Suggestions for simulation cases

Overall Organization

- Recall that we decided to organize the cases along the following categories:

1. Ice shapes on 3D geometries
   - Includes swept wings, rotors, fans, propellers.
2. Ice shapes on 2D geometries
   - Includes low-Re ice shapes, high-Re ice shapes and different icing tunnels.
3. Collection efficiency on 2D and 3D geometries

Ice shapes on 3D geometries

Ice shapes on 3D geometries

- 3D Scanned ice shapes on 36-in swept NACA0012 from NASA IRT
- AIAA 2014-2613

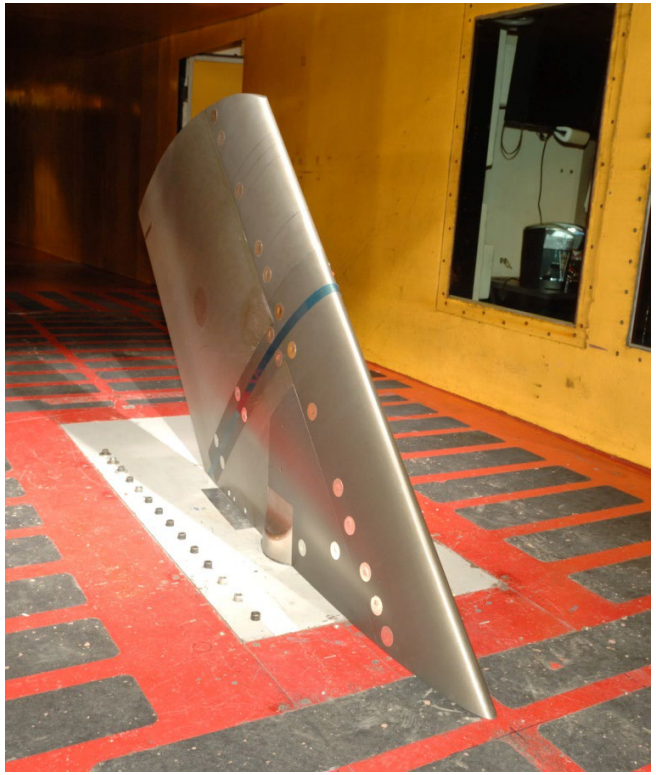
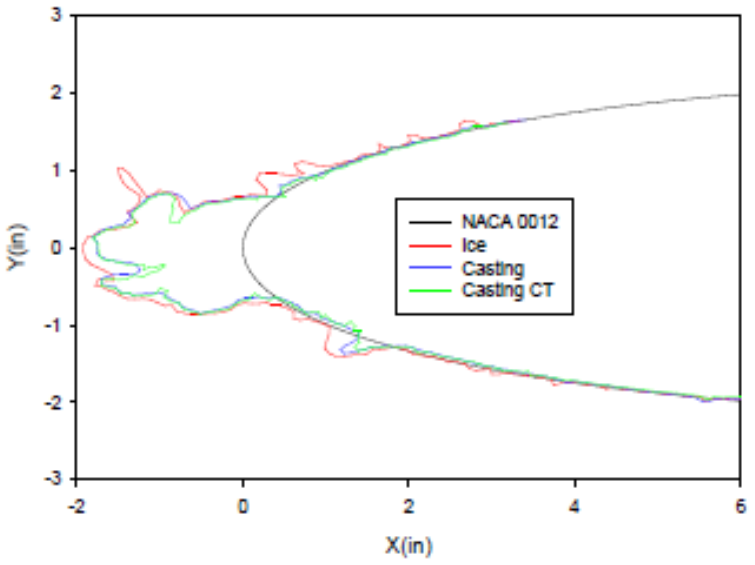


Table 3 Ice shapes tested for swept wing

Ice Shape	Run Number	Λ (°)	α (°)	V (kts)	LWC (g/m^3)	MVD (μm)	T_0 (°C)	Spray (min)
Complete Scallop	AF2037	45	0	200	0.54	32.6	-6.7	19
Incomplete Scallop	AF2032	30	4	200	0.6	15	-6.7	15
Roughness	AF2029	30	4	200	0.45	32	-7.2	3
Rime	AF2028	30	4	200	0.6	15	-17.8	15

a) Water-tight scan

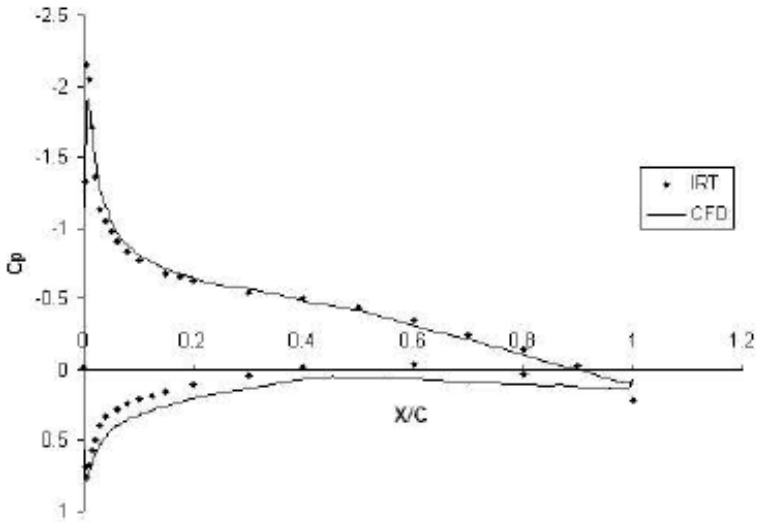


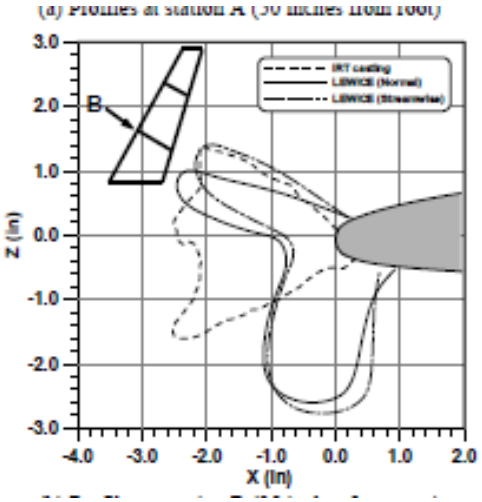
b) Cross sectional cuts

Ice shapes on 3D geometries

- Ice shapes on swept GLC305 wing from NASA IRT (no scan data, only tracings)
- AIAA 2003-730; DOT/FAA/AR-05/39

Icing Condition	Description	Angle of Attack (degrees)	Velocity (mph)	Total Temperature (°F)	LWC (g/m^3)	MVD (μm)	Ice Accretion Time (min)
1	Complete Scallop	4	250	25	0.68	20	10
2	Incomplete Scallop	4	150	25	0.65	20	10
3	Scaled to 2D test results	6	201.3	11.7	0.51	14.5	5
4	Complete Scallop – short duration	4	250	25	0.68	20	2
5	Complete Scallop – long duration	4	250	25	0.68	20	22.5
6	22.5 minute failed IP – App. C	4	150	27	0.46	20	22.5

