Overview of Designing a Freezing Point Depressant Ice Protection System

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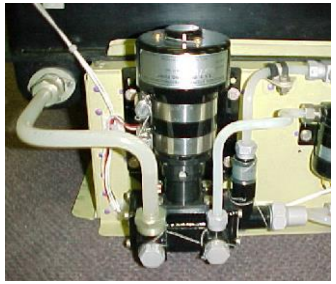
2019

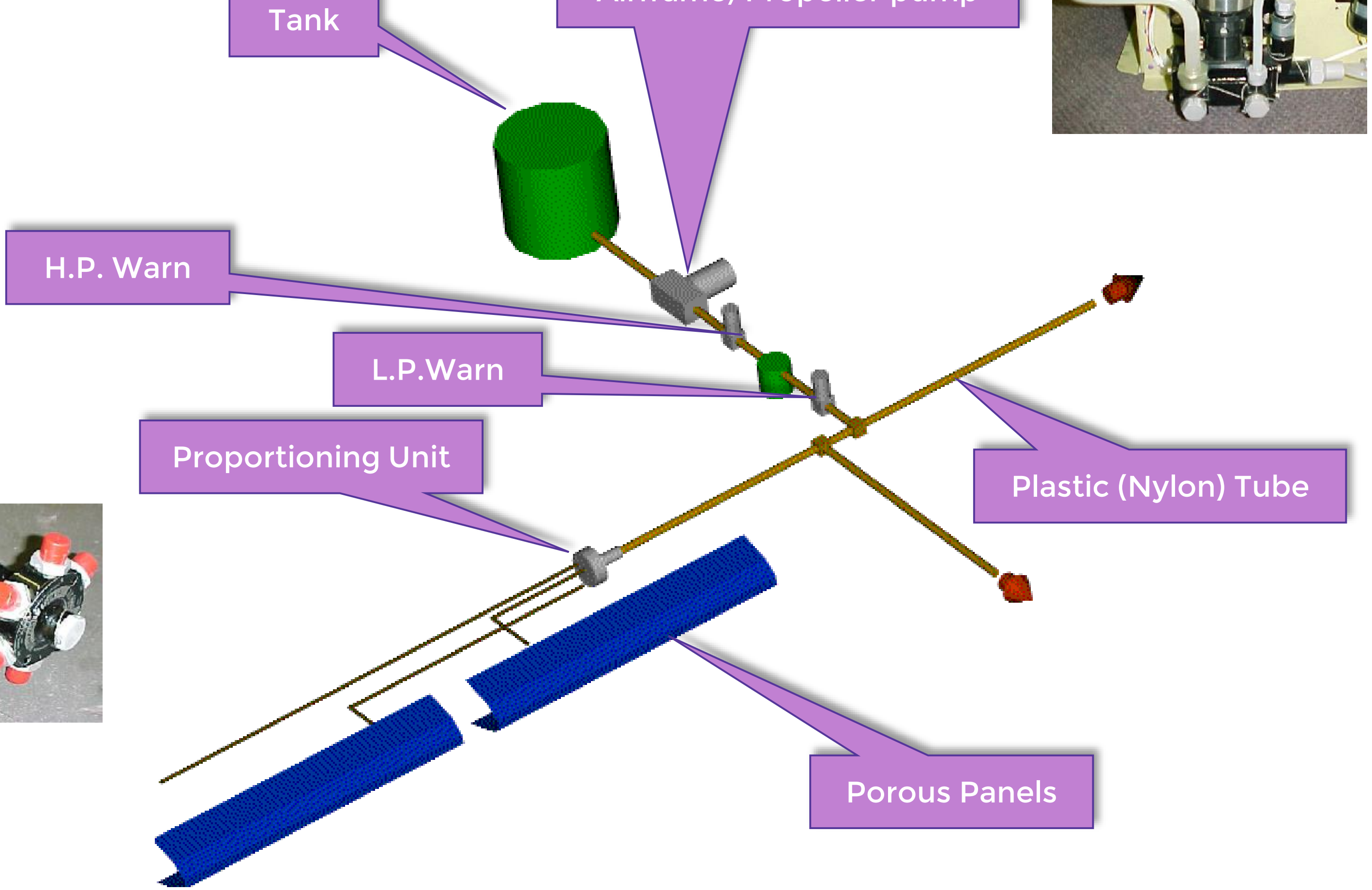
Aircraft Physical Description

- Freezing Point Depressant (FPD) System Description
- Design Overview
- Aircraft Physical Description
- Icing Envelope Analysis
- Panel Design Process
- Typical System Operation
- System Flow Balance
- Design Process Summary

FPD System Description

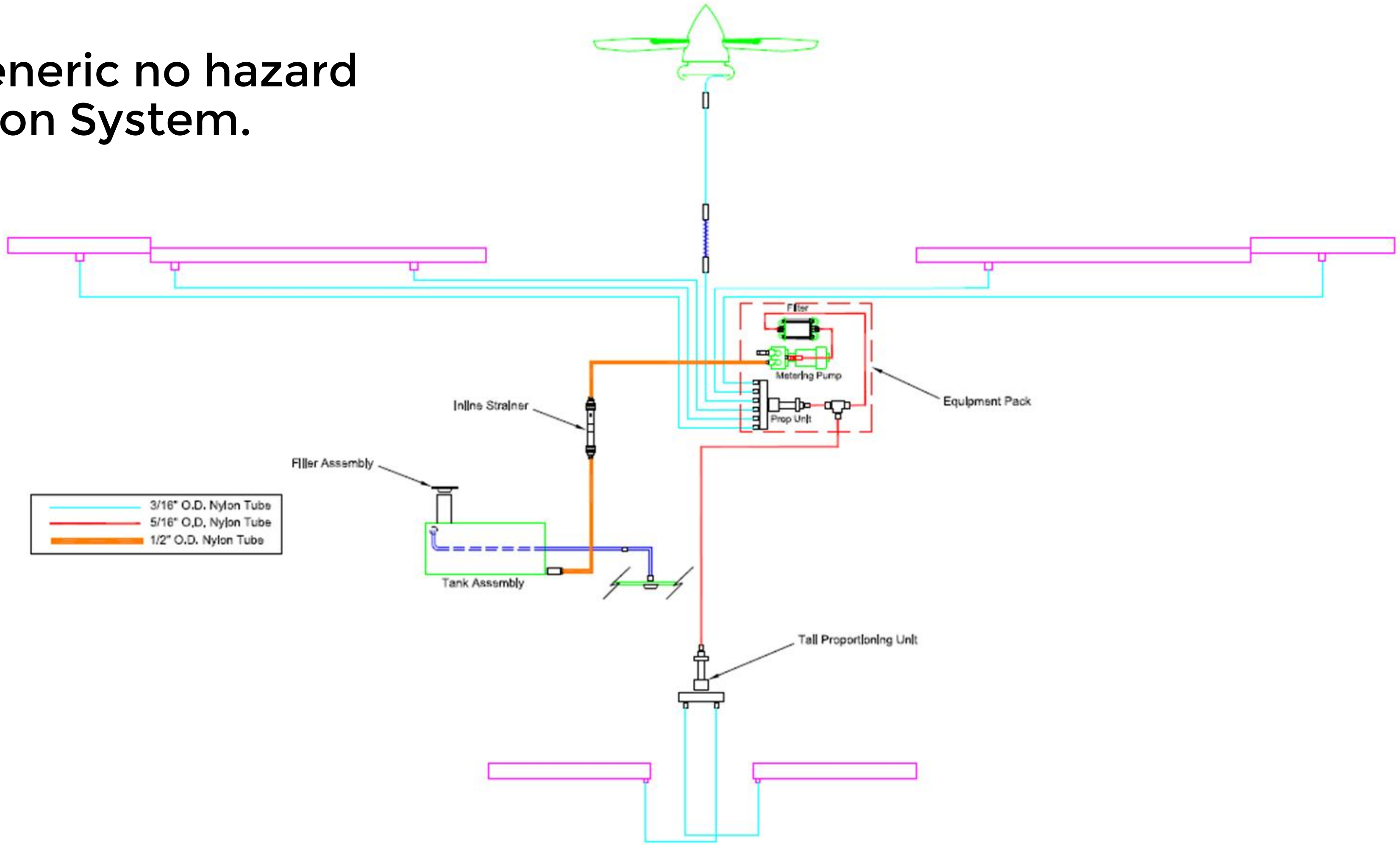
Liquid is pumped from tank to porous panels through a branching system of nylon tubing.





FPD System Description

Schematic of a generic no hazard TKS® Ice Protection System.

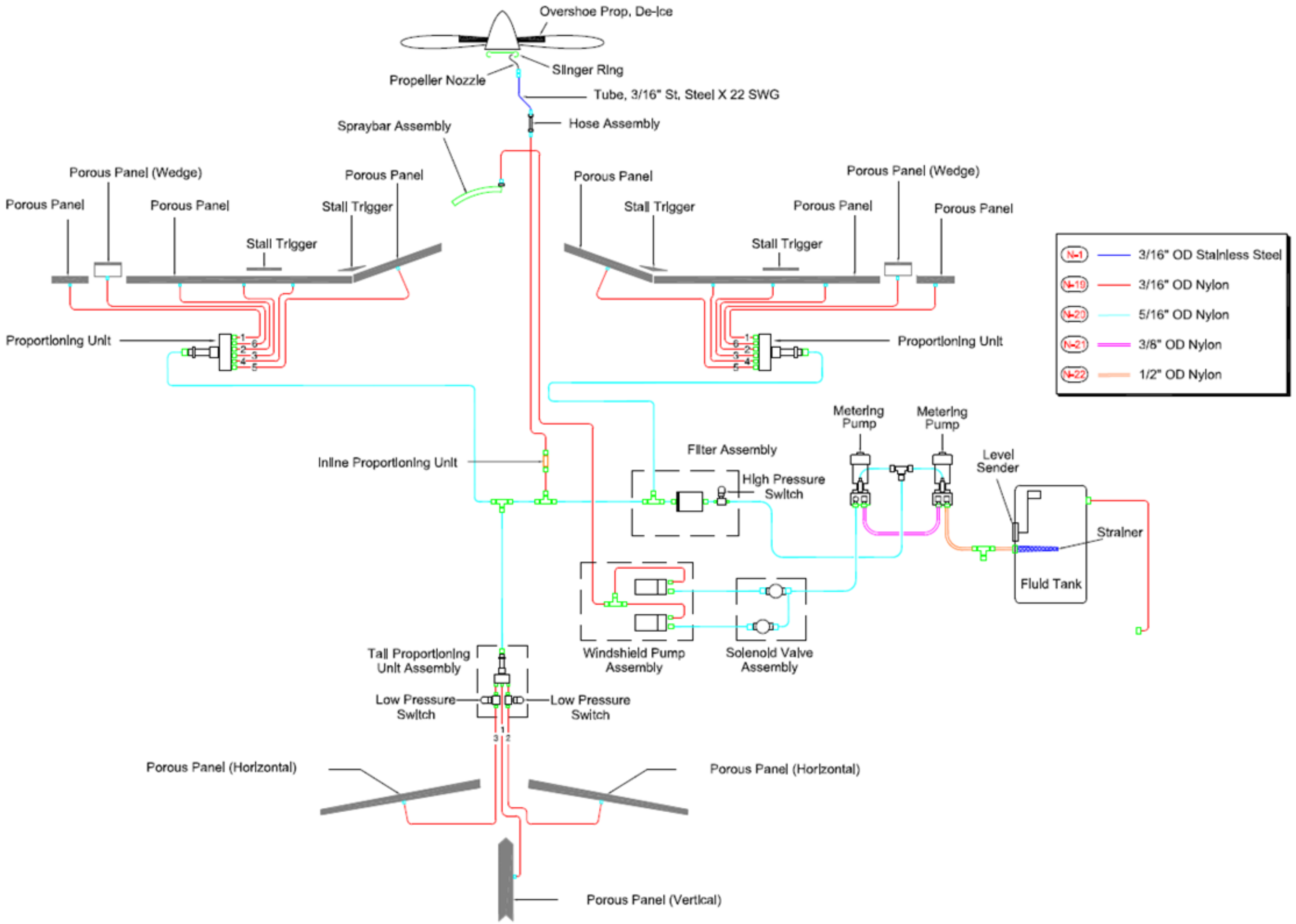


FPD System Description

Schematic of a Bonanza G36 FIKI TKS® Ice Protection System.

