

OVERVIEW OF CERTIFYING A FREEZING POINT DEPRESSANT ICE PROTECTION SYSTEM

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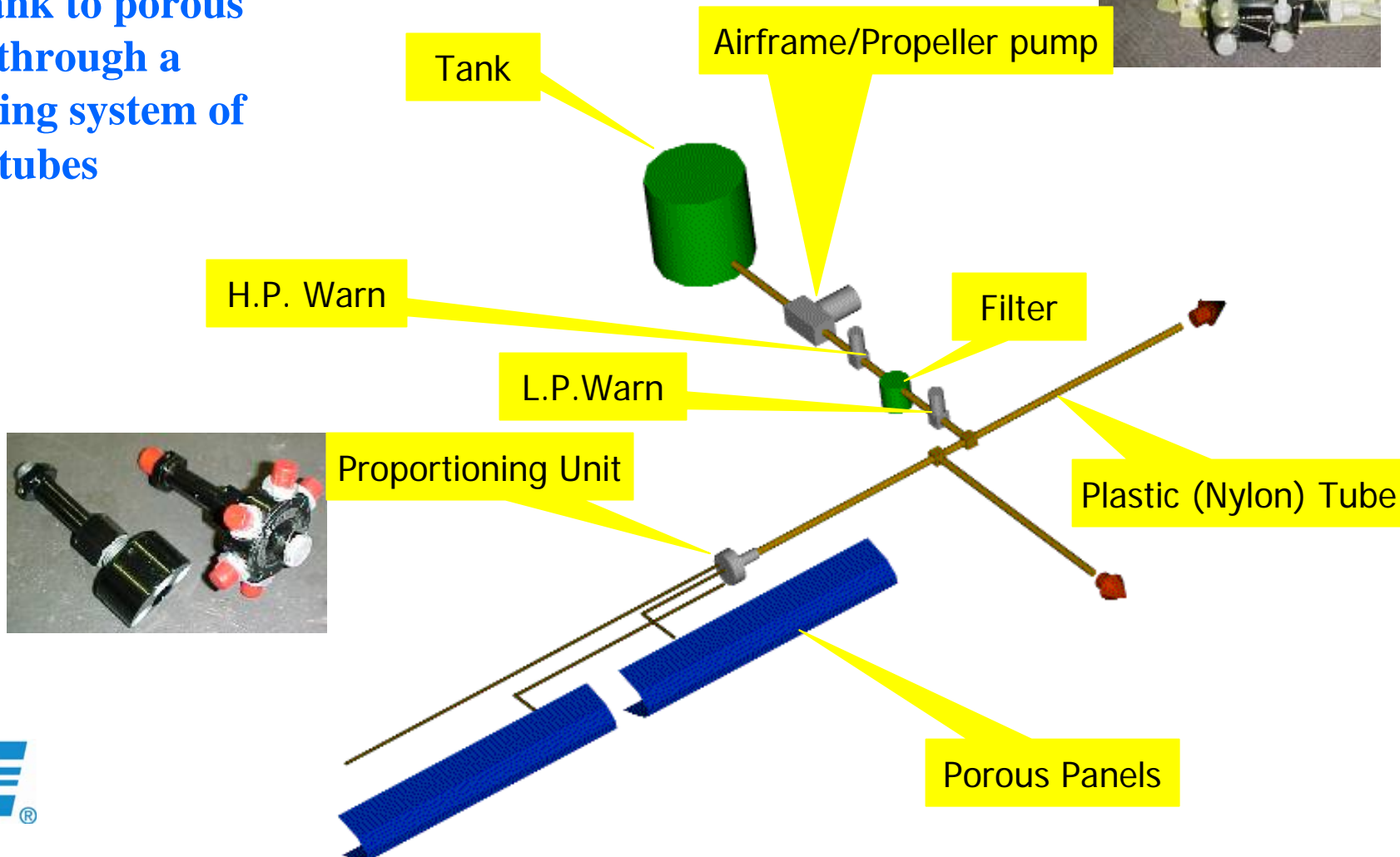
Presentation Outline

- Freezing Point Depressant (FPD) System Description
- Aircraft Icing Envelope Design
- AOA Flight Testing
- Analysis Tool Description
- Icing Wind Tunnel (IWT) Validation
- Ice Shape Flight Testing
- Natural Ice Flight Testing



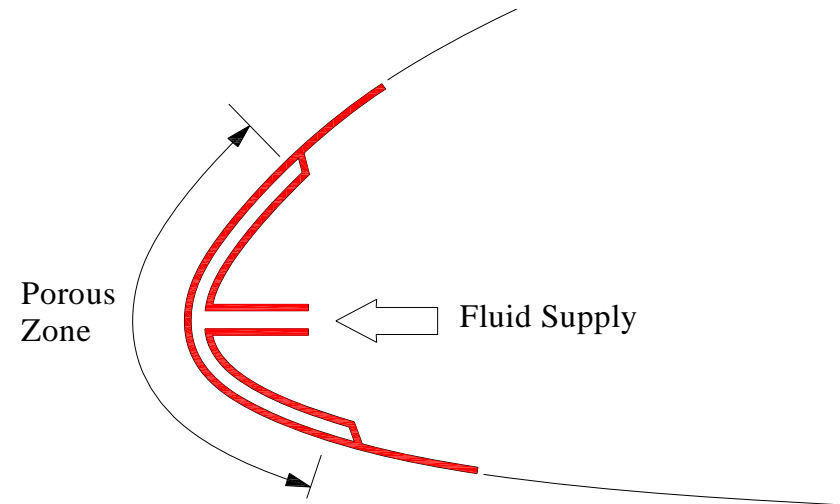
FPD System Description

Liquid pumped from tank to porous panels through a branching system of plastic tubes



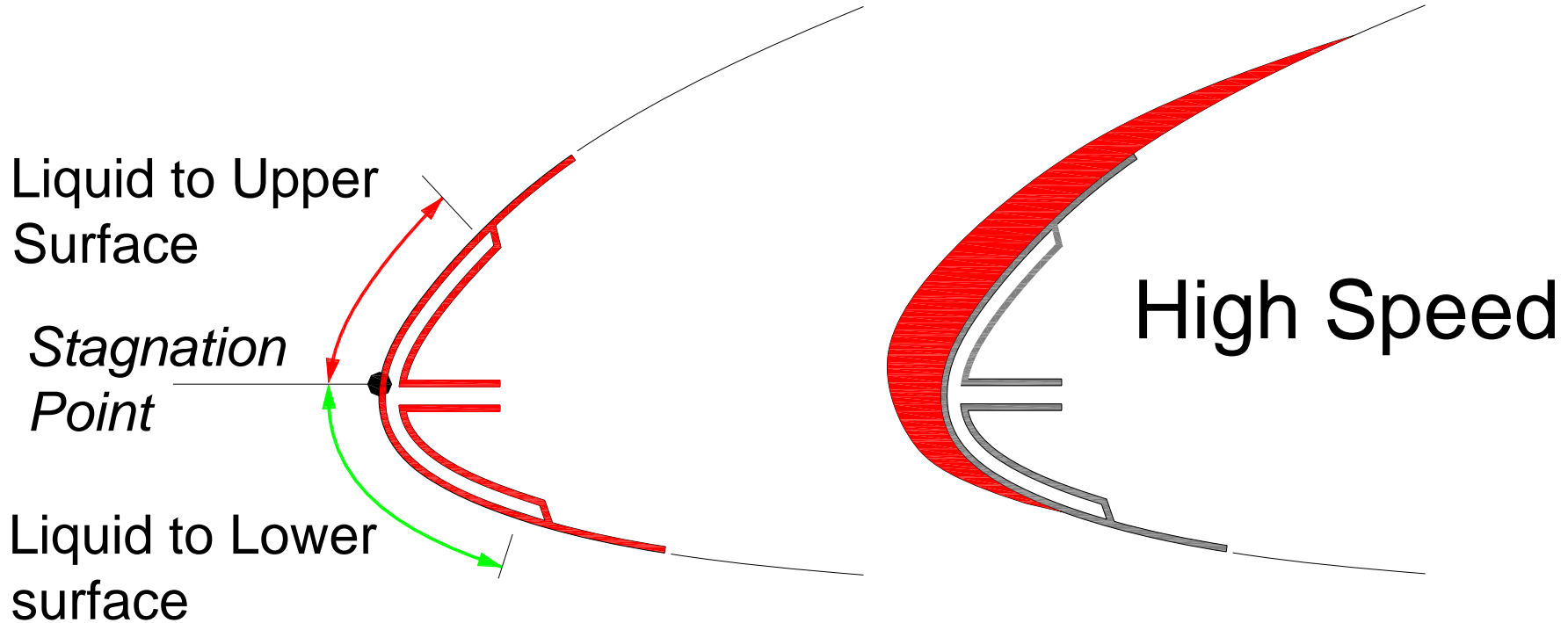
FPD System Description

Porous panels inserted in leading edges of protected zones.
Liquid pumped into cavity exudes through surface to provide a protective film.



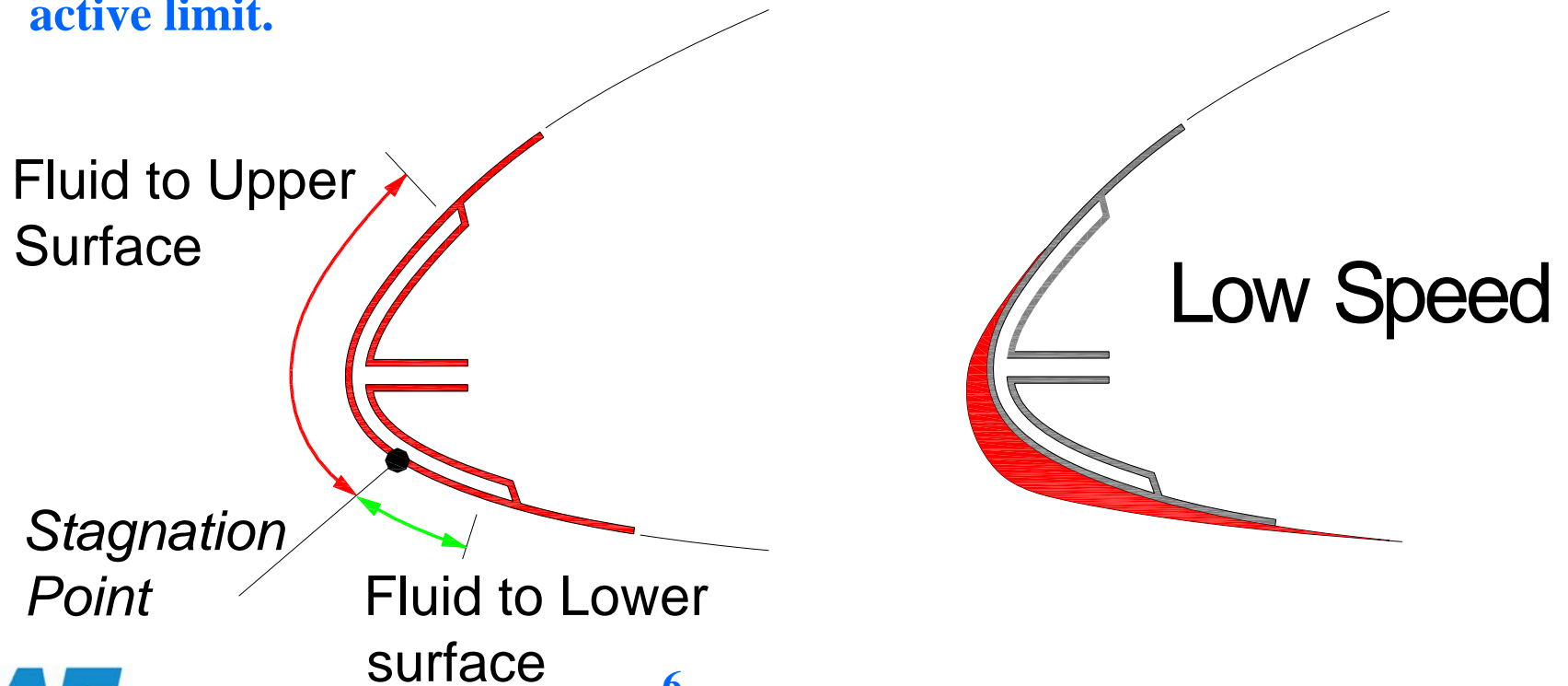
- Aircraft operating conditions

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

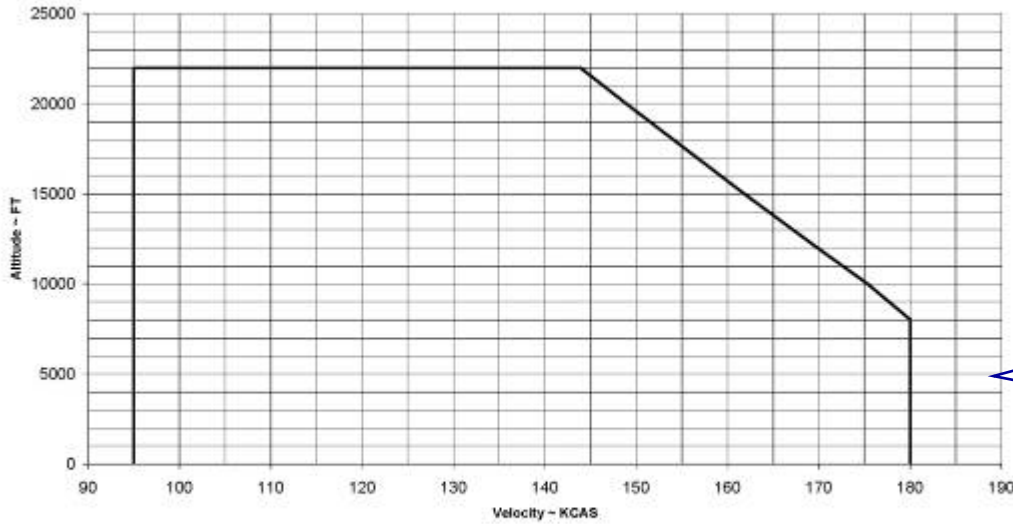


- Aircraft operating conditions

At lower speed Ice Formation shifts downwards but less fluid is available for lower surface. However, since water catch rate is lower due to reduced velocity this may or may not force design for lower active limit.



