure efficient weather monitoring, the Flight Crew must effectively manage the tilt, taking into account the flight phase and the ND range. Usually, the appropriate tilt value provides ground returns on the top of the ND.

To ensure proper tilt management along the flight, the Flight Crew should set the TILT sw to AUTO and use manual tilt when required (for cell analysis).

In MAN mode, the AUTOTILT and MULTISCAN radars operate like a conventional WXR i.e. the pilot controls tilt.

In AUTO mode, the MULTISCAN and FULLY AUTOMATIC radars are designed to detect and display weather returns as far as 320nm away while removing ground clutter returns. The MULTISCAN WXR displays weather along the aircraft's flight path. Weather returns approximately 6,000ft below the aircraft and those determined not to be a threat by the system are not displayed to prevent unnecessary deviations.

Note: For MULTISCAN radar: In cruise, the MULTISCAN function provides a large view of the weather ahead i.e. display of weather cells located on and below aircraft path. Before planning a route change in front of an ambiguous or unexpected weather display, the flight crew should confirm the potential conflicts with aircraft path, using manual tilt periodically.

GAIN CONTROL

The Flight Crew uses GAIN knob to adjust the intensity of the colours of the weather displayed.

In standard operation, on all types of radars, the flight crew should set the GAIN knob to AUTO/CAL.

The Flight Crew may manually tune the gain to analyse cells. To detect the strongest part of a cell displayed in red on the ND, the flight crew can slowly reduce the gain. The red areas will slowly become yellow areas, and the yellow areas will become green areas. The last part of the cell to turn yellow is the strongest area. After a cell analysis, the Flight Crew should reset the GAIN knob to AUTO/CAL.

In AUTO mode, the MULTISCAN and FULLY AUTOMATIC radars use a temperature-based gain to compensate for poor storm reflectivity in the upper two thirds of the storm and, thus, lessens the possibility of inadvertent storm top penetration. As temperature decreases, the gain is automatically increased. As a result, at cruise altitudes, operating in AUTO mode with gain in the AUTO/CAL position is roughly equivalent to operating in manual mode with the maximum gain setting.

TURB MODES

The Flight Crew can use WX+T or TURB modes to locate the wet turbulence area.

WX+T and TURB modes detect wet turbulence within 40 nm, and are not affected by the gain. TURB mode should be used to isolate turbulence from precipitation.

GROUND CLUTTER SUPPRESSION (GCS)

Where fitted, the Ground Clutter Suppression operates in WX mode, and inhibits the ground echoes on the ND.

It should normally be selected off and only used to separate cells from ground clutter for better analysis and avoidance planning when required.

Ground Clutter Suppression is an automatic function of the MULTISCAN and FULLY AUTOMATIC radars.

RECOMMENDATIONS

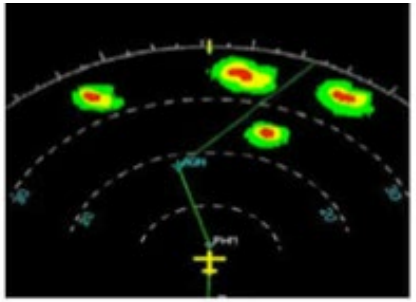
GENERAL

Effective tilt and ND range management is a key element for weather radar operation:

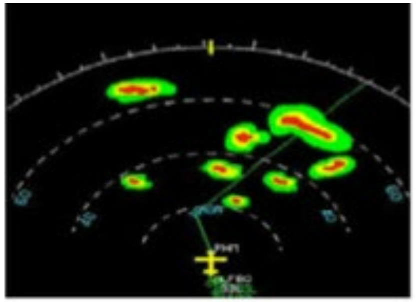
1. First, select a ND range, based on FL and detection requirement (long distance/short distance) and on the line of sight;
2. Then, (for MANUAL radars) the Flight Crew adjusts tilt to maintain ground return on top of ND (except during takeoff, climb and approach).
3. Before top of descent (for AUTO TILT and MULTISCAN radars), since the weather well below the airplane flight path may not be shown, select MAN mode and tilt the antenna down to determine if convective weather is present below the airplane flight path. Once the descent is started, reselect AUTO mode.