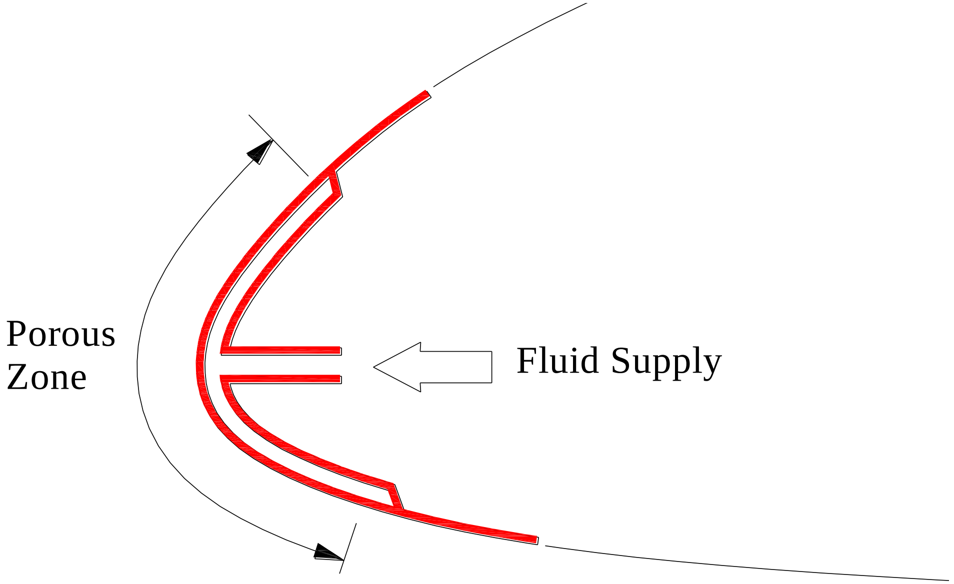
Current design practices for FIKI systems use 1/2” lines for the arterial portion and 5/16” lines from proportioning units to panels.

Some systems also contain a flow meter for monitoring purposes.



FPD System Description

Porous panels are inserted as a cuff over the leading edge of protected zones. Liquid pumped into cavity exudes through surface to provide a protective film.



FPD System Description

- Hardware components with electrical aspects have been qualified to DO-160F standards.
- FPD system can operate in anti-ice and de-ice modes.
- If liquid exuded > liquid required to maintain water catch as a liquid, system will prevent any ice formation (anti-icing).
- If liquid exuded < liquid required to maintain water catch as a liquid, ice will form and shed in a natural de-ice cycle.

3 Major Parts of the System Design Process

1. Flow Rate Determination
    - Panel Design
    - Flow Rate Determination

3 Major Parts of the System Design Process

2. System Layout
    - Determination of required components
    - Determination of placement of components in aircraft
    - Tube Routing
    - Tank sizing (based on flow rate and desired endurance)
    - System operation and monitoring design

3 Major Parts of the System Design Process

3. Flow Balance

- Determines proportioning unit sizing to properly balance flow based on system layout and panel design requirements.
- Provides analytical evaluation of the performance of the system throughout the icing envelope.

Aircraft Physical Description

- **Descriptions needed prior to panel design:**
  - Define surfaces to be protected
  - Define number of panels on each surface
  - Determine number of inlets per panel
- **Descriptions needed prior to proportioning unit sizing:**
  - Locations of equipment (pump(s), filter(s), pressure switches, proportioning units(s), etc.
  - Definition of tube routings, lengths and sizes

Icing Envelop Analysis

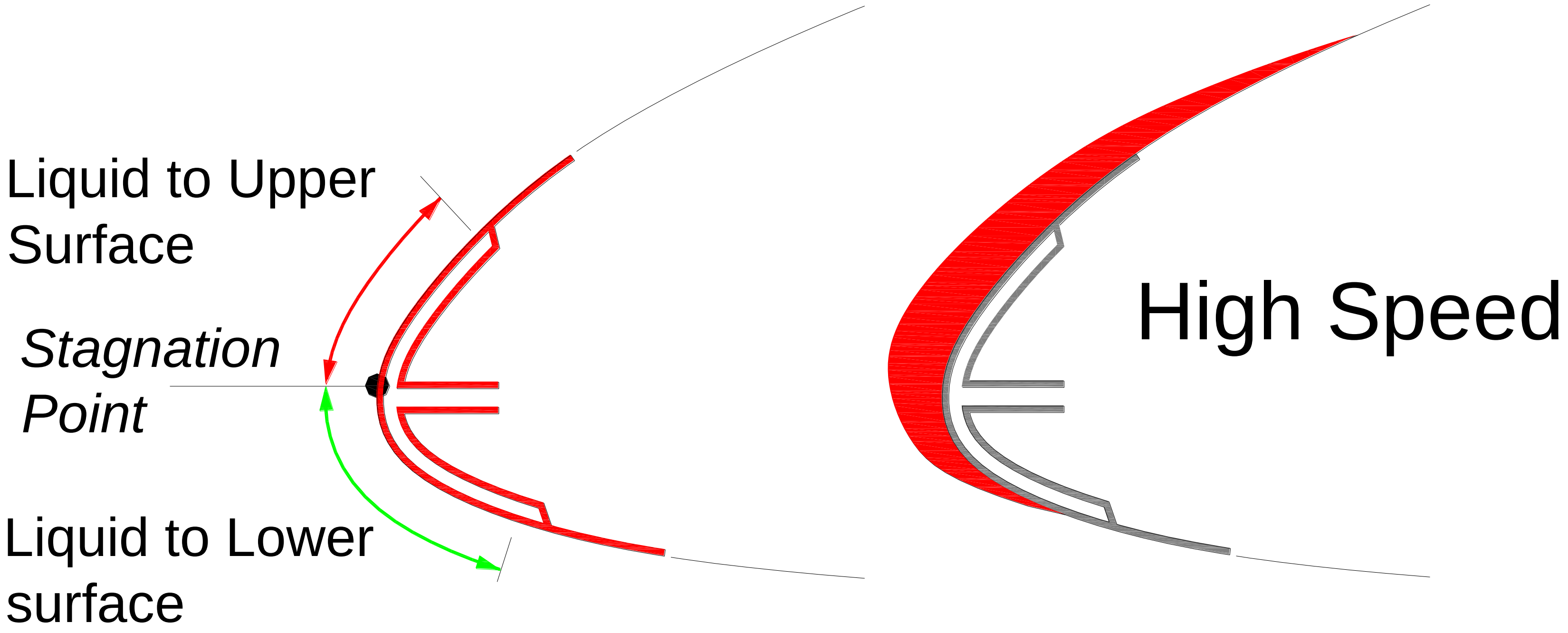
Icing envelop analysis determines the design points for the TKS® Ice Protection System, which depend upon:

- Performance properties of the aircraft
- Characteristics of the Continuous Maximum icing envelope

Design points are used to define the parameters for the impingement analysis.

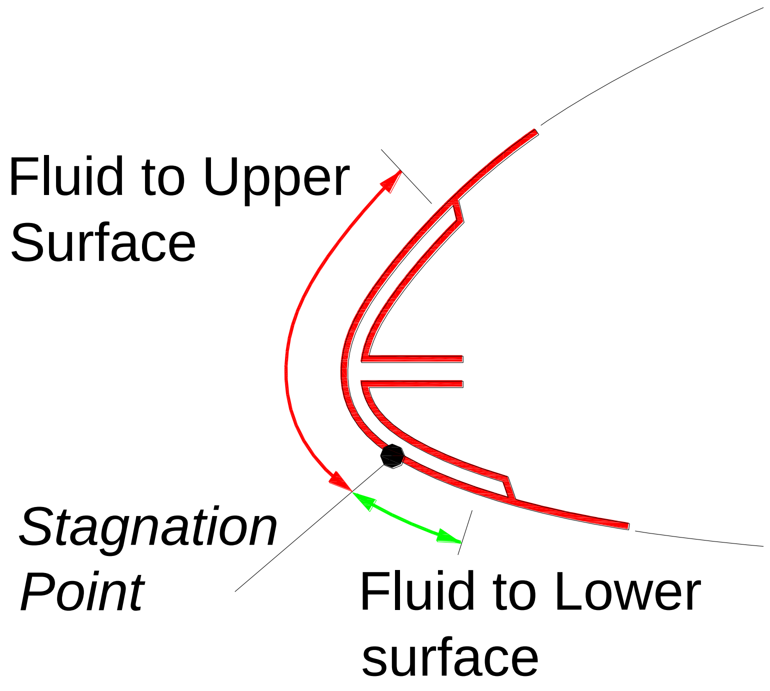
Icing Envelop Analysis: Aircraft Performance

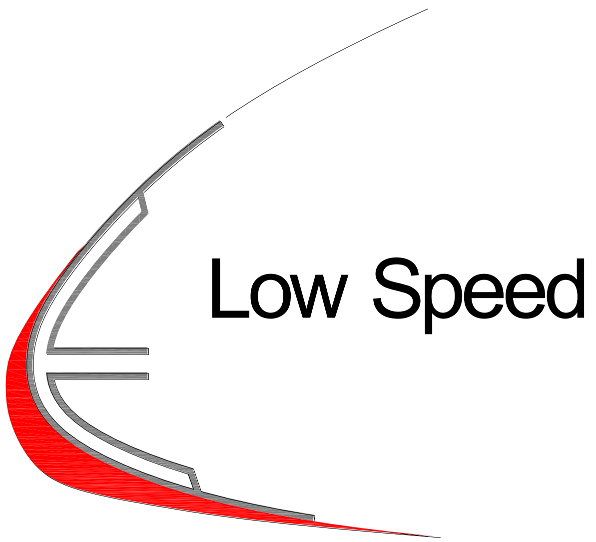
Airfoil aerodynamics have a particular effect with FPD systems due to the influence of the stagnation point location on liquid dispersion.



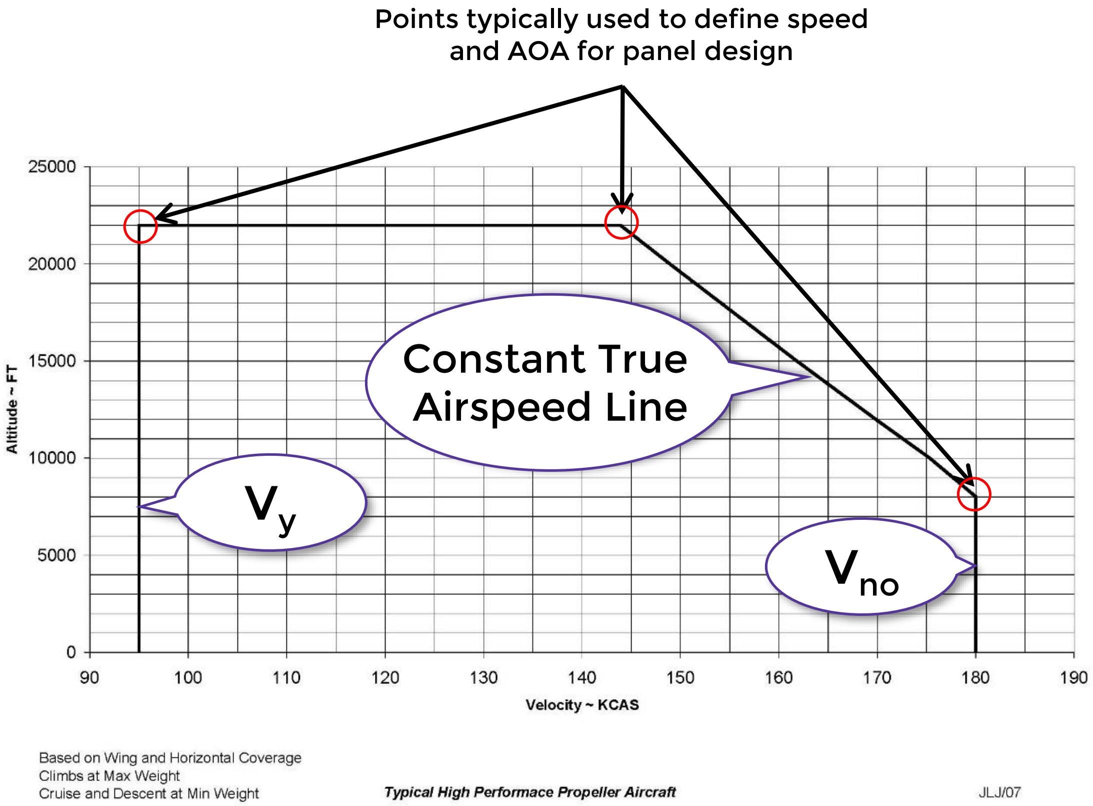
Icing Envelop Analysis: Aircraft Performance

At lower speeds, ice formation shifts downwards, but less fluid is available for the lower surface. However, since water catch rate is lower due to reduced velocity, this may or may not force design for lower active area extents.