Typical Icing Envelope Designs



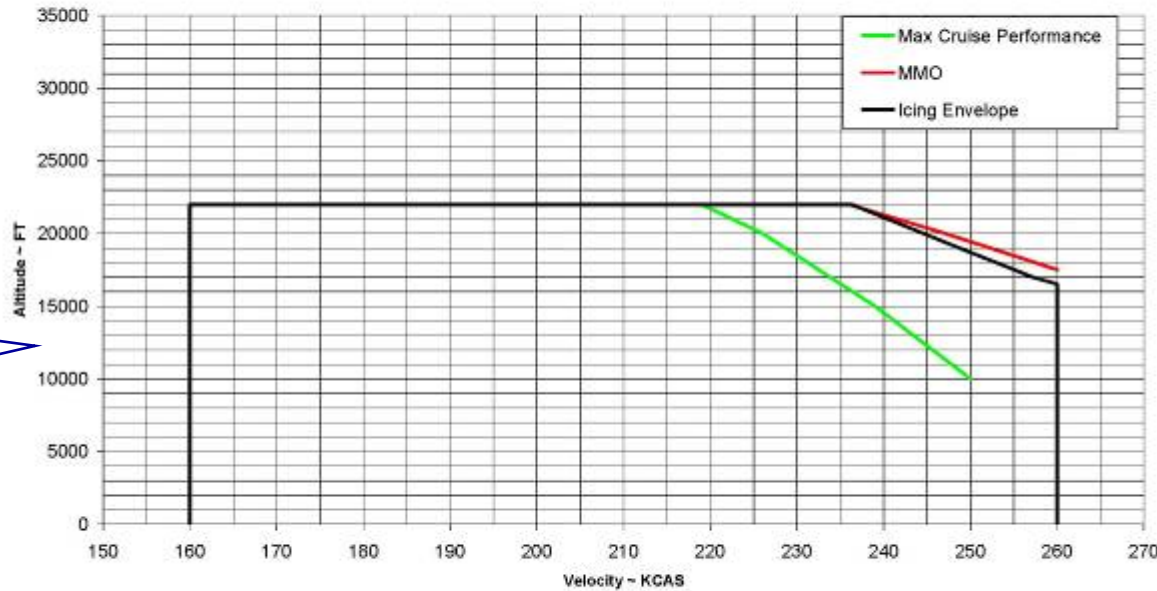
Typical High Performance Propeller Aircraft

Based on Wing and Horizontal Coverage
 Climbs at Max Weight
 Cruise and Descent at Min Weight

Typical High Performance Propeller Aircraft

JL.V07

Higher Speed Aircraft



Based on Wing and Horizontal Coverage
 Climbs Max Heavy
 Cruise and Descent Min Weight

High Speed Aircraft

JL.V07

Flight Testing is Required to Determine The Local Angle of Attack at Key Wing and Horizontal Surface Locations

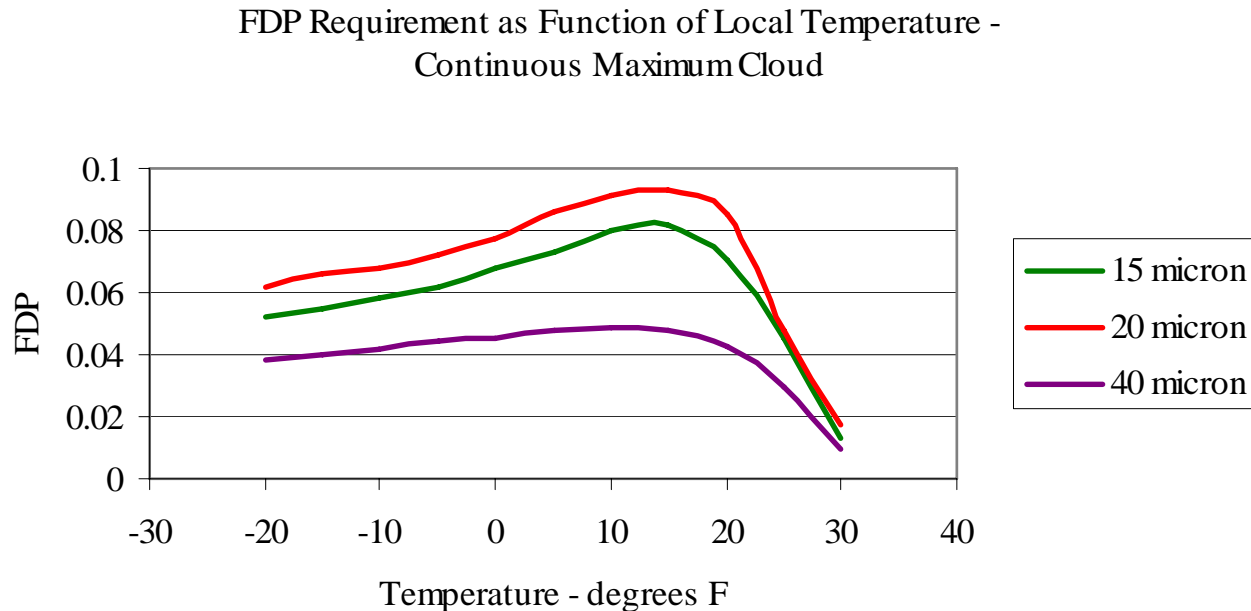
- Pressure belts are installed at the key locations
- The stagnation point is determined for a range of airspeeds at each of the key locations
- Airfoil flow analysis is used to determine the local AOA at each of the key locations
- The corresponding AOA's are matched to icing envelope points and flight speeds
- This data is used to design the leading edge panel with the FPD Analysis Tool

Example of Pressure Belt Installation Using Ribbon Tubes

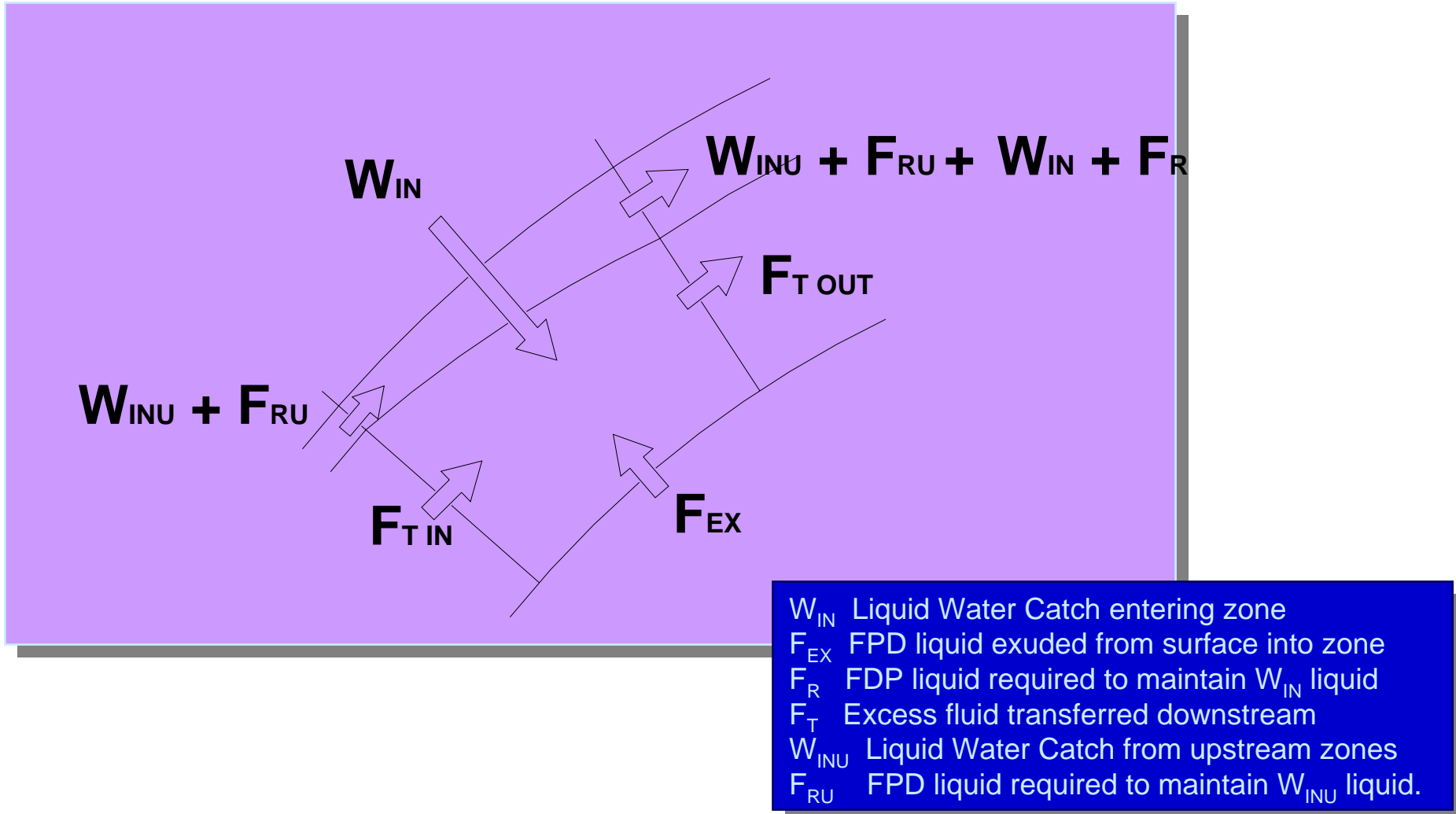


Determination of Design Points

- To ensure that testing adequately covers envelope, worst cases are identified as Design Points.
- Worst cases are function of Local Temperature, LWC and FPD fluid characteristics



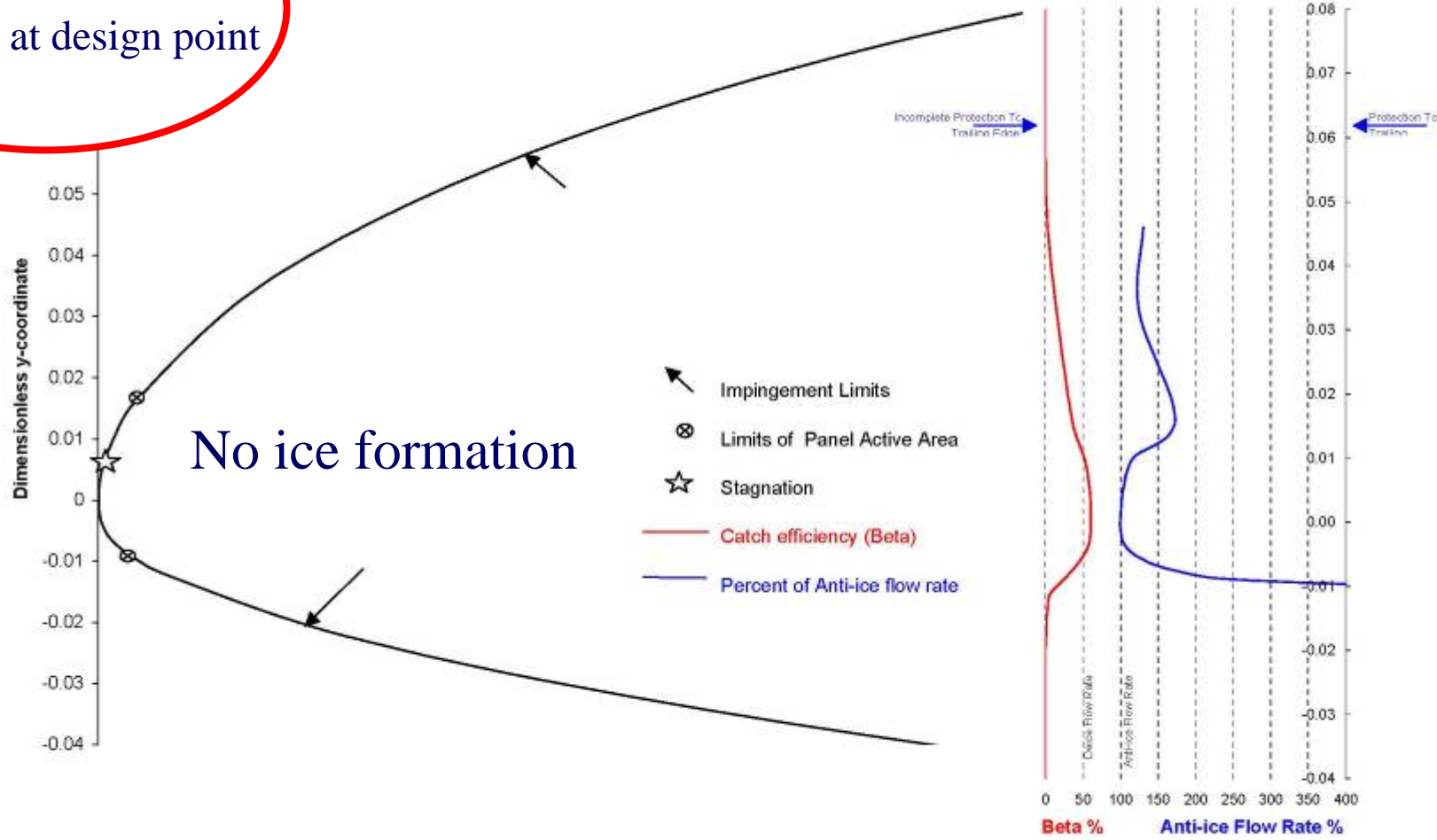
FPD Analysis Tool



Flow and active zone optimised at design point

Configuration: 172.4m/sec Cruise @ 22000 ft, AOA -1.8
(Note AOA To Match 250 KCAS @ Light Weight)

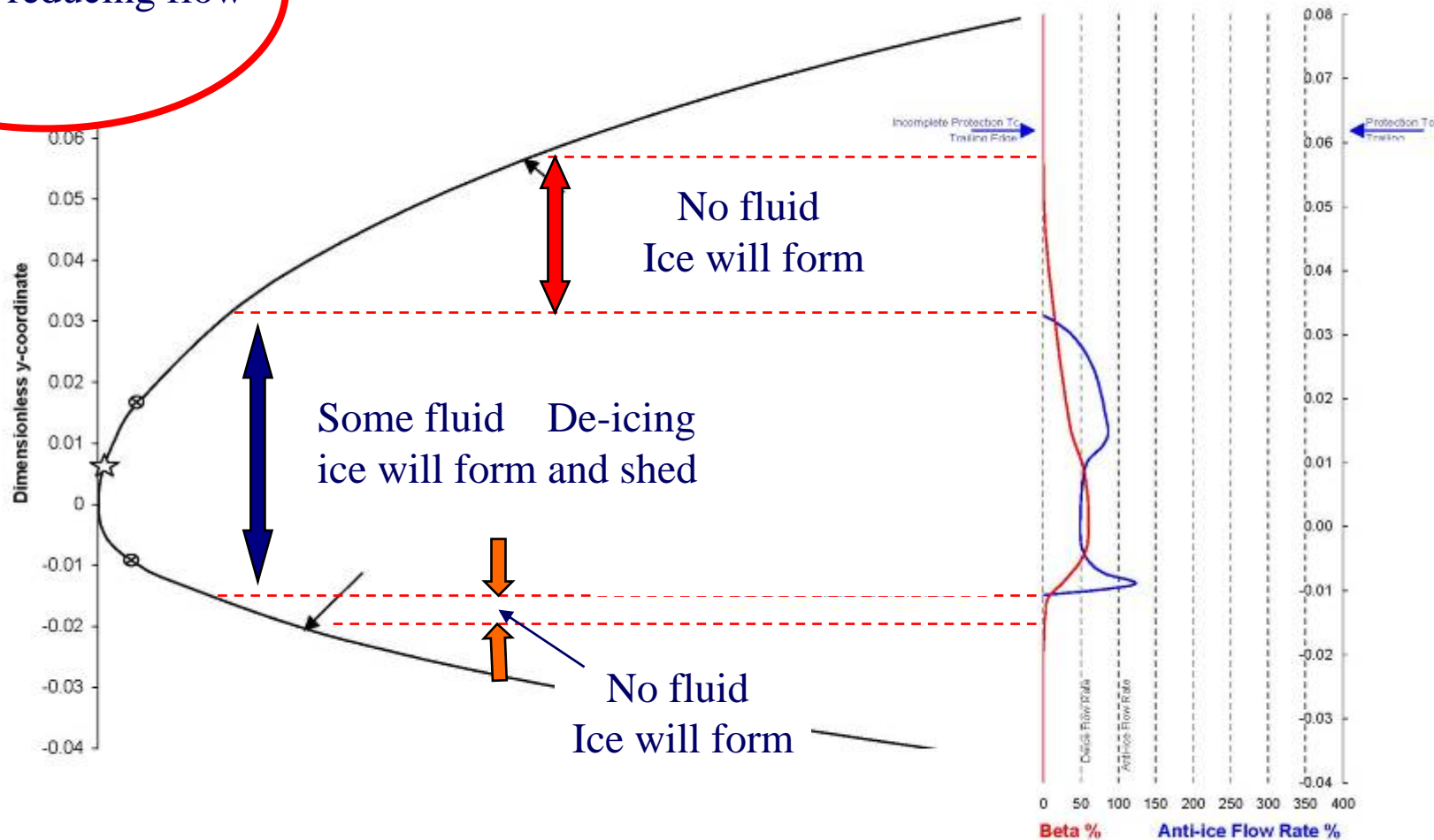
Icing Conditions: -10 Deg. F.
0.286 LWC, 15 Micron Droplets