RANGE MANAGEMENT

The Flight Crew should monitor the weather at long range, as well as at shorter ranges, in order to be able to efficiently plan course changes, and to avoid the blind alley effect (depicted below)



ND Range = 40 NM



ND Range = 80 NM

GENERAL WEATHER RADAR USE

For each phase below, the guidance is provided in the first instance for MANUAL RADAR operation and then for AUTO TILT & MULTISCAN modes.

PHASE	DETECTION & MONITORING	COMMENTS
TAXI	Clear of parking area, set ND to lowest range. Tilt down then up. Check the appearance/disappearance of ground returns	Antenna tilt check (away from people)
T-OFF	If weather activity is suspected: slowly scan up to detect weather (Max 15°up), otherwise: set tilt to 4° up or AUTO	Enables scanning along the departure path
CLB	Adjust the ND range as required and decrease the tilt angle as the aircraft climbs. or TILT sw on AUTO GAIN knob on AUTO Use TURB to isolate turbulence	Avoids over scanning of weather On AUTO TILT & MULTISCAN radars, manual TILT and GAIN for weather analysis is done as required
LEVEL FLIGHT/ CRZ	Depending on FL and detection requirement, adjust ND range. Initially select a tilt down that maintains the ground return on the top of the ND. Then, regularly scan the weather vertically by modifying the Tilt. Once the scan is done, adjust the tilt to maintain ground returns back on the top of the ND. or TILT sw on AUTO GAIN knob on AUTO Use TURB to isolate turbulence	On AUTO TILT & MULTISCAN radars, manual TILT and GAIN for weather analysis is done as required. In cruise, for efficient weather awareness, the following ranges can be selected: - 160 nm on the PNF ND - 80 nm on the PF ND. Shorter ranges can be used to track/avoid closing weather
DES	During descent, tilt upward to maintain the ground return on the top of the ND. or TILT sw on AUTO GAIN knob on AUTO Use TURB to isolate turbulence	On AUTO TILT & MULTISCAN radars, manual TILT and GAIN for weather analysis is done as required
APPCH	Tilt 4° up or TILT sw on AUTO GAIN knob on AUTO	Avoids ground returns

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Note: 1

On MULTI SCAN radar, AUTO mode provides efficient ground clutter rejection. During operations in good or non-significant weather, no weather pattern will be displayed on ND›s. In such situations, to check correct radar operation, the flight crew should use manual tilt periodically.

Note: 2

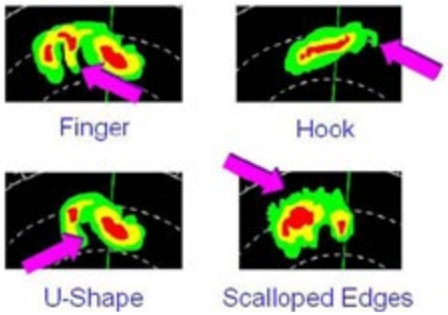
On AUTO TILT radar, AUTO mode adjusts the tilt to get a minimum ground return on the ND. The flight crew should monitor the weather radar display in automatic tilt mode, and confirm any ambiguous or unexpected weather display using manual tilt according to standard techniques.

TURBULENCE DETECTION

The turbulence display is most effective when the ND is set to 40 nm (this corresponds to the maximum TURB mode turbulence detection range).

Closely spaced (or thin lines between) color gradations are usually associated with severe turbulence.

Shapes may be good indicators of adverse weather and turbulence. Fast changing shapes, regardless of their form, also indicate high activity.



LOW ALTITUDE WEATHER DETECTION

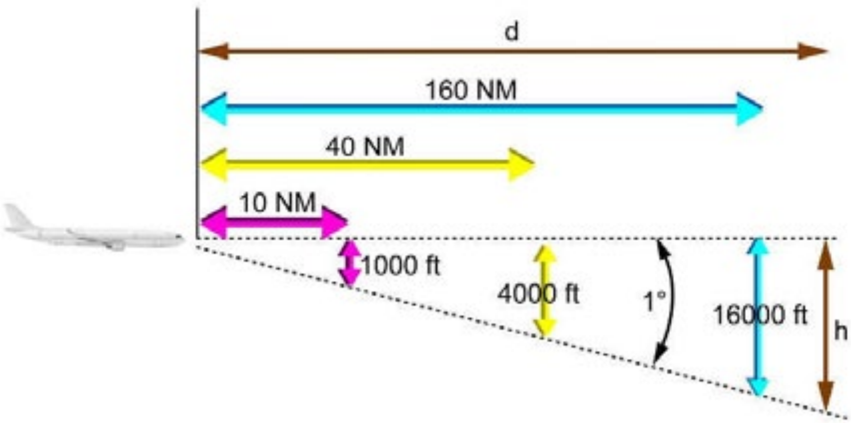
On MULTI SCAN radar at lower altitudes, i.e., below 20,000 feet, convective weather with low altitude tops may not be shown on the ND. Increasing the gain will display these low reflectivity cells on the ND.