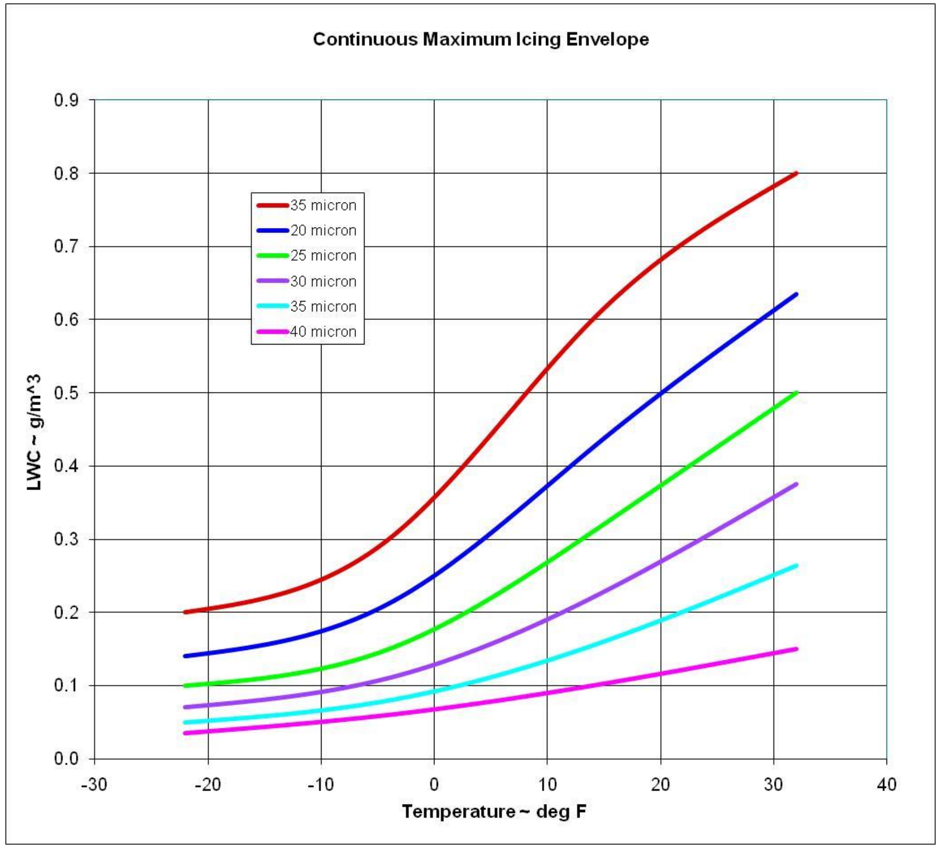
Icing Envelop Analysis: Aircraft Performance



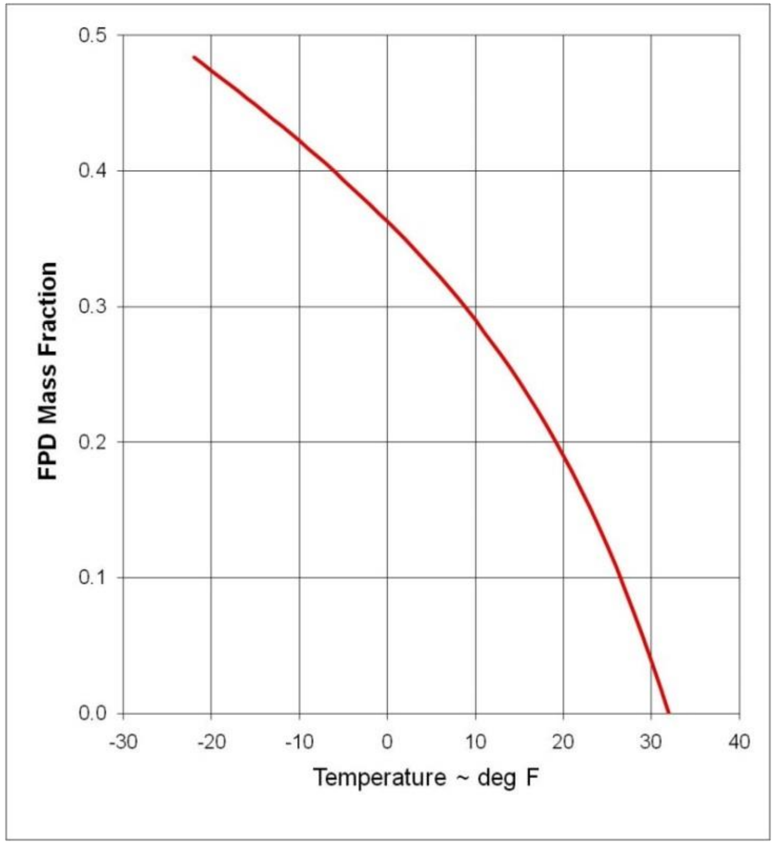
Typical High Performance Propeller Aircraft

Performance of installed system on the
aircraft will directly depend upon quality
of data provided that defines the
performance envelope presented.

Icing Envelope Analysis: Fluid & Meteorological Influence



Continuous Maximum Icing Envelope



Fluid Mass Fraction Characteristics (Aircraft Icing Handbook and ADS-4)

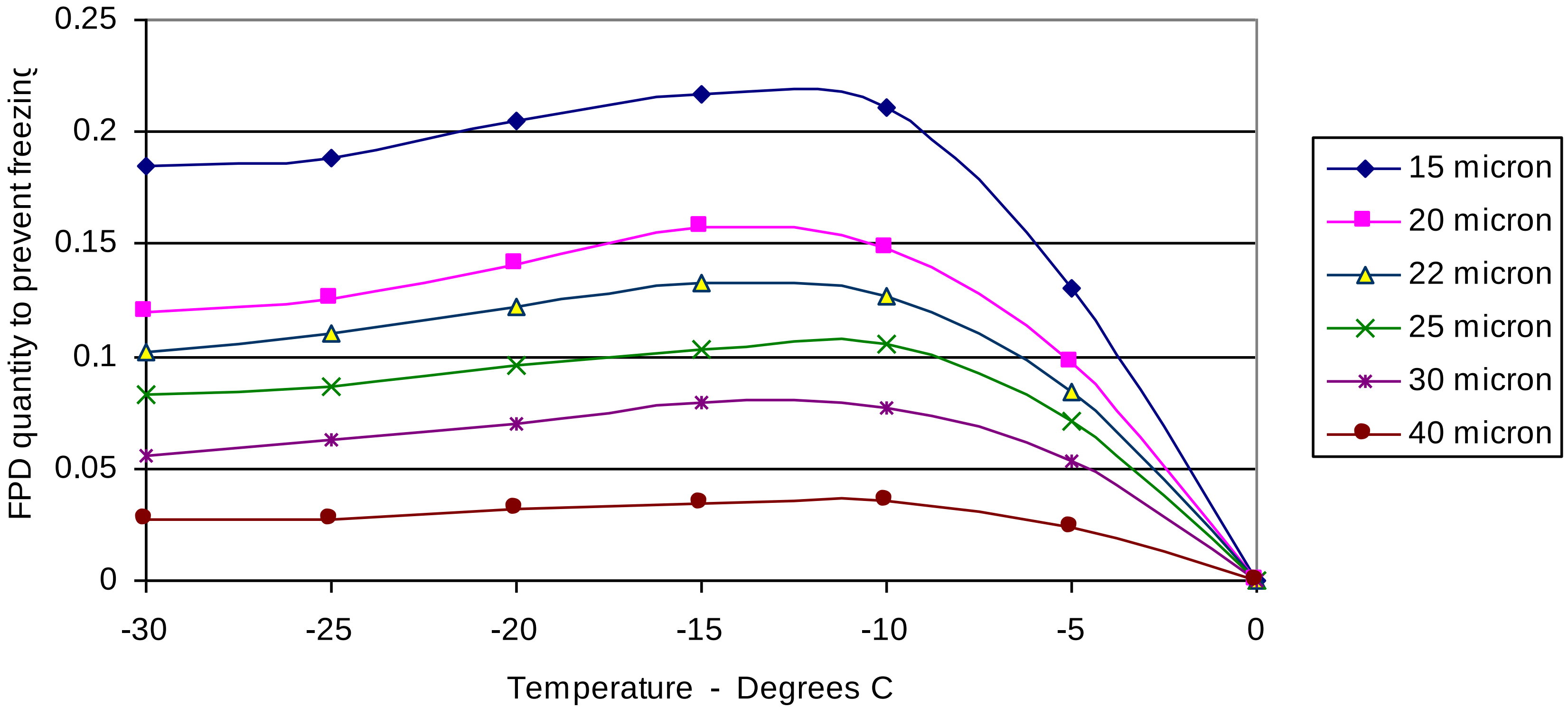
$$V_F = \frac{V_W x FPD}{(1 - FPD)}$$

Where: V_F = volume of fluid, V_W = volume of water, FPD = mass fraction value

Icing Envelop Analysis: Fluid & Meteorological Influence

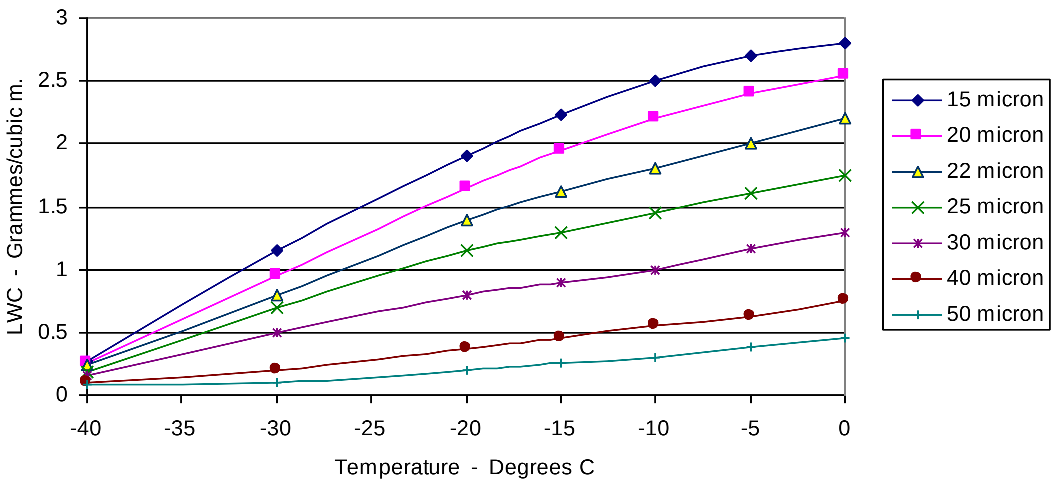
Combining the two previous figures with the given equation yields the required fluid for the icing envelope.