Effect of reducing flow

Configuration: 172.4m/sec Cruise @ 22000 ft, AOA -1.8
(Note AOA To Match 250 KCAS @ Light Weight)

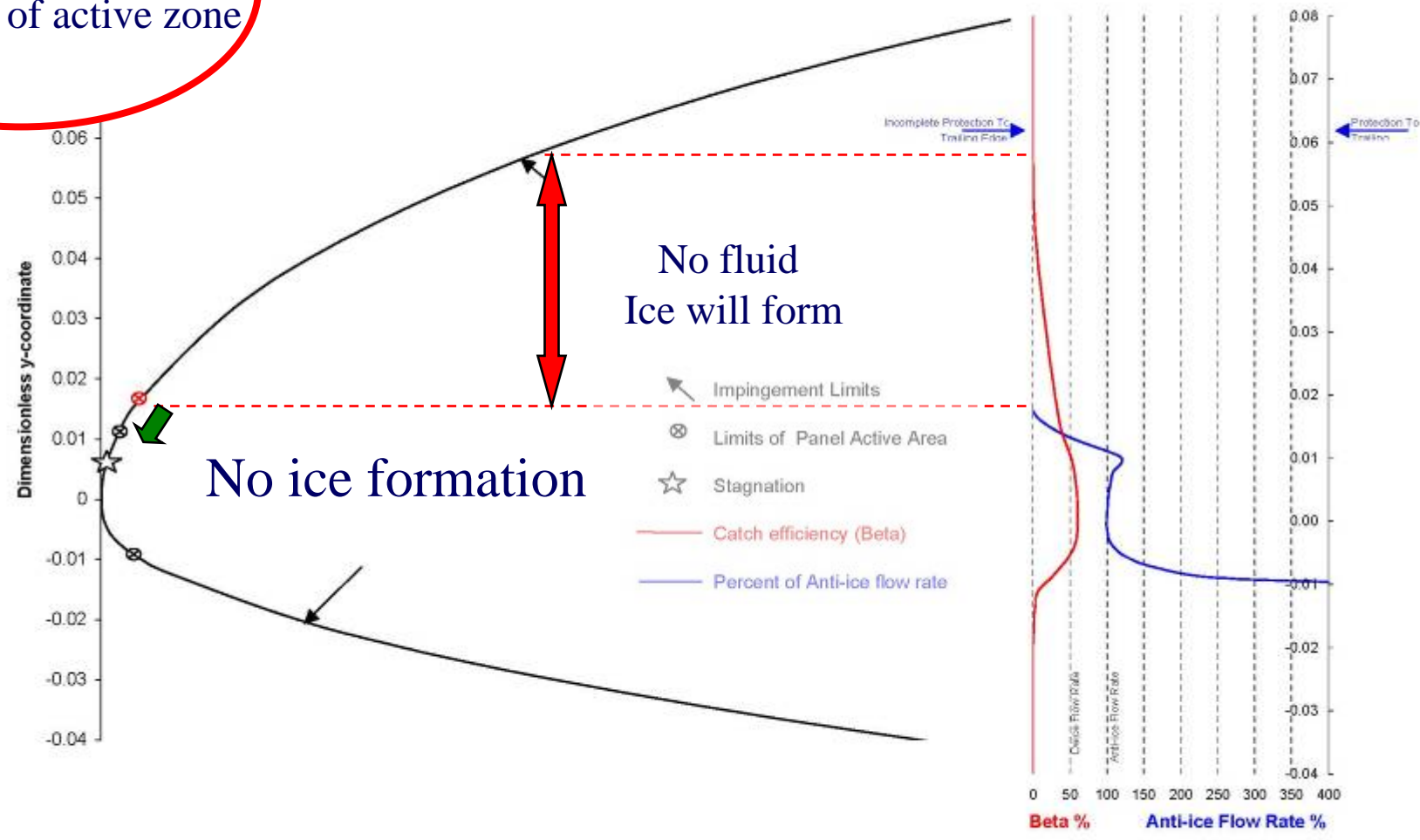
Icing Conditions: -10 Deg. F.
0.286 LWC, 15 Micron Droplets



Effect of lowering upper limit of active zone

Configuration: 172.4m/sec Cruise @ 22000 ft, AOA -1.8
(Note AOA To Match 250 KCAS @ Light Weight)

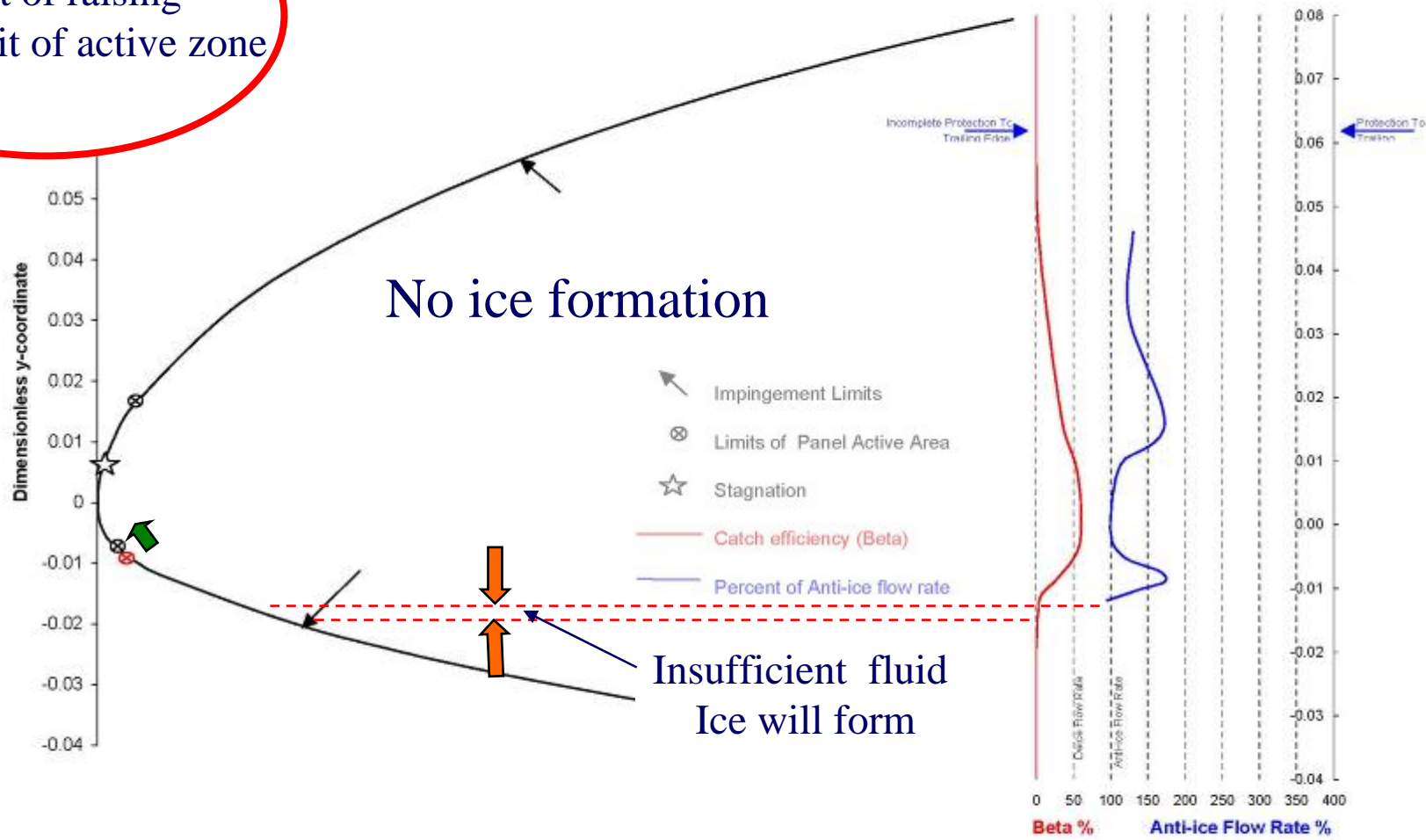
Icing Conditions: -10 Deg. F.
0.286 LWC, 15 Micron Droplets



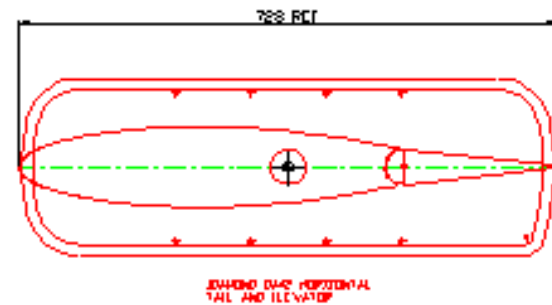
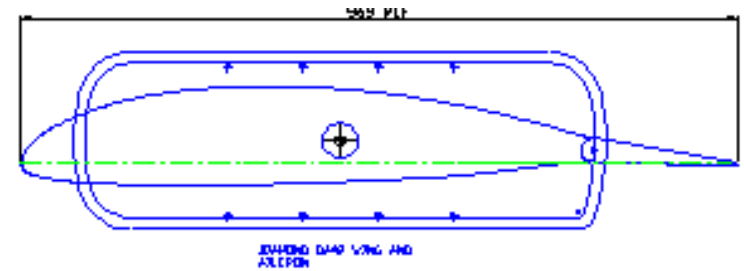
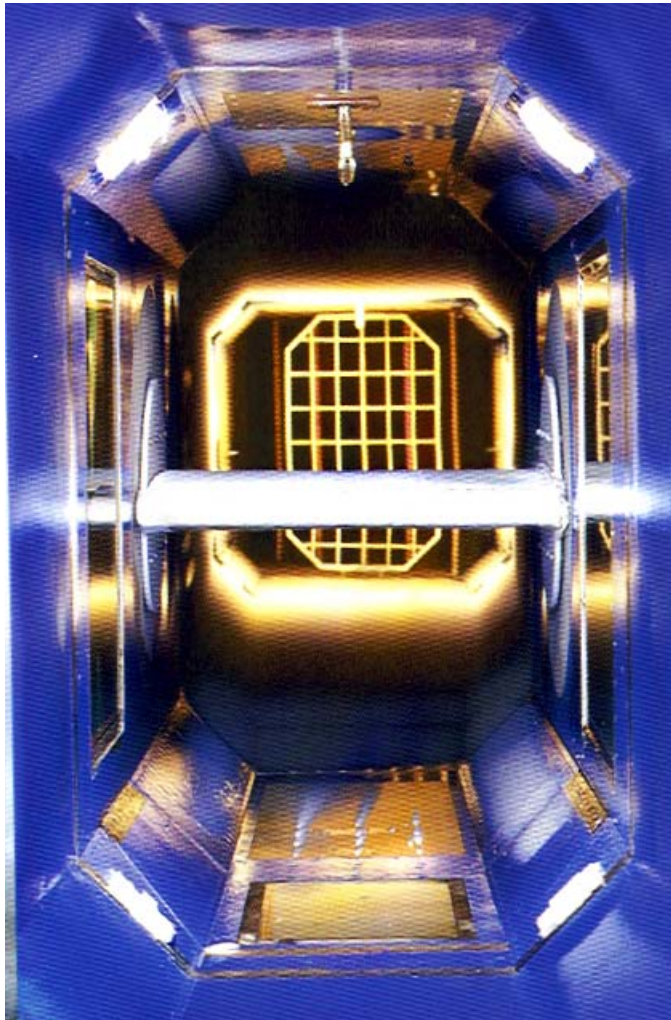
Effect of raising lower limit of active zone

Configuration: 172.4m/sec Cruise @ 22000 ft, AOA -1.8
(Note AOA To Match 250 KCAS @ Light Weight)

Icing Conditions: -10 Deg. F.
0.286 LWC, 15 Micron Droplets

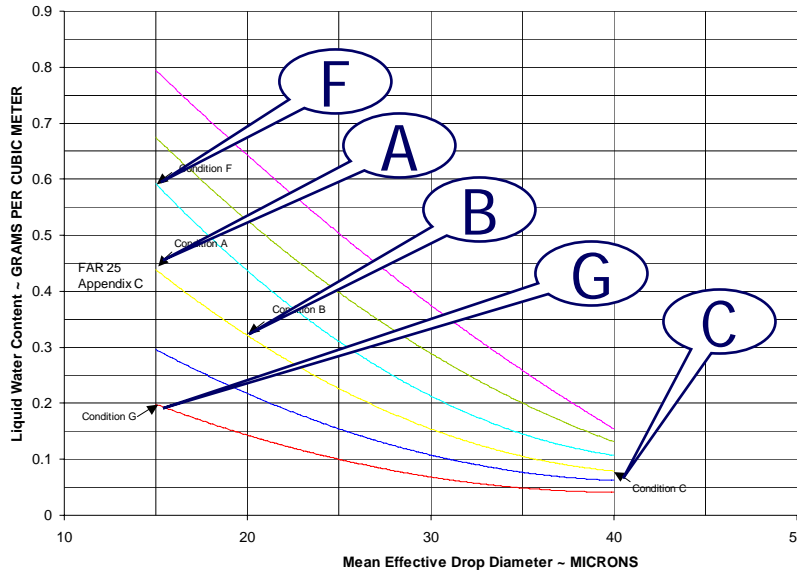


IWT Test Section



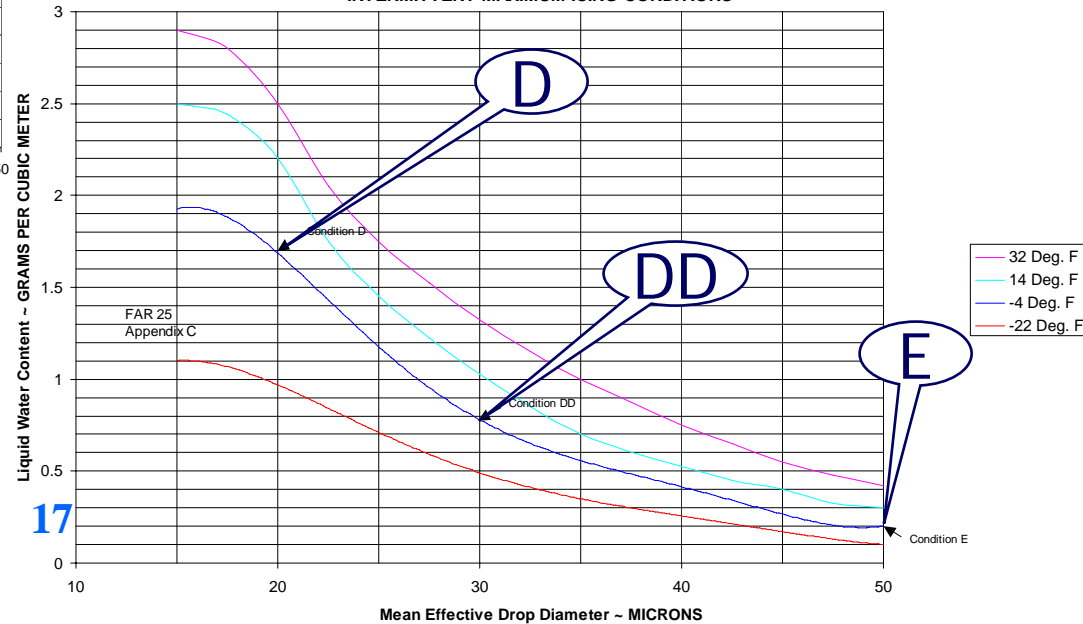
Test Points In The Icing Envelopes

CONTINUOUS MAXIMUM ICING



- 32 Deg. F
- 14 Deg. F
- 4 Deg. F
- 22 Deg. F
- 23 Deg. F
- 5 Deg. F

INTERMITTENT MAXIMUM ICING CONDITIONS



- 32 Deg. F
- 14 Deg. F
- 4 Deg. F
- 22 Deg. F

Example of IWT Test Matrix

Run No	Model	Flight Mode	Alt ft	EAS mph (tunnel)	TAS M/s (flight)	AOA	Temp °C/°F	LWC Flight/tunnel	Drop Dia	Time
1A	Wing A	Cruise	13000	183	100.33	0.0	-15/5	.445 .543	15	cont
1B	Wing A	Cruise	13000	183	100.33	0.0	-15/5	.31 .378	20	cont
1C	Wing A	Cruise	13000	183	100.33	0.0	-15/5	.075 .091	40	cont
1D	Wing A	Cruise	13000	183	100.33	0.0	-20/-4	1.7 2.07	20	0.8 min
1E	Wing A	Cruise	13000	183	100.33	0.0	-20/-4	.2 .244	50	0.8 min
1F	Wing A	Cruise	13000	183	100.33	0.0	-10/14	.6 .731	15	cont
1G	Wing A	Cruise	13000	183	100.33	0.0	-30/-22	.2 .241	15	cont
2A	Wing A	Climb	18000	138	81.79	2.0	-15/5	.445 .589	15	cont
2B	Wing A	Climb	18000	138	81.79	2.0	-15/5	.31 .411	20	cont
2C	Wing A	Climb	18000	138	81.79	2.0	-15/5	.075 .099	40	cont
2D	Wing A	Climb	18000	138	81.79	2.0	-20/-4	1.7 2.25	20	1.0 min
2E	Wing A	Climb	18000	138	81.79	2.0	-20/-4	.2 .264	50	1.0 min
2F	Wing A	Climb	18000	138	81.79	2.0	-10/14	.6 .792	15	cont
2G	Wing A	Climb	18000	138	81.79	2.0	-30/-22	.2 .264	15	cont