On all radar types, when flying around areas of highly reflective weather, e.g., monsoons, significant convection, etc., increasing the gain may show higher intensity weather returns than actual. Use the AUTO gain for these situations.

EVALUATION OF CELL VERTICAL EXPANSION

When flying towards a cell, the Flight Crew can get an estimate of the vertical expansion of the cloud above/below the aircraft altitude with the following formula: h(ft)=d(NM)xTilt(˚) x100.Tilt represents the tilt selected so that the cell image disappears from the display.
For example, an echo disappearing at 40 nm with 1 ° tilt down has a top located 4 000 ft below the aircraft altitude.

NOTE: With the FULL AUTOMATIC radar, an equivalent evaluation may be performed by using the ELEVN mode, and selecting a FL at which the echo disappears.



CAUTION: On ALL radar types when using the above technique to assess "tops", crew must be aware that the upper third of a storm cell is mostly composed of ice crystals that produce poor or no radar returns. Therefore, the flight crew should increase the gain to make the frozen (less reflective) storms top more visible.

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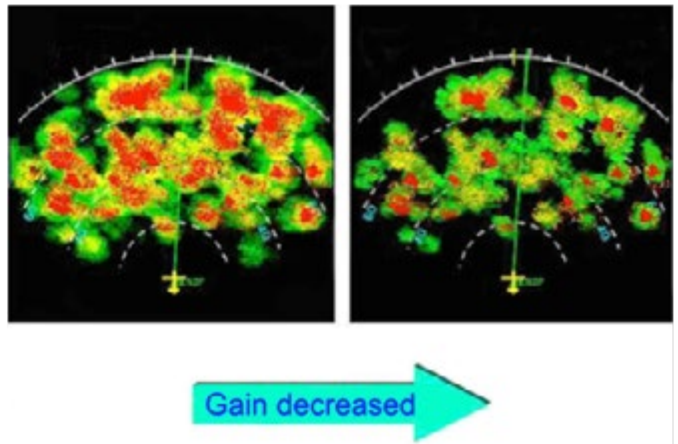
SATURATED WEATHER RETURN

To assess the general weather conditions the Flight Crew may use manual gain. Manual gain is particularly useful, when operating in heavy rain, if the radar picture is saturated. In this case, reduced gain will help the Flight Crew to identify the areas of heaviest rainfall, which are usually associated with active storm cells. To recover optimum radar sensitivity once the cell assessment is done, the flight crew must reset the GAIN knob to AUTO/CAL.

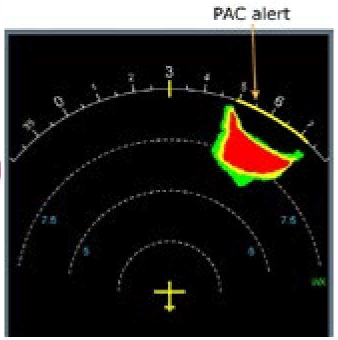


WEATHER AVOIDANCE

- Decisions to avoid large storm cells must be taken early – approximately 40nm before the said cell.
- The Flight Crew should deviate upwind instead of downwind of a cell (less probability of turbulence or hail).
- For storm avoidance planning, the flight crew should consider the height of the storm:
  - Avoid all yellow, red, or magenta areas by at least 20 nm
  - Avoid all green, yellow, red, and magenta areas of cells taller than 25000ft by at least 25 nm.
  - Cells exceeding 30 000ft should be considered extremely hazardous and additional separation (at least 30 nm) should be used.
- If the top of cell is at or above 25 000ft, any overflying should be avoided due to the possibility of encountering turbulence stronger than expected.
- The Flight Crew should not attempt to penetrate a cell or clear its top by less than 5 000ft vertically as there is a real risk of encountering severe turbulence.
- Flight Crew should also avoid flying under a thunderstorm because of possible windshear, microbursts, severe turbulence, or hail.