FPD liquid required to prevent freezing (Unity catch efficiency)



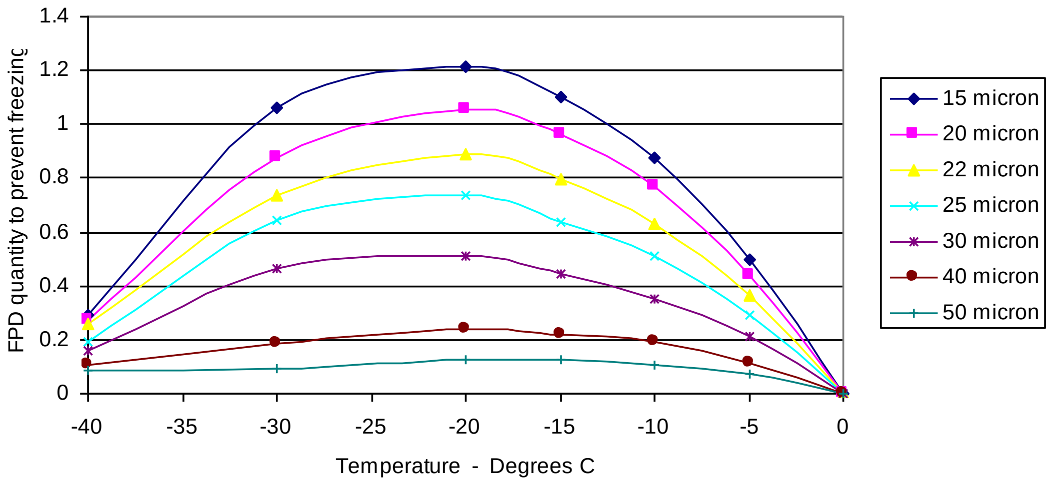
Icing Envelop Analysis: Fluid & Meteorological Influence

Temperature / LWC



FAR 1419 Appendix C
Cloud Definition

Intermittent Maximum Cloud



FPD liquid required to prevent
freezing (unity catch efficiency)

Panel Design Process

LEWICE

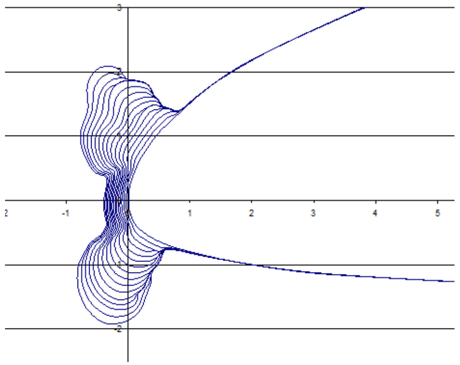
Inputs

Chord Length
Velocity (TAS)
Altitude
Droplet Diameter

Aerodynamic Profile
C_L or AOA

Outputs

Aerodynamic Profile
Stagnation Point Location
Beta (local catch efficiency)



N.B Inputs indicated in italics for Lewice and FPD must be the same

FPD ANALYSIS TOOL

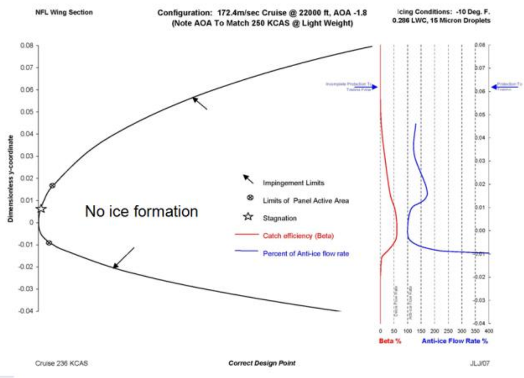
Inputs

Chord Length
Velocity (TAS)
Altitude
Droplet Diameter

Temperature
LWC
FPD Liquid Characteristics (G)
Liquid Flow Rate (per unit area)
Limits of Porous Zone

Outputs

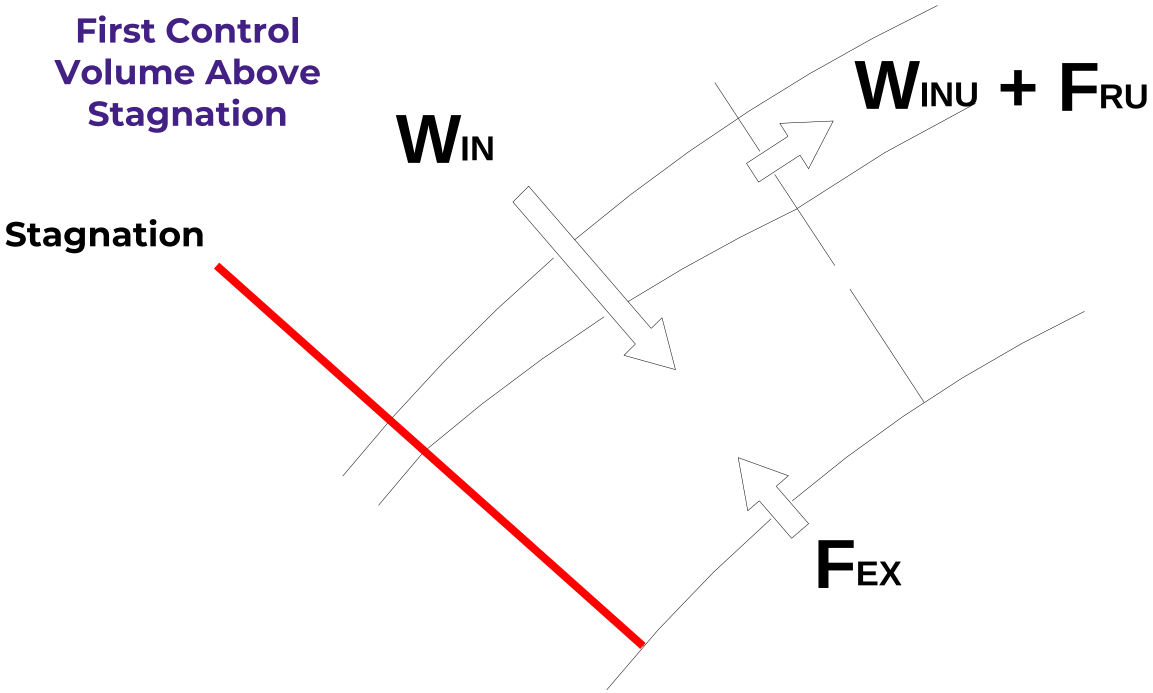
Anti-icing performance indicators
Liquid usage (per m span)
Porous panel mass (per m span)



Analysis currently performed using LEWICE 3.2. Performed at the determined design meteorological and aircraft conditions. Analysis performed at the defined tip and root location of each panel.

Panel Design Process

Results from LEWICE impingement analysis are used to determine water catch and fluid requirement in FPD analysis tool.



W_{IN} Liquid Water Catch entering zone

F_{EX} FPD liquid exuded from surface into zone

F_R FDP liquid required to maintain W_{IN} liquid

F_{TIN} Excess fluid transferred downstream

W_{INU} Liquid Water Catch from upstream zones

F_{RU} FPD liquid required to maintain W_{INU} liquid.

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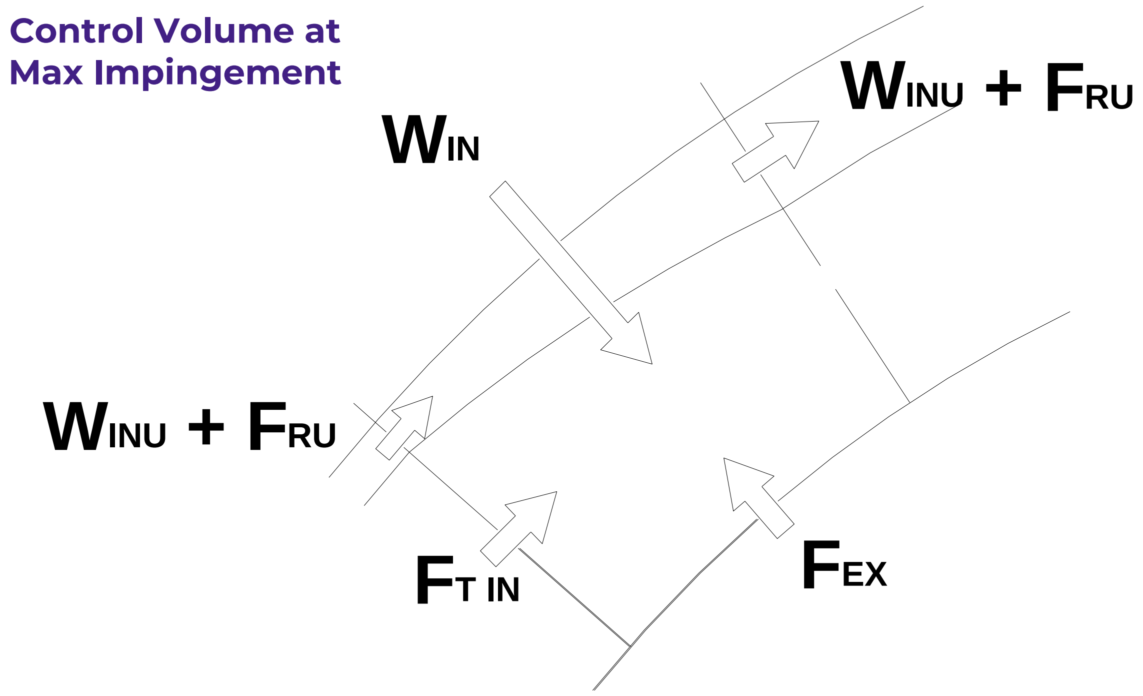

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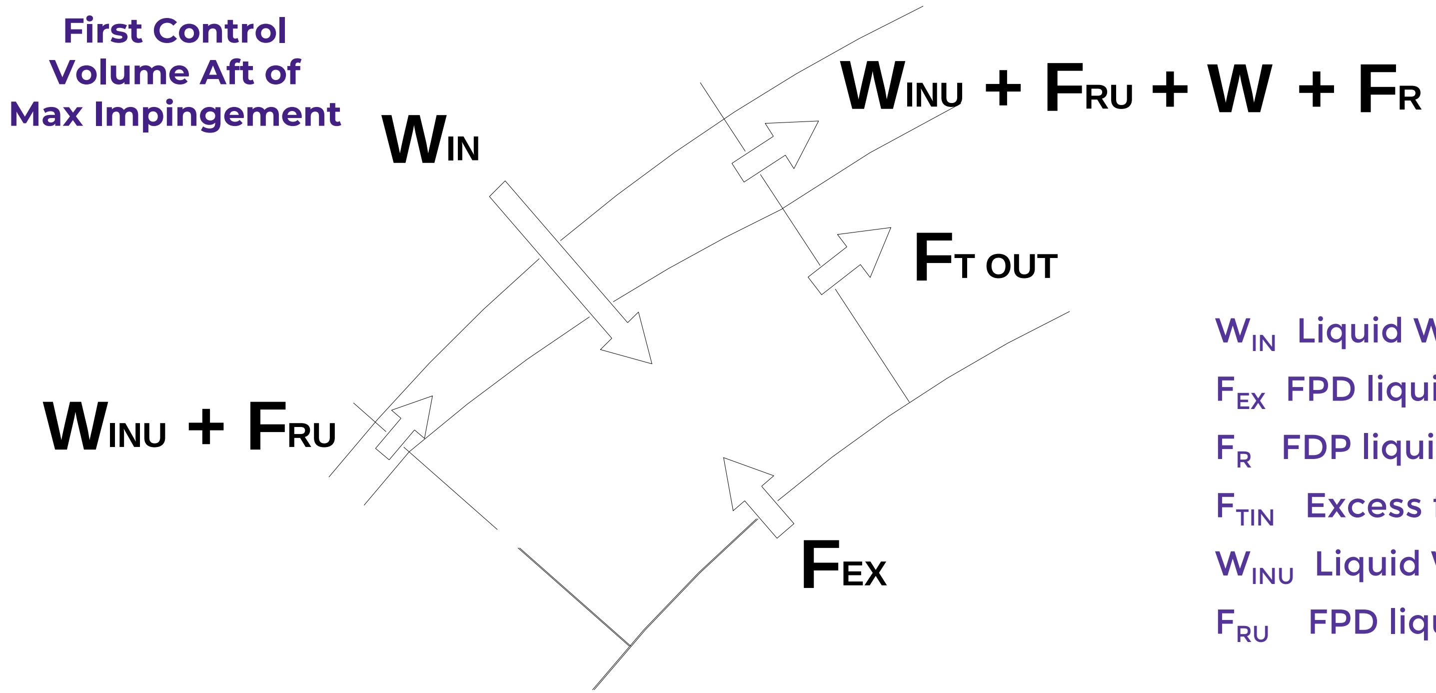