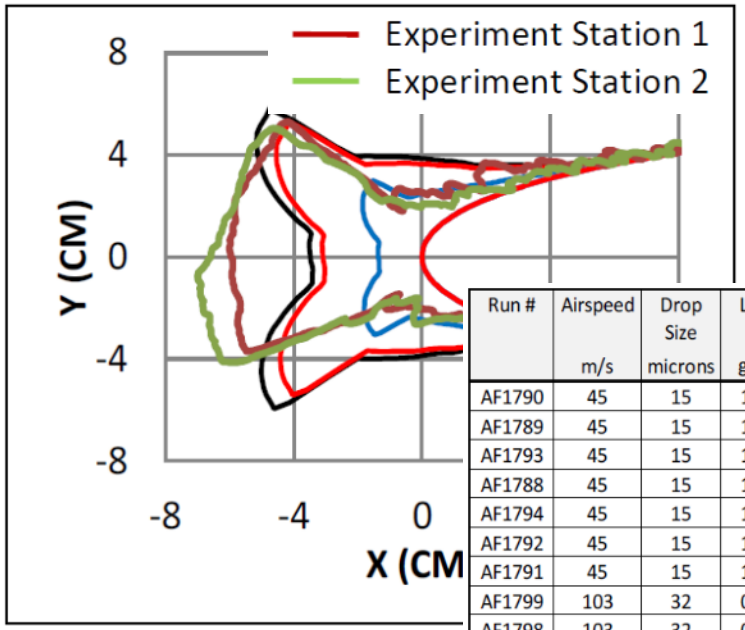




AIAA-2014-2200, Bidwell, C. S., "Icing Analysis of a Swept NACA 0012 Wing Using LEWICE3D Version 3.48"

Experiment Details:

- NASA Glenn IRT
- NACA 0012 wing
  - chord length approx. 3 ft (0.9 m)
  - span length approx. 40 inches (1 m)
  - 30° sweep
  - 45° sweep
- Conditions ranging from Rime to Glaze for two different inertia values



Data Available:

- ice mass
- ice density (calculated from tracings)
- ice shape tracings (2 locations)
- surface pressure
- ice shape photos

Concerns:

- tracings must be extracted from plots
- Colin has retired from NASA, so not sure how easy it is to get additional data

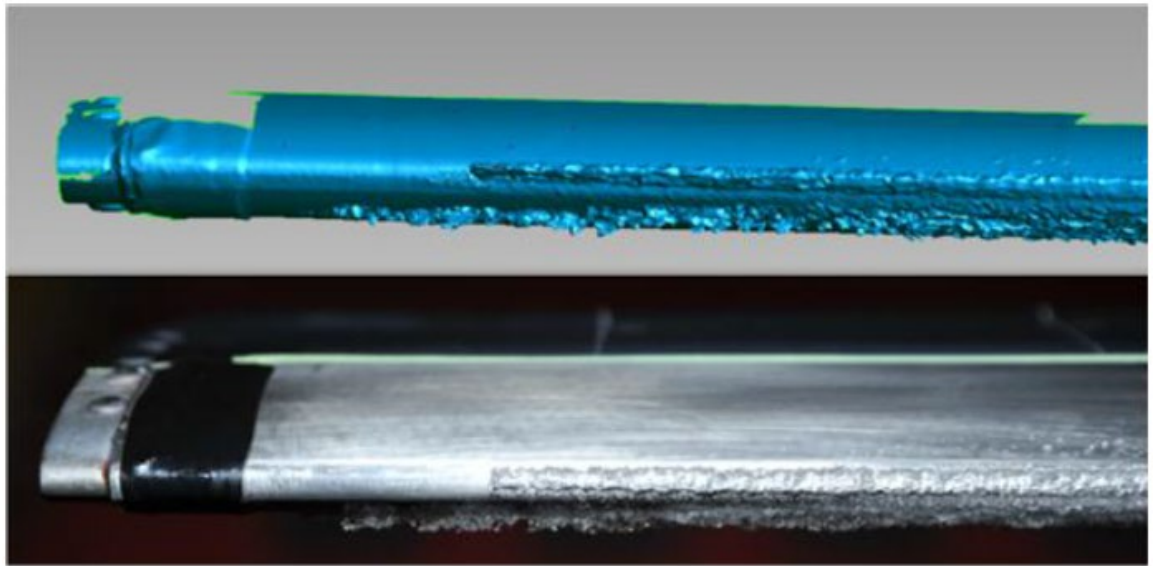
Run #	Airspeed m/s	Drop Size microns	LWC g/m^3	Static Temperature K	Experimental Ice Mass per Unit Length g/m	Corrected Experimental Ice Mass per Unit Length g/m	LEWICE3D Ice Mass per Unit Length g/m	Experimental Void Density Kg/m^3
AF1790	45	15	1.50	257	380	454	536	325
AF1789	45	15	1.50	259	376	483	546	323
AF1793	45	15	1.50	262	416	491	560	407
AF1788	45	15	1.50	265	536	557	581	380
AF1794	45	15	1.50	265	526	594	581	351
AF1792	45	15	1.50	267	702	706	582	374
AF1791	45	15	1.50	269	534	538	579	380
AF1799	103	32	0.45	257	1476	1582	1440	437
AF1798	103	32	0.45	261	1467	1576	1475	328
AF1797	103	32	0.45	263	1339	1432	1497	283
AF1796	103	32	0.45	265	1340	1438	1539	367
AF1795	103	32	0.45	266	1449	1599	1548	402

Ice shapes on 3D geometries

- Ice shapes on a helicopter tail rotor from NASA IRT
- AIAA 2014-2612
- Need to verify availability of geometry and test data

Table 1 Summary of Run Conditions

Run Condition	Run Number	Airspeed (knots)	RPM	MVD (μm)	LWC (g/m^3)	Collective. (deg.)	Static Temp. (°F)	Spray Time (min.)
Cold blade	29	60	1200	15	0.50	2	14	3:00
Cold blade	47	60	2100	15	0.50	2	14	1:00
Cold blade	53	60	1200	15	0.50	2	14.2	3:00
Cold blade	54	60	2100	15	0.50	8	15	1:00
Self shed	55	150	2100	15	0.50	2	16.9	1:30
Chordwise de-ice	65	60	2100	15	0.50	5	-4	5:18
SLD Cold Blade	68	150	2100	110	0.50	5	-4	1:00
Spanwise de-ice	76	150	2100	15	0.50	5	-4	5:22
SLD Cold Blade	81	150	2100	110	0.50	2	-4	1:00
Self shed	82	60	2100	15	0.50	2	14	2:30
Self shed	83	60	2100	15	0.50	2	9	3:00



Ice shapes on 3D geometries

- Icing on small scale fan from Iowa State University
- AIAA 2018-3013
- Need to verify availability of geometry and test data