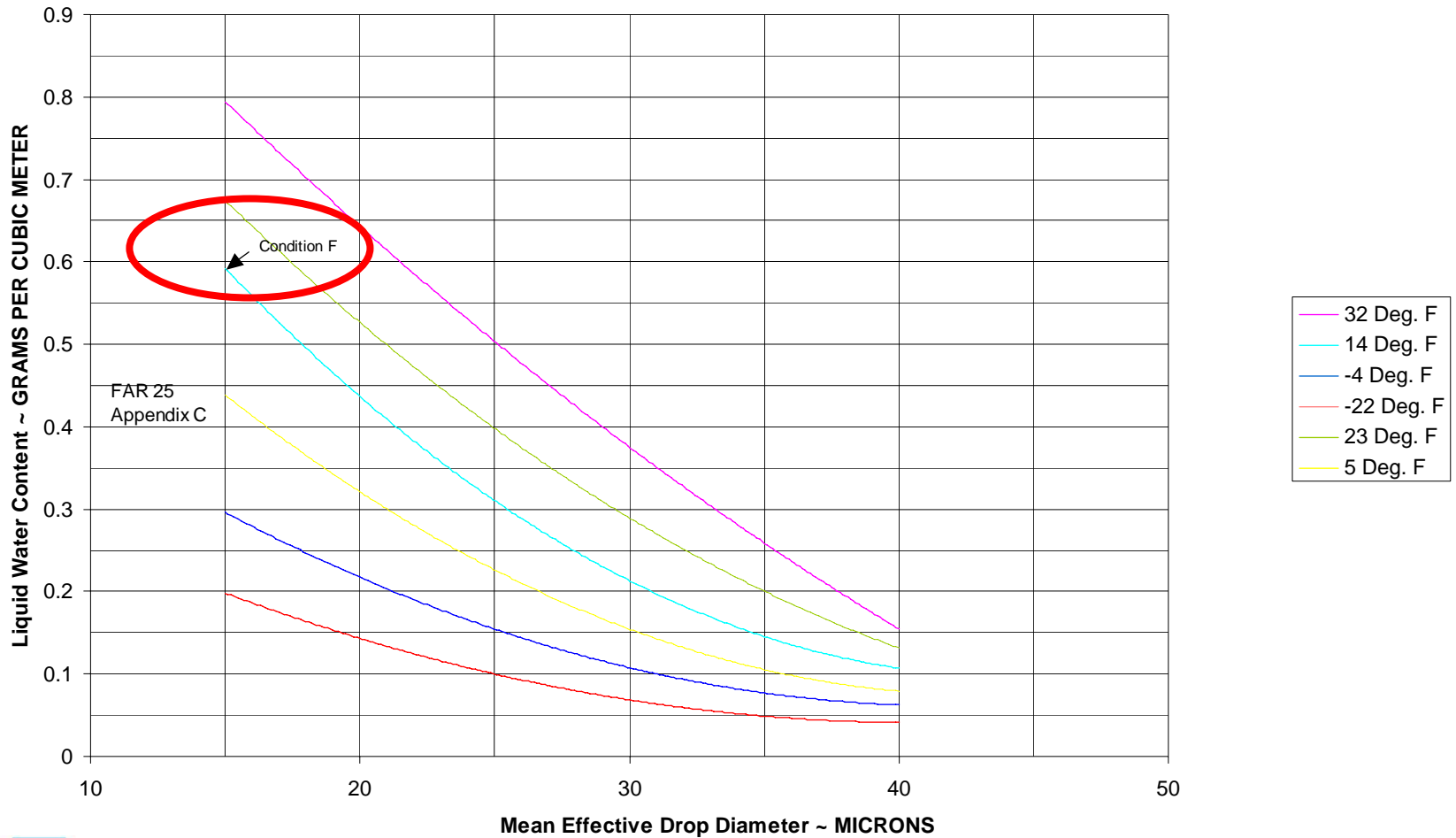
WING TEST POINTS

Test Point (1F)

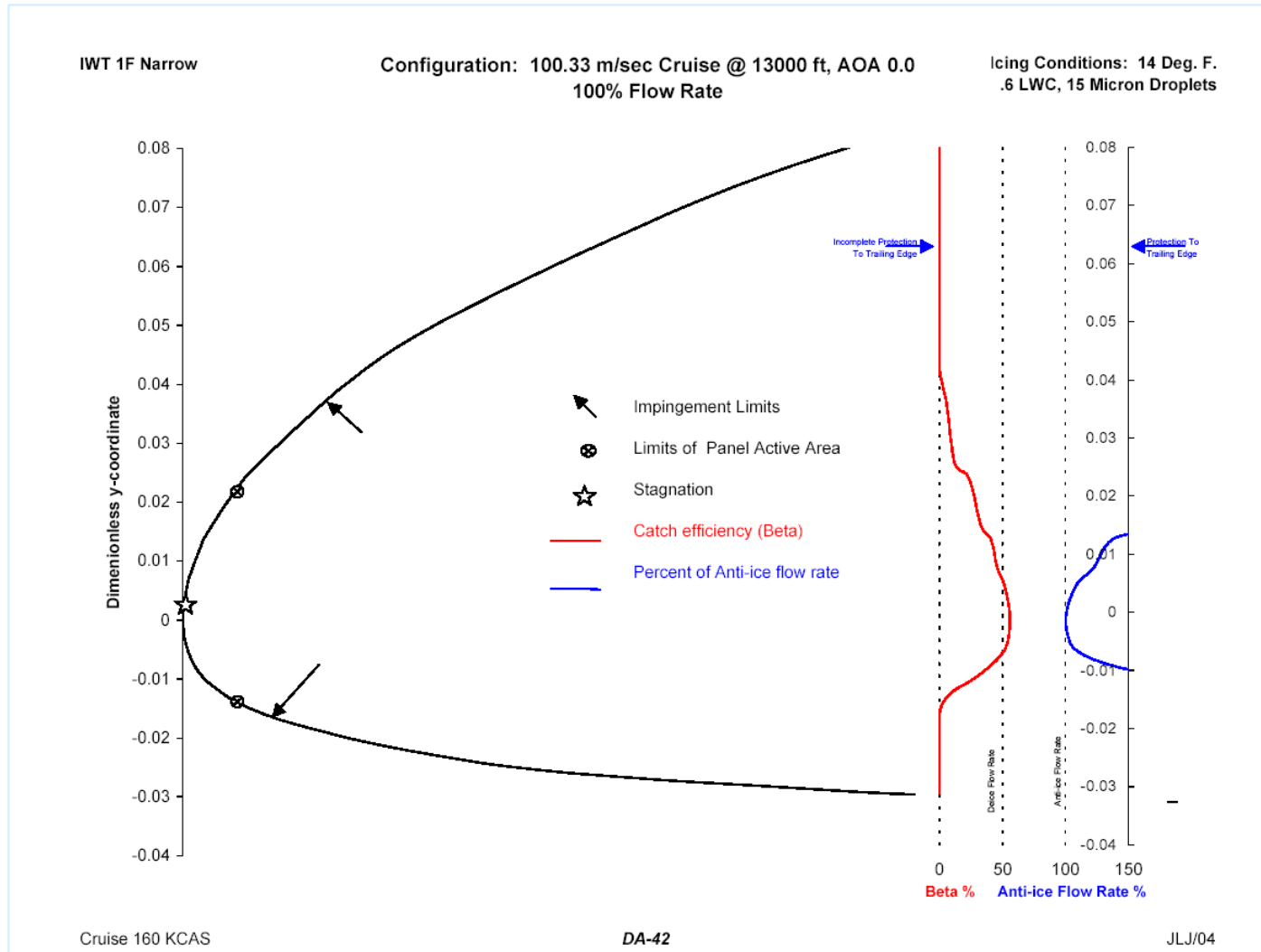
1F	Wing A	Cruise	Altitude 13000	RASm/h 183	IAS M/s 100.33	AOA 0.0	Temp C/F- 10/14	LWC Flt .6 IWT.73	Drop Dia 15	Enctr time cont
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CONTINUOUS MAXIMUM ICING

1



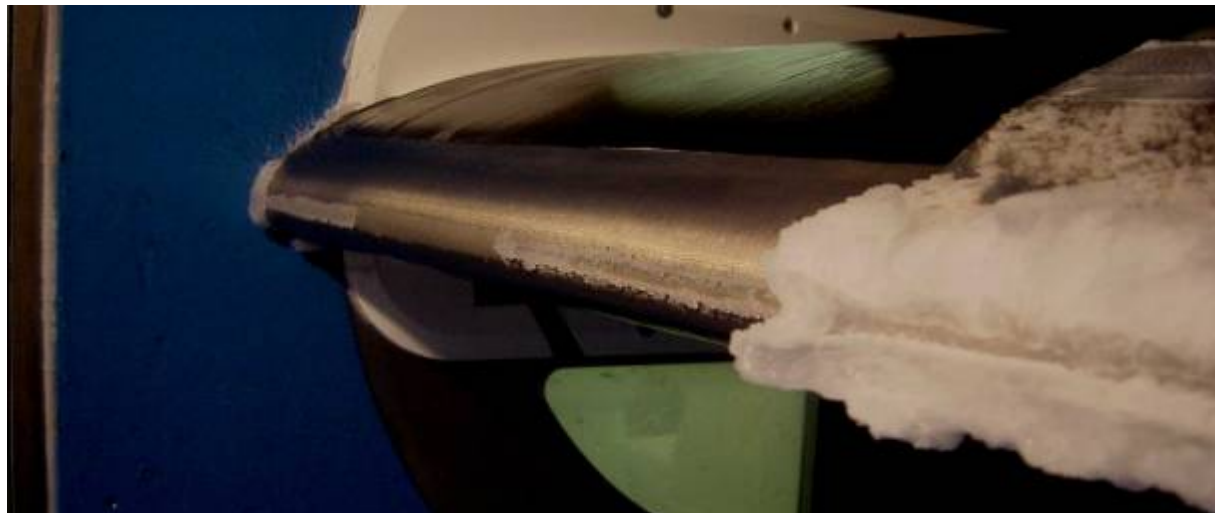
Test Point Analysis (1F)



Test Continuing After 2 Minute Delayed Activation



Typical Panel In IWT Conditions (1F)



Upper Surface



Lower Surface

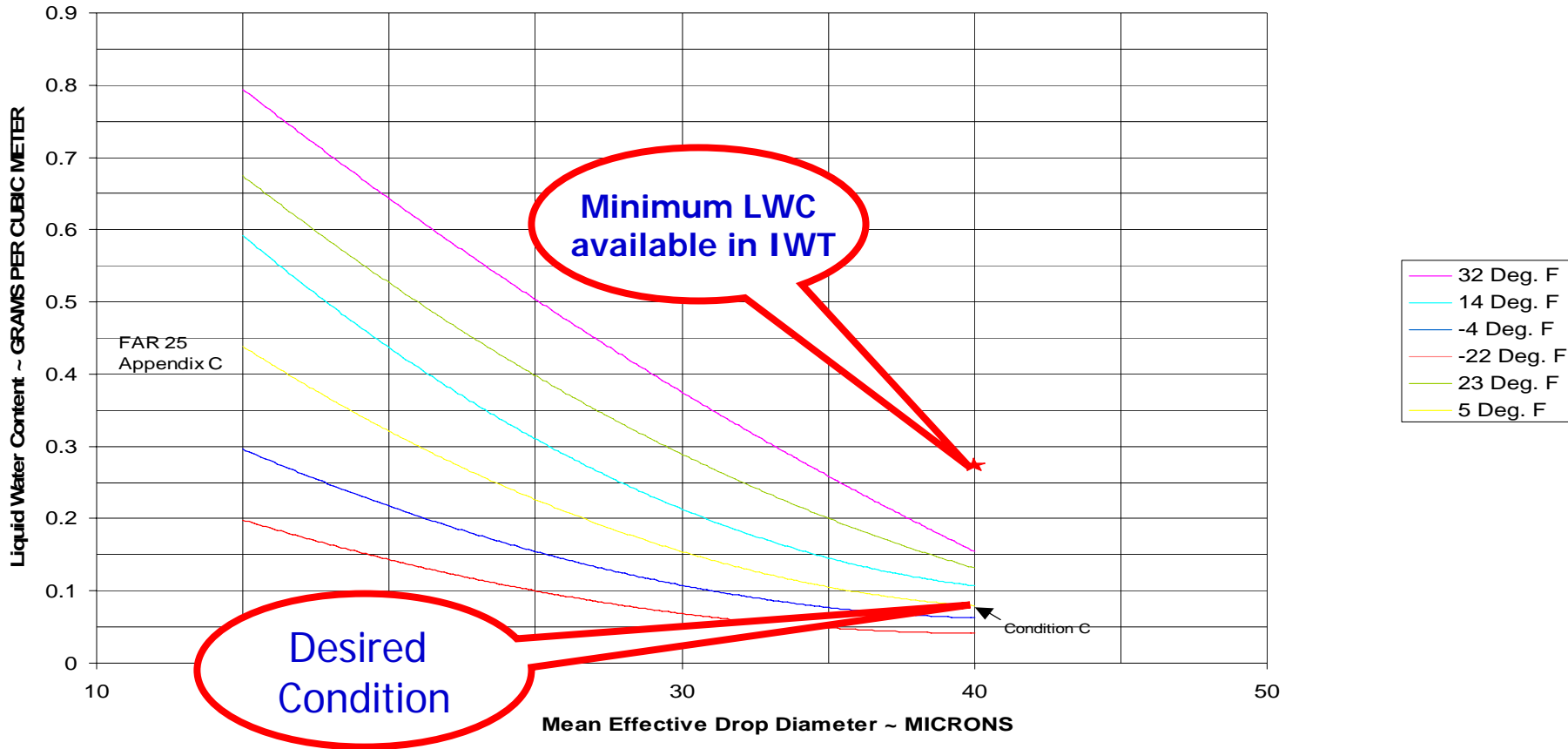


Test Point (1C)