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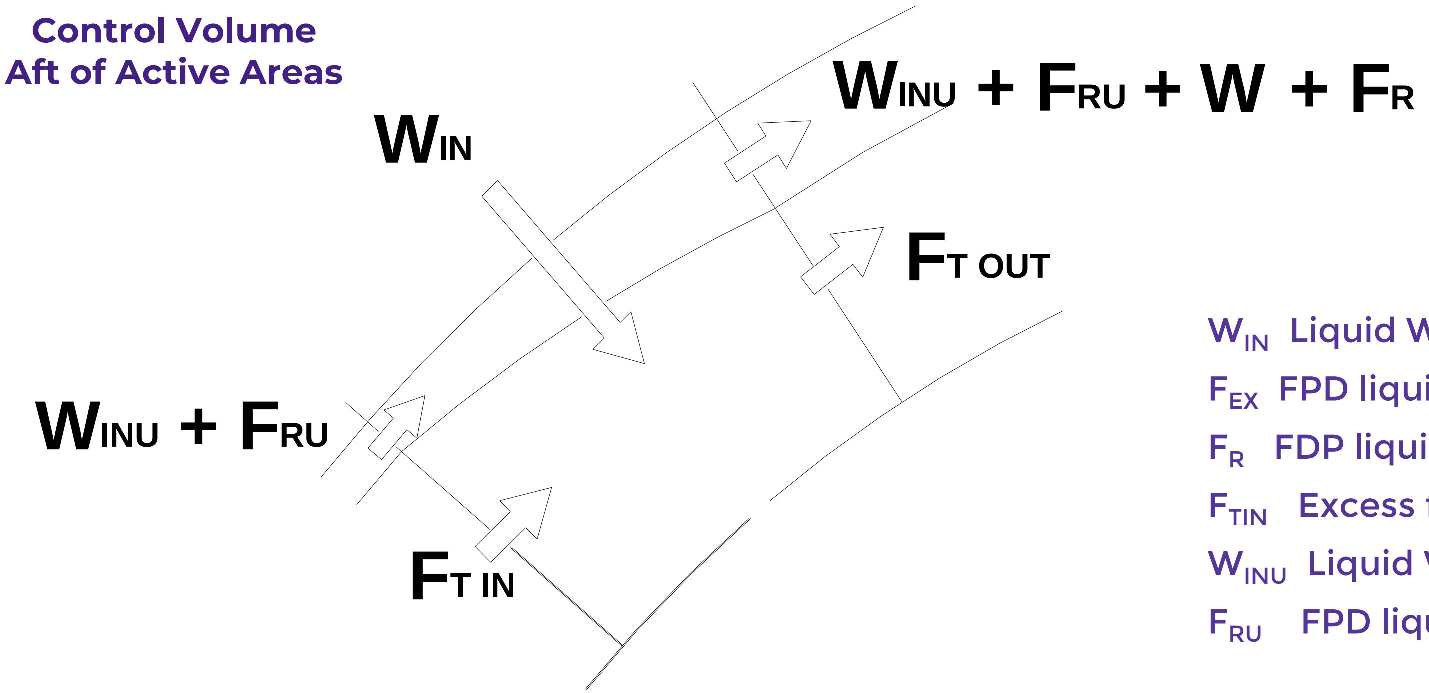

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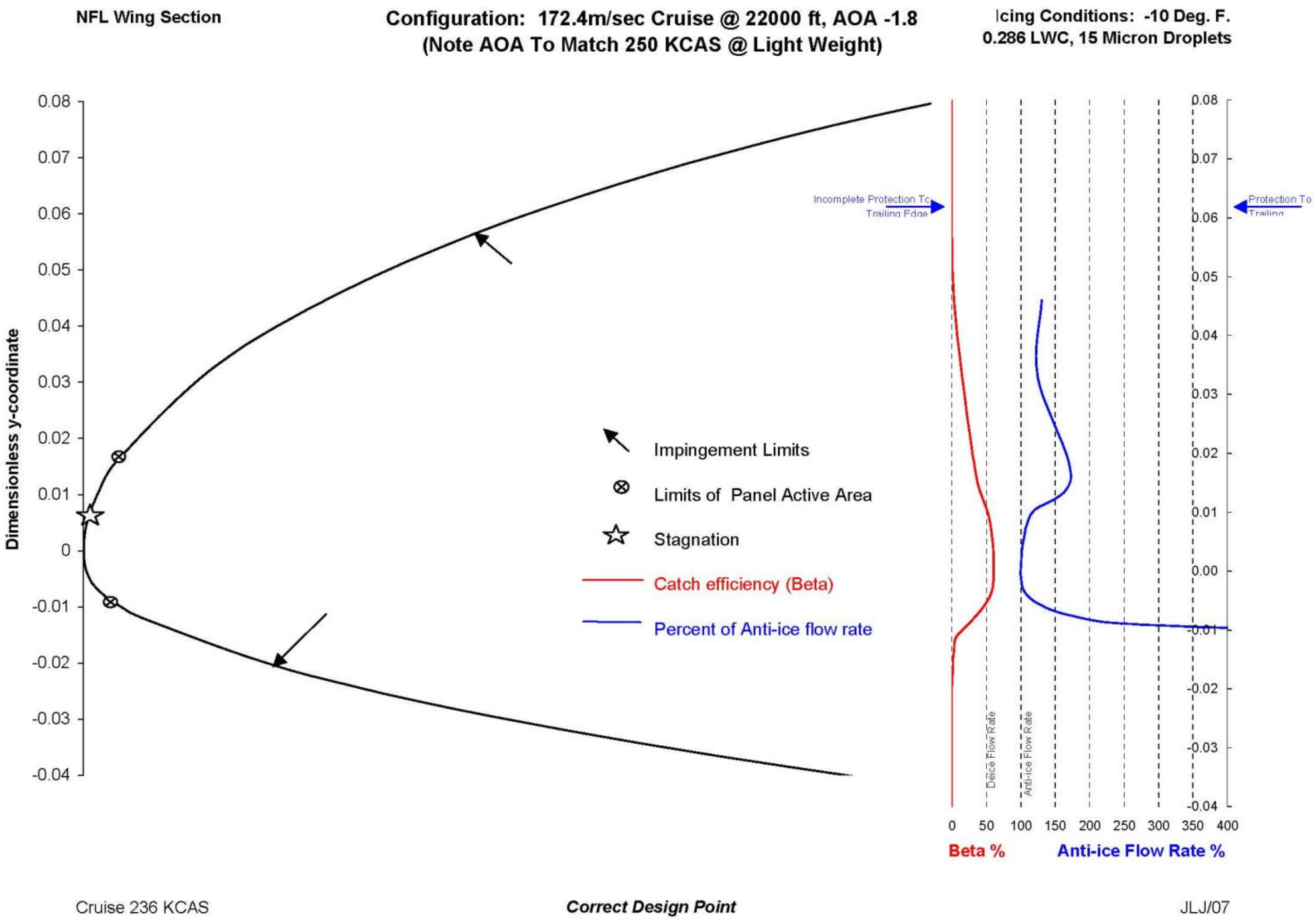
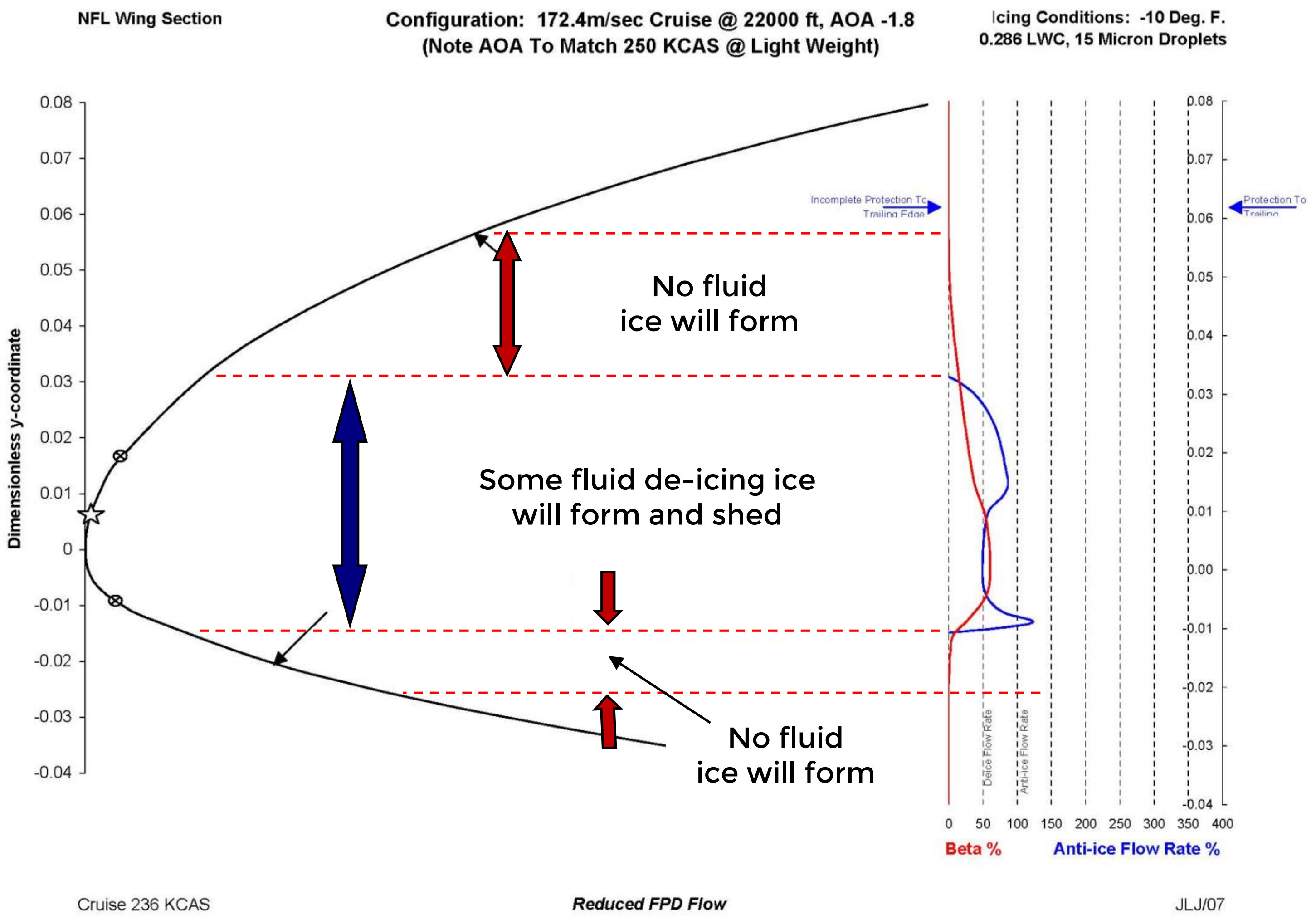
Panel Design Process

Flow and active zone optimised at design point.