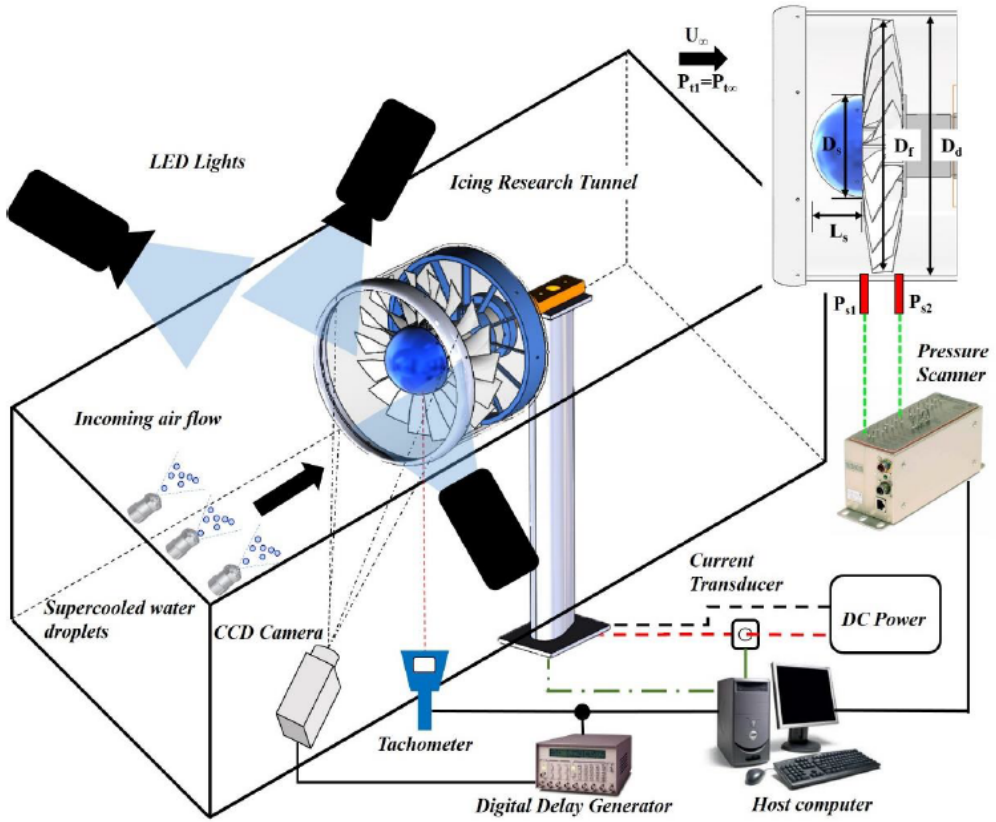
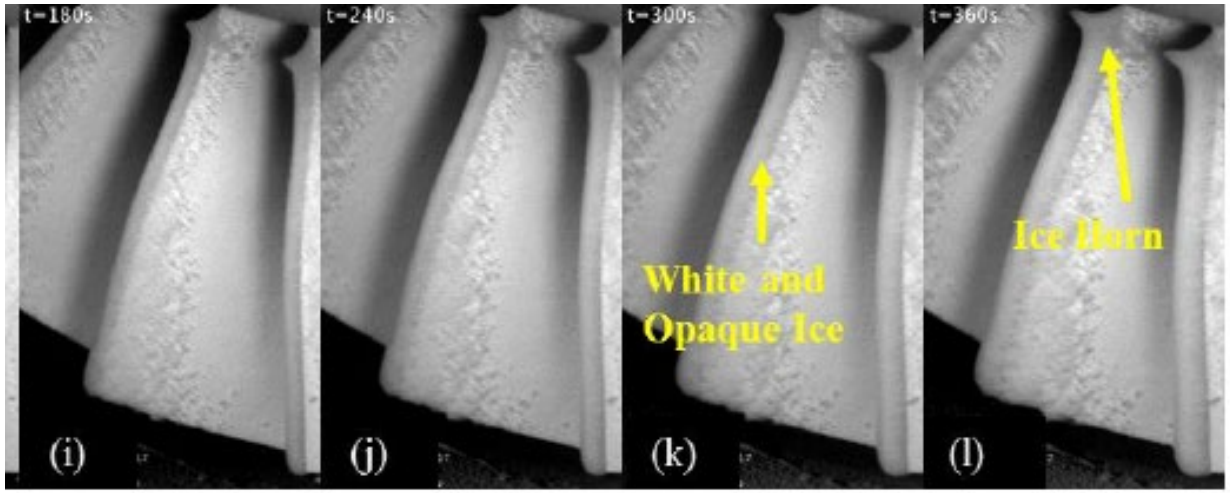


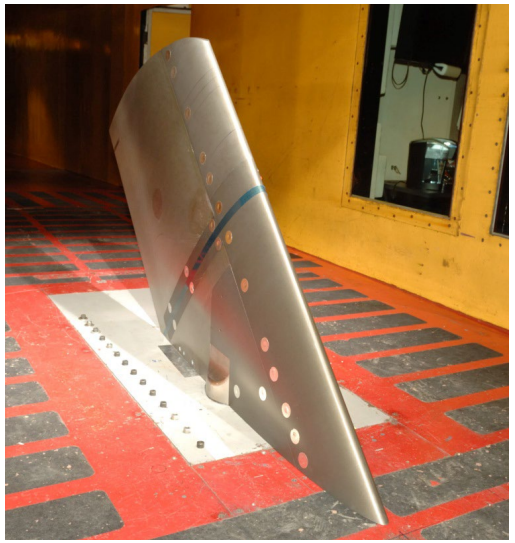
Table 1. The icing test conditions

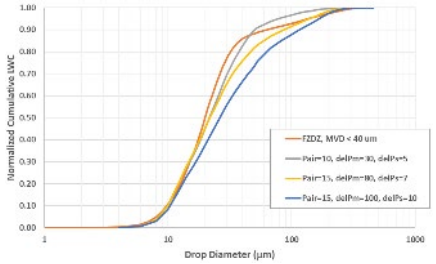
Case	T∞ (°C)	LWC (g/m^3)	Icing Time (s)	MVD (μm)	n (rpm)	U∞ (m/s)
1	-5°C	0.5	360			
2	-5°C	1.0	180			
3	-5°C	2.0	90			
4	-10°C	0.5	360			
5	-10°C	1.0	180	20~100	2500	15
6	-10°C	2.0	90			
7	-15°C	0.5	360			
8	-15°C	1.0	180			
9	-15°C	2.0	90			

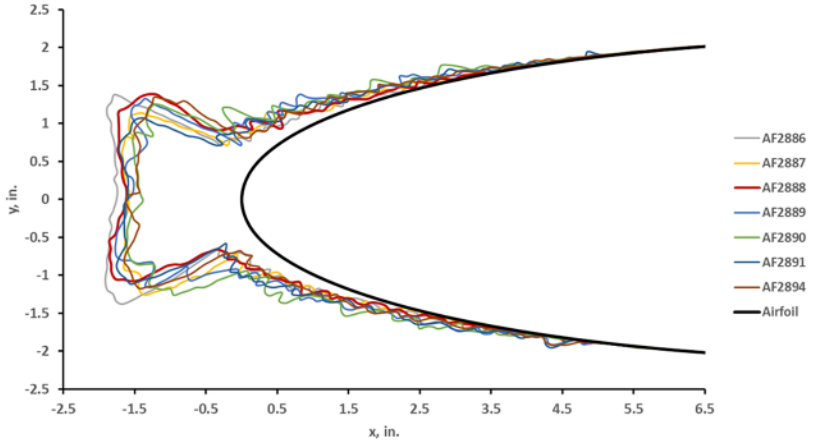


Ice shapes on 3D geometries

- 3D Scanned ice shapes on 36-in swept NACA0012 from NASA IRT
- AIAA-2020-2814







Test Results (*Reference AF2173*)

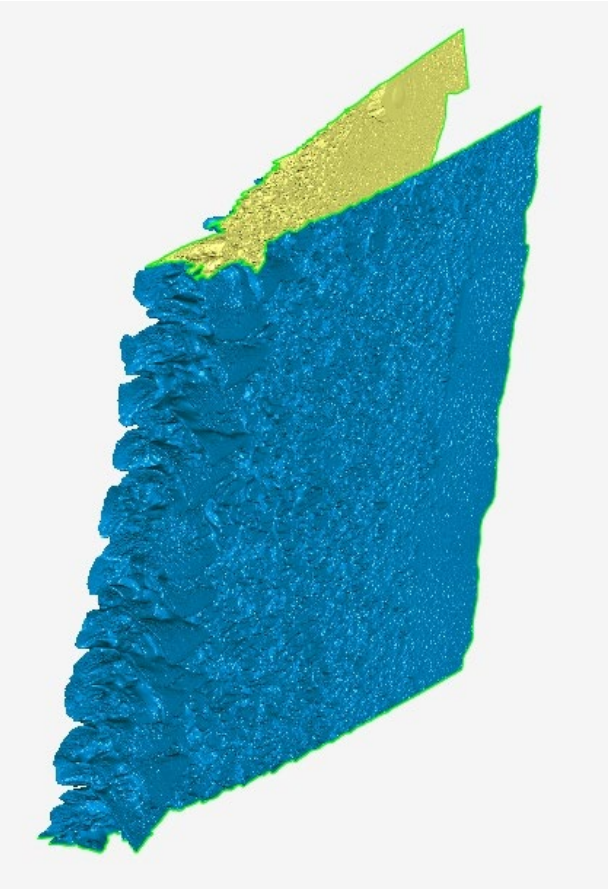
Run Number	V (kts)	MVD (μm)	LWC (g/m³)	Ts (°C)	Tt (°C)	Time (min)	$\beta_0 Ac$	n_0	Mod-1 P_{air} (psig)	Mod-1 delP (psid)	Std P_{air} (psig)	Std delP (psid)	Mass g	Volume in³	ρ_{eff} (g/cm³)
AF2881	224.0	20.00	0.50	-10.0	-3.4	17.7	1.33	0.40	19.4	49.9			365.5	36.1	0.62
AF2882	224.0	21.40	1.12	-15.2	-8.5	7.7	1.33	0.40			15.6	11.6	322.1	28.1	0.70
AF2883	224.0	21.40	1.12	-15.2	-8.5	7.7	1.33	0.40	10.0	30.0	10.0	5.0	340.8	29.0	0.72
AF2884	224.0	21.30	1.54	-17.5	-10.9	5.6	1.33	0.40	15.0	80.0	15.0	7.0	366.7	30.2	0.74
AF2885	224.0	25.00	1.85	-19.4	-12.8	4.4	1.33	0.40	15.0	100.0	15.0	10.0	366.5	29.8	0.75
AF2893	224.0	21.30	1.54	-17.5	-10.9	5.6	1.33	0.40	15.0	80.0	15.0	7.0	346.4	29.7	0.71