(Large droplets - also example of IWT LWC limitation)

1C	Wing A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA 0.0	Temp C/F- 15/5	LWC .075 .091 .230	Drop Dia 40	Enctr Time cont
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CONTINUOUS MAXIMUM ICING



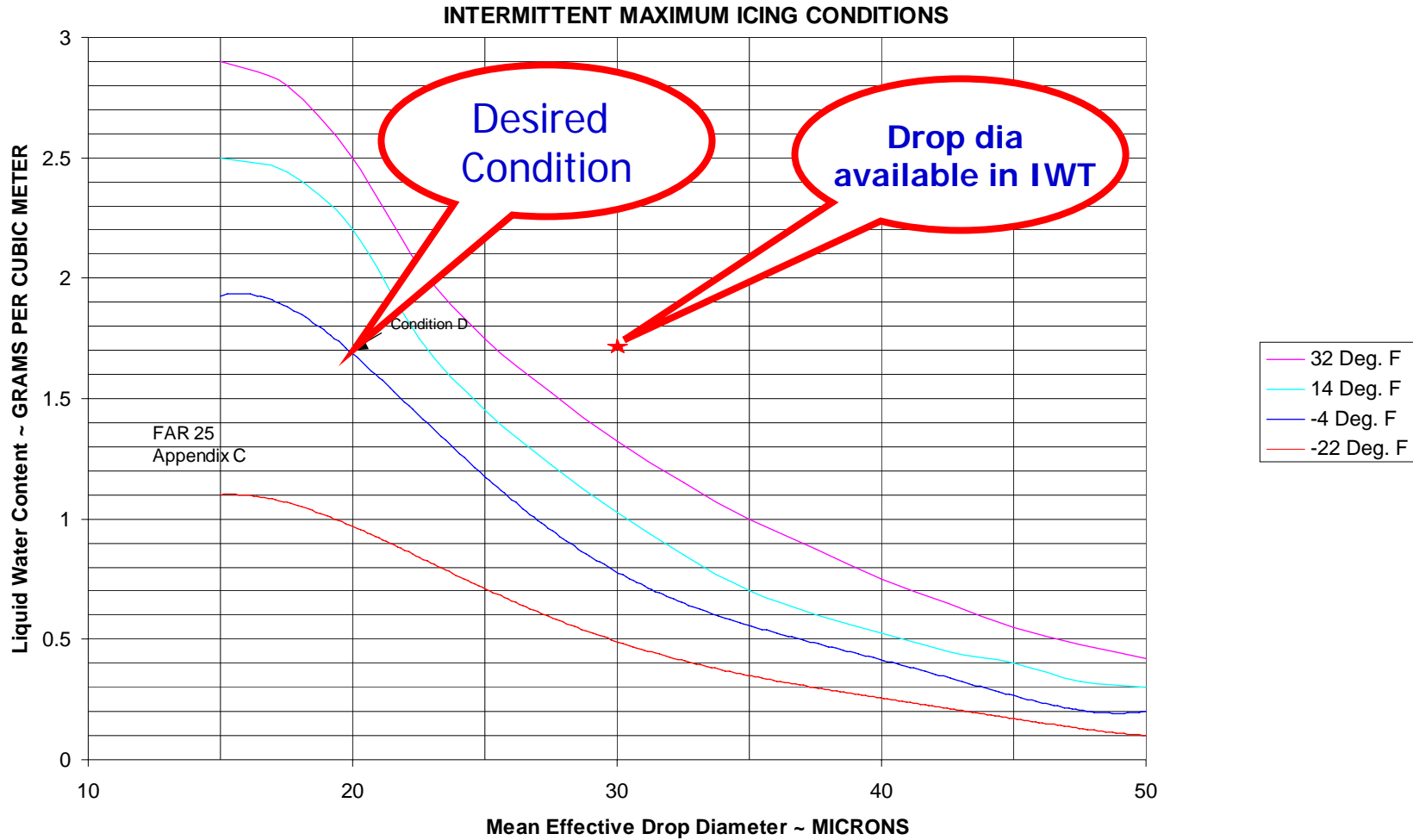
Typical Panel In IWT Conditions (1C)



Test Point (1D)

(Intermittent Case - also example of IWT Droplet Size Limitation)

1D	Wing A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA 0.0	Temp C/F- 20/-4	LWC 1.7 2.07	Drop 20 30	Time 0.8 min
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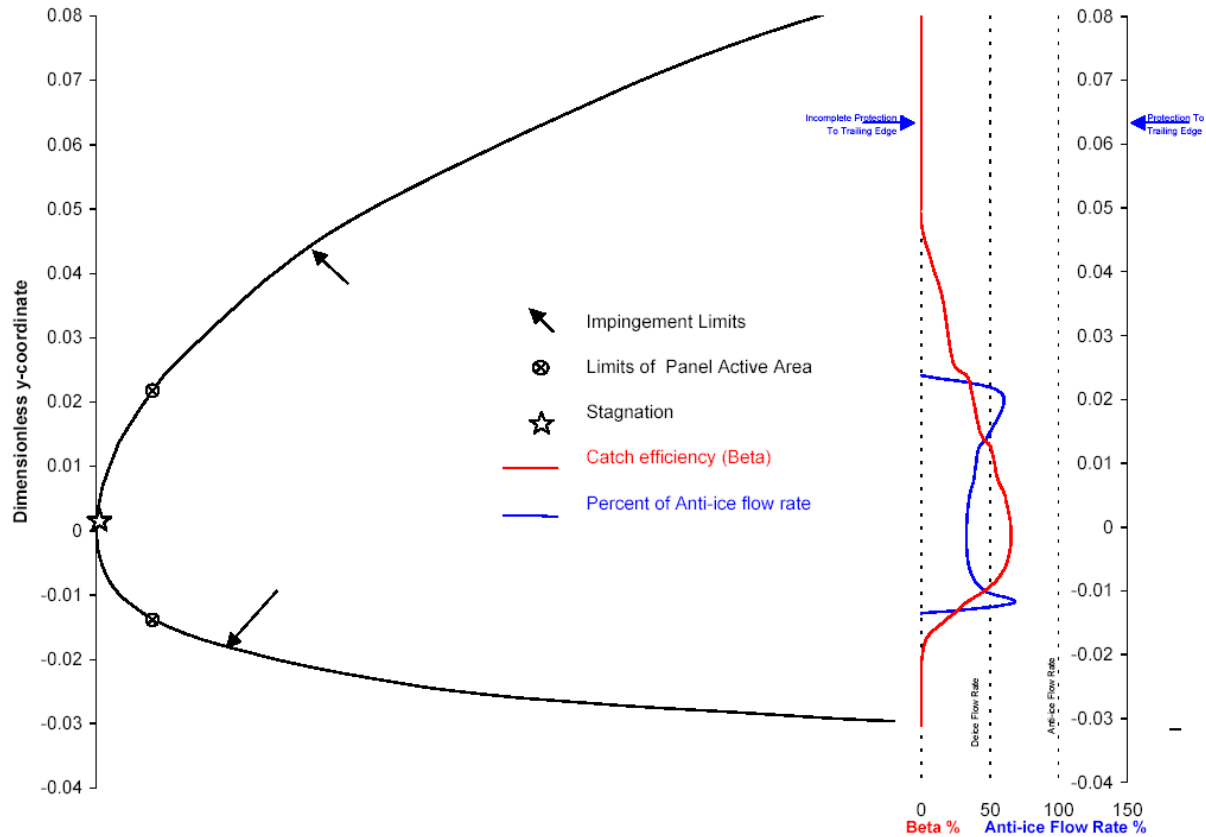


Test Point Analysis (1D) Flight Condition

IWT 1D Narrow

Configuration: 100.33 m/sec Cruise @ 13000 ft, AOA 0.0
200% Flow Rate

Icing Conditions: -4 Deg. F.
1.7 LWC, 20 Micron Droplets

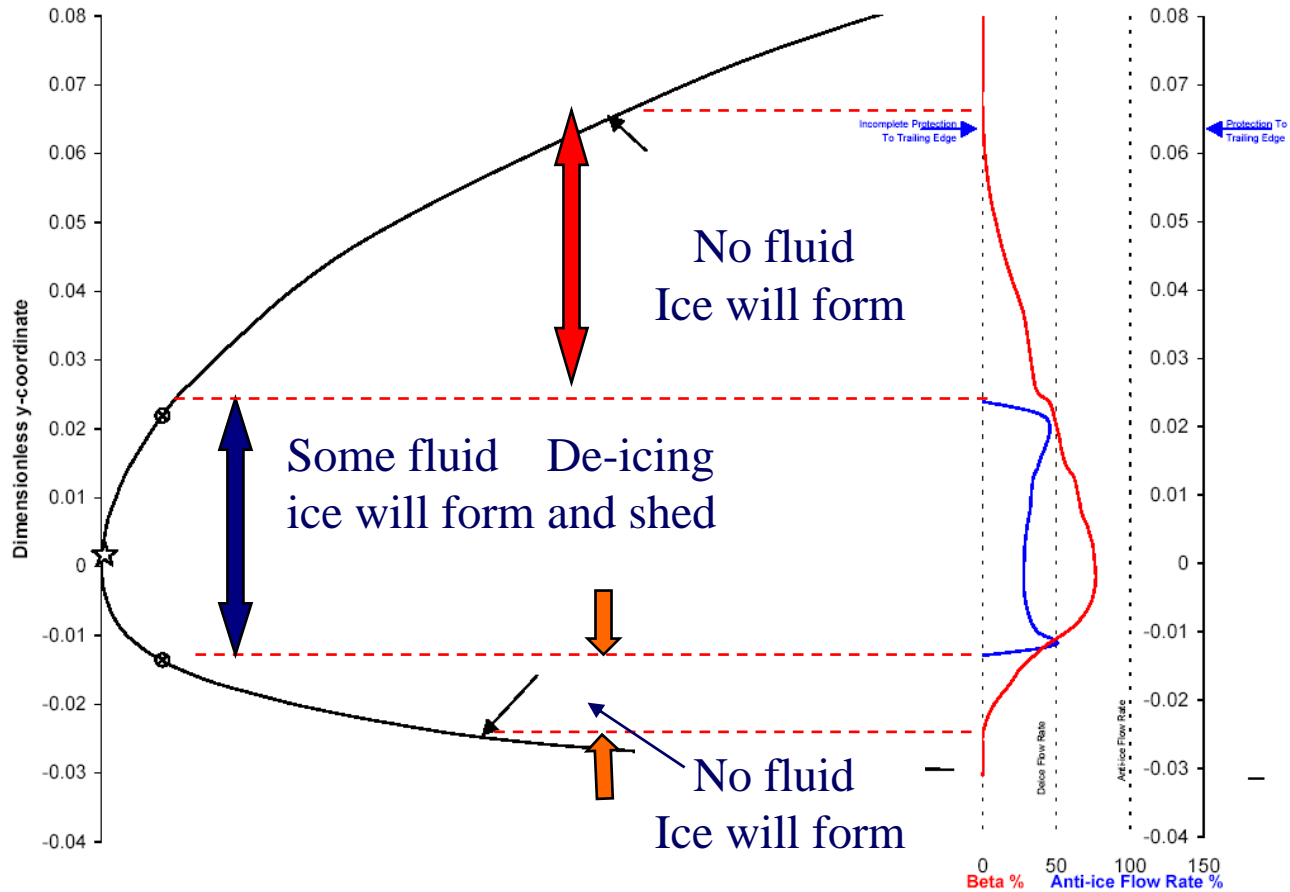


Test Point Analysis (1D) "IWT Test"

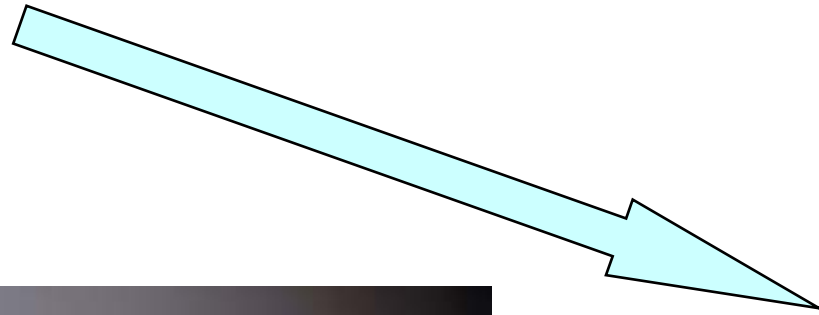
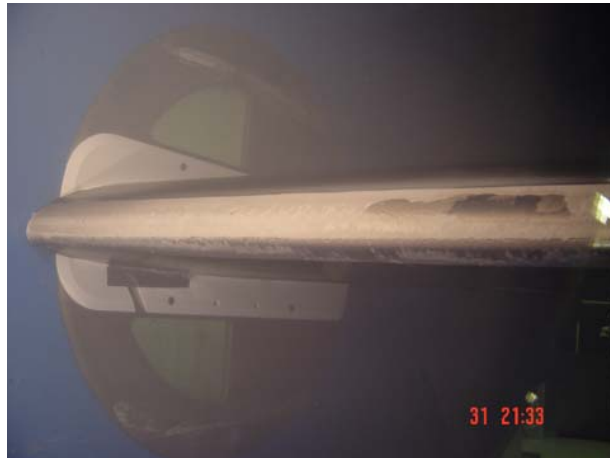
IWT 1D Narrow (IWT TEST)

Configuration: 100.33 m/sec Cruise @ 13000 ft, AOA 0.0
200% Flow Rate

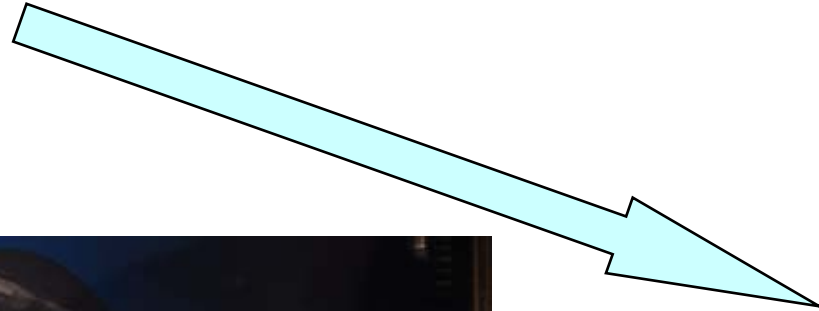
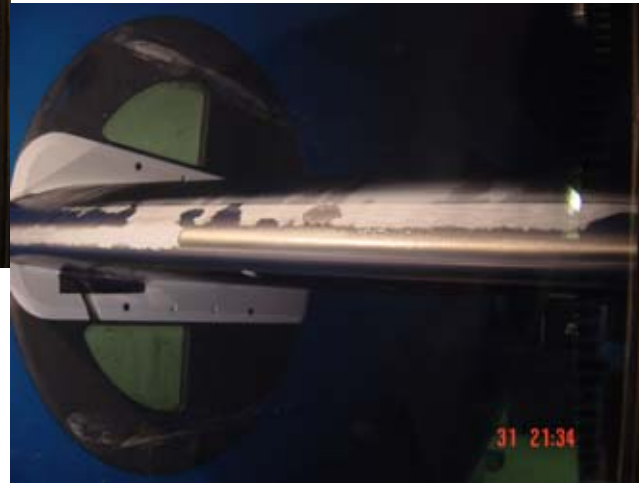
Icing Conditions: -4 Deg. F.
1.7 LWC, 30 Micron Droplets