PATH ATTENUATION

Some precipitation levels may be so strong as to not allow the radar beam to penetrate them. Consequently they mask the weather behind them.



Remember: The black hole behind a red area is a potentially very active zone.

On MULTISCAN radars only, a Path Attenuation Control (PAC) alert visual cue is displayed as a yellow arc on the outermost range ring. This PAC alert is only available with CAL gain and for attenuation within 80 nm.

ICE CRYSTAL ICING (ICI) CONDITIONS
High concentrations of ice crystals can sometimes be found above and close to areas of heavy convective precipitation. Ice crystals are poor reflectors of radar signals and are thus difficult to detect. Use of Manual tilt mode (ELEVN mode on FULLY AUTOMATIC radar) is recommended, to allow for tilting the antenna down to determine if convective weather is present below the airplane path. Reselect AUTO mode as needed.

During flight at night or in Instrument Meteorological Conditions (IMC), avoid flying directly over significant yellow or red radar returns indicating moderate to heavy convective precipitation, even if there are no returns at the airplane altitude.

CAUTION: On MULTISCAN and FULLY AUTOMATIC radars, weather returns approximately 6,000ft below the aircraft and those determined not to be a threat by the system are not displayed.

CAUTION: On MULTISCAN and FULLY AUTOMATIC radars, as temperature based gain compensation is only available in AUTO mode, it might be necessary to adjust the gain to improve detection capability.

CONCLUSION
Technologically advanced equipment has greatly improved Flight Crew capacity to deal with the challenges in-flight. This is particularly true when considering the reliability of the equipment, the amount of data available and the way the information is presented to the pilot. It must be noted though that one of the effects of this advance is the pilot's overreliance and increasing dependence on technology.

Analysis of some of the recent accidents/incidents reveals that pilot skills, situational awareness and decision-making may have been somewhat degraded due to this phenomenon.

It must be emphasized that the technology is not meant to replace common sense, experience and airmanship. Thorough understanding of the system and its limitations is absolutely essential as well. Real flight safety can be achieved only when all of these elements complement each other.

Appendix 4

Ice Crystals at Altitude Article

ENGINE POWER-LOSS IN ICE CRYSTAL CONDITIONS

High-altitude ice crystals in convective weather are now recognized as a cause of engine damage and engine power-loss that affects multiple models of commercial airplanes and engines. These events typically have occurred in conditions that appear benign to pilots, including an absence of airframe icing and only light turbulence. The engines in all events have recovered to normal thrust response quickly. Research is being conducted to further understand these events. Normal thunderstorm avoidance procedures may help pilots avoid regions of high ice crystal content.

ICE CRYSTAL ICING CAN OCCUR DEEP IN THE ENGINE WHERE SURFACES ARE WARMER THAN FREEZING.

Since 1990, there have been at least 100 jet engine power-loss events on both commuter and large transport airplanes, mostly at altitudes higher than 22,000 feet, the highest altitude where airframe icing is expected to exist. “Power-loss” is defined as engine instability such as a surge, stall, flame out, or rollback that results in a subidle operating condition. High altitude ice crystals are believed to have caused most or all of these events.

This article explains the ice crystal phenomenon, how ice crystals cause power-loss, the types of power-loss events, where and when engine power-loss events have occurred, conditions associated with ice crystal formation, and recommendations for flight near convective weather. It also discusses the importance of pilot reporting of ice crystal power-loss events.

HIGH-ALTITUDE ICE CRYSTAL ICING

Several engine power-loss and damage events have occurred in convective weather above the altitudes typically associated with icing conditions. Research has shown that strong convective weather (thunderstorm activity) can lift high concentrations of moisture to high altitudes where it can freeze into very small ice crystals, perhaps as small as 40 microns (the size of flour grains). These are the crystals that can affect an engine when flown through convective weather. The industry is using the phrase “ice crystal icing” to describe these icing conditions, and to differentiate it from icing conditions due to supercooled liquid.