Test Results (*Reference AF2175*)

Run Number	V (kts)	MVD (μm)	LWC (g/m³)	Ts (°C)	Tt (°C)	Time (min)	$\beta_0 Ac$	n_0	Mod-1 P_{air} (psig)	Mod-1 delP (psid)	Std P_{air} (psig)	Std delP (psid)	Mass g	Volume in³	ρ_{eff} (g/cm³)
AF2886	150.0	20.00	0.64	-7.5	-4.5	22.5	1.33	0.40	19.5	50.5			368.3	34.4	0.65
AF2887	150.0	21.40	1.43	-12.7	-9.7	9.7	1.33	0.40			15.7	11.7	329.9	29.6	0.68
AF2888	150.0	21.40	1.43	-12.7	-9.7	9.7	1.33	0.40	10.0	30.0	10.0	5.0	351.0	31.4	0.68
AF2889	150.0	21.30	1.96	-15.1	-12.1	7.1	1.33	0.40	15.0	80.0	15.0	7.0	359.3	31.2	0.70
AF2890	150.0	25.00	2.36	-17.3	-14.3	5.4	1.33	0.40	15.0	100.0	15.0	10.0	373.4	31.9	0.71
AF2891	150.0	21.30	1.96	-15.1	-12.1	7.1	1.33	0.40	15.0	80.0	15.0	7.0	384.7	31.9	0.74
AF2894	150.0	21.30	1.96	-15.1	-12.1	7.1	1.33	0.40	15.0	80.0	15.0	7.0	362.1	31.7	0.70

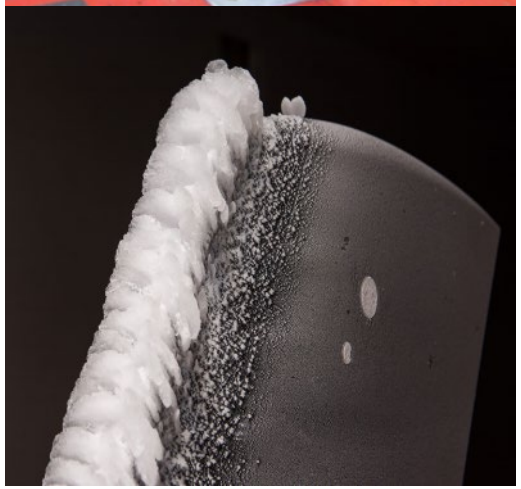
Test Results (*Reference AF2178*)

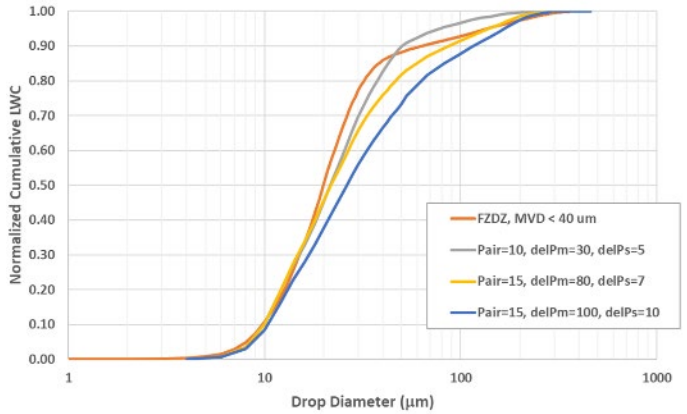
Run Number	V (kts)	MVD (μm)	LWC (g/m³)	Ts (°C)	Tt (°C)	Time (min)	$\beta_0 Ac$	n_0	Mod-1 P_{air} (psig)	Mod-1 delP (psid)	Std P_{air} (psig)	Std delP (psid)	Mass g	Volume in³	ρ_{eff} (g/cm³)
AF2892	224.0	20.00	0.50	-13.4	-6.8	17.7	1.33	0.60	19.4	49.9			291.2	26.8	0.66
AF2895	224.0	21.40	1.12	-21.7	-15.1	7.7	1.33	0.60			15.6	11.6	307.2	26.1	0.72
AF2896	224.0	21.30	1.54	-25.5	-18.8	5.6	1.33	0.60	15.0	80.0	15.0	7.0	367.0	29.9	0.75
AF2897	224.0	21.30	1.54	-25.5	-18.8	5.6	1.33	0.60	15.0	80.0	15.0	7.0	361.1	29.4	0.75
AF2898	224.0	21.40	1.12	-21.7	-15.1	7.7	1.33	0.60	10.0	30.0	10.0	5.0	323.5	27.6	0.72

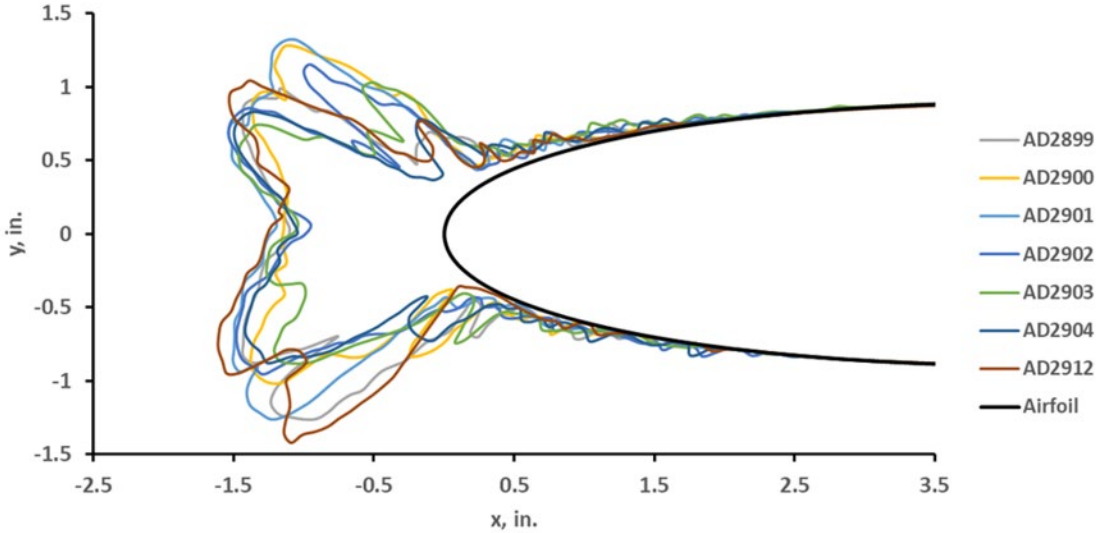


Ice shapes on 3D geometries

- 3D Scanned ice shapes on 15-in swept NACA0012 from NASA IRT
- AIAA-2020-2814







Test Results (*Reference AD2787*)