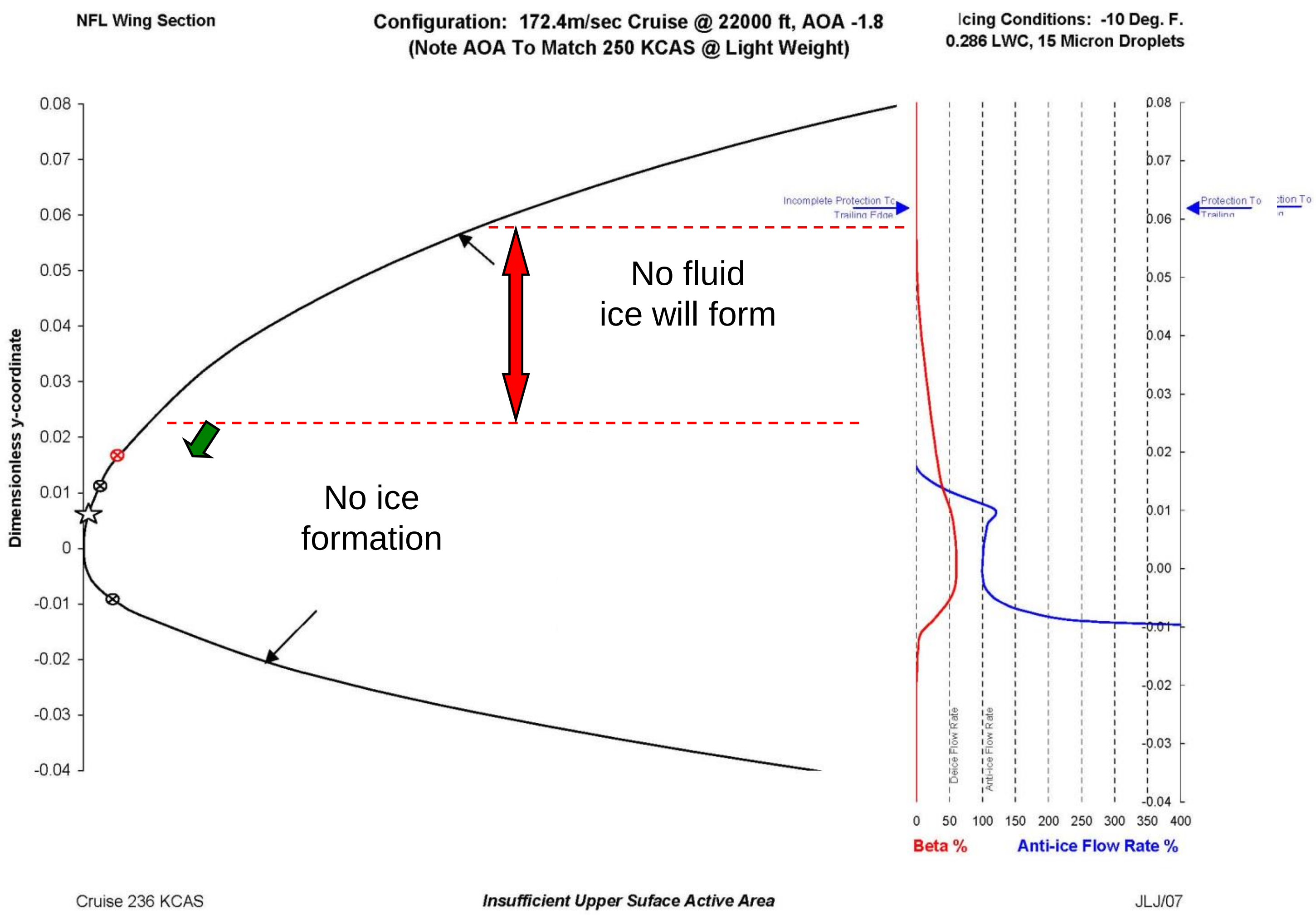
Panel Design Process

Effect of reducing flow.



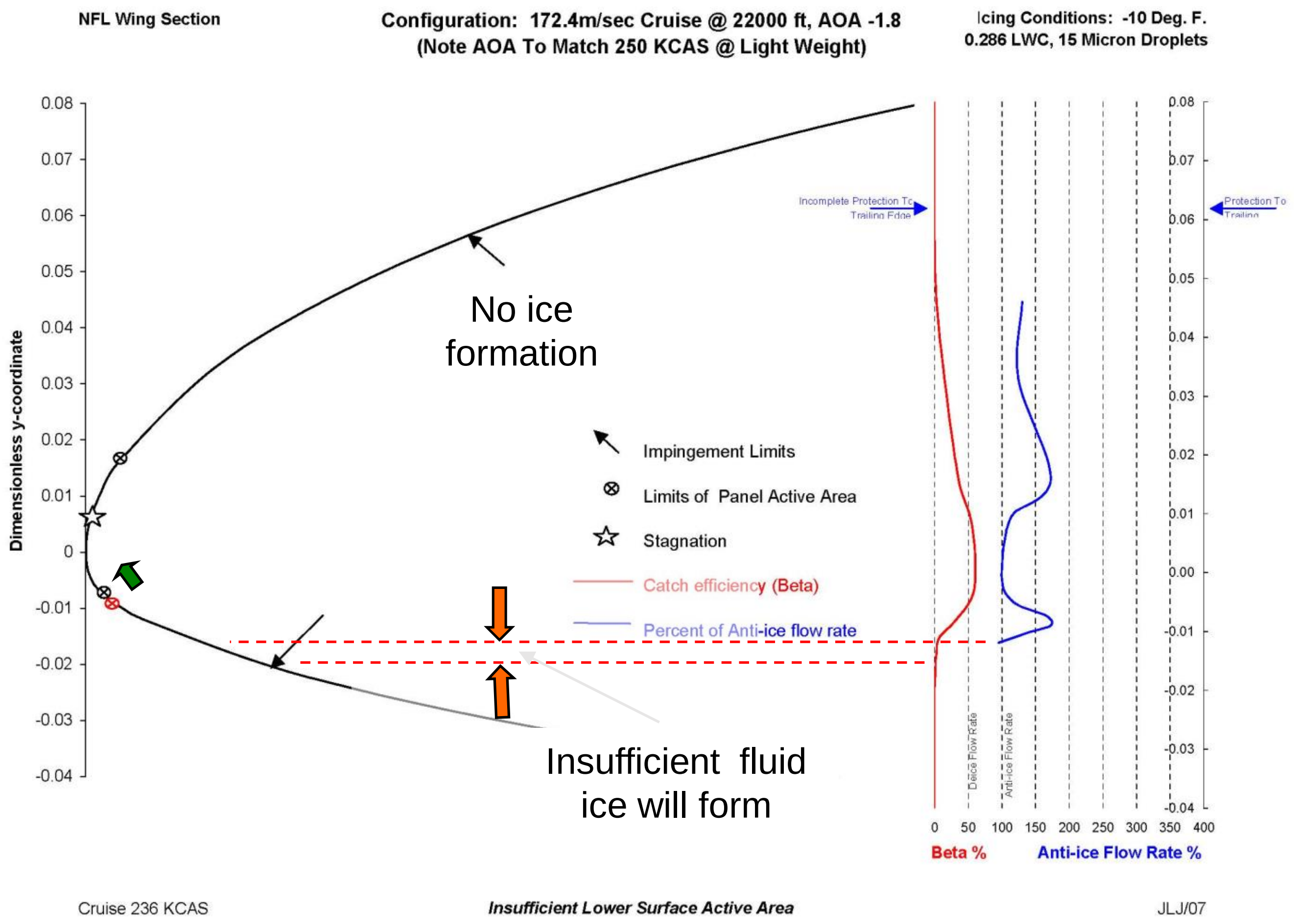
Panel Design Process

Effect of lowering upper limit of active zone.



Panel Design Process

Effect of raising lower limit of active zone.



Aircraft Physical Description

Porous panels capable of producing flow at one specific flow rate.

- Tip of panel critical due to smaller radius providing higher catch efficiency.
- Cruise critical due to higher airspeed and therefore higher water catch.

Panels are sized chord-wise at the root and tip sections.

- Cruise condition used for upper surface due to lower AOA
- Climb condition typically used for lower surface due to higher AOA

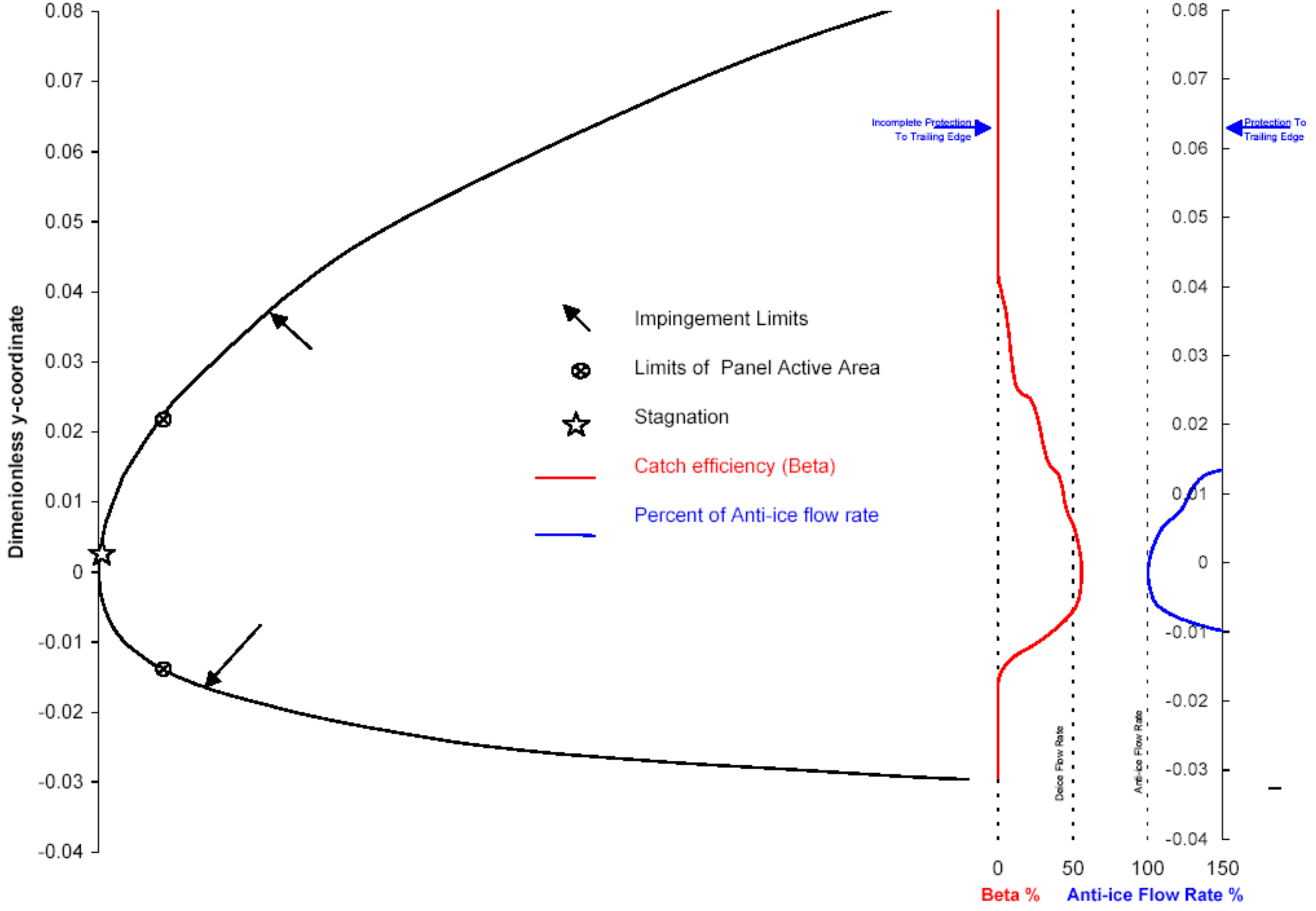
Local angles of attack typically determined by flight test or CFD data.