Ice crystals do not adhere to cold airframe surfaces because the ice crystals bounce off. However, the crystals can partially melt and stick to relatively warm engine surfaces.

“Glaciated Conditions” refers to atmospheric conditions containing only ice crystals and no supercooled liquid. “Mixed phase conditions” refers to atmospheric conditions containing both ice crystals and supercooled liquid. Both glaciated and mixed phase conditions occur in convective clouds and have been present during engine power-loss and damage events.

OnBoard weather radar can detect large particles such as hail, rain, and large ice crystal masses (snowflakes, small particles, such as ice crystals in high concentrations near thunderstorms, are invisible to onboard weather radar, even though they may comprise the majority of the total mass of a cloud (see figure 1).

Sophisticated satellite radar technology has been used to detect crystals smaller than the lower limit of onboard weather radar. Above the freezing level, where icing can occur in a deep convective cloud, satellite radar has confirmed that large particles, which can be detected by onboard weather radar, are only found near the convective precipitation core.

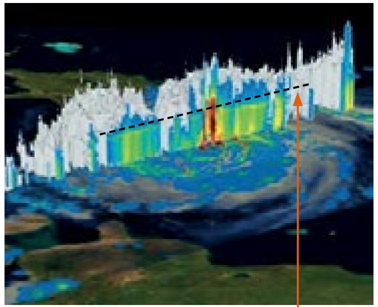


Photo Credit: NASA TRMM image by Hal Pierce (SSAI/GSFC)

Freezing level

SATELLITE/RADAR IMAGE OF A HURRICANE CONVECTIVE STORM Figure 1

This NASA Tropical Rainfall Measurement Mission (TRMM) combined satellite radar image shows a vertical cross-section of a convective storm. The image shows the freezing level clearly by the “bright band” where ice particles become coated with melted water and are excellent reflectors of radar energy. Below the freezing level, liquid water is highly reflective. Above the freezing level, while the concentration of moisture may still be high, the cloud is mostly composed of frozen ice particles with radar reflectivity below 20dBz (units of radar energy). Small ice crystals are irregular in shape and poor reflectors of radar energy. These small ice crystals are believed to be associated with engine power-loss events.

Away from the convective precipitation core, satellite radar has confirmed that small ice crystals, which are invisible to onboard weather radar, exist.

For this reason, flight in visible moisture near deep convective weather, even without radar returns, and at temperatures below freezing, is very likely to be in ice crystal conditions.

Ice building up on the inlet, fan, or spinner would likely shed outward into the fan bypass duct without causing a power-loss. Therefore, in these power-loss events, it is reasonable to conclude that ice must have been building up in the engine core.

It is now believed that ice crystal icing can occur deep in the engine where surfaces are warmer than freezing (see figure 2). Both older generation jet engines and the new generation of jet engines (high bypass ratio engines with electronic engine controls) can be affected by ice crystal icing.

TYPES OF POWER-LOSS EVENTS

The actual mechanism for ice crystalrelated engine power-loss takes many forms, depending on the design characteristics of each particular engine type (see table below).

POWER-LOSS TYPE	DESCRIPTION	EFFECT	RECOVERY
Surge/Stall*	Ice shed into compressor drives engine to surge, then stall causes rotor speeds to decay, and reducing airflow while combustor remains lit.	Thrust loss and high exhaust gas temterature.	Throttle to idle. Cycling of the fuel switch may be required to clear some stalls.
Flameout*	Ice shed into the combustor quenches the flame.	Thrust loss and all parameters dropping.	Ignition. Many events selfrecover due to autorelight or having the ignition already on.
Engine Damage	Engine blades become damaged as shed ice impacts them.	Typically no effect at time of initial damage, but damaged blades may fail later causing vibration or engine stall.	As appropriate — refer to quick reference Handbook.

WHERE AND WHEN ICE CRYSTAL POWER-LOSS EVENTS HAVE OCCURRED

About 60 percent of recorded ice crystal power-loss events have occurred in Asia. Researchers speculate that this may be due to the fact that the highest sea surface temperatures are also found in this region higher temperature air can hold more water. There is a heavy concentration of ice crystal power-loss events between 20 and 40 degrees north latitude with a few events farther than 45 degrees from the equator (see figure 3).