Run Number	V (kts)	MVD (μm)	LWC (g/m³)	Ts (°C)	Tt (°C)	Time (min)	$\beta_0 Ac$	n_0	Mod-1 p_{air} (psig)	Mod-1 Dp (psid)	Std p_{air} (psig)	Std Dp (psid)	Mass g	Volume in³	ρ_{eff} (g/cm³)
AD2899	217.4	20.00	0.75	-10.1	-3.9	10.0	3.17	0.38	34.3	121.4			142.4	11.9	0.73
AD2900	217.4	21.40	1.14	-12.6	-6.4	6.4	3.16	0.38			15.6	11.6	140.0	12.4	0.69
AD2901	217.4	21.40	1.14	-12.6	-6.4	6.4	3.16	0.38	10.0	30.0	10.0	5.0	149.7	13.2	0.69
AD2902	217.4	21.30	1.56	-14.7	-8.4	4.7	3.16	0.38	15.0	80.0	15.0	7.0	142.2	11.9	0.73
AD2903	217.4	25.00	1.88	-16.3	-10.0	3.8	3.16	0.38	15.0	100.0	15.0	10.0	145.5	12.3	0.72
AD2904	217.4	21.30	1.56	-14.7	-8.4	4.7	3.16	0.38	15.0	80.0	15.0	7.0	142.1	11.8	0.73
AD2912	217.4	21.40	1.14	-12.6	-6.4	6.4	3.16	0.38	10.0	30.0	10.0	5.0	152.7	13.4	0.70

Test Results (*Reference AD2789*)

Run Number	V (kts)	MVD (μm)	LWC (g/m³)	Ts (°C)	Tt (°C)	Time (min)	$\beta_0 Ac$	n_0	Mod-1 p_{air} (psig)	Mod-1 Dp (psid)	Std p_{air} (psig)	Std Dp (psid)	Mass g	Volume in³	ρ_{eff} (g/cm³)
AD2905	217.4	20.00	0.75	-14.3	-8.1	10.0	3.16	0.60	34.3	121.4			144.8	13.0	0.68
AD2906	217.4	21.40	1.14	-18.6	-12.3	6.4	3.16	0.60			15.6	11.6	135.3	11.2	0.74
AD2907	217.4	21.40	1.14	-18.6	-12.3	6.4	3.16	0.60	10.0	30.0	10.0	5.0	145.3	11.9	0.75
AD2908	217.4	21.30	1.56	-22.1	-15.8	4.7	3.16	0.60	15.0	80.0	15.0	7.0	140.2	11.8	0.73
AD2909	217.4	25.00	1.88	-24.7	-18.5	3.8	3.16	0.60	15.0	100.0	15.0	10.0	143.0	11.1	0.79
AD2910	217.4	21.30	1.56	-22.1	-15.8	4.7	3.16	0.60	15.0	80.0	15.0	7.0	144.6	12.0	0.74
AD2911	217.4	21.40	1.14	-18.6	-12.3	6.4	3.16	0.60	10.0	30.0	10.0	5.0	148.7	12.3	0.74

Icing Simulation Research Supporting the Ice-Accretion Testing of Large-Scale Swept-Wing Models

- CRM Inboard Hybrid Model
- CRM Midspan Hybrid Model
- 3D ice shape scans
- Re= 10 – 20 10^6 / Ma=0.2
- TG2418 (-3.7C)
- TG2408 (-17.3C)
- TH2464 (-3.6C)
- TH2431 (-17.5C)

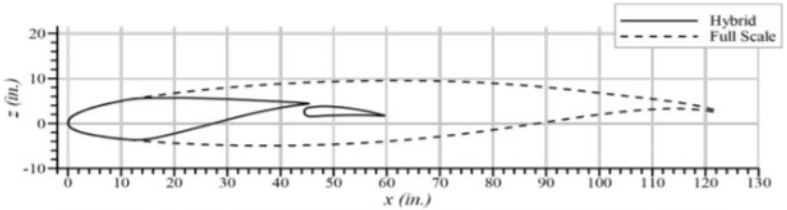


Figure 1.2.—Schematic comparison of a hybrid and a full-scale section of the CRM65.

TABLE 4.2.—ICING CONDITIONS FOR CRM65 WB CONFIGURATION

Case	Flight phase	Weight	AoA, degree	Static pres., kPa	Mach	TAS, knots	Total temperature, °C	Static temperature, °C	MVD, μm	LWC, g/m³	Exposure time, minute
WB33 T-4	Hold	LGW	3.7	69.7	0.36	232	3.2	–4.0	20	0.55	45.0
WB33 T-6	Hold	LGW	3.7	69.7	0.36	231	1.1	–6.0	20	0.51	45.0
WB33 T-13	Hold	LGW	3.7	69.7	0.36	228	–6.1	–13.0	20	0.36	45.0
WB33 T-25	Hold	LGW	3.7	69.7	0.36	223	–18.4	–25.0	20	0.17	45.0
WB41 T-6	Hold	HGW	4.4	84.3	0.35	225	0.6	–6.0	20	0.51	45.0
WB41 T-13	Hold	HGW	4.4	84.3	0.35	222	–6.6	–13.0	20	0.36	45.0
WB41 T-25	Hold	HGW	4.4	84.3	0.35	217	–18.9	–25.0	20	0.17	45.0
WB52 T-6	Descent	Nominal	2.1	84.3	0.41	263	3.1	–6.0	20	0.51	4.0
WB52 T-13	Descent	Nominal	2.1	84.3	0.41	259	–4.1	–13.0	20	0.36	4.0
WB52 T-25	Descent	Nominal	2.1	84.3	0.41	253	–16.5	–25.0	20	0.17	4.1

TABLE 4.3.—ICING CONDITIONS FOR CRM65 WB CONFIGURATION

Ice type	Run no.	Repeat run no.	AoA, degree	Flap, degree	Speed, knots	Ps, psia	Ts, °C	MVD, μm	LWC, g/m³	Spray time, minute	Mach number	Alt., feet
Inboard Model												
Temperature sweep	TG2418	TG2409	3.7	13.8	129	13.77	–3.7	25.0	1.00	29.0	0.20	1767
	TG2408	----------	3.7	14.1	129	14.01	–17.3	25.0	1.00	29.0	0.21	1316
	TG2415	TG2412	3.7	14.1	130	14.08	–26.2	25.0	1.00	29.0	0.21	1168
Higher AoA	TG2417	----------	4.4	13.8	129	13.75	–3.7	28.0	1.00	25.5	0.20	1808
	TG2416	----------	4.4	13.8	129	13.73	–8.6	25.0	1.00	25.5	0.20	1839
Lower AoA	TG2420	----------	2.1	14.0	130	13.91	–6.1	25.0	1.00	29.0	0.20	1501
	TG2419	----------	2.1	13.9	130	13.89	–8.6	25.0	1.00	29.0	0.20	1542
WB52 T-13[a]	TG2430	----------	2.1	14.1	130	14.05	–3.0	34.0	1.23	4.0	0.20	1229
Midspan Model												
Temperature sweep	TH2464	TH2446	3.7	24.9	129	13.93	–3.6	25.0	1.00	29.0	0.20	1458
	TH2431	----------	3.7	25.0	129	14.05	–17.5	25.0	1.00	29.0	0.21	1229
	TH2459	TH2447	3.7	25.0	129	13.80	–26.2	25.0	1.00	29.0	0.21	1708
Lower AoA	TH2457	----------	2.1	14.0	130	13.80	–6.1	25.0	1.00	29.0	0.20	1714
	TH2448	----------	2.1	14.1	128	13.65	–8.6	25.0	1.00	29.0	0.20	2012
Higher speed	TH2461	----------	3.7	25.0	181	13.50	–18.0	22.0	0.40	25.6	0.29	2308
	TH2444	----------	3.7	24.8	179	13.57	–6.3	24.0	0.65	32.2	0.28	2161
Beak ice	TH2443	----------	2.1	15.9	257	12.82	–7.4	21.0	0.37	40.3	0.41	3674
WB52 T-13[b]	TH2437	----------	2.1	15.9	257	12.82	–14.7	21.0	0.36	4.0	0.41	3663
WB52 T-13[c]	TH2436	----------	2.1	14.1	129	13.99	–12.5	27.0	0.71	4.0	0.20	1352
Outboard Model												
Temperature sweep	TI2487	TI2463	3.7	14.0	130	14.02	–3.7	25.2	1.00	29.0	0.20	1291
	TI2464	----------	3.7	13.9	130	13.97	–17.4	25.2	1.00	29.0	0.21	1375
	TI2480	TI2467	3.7	14.2	129	13.87	–26.2	25.2	1.00	29.0	0.21	1582
Lower AoA	TI2483	----------	2.1	9.1	130	13.93	–6.2	25.2	0.99	29.0	0.20	1457
	TI2481	TI2473	2.1	9.1	130	13.91	–8.7	25.2	1.00	29.0	0.20	1497
Higher speed	TI2489	----------	3.7	14.2	231	13.10	–8.0	20.0	0.55	18.0	0.36	3099
	TI2494	----------	3.7	14.1	232	13.09	–18.4	19.9	0.30	25.3	0.37	3118
Beak ice	TI2475	----------	2.1	8.9	248	13.00	–7.0	21.9	0.38	30.0	0.39	3305
WB52 T-13[b]	TI2474	----------	2.0	9.0	247	12.97	–14.4	20.9	0.38	4.0	0.39	3357
WB52 T-13[c]	TI2472	----------	2.1	9.0	131	13.90	–12.5	26.9	0.71	4.0	0.21	1519