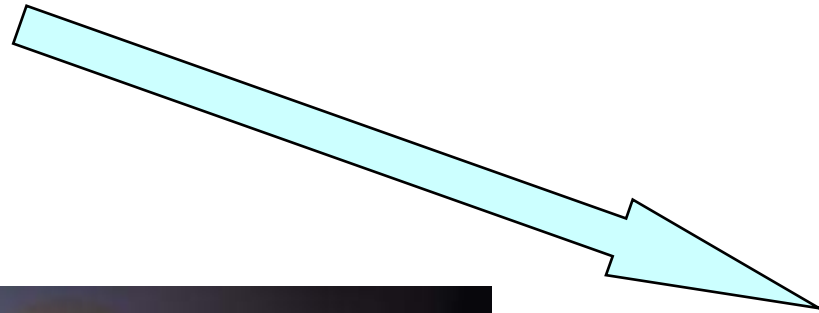
Flow Normal During 1st Intercept



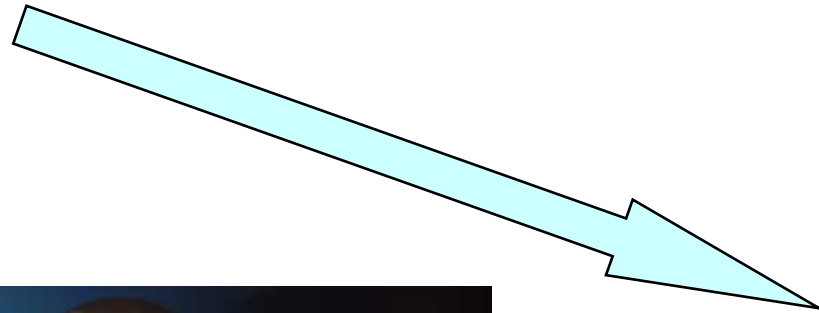
Flow Set To HI After Exiting Cloud



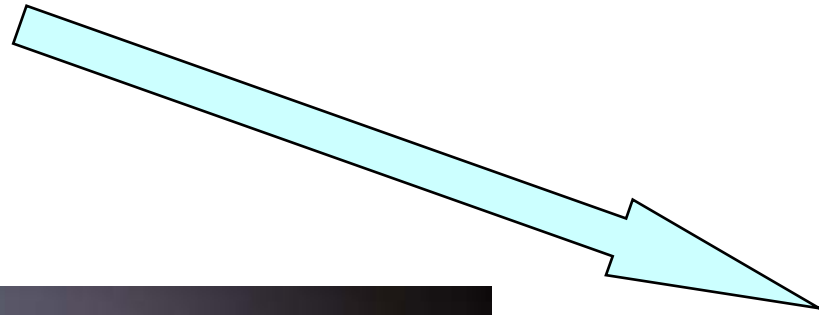
Leading Edge Builds and Sheds Ice



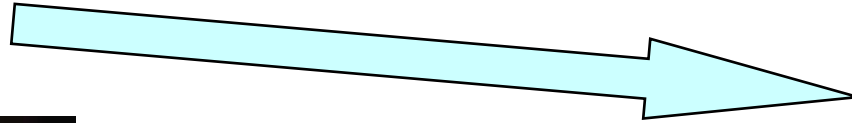
Airfoil Clears Before 3rd Intercept



Airfoil Ice Build During 3rd Intercept

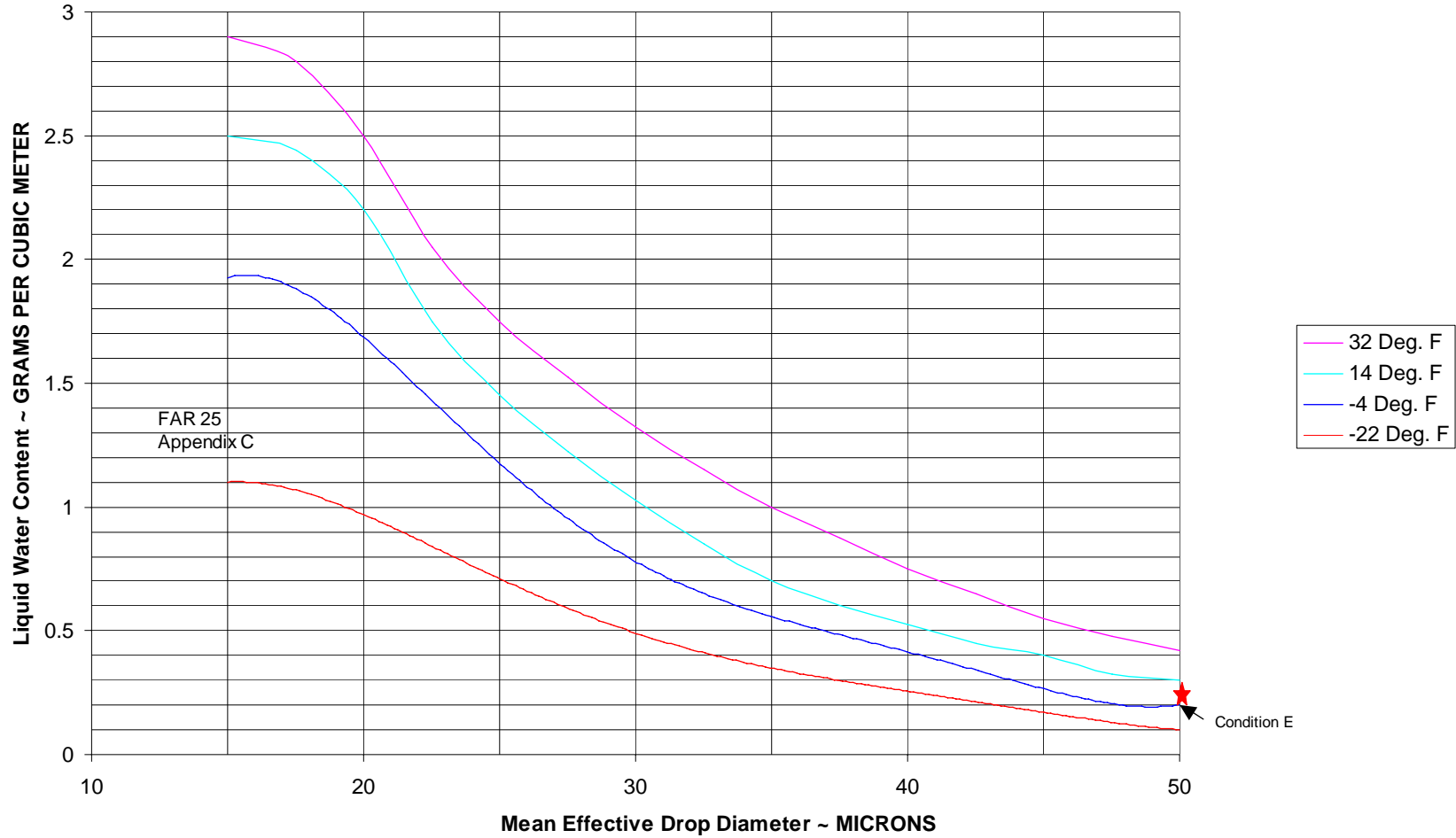


Airfoil Clears Within 1.5 Minutes

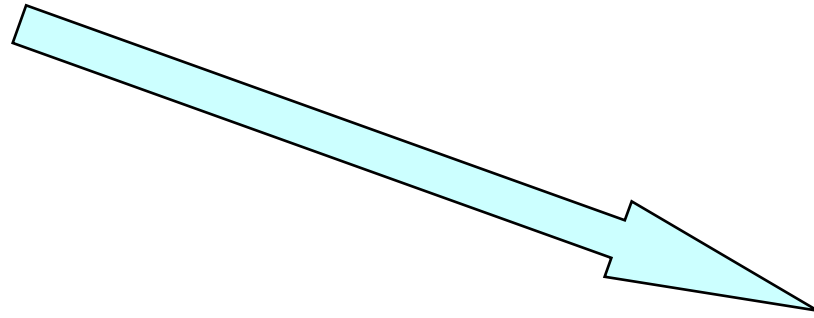


1E	Wing A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA 0.0	Temp C/F- 20/-4	LWC .2 .244 .299	LWC 50	Time 0.8 min
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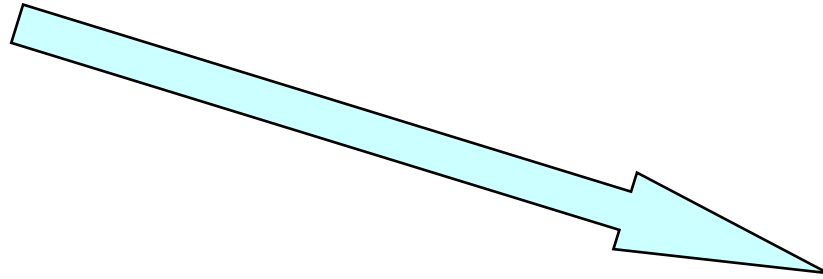
INTERMITTENT MAXIMUM ICING CONDITIONS



.8 Minute Delayed Start (1E)

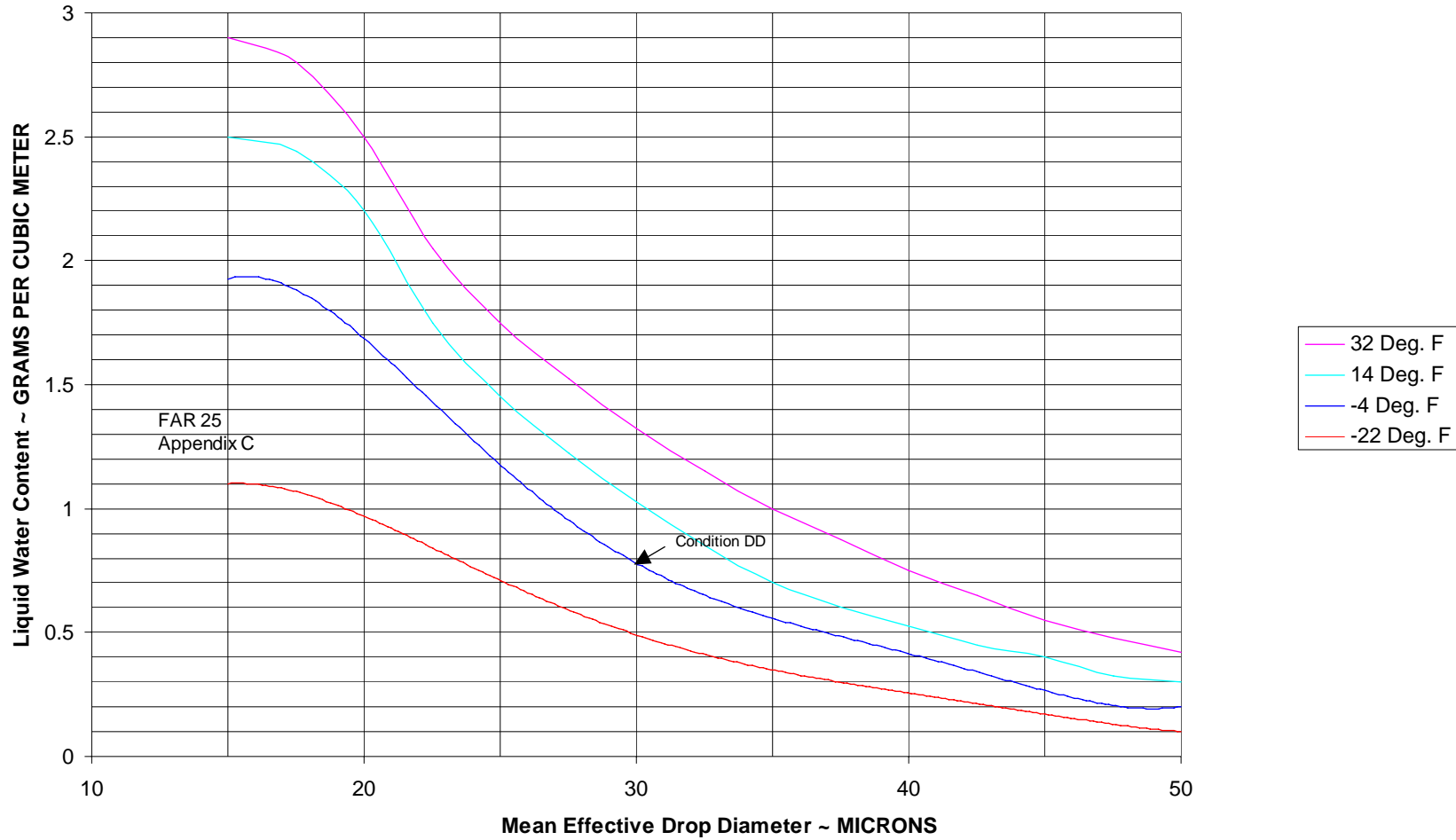


Airfoil Clears Within 1.5 Minutes



IDD	Wing A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA 0.0	Temp C/F- 20/-4	LWC 78 .95	Drop dia 30	Time 0.8 min
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INTERMITTENT MAXIMUM ICING CONDITIONS

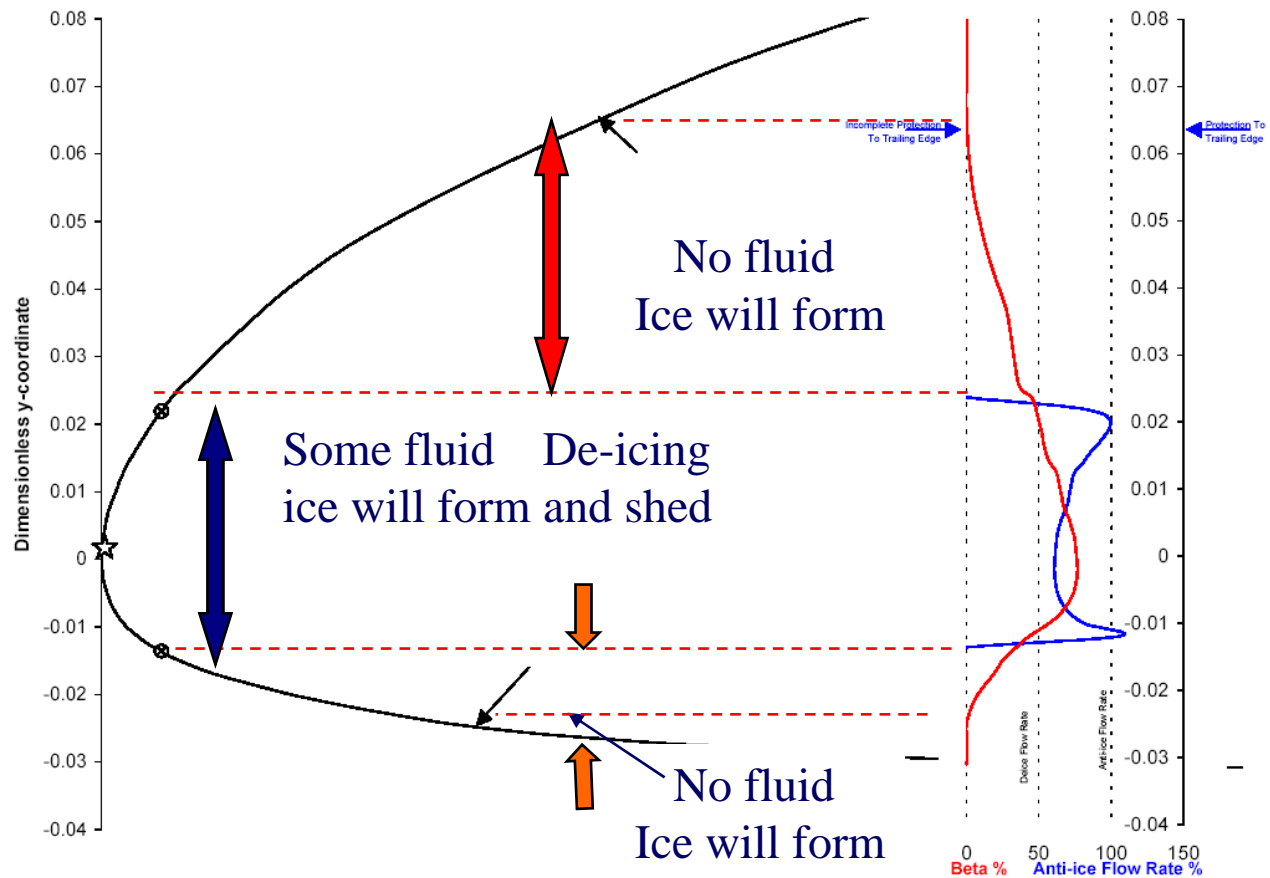


Test Point Analysis (1DD)