Engine power-loss events have occurred in three phases of flight, climb, cruise, and descent. However, most events occur during the descent phase, most likely because of a combination of two factors. First, for icing to occur, the ambient temperature must be below the freezing level, and therefore icing tends to occur at the higher altitude associated with the descent phase. Second, the engine is least tolerant to ice shedding at idle power, which occurs in the descent phase. Icing at high power and high altitude is possible due to the existence of high concentrations of ice crystals for long distances, such as in the anvil of a large convective storm, and the fact that ice can build up on warm engine surfaces.

RECOGNIZING HIGH ICE CRYSTAL CONDITIONS

Researchers have identified several conditions that are connected to engine ice crystal icing events. The most important factors are:

- *High altitudes and cold temperatures*. Commercial airplane power-loss events associated with ice crystals have occurred at altitudes of 9,000 to 39,000 feet, with a median of 26,800 feet, and at ambient temperatures of −5 to −55 degrees C with a median of −27 degrees C. The engine power-loss events generally occur on days when the ambient temperature is warmer than the standard atmosphere (see fig. 4).
- *The presence of convective clouds*. Convective weather of all sizes, from isolated cumulonimbus or thunderstorms to squall lines and tropical storms, can contain ice crystals. Convective clouds can contain deep updraft cores that can lift high concentrations of water thousands of feet into the atmosphere, during which water vapor is continually condensed and frozen as the temperature drops. In doing so, these updraft cores may produce localized regions of high ice water content which spread downwind. Researchers believe these clouds can contain up to 8 grams per cubic meter of ice water content; by contrast, the design standard for supercooled liquid water for engines is 2 grams per cubic meter.
- *Areas of visible moisture above the altitudes typically associated with icing conditions*. This is indicated by an absence of significant airframe icing and the ice detector (when installed) not detecting ice, due to its ability to detect only supercooled liquid, not ice crystals.

These additional conditions are also typically found during engine ice crystal power-loss events:

- No pilot reports of weather radar returns at the event location.
- Temperature significantly warmer than standard atmosphere.
- Light-to-moderate turbulence.
- Areas of heavy rain below the freezing level.
- The appearance of precipitation on heated windshield, often reported as rain, due to tiny ice crystals melting.
- Airplane total air temperature (TAT) anomaly reading zero, or in error, due to ice crystal buildup at the sensing element (see case study on following page).
- Lack of observations of significant airframe icing.

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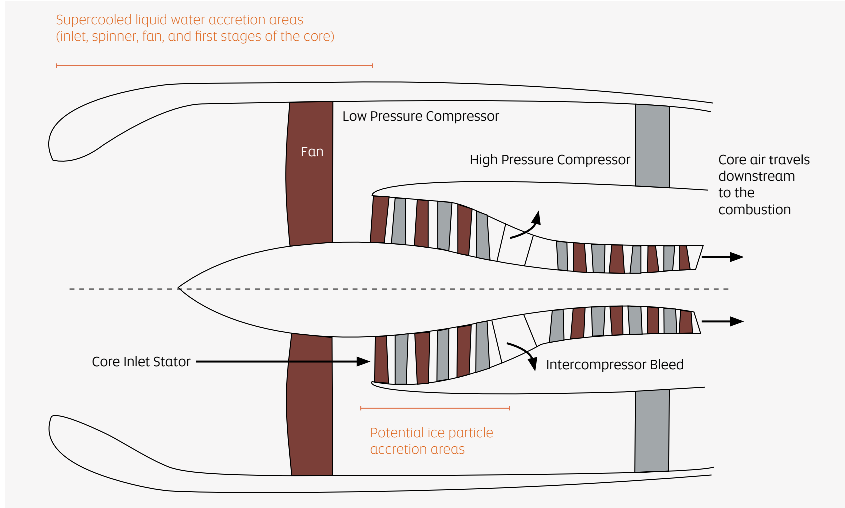
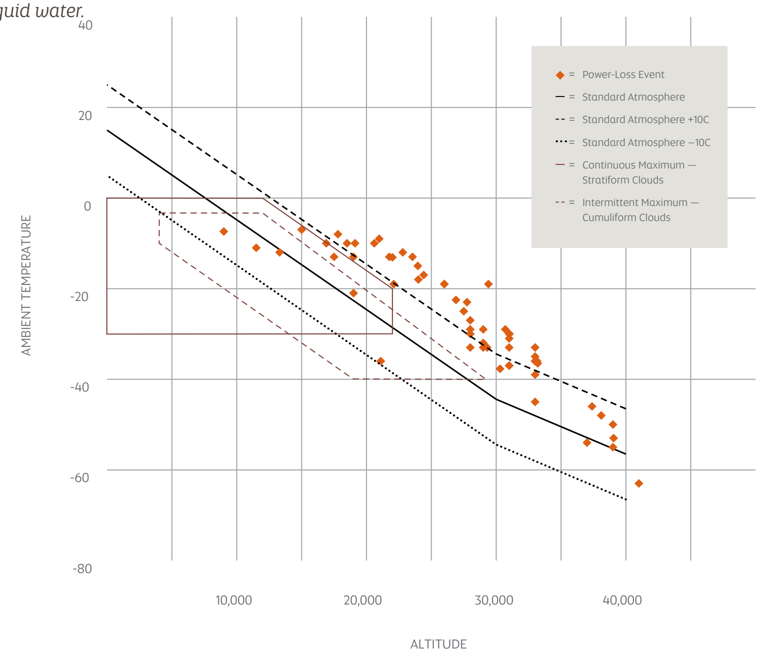
HOW ICE CRYSTALS ACCRETE IN A JET ENGINE Figure 2