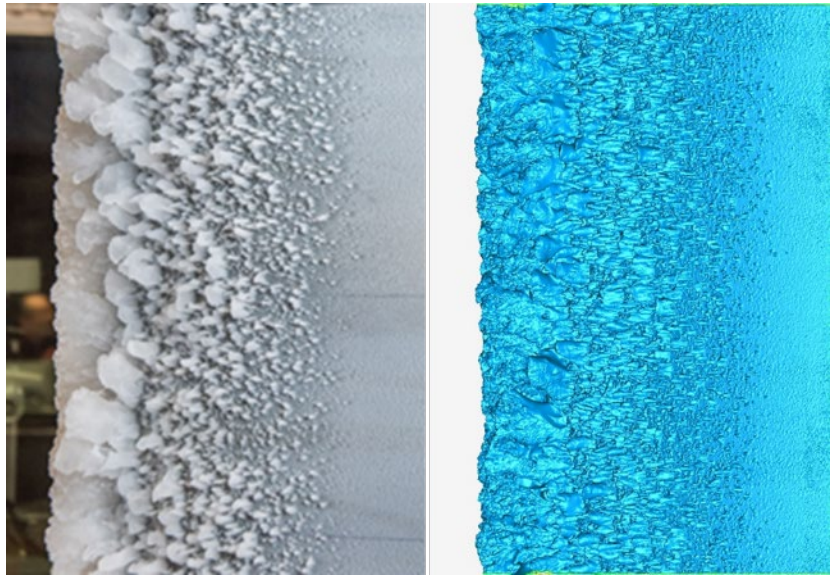
[a]Incorrect scale
[b]Reference
[c]Scale

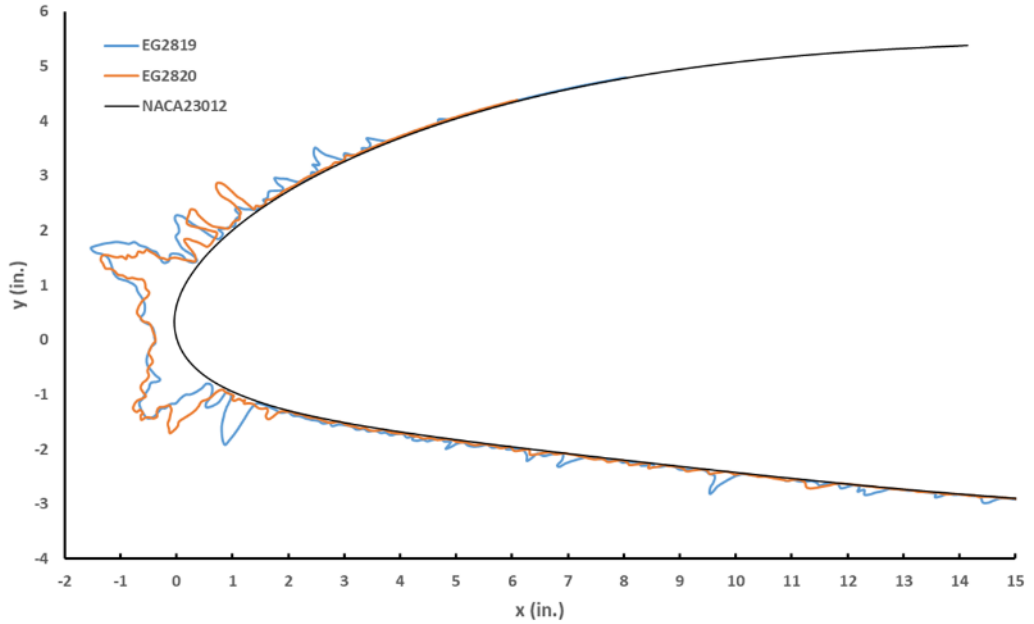
Yadlin, Monnig, Malone, Paul; NASA/CR—2018-219781 Icing Simulation Research Supporting the Ice-Accretion Testing of Large-Scale Swept-Wing Models; 2018

Ice shapes on 2D geometries

Ice shapes on 2D geometries

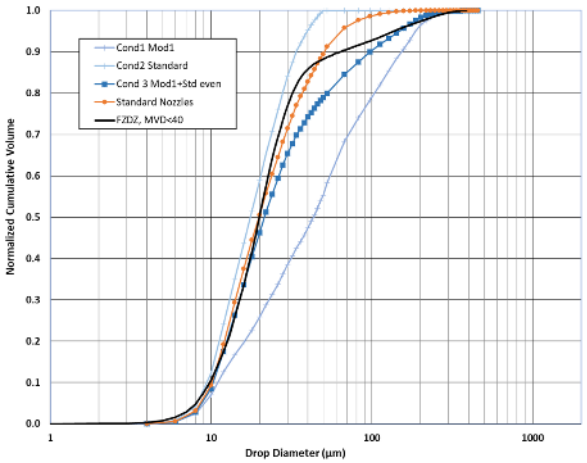
- 3D Scanned ice shapes on 72-in NACA23012 airfoil from NASA IRT
- SAE Technical Paper 2019-01-2022, 2019, doi:10.4271/2019-01-2022