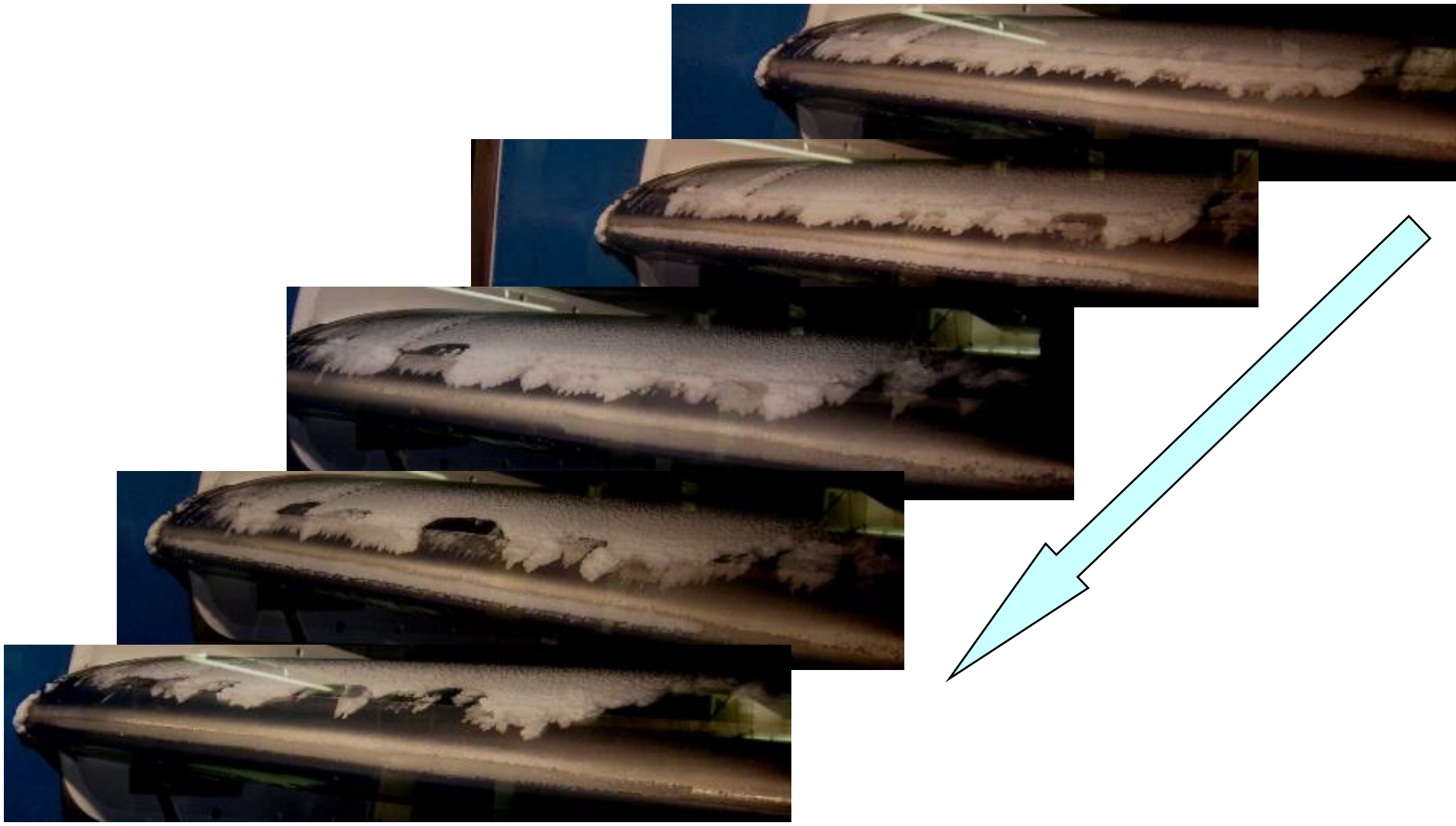
IWT 1DD Narrow

Configuration: 100.33 m/sec Cruise @ 13000 ft, AOA 0.0
200% Flow Rate

Icing Conditions: -4 Deg. F.
.78 LWC, 30 Micron Droplets



3 Minute Continuous Operation In Maximum Intermittent (1DD)



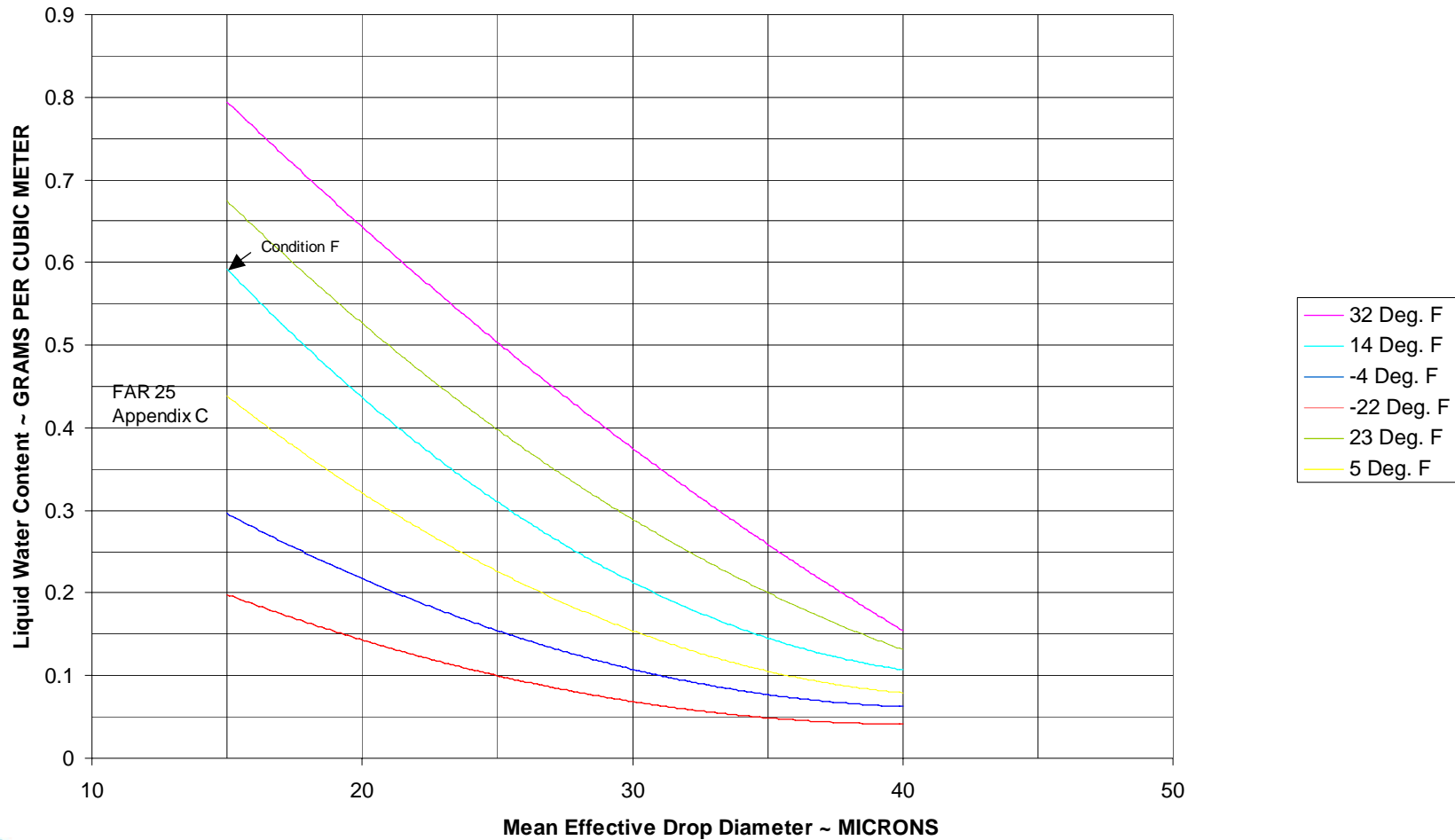
Airfoil Clears Within 1.5 Minutes



HORIZONTAL TEST POINTS

3F	Horizl. A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA -3.8	Temp C/F -10/14	LWC .6 .731	Drop dia 15	Time cont
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CONTINUOUS MAXIMUM ICING

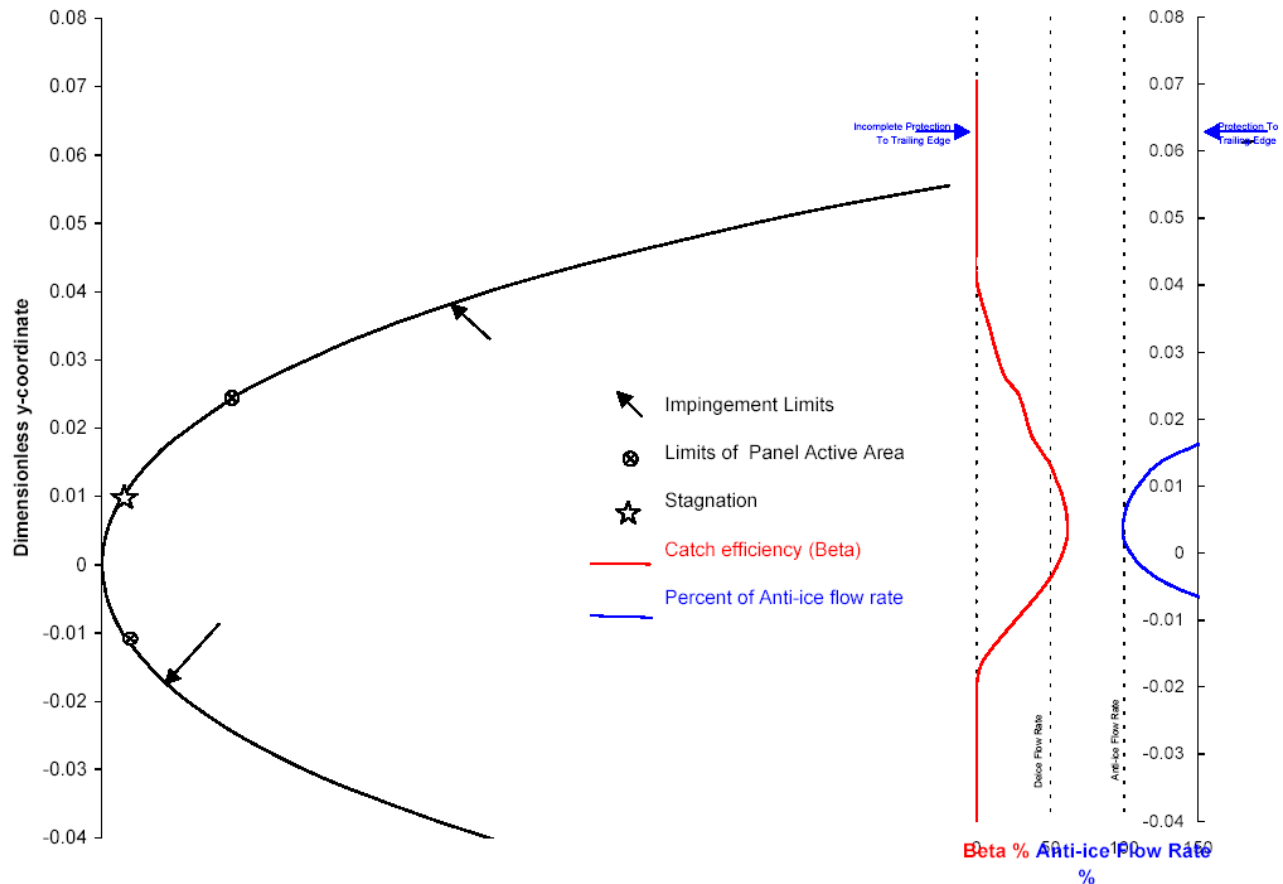


Test Point Analysis (3F)

IWT 3F Narrow

Configuration: 100.33 m/sec Cruise @ 13000 ft, AOA -3.8
100% Flow Rate

Icing Conditions: 14 Deg. F.
.6 LWC, 15 Micron Droplets

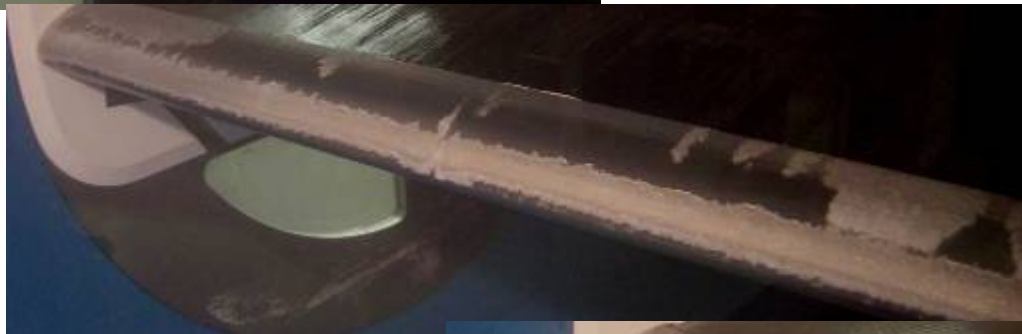
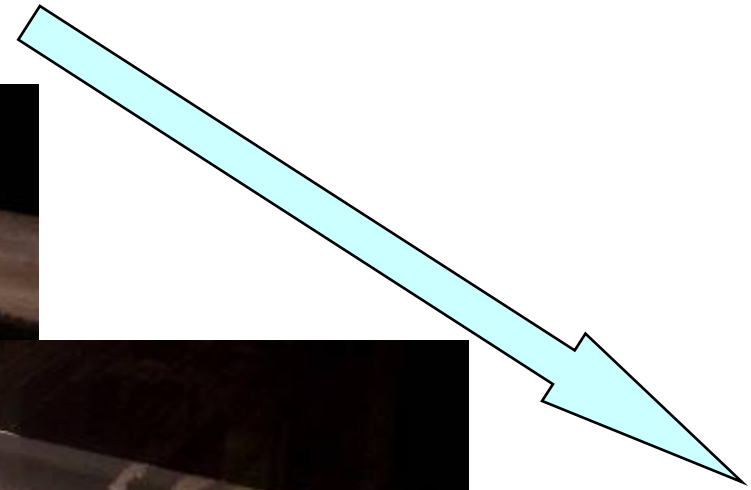