Researchers hypothesize that ice particles enter the engine and bounce off surfaces colder than freezing (inlet, fan, and spinner). Once reaching surfaces warmer than freezing in the core, some of the small particles can melt and create a film of water on the surface to which additional incoming ice crystals can stick. This process gradually reduces the temperature of the surface until ice can begin to build up.



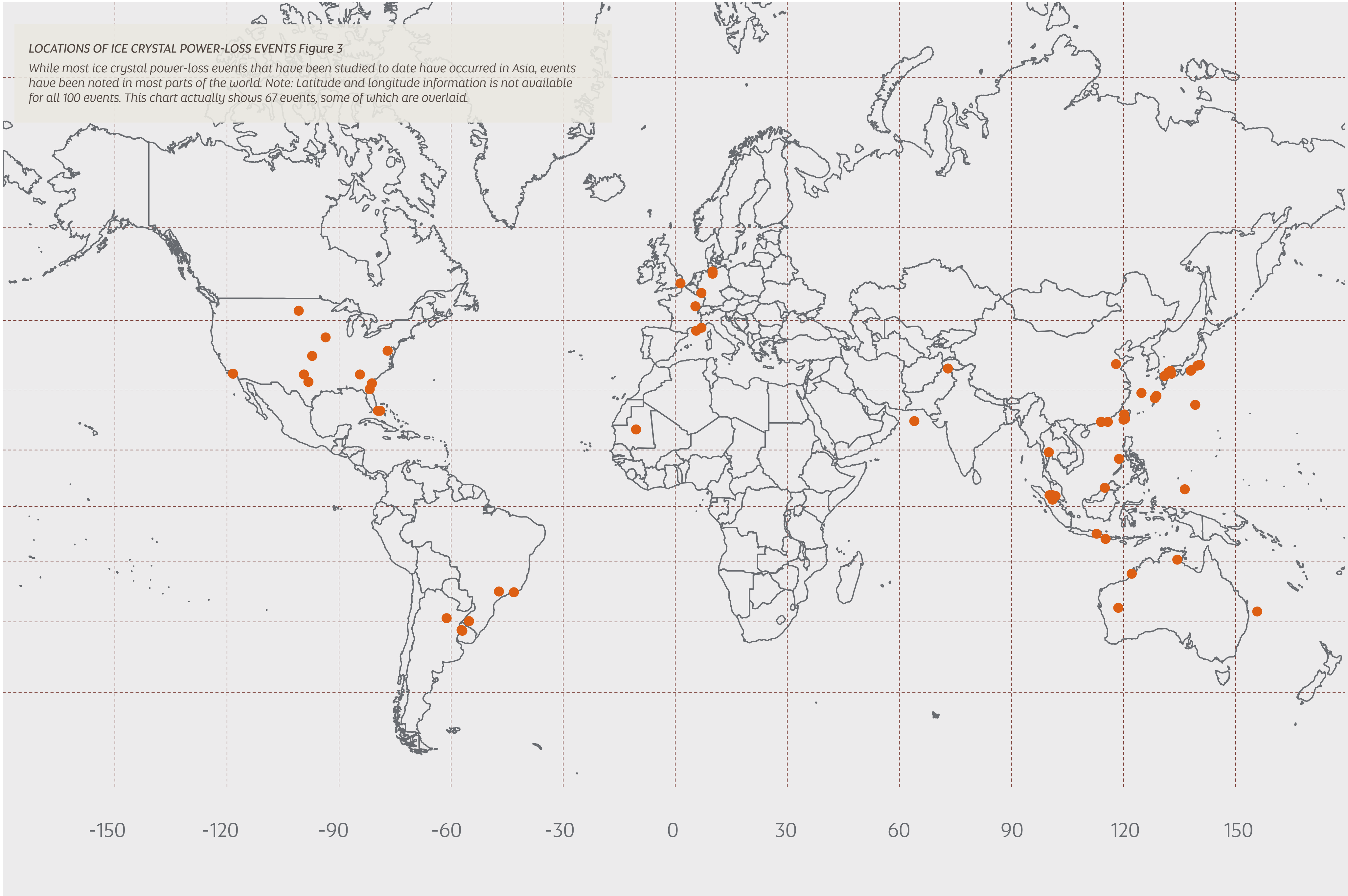
ALTITUDE AND TEMPERATURE OCCURRENCE OF ENGINE POWER-LOSS Figure 4