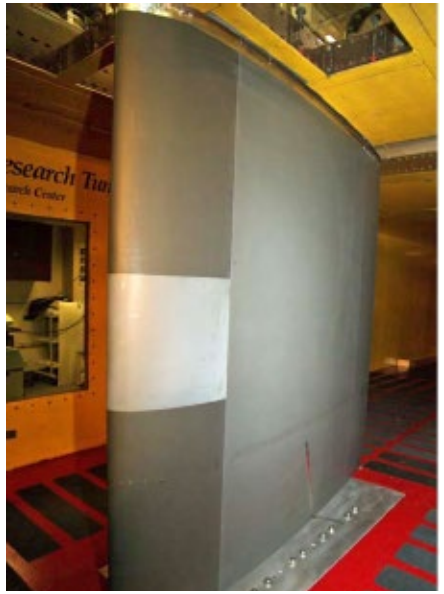
NACA23012 Airfoil Test Results											
Run Numbers	Mass bimodal (g)	Mass monomodal (g)	Δm (g)	Δm (%)	Volume bimodal (in^3)	Volume monomodal (in^3)	ΔVol. (in^3)	ΔVol. (%)	$\rho_{eff,b}$ (g/cm^3)	$\rho_{eff,m}$ (g/cm^3)	$\Delta\rho_{eff}$ (%)
EG2814/EG2815	476.8	385.0	91.8	23.8%	34.09	30.28	3.81	12.6%	0.854	0.776	10.0%
EG2816/EG2817	58.3	50.2	8.1	16.1%	3.64	3.12	0.52	16.7%	0.977	0.982	-0.5%
EG2818/EG2822	478.5	381.0	97.5	25.6%	42.57	31.09	11.48	36.9%	0.686	0.748	-8.3%
EG2819/EG2820	667.0	549.6	117.4	21.4%	52.47	43.07	9.40	21.8%	0.776	0.779	-0.4%
EG2821/EG2823	467.4	361.7	105.7	29.2%	32.65	25.29	7.36	29.1%	0.874	0.873	0.1%
EG2824/EG2825	320.6	320.0	0.6	0.2%	23.67	24.93	-1.26	-5.1%	0.827	0.783	5.5%

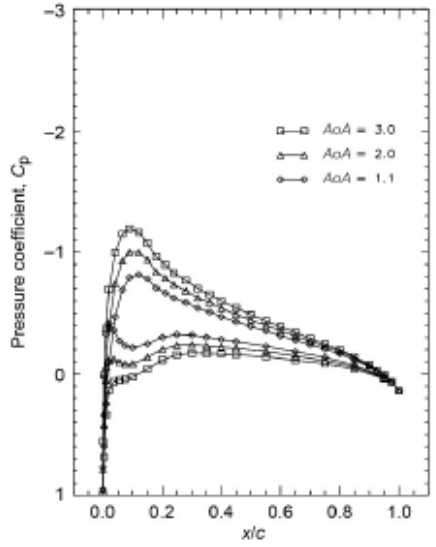
NACA23012 Airfoil Repeatability Test Results											
Run Numbers	Mass 1 (g)	Mass 2 (g)	Δm (g)	Δm (%)	Volume 1 (in^3)	Volume 2 (in^3)	ΔVol. (in^3)	ΔVol. (%)	$\rho_{eff,b}$ (g/cm^3)	$\rho_{eff,m}$ (g/cm^3)	$\Delta\rho_{eff}$ (%)
EG2814/EG2818	476.8	478.5	-1.7	-0.4%	34.09	42.56	-8.47	-19.9%	0.854	0.686	24.4%
EG2815/EG2822	385.0	381.0	4.0	1.0%	30.28	31.09	-0.81	-2.6%	0.776	0.748	3.8%
EG2819/EG2826	667.0	665.4	1.6	0.2%	52.47	51.61	0.86	1.7%	0.776	0.787	-1.4%

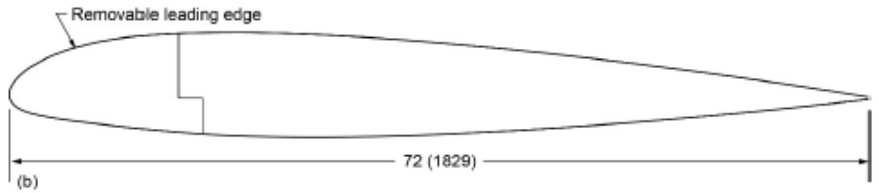


Ice shapes on 2D geometries

- Ice shapes on 6-foot chord NACA 23012 from NASA IRT
- Clean model pressure data; ice shape pictures and tracings
- NASA/TP-2016-218348



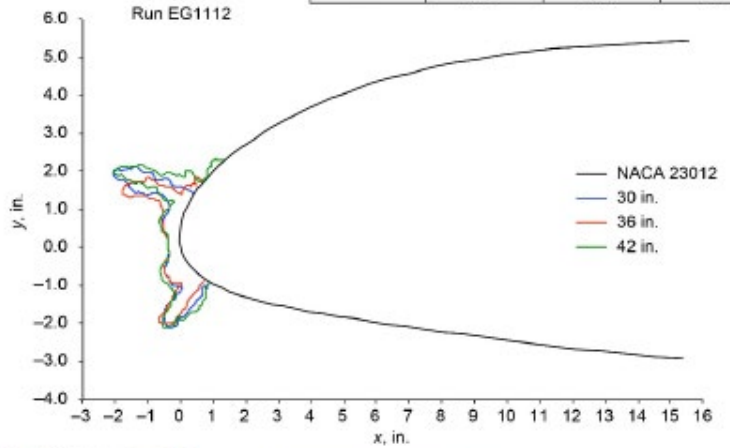


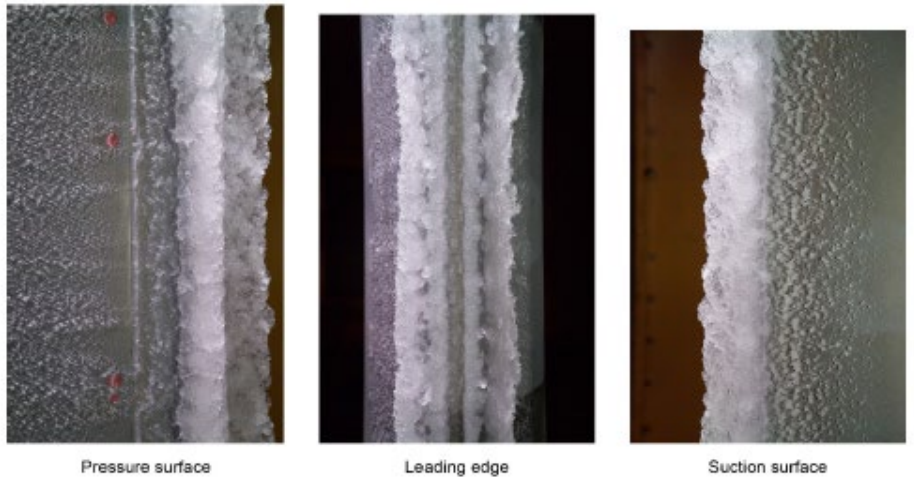


Measured ice thickness

Station	Upper max, in.	Stag. line, in.	Lower max, in.
30	2.36	0.38	1.75
36	2.09	0.39	1.75
42	2.52	0.37	1.70

V = 200 kt
T_t = −2.2 °C
T_s = −7.4 °C
AoA = 2.0°
LWC = 0.50 g/m^3
MVD = 20.0 μm
Exposure time = 22.5 min





Ice shapes on 2D geometries

- Ice shapes on 1.5-foot chord NACA 23012 from NASA IRT
- NASA/TP-2016-218348--Clean model pressure data; ice shape pictures and tracings
- AIAA 2014-2613—Ice shape pictures, tracings and 3D scans