Test Continuing After 2 Minute Delayed Activation

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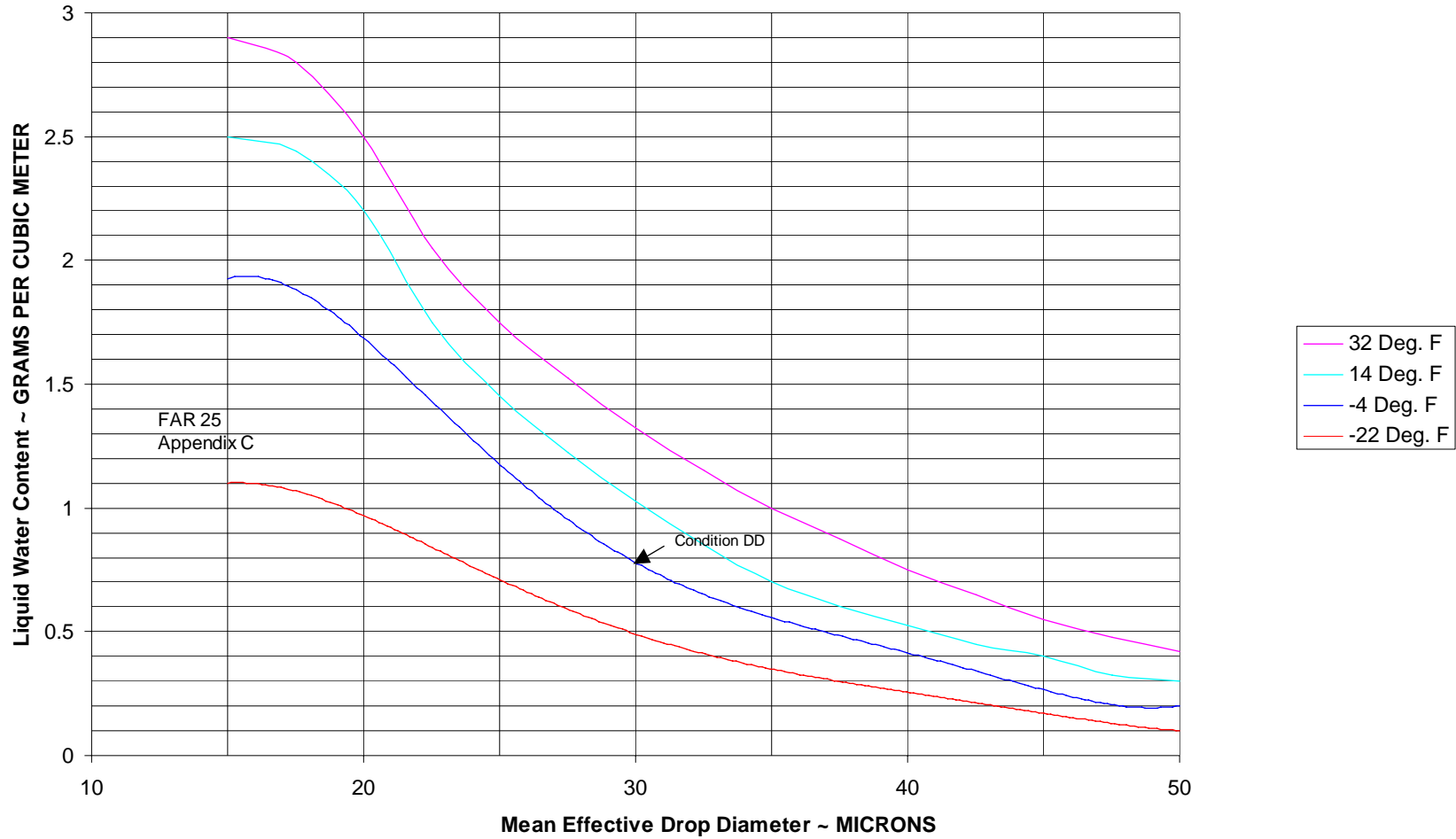


Airfoil Clears Within 1.5 Minutes



3DD	Horiz A	Cruise	Alt ft 13000	EAS mph 183	TAS M/s 100.33	AOA 0.0	Temp C/F- 20/-4	LWC .78 .95	Drop dia 30	Time 0.8 min
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INTERMITTENT MAXIMUM ICING CONDITIONS

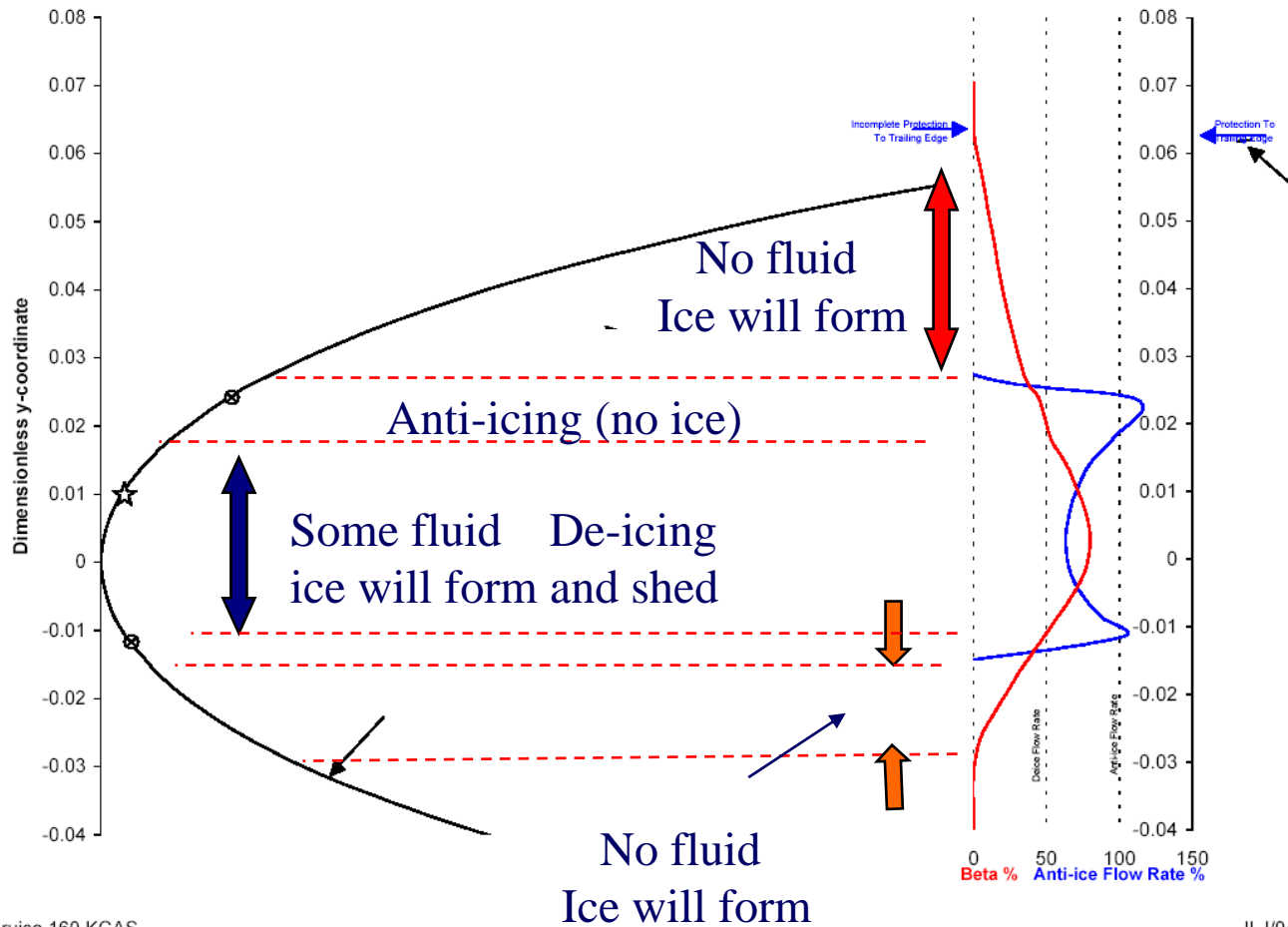


Test Point Analysis (3DD)

IWT 3DD Narrow

Configuration: 100.33 m/sec Cruise @ 13000 ft, AOA -3.8
200% Flow Rate

Icing Conditions: -4 Deg. F.
.78 LWC, 30 Micron Droplets



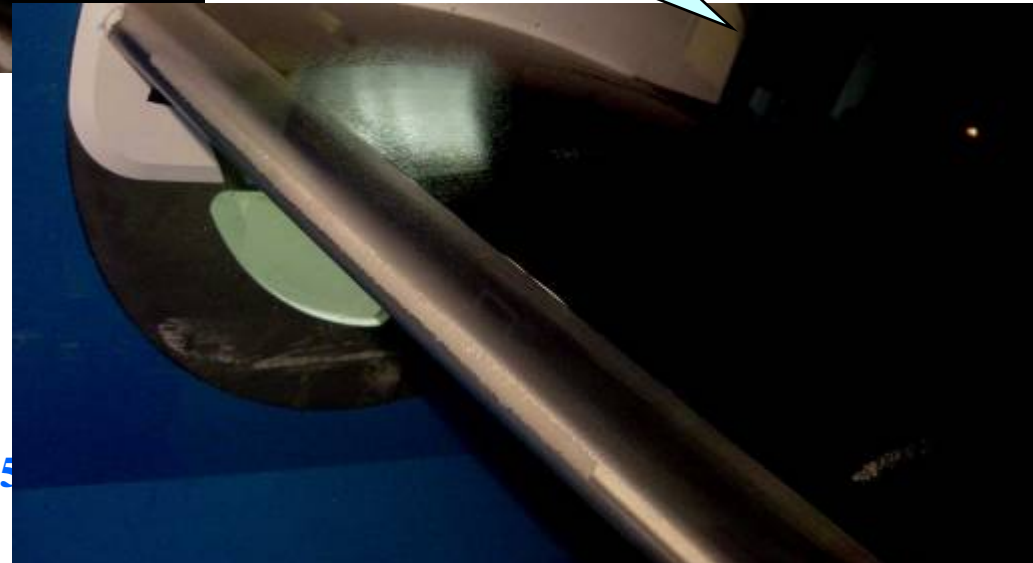
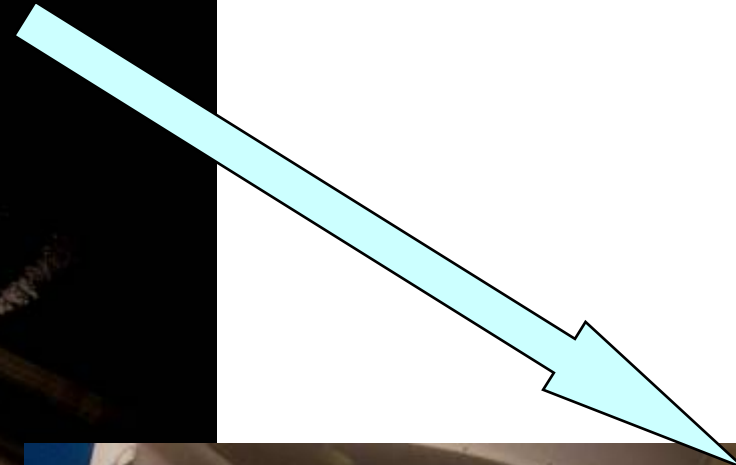
Cruise 160 KCAS

JLJ/04

.8 Minute Operation At Normal Flow



Airfoil Clears Within 1.5 Minutes

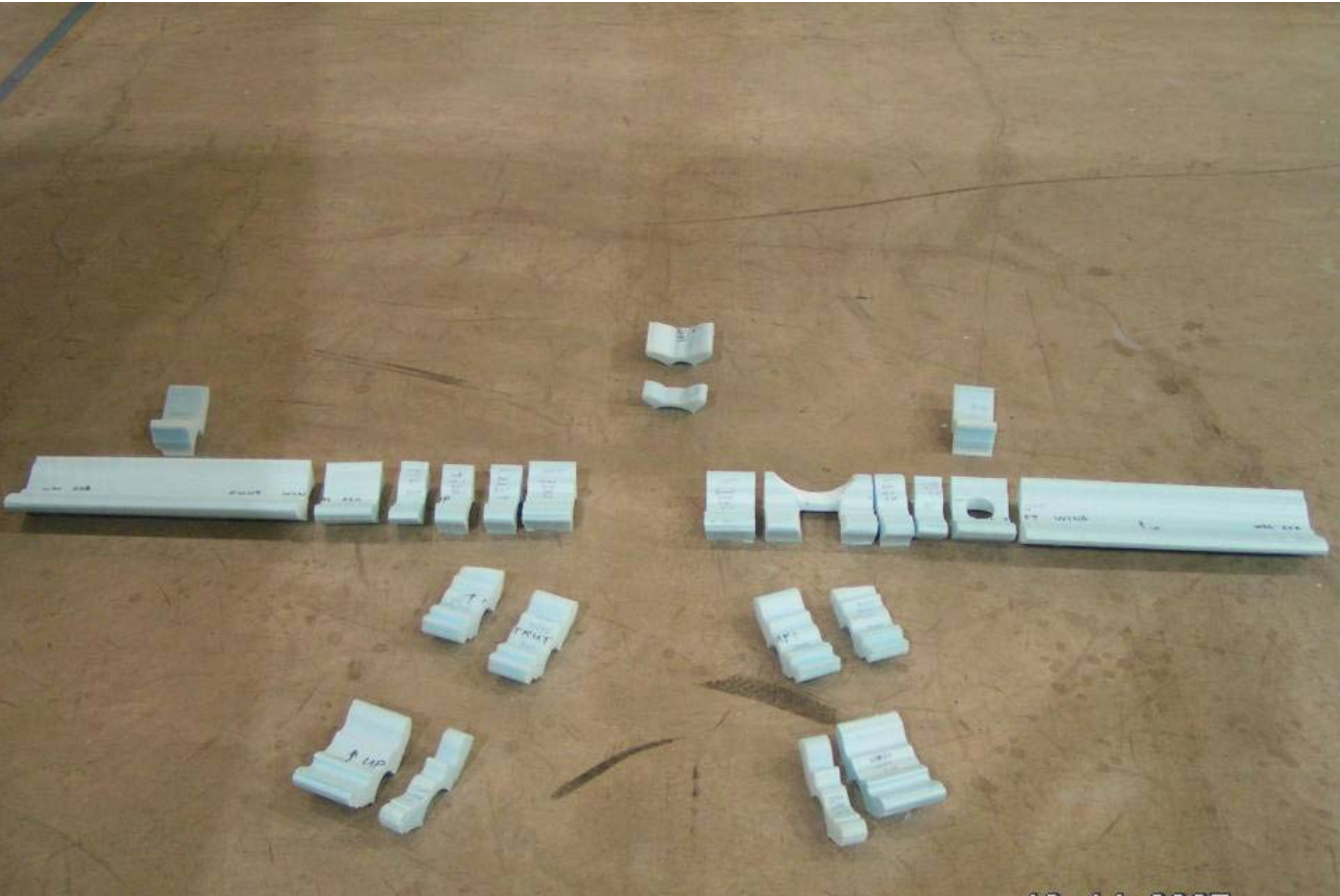


EXAMPLES OF PRE-ACTIVATION ICE SHAPES

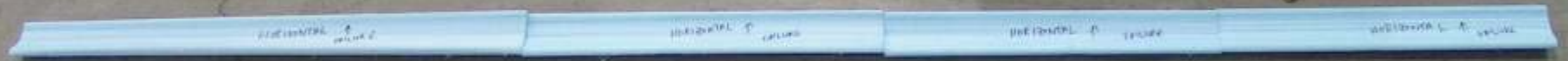


EXAMPLES OF 45 MINUTE ICE SHAPES





EXAMPLES OF ICTS ICE SHAPES



EXAMPLES OF FAILURE ICE SHAPES





EXAMPLES OF NATURAL ICE SHAPES