Temperatures for the majority of the events for which data is available are significantly warmer than standard day temperatures, and also fall outside of the current icing design envelopes for supercooled liquid water.



LOCATIONS OF ICE CRYSTAL POWER-LOSS EVENTS Figure 3

While most ice crystal power-loss events that have been studied to date have occurred in Asia, events have been noted in most parts of the world. Note: Latitude and longitude information is not available for all 100 events. This chart actually shows 67 events, some of which are overlaid.



RECOMMENDATIONS FOR FLIGHT NEAR CONVECTION

Even when there are no radar returns, there may be significant moisture in the form of ice crystals at high altitudes. These are not visible to airborne radar. As a result, it is not possible to avoid all ice crystal conditions. However, normal thunderstorm avoidance procedures may help pilots avoid regions of high ice crystal content.

These avoidance procedures include:

- Avoiding flying in visible moisture over storm cells. Visible moisture at high altitude must be considered a threat since intense storm cells may produce high concentrations of ice crystals at cruise altitude.
- Flying upwind of storms when possible.
- Using the radar antenna tilt function to scan the reflectivity of storms ahead. Assess the height of the storms. Recognize that heavy rain below the freezing level typically indicates high concentrations of ice crystals above.
- Avoiding storm reflectivity by 20 nautical miles has been commonly used as a recommended distance from convection. This may not be sufficient for avoidance of high concentrations of ice crystals, as they are not visible on airborne radar.

FURTHER RESEARCH

Today, knowledge of the nature of convective weather and the exact mechanism of ice crystal buildup and shedding in the engine is limited. A research program is being developed by an industry icing group to address these needs. it involves flights into convective clouds to measure their properties, as well as groundbased engine testing.

Most of what is currently understood about the environment associated with engine events is based on pilot reports and flight data. Additional pilot reports of high-altitude ice crystal encounters (with or without engine events) will help researchers understand the conditions associated with engine events, ensure that the flight program is directed into the appropriate flight conditions, and help develop cues for these flight conditions.

Pilots encountering conditions such as those described in this article are encouraged to provide as many details about the conditions as possible to their airlines for subsequent use by researchers.

SUMMARY

Ice crystal icing conditions have been recognized as a hazard to turbofan engines. Ice can build up deep in the engine core. Pilots are advised to familiarize themselves with the conditions under which ice crystal icing typically occurs and follow the recommendations in related technical bulletins.

Airline awareness of the potential for ice crystal icing on all engine models/airplane types may provide additional information that will help Boeing and the industry better understand this phenomenon.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