Panel Design Process

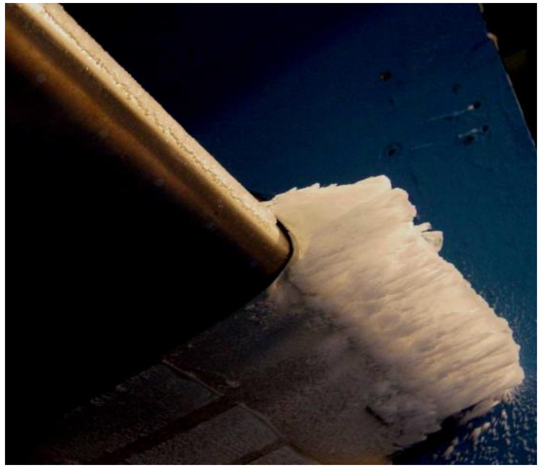
Analysis for Design Condition

Icing Wind Tunnel test typically used to verify panel design.

Same panel design tool used for icing wind tunnel predictive analysis which verifies tool.

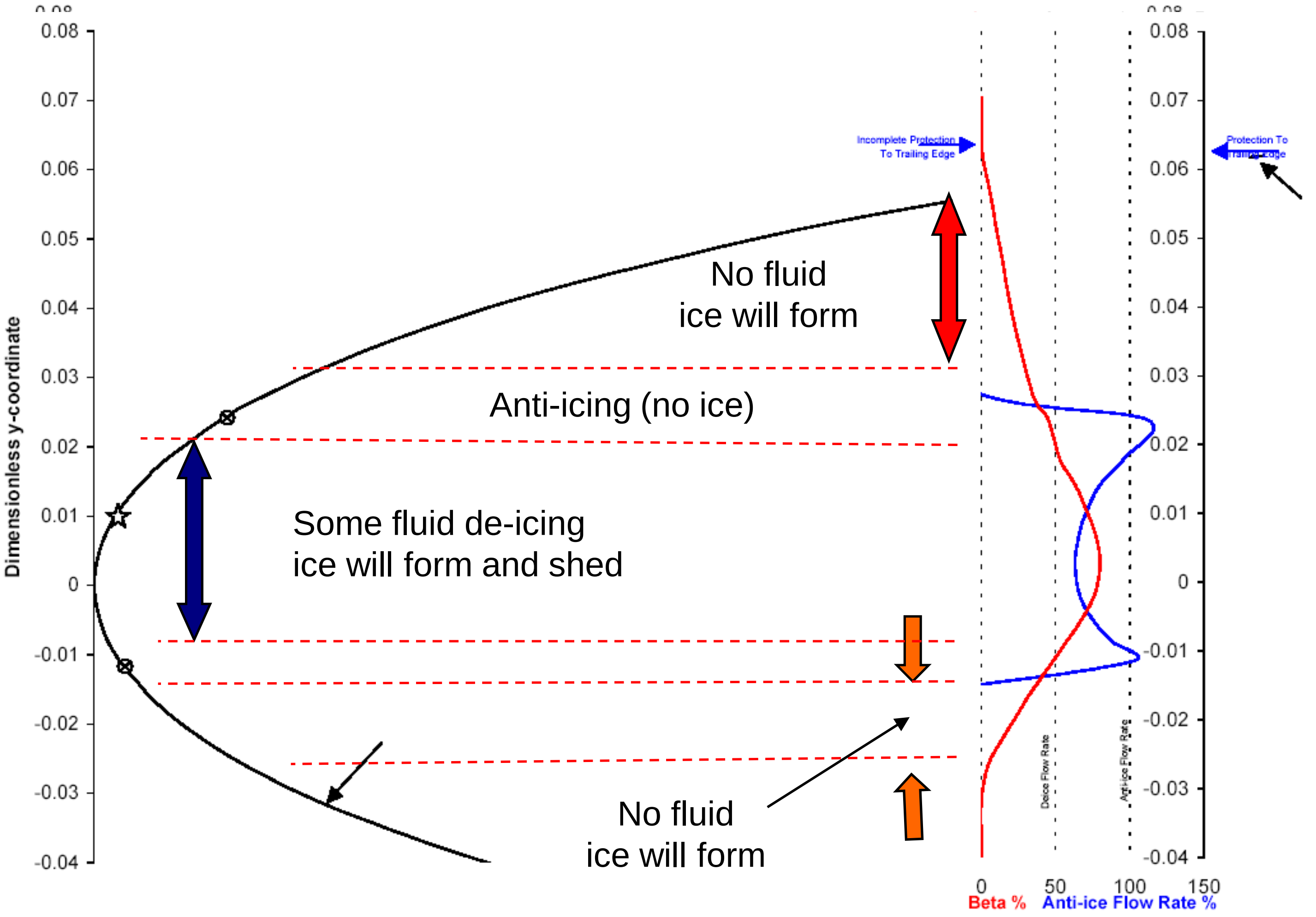


Panel Design Process



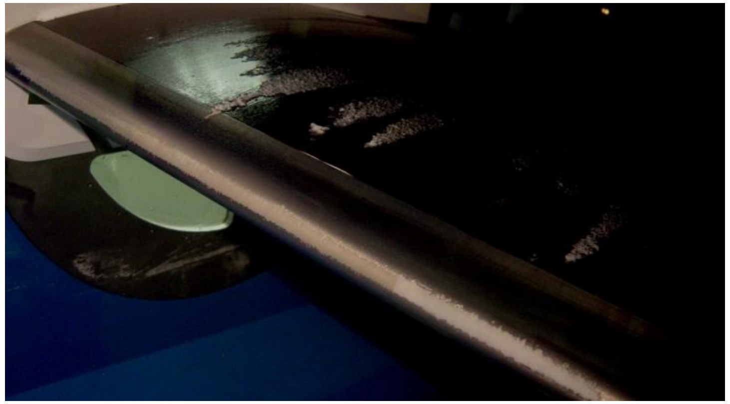
Panel Design Process

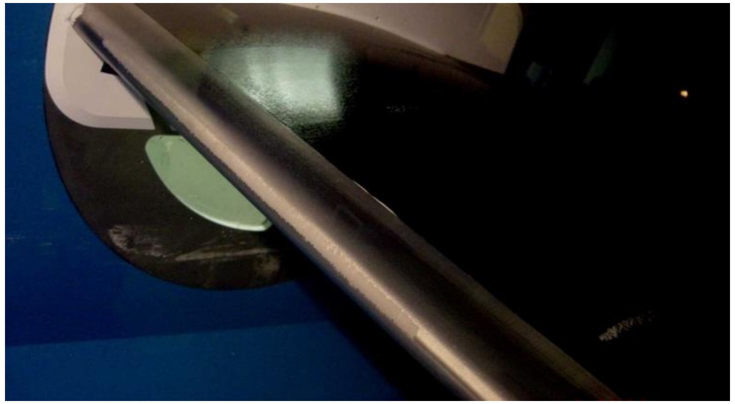
Analysis can also predict performance in environments beyond the design condition where system functions in de-ice mode.



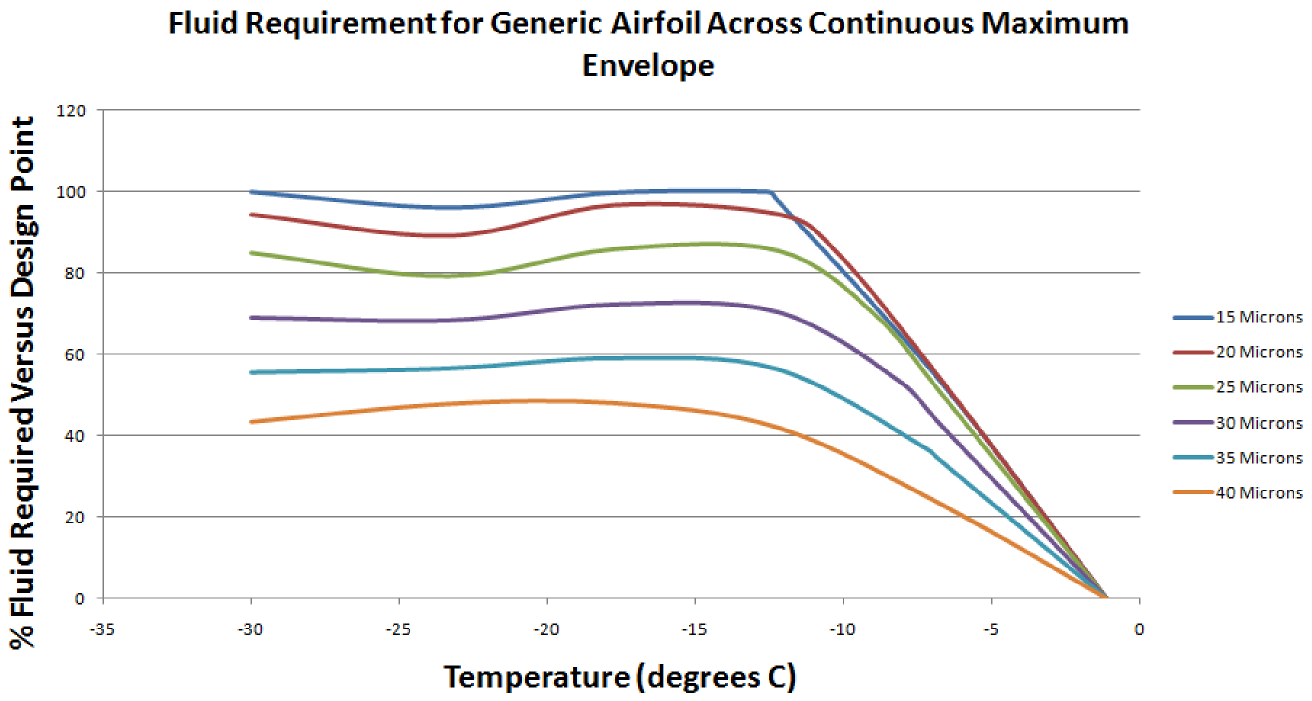
Panel Design Process

System will clear ice once encounter is over.





