The Ice Crystal Icing Hazard & Risk Mitigation: Delta Air Lines’ Perspective

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Ice Crystal Icing (ICI)

What is it?
&
What can we do about it?
Airframe Icing Conditions

Question:
What Temperatures & Cloud Conditions produce Airframe Icing?

Answer:
Temps Warmer than -40°C & Liquid Cloud droplets below freezing.

Typical Icing Requires Super-cooled Liquid Droplets
• Liquid freezes on contact with cold wings & fuselage surfaces.
• Ice crystals, regardless of size, do not adhere to a cold airframe

Source: NASA-Lewis/FAA/NCAR-RAP
**Question:**
What conditions produce Ice Crystal Icing (ICI)?

**Short Answer:**
High Concentrations of Ice Crystals, also called High Ice Water Content (HIWC)

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**Ice Crystals Build-up in Compressor**

FAA has an Advisory Circular in effect for B787
What is the physical process producing ICI risk?

- Portions of Engine Compressor are above freezing
  - Very small ice crystals are ingested into the engine →
- Ice crystals partially melt & stick to warmer engine surfaces
  - Ice crystals melt as they impact the warm internal engine components →
  - If, encounter persists, a thin film develops over parts of the engine →
  - This enables further capture of ice crystals →
- If prolonged Encounter: Engine Temperature is reduced < 0°C:
  - Ice crystals begin to aggregate →

  Ice can block flow into engine core or shed into core →
  Leading to various engine malfunctions
  (engine vibration, power loss or damage)
Where have ICI incidents occurred?

- 67 events shown worldwide (some overlaid) by Boeing 1990’s-2009.
- Well over 100 events have been identified.
- The greatest # of events have occurred in Asia Inter-port area.

**Question:**
What weather/flying conditions produce most Ice Crystal Icing (ICI)?

**Answer:**
- Deep convective systems over both ocean & land in a Tropical Airmass
- ICI potential increases with denser convection & extended exposure.
- Typically, at cruise level altitudes & in clouds, above strong convection where little or no weather radar returns observed at flight altitude.

**ICI Awareness Tools**
- **Radar:** Tactical ICI avoidance is a challenge because not easily identified on radar.
- **HIWC:** Areas of High Ice Water Content (HIWC) are being estimated & provided by some aviation weather vendors.
High Ice Water Content Awareness
A Tool & a Delta Meteorology Product

Tool:
Risk Areas for ICI
- Last 1 Hr HIWC
- 2 Hrs previous
- 3 Hrs previous

Enroute Product:
Preflight

*Depiction Product contains*
- Forecast of tstrom coverage & area

*Process*
- Dispatchers consider alternative routes to avoid possible ICI when:
  - BKN (>=50%) tstrom coverage fcsted &
  - Flt route through tstrom area is 100NM or greater in distance.

Example: TP Message

```
TP CB19 051441Z
1.CBA
2.* ALERT *
HAZ:TSTMS
SOURCE:SATELLITE
AREA:02N071W 00N068W 02N066W 04N070W
CVRG:BKN
TOPS:FL450
TREND:NC
MVG FROM:CELLS VRBL
INFO: RISK ICE CRYSTAL ICING-B757 ACTION RQRD
3.VALID 051441Z/060000Z
4.CANCEL NONE
```
Why the Attention?

An ICI Event
• On 09 November 2014 a Delta B757-200 operating from Japan to Mariana Islands experienced an engine irregularity & then diverted to Iwo Jima.
• Post event analysis determined that ice crystal icing was a factor in the engine shut down.

A Boeing 757 Aircraft
• Although ICI can occur on any aircraft on any Delta fleet:
  • Fleets other than the B757 have engine auto re-ignite / restart capability.
  • On B757 fleet “continuous ignition” must be activated manually.
A Coordinated Effort Between:

Meteorology

Dispatch

Pilots
Multi Layered Approach

1. Strategic Avoidance

2. Tactical Avoidance

3. Mitigation if Encountered
Pilot Preflight Planning example: at 00z for JFK-SJU Flight

Upper Air Depiction: Issued at 19z Features Valid 06z

TP - Issued & Valid 23z
Included in preflight paperwork

TP CB36 102306Z
1. BD
2. * ALERT *
HAZ: TROP STORM
NAME: KATE
LAT/LON: 32.5N072.7W
TIME: POSN AT 10/2100Z
MVG FROM: 23026
WIND: SFC 60G75KT
TREND: NC
...
INFO: RISK ICE CRYSTAL ICING-B757 ACTION RQRD
3. VALID 102306Z/110900Z
4. CANCEL CB29
Pilot Preflight Planning example:

NRT-GUM Flight

Only Scattered (SCT) or less tstrm coverage forecast along route of flight
Operating in ICI conditions
Tactical Avoidance

Cockpit Preparation
En Route NRT- GUM

Text of TP

TP AI23 031837Z
1.GM
2.* ALERT *
HAZ:TSTMS
SOURCE:SATELLITE
AREA:14N141E 11N146E
12N149E 17N145E
CVRG:SCT TOPS:FL540
TREND:INC MVG
FROM:CELLS 12015
INFO:RISK ICE CRYSTAL ICING-B757 ACTION RQRD
3.VALID 031837Z/040200Z
4.CANCEL AI07
Operating in ICI conditions

Tactical Avoidance

Radar Operation

Aggressive Down Tilt Recommended to See Amber at Freezing Level

- Use manual tilt control mode, tilt the antenna down below the freezing level, and adjust the gain as necessary to help determine whether heavy (amber or red) returns are present below the airplane's flight path.
- Avoid flying directly over significant amber or red radar returns (which indicate moderate to heavy convective precipitation) when flying in instrument meteorological conditions (IMC).

At Cruise on a tropical ISA+15 Day, 3 to 5 degrees down-tilt recommended to obtain freezing level returns starting at 30 nm.
Mitigation

When in IMC at or above xx,000’ and operating within an area identified by Boeing’s High Ice Water Content (HWIC) map:

ENGINE START SELECTORS …………………..FLT
   Increases engine flameout protection.

ENGINE ANTI-ICE Switches……………………..ON
   Increases engine stall margins
In-flight restarts after ICI event

Typically there is no engine damage after the ice has been ingested and the engine may be restarted.

**Question:** Should an in-flight restart be considered?

**Answer:** Yes
ICI is manageable.

Meteorology, Dispatch, and Pilot teamwork & training are key.