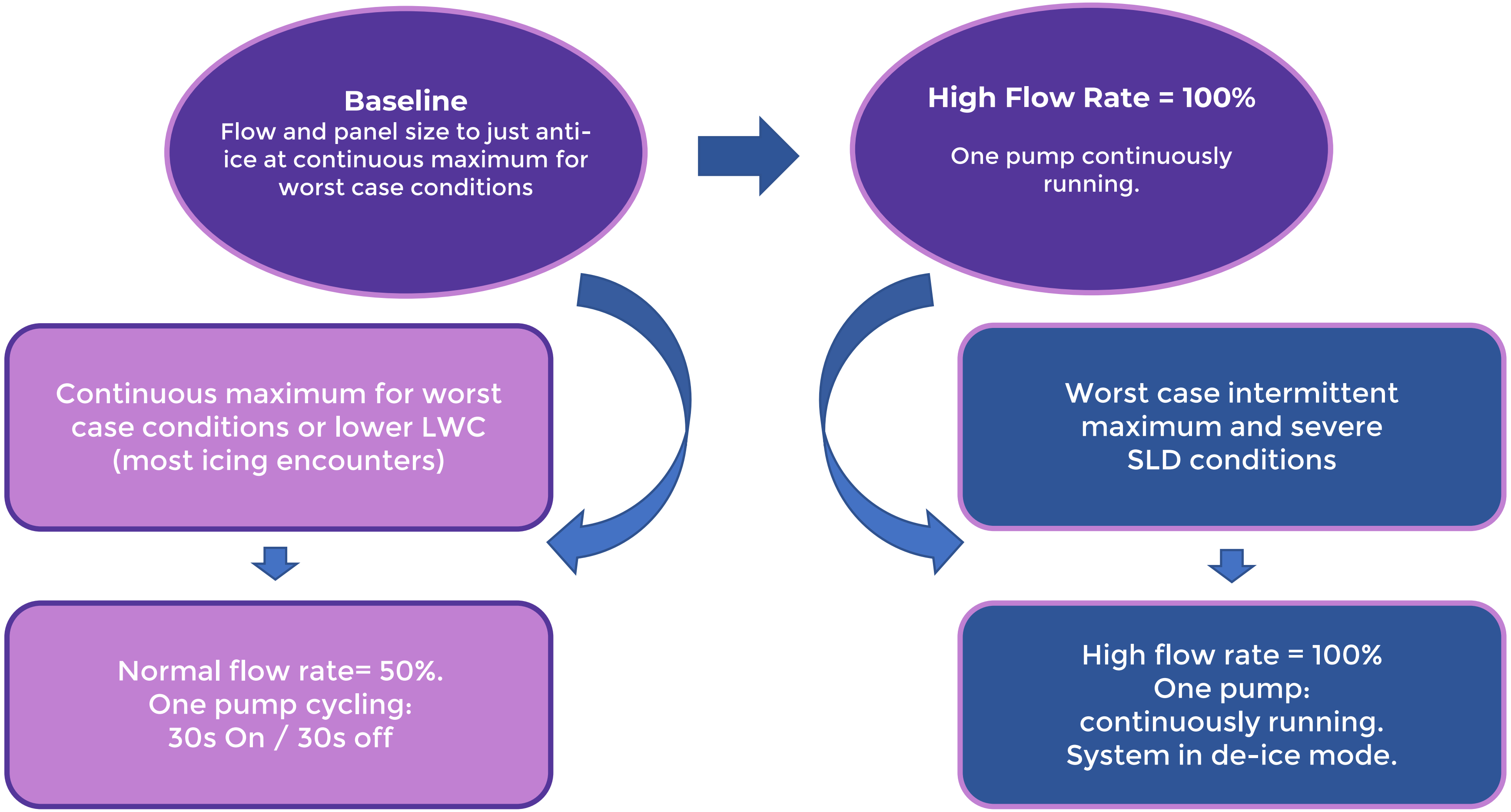
Panel Design Process



Panel designed to provide anti-ice performance across the Continuous Maximum envelope and de-ice performance across the Intermittent Maximum envelope.

Actual airfoil does not have unity catch efficiency. Study shows critical point in icing envelope for unity catch efficiency is still critical for an airfoil.

Typical No-Hazard System Operation



Typical FIKI System Operation

Baseline
Flow and panel size to just anti-ice at continuous maximum for worst case conditions

High Flow Rate = 100%

One pump continuously running.

Continuous maximum away from worst case conditions or lower LWC (most icing encounters)

Normal flow rate= 50%.
Two pumps cycling:
30s On / 90s off

Worst case intermittent maximum and severe SLD conditions

Max flow rate = 200%
Two pumps: continuously running a two min cycle.
System in de-ice mode.

FIKI contains a backup mode of operation, which is equivalent to high mode with one pump continuously running. The pump is controlled by an independent power source and switch.

System Flow Balance

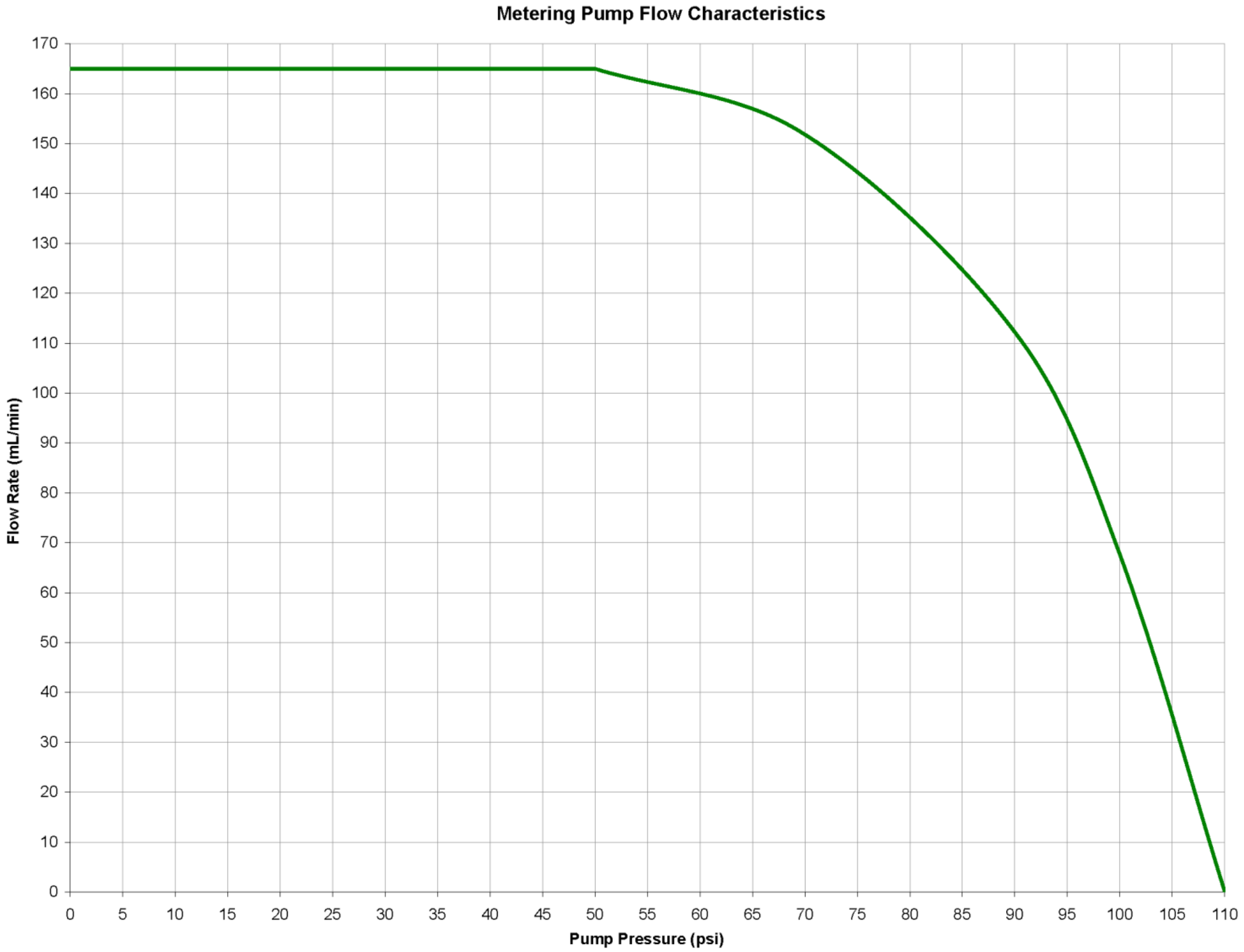
System is balanced by introduction of proportioning unit(s) which provide a defined pressure drop to direct flow appropriately.

Proportioning unit sizing is dependent upon flow rate, line lengths and line sizes.

Upon sizing of proportioning unit, analysis can be performed to estimate system performance (pressures and flow rates) across the entire icing envelope.

System Flow Balance

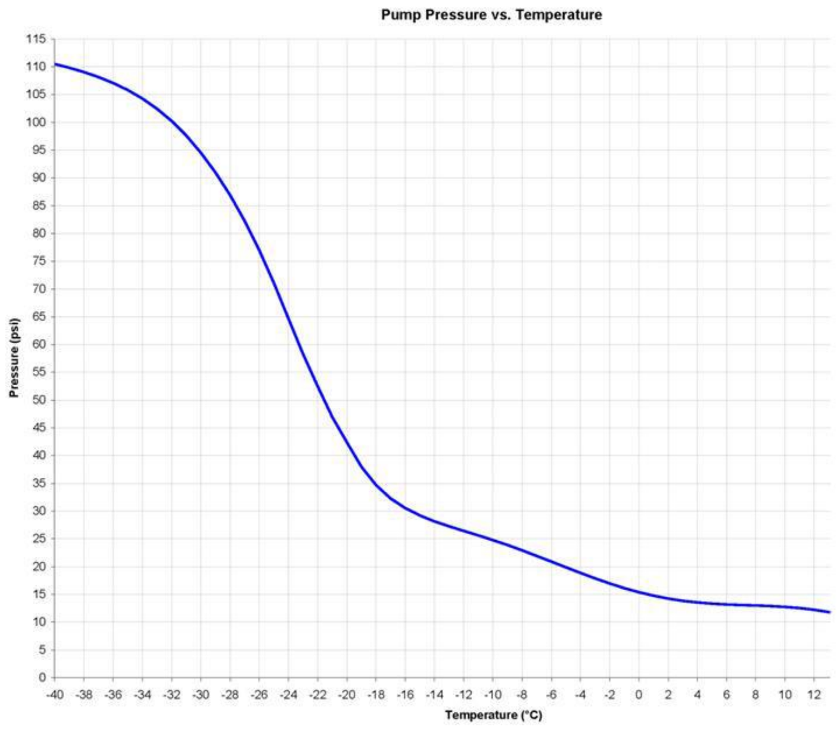
Pump flow rate is a function of pressure

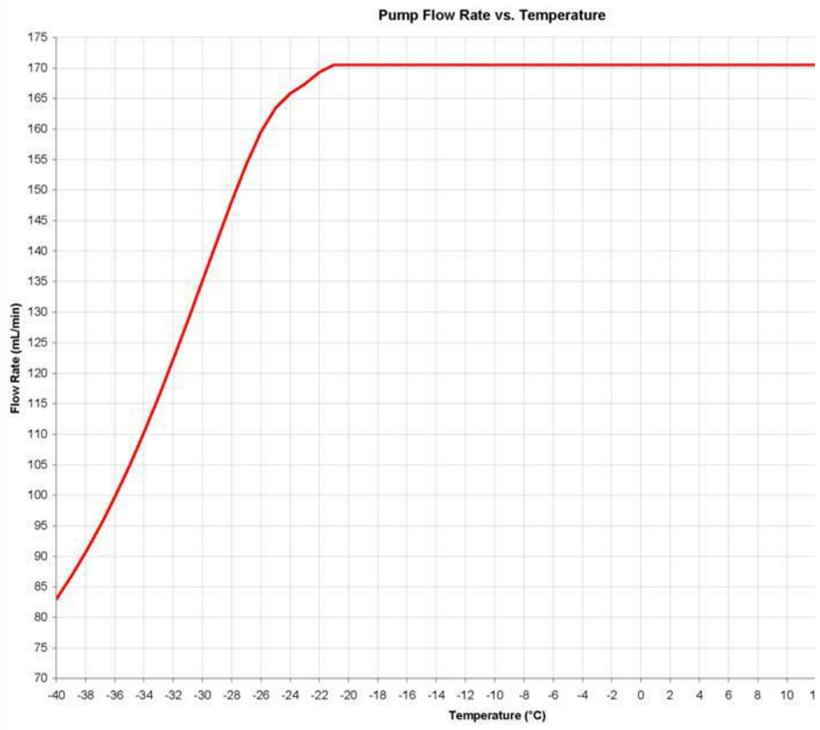


System Flow Balance

Pump pressure changes with temperature

· Caused by change in viscosity · Influenced by line sizes · Influenced by number of filters





Design Process Summary

Aircraft physical description and aerodynamic data is defined.

Using obtained information, panels are designed, components are chosen and the system is laid out.

Using the system layout and panel design, a flow balance is performed to define proportioning unit requirements.

During the process, various tests and analysis are performed to ensure the system meets regulations for certification.

Thank You

To find out more about partnering with CAV™ for your aircraft's TKS® ice protection system, please get in touch at the details below:

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