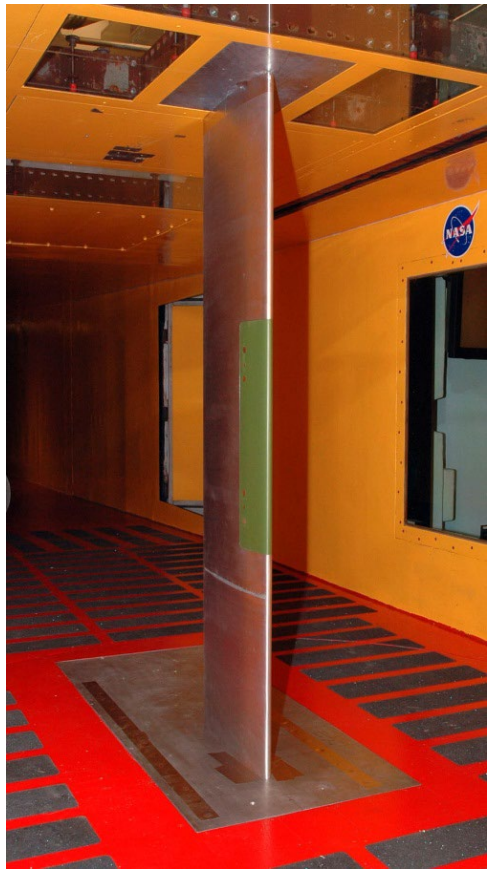
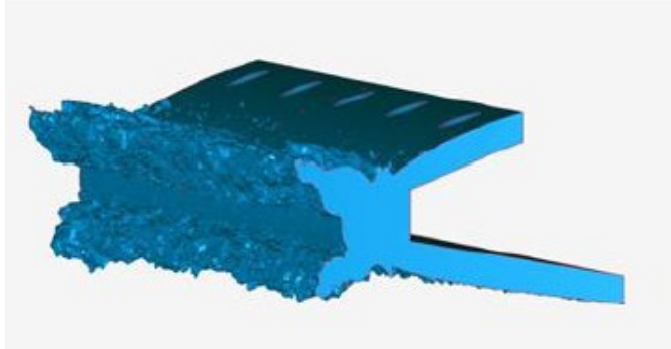
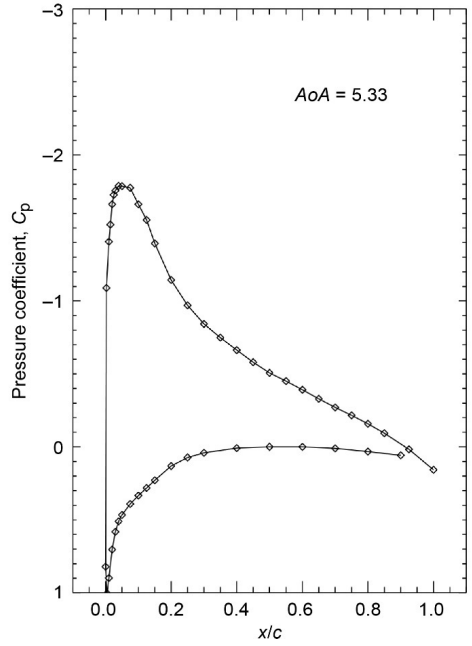
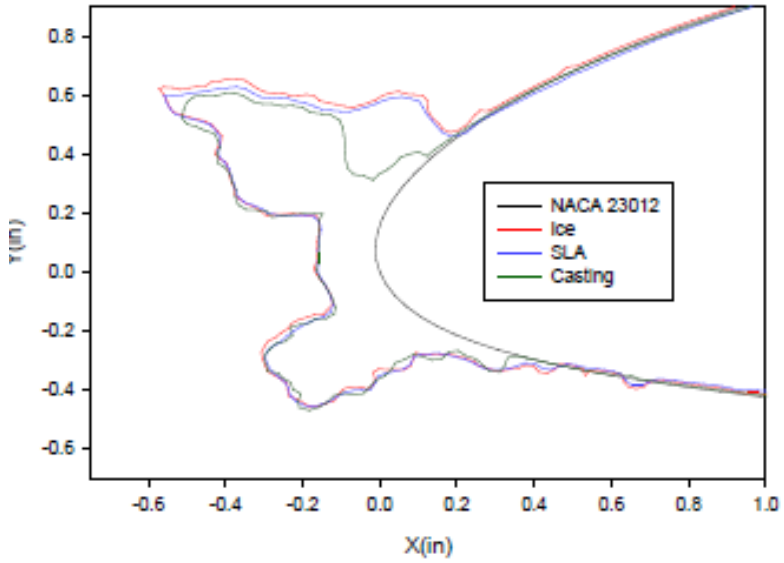


Table 1 Ice shapes tested for straight wing.

Ice Shape	Run Number	α (°)	V (kts)	LWC (g/m^3)	MVD (μm)	T_0 (°C)	Spray (min)
Glaze (Horn)	ED1978	2	200	0.75	15	-2.2	5
Roughness	ED1974	2	200	0.75	15	-2.2	0.5
Roughness	ED1983	2	200	0.4	30	-17.8	1
Rime (Streamwise)	ED1977	2	200	0.4	30	-17.8	5
Rime (Streamwise)	ED1966	5	175	0.3	15	-17.8	5
Runback (Spanwise Ridge)	ED1967	1	175	0.64	15	-4.4	9.5



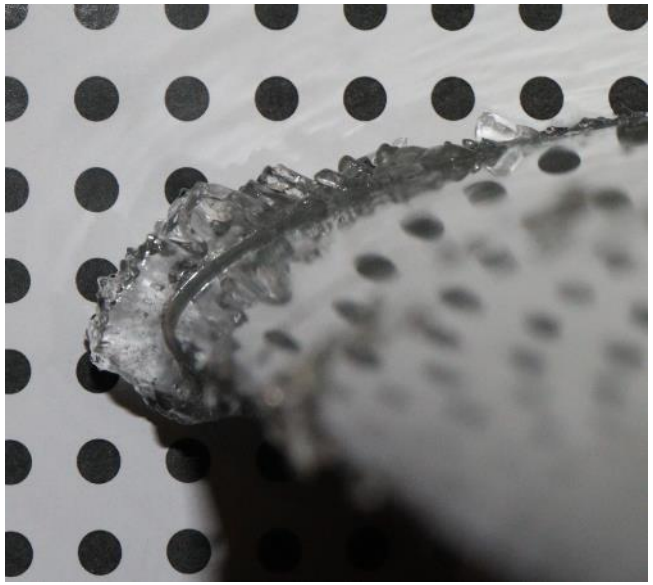


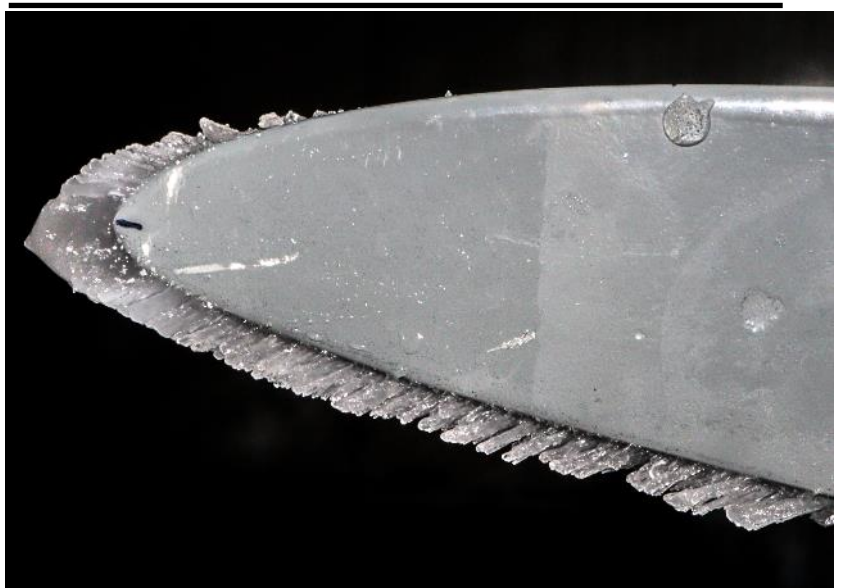


Ice shapes at low Reynolds numbers

- Icing at low Renyolds number (1×10^6) with rime, glaze, and mixed ice conditions on RG-15
- Low-speed icing wind tunnel in Finland (VTT)
- Manual hand tracings, photographs, multiple runs
- Aerodynamic performance data planned for Q4 2020

Test conditions	
Airspeed v	25 m/s
Chord c	0.45m
Temperature	[-2, -5, -10]°C
MVD	16, 26 µm
LWC	0.44 g/m³
AOA	[0, 4, 8]°





Collection efficiency

NASA/TM—2011-216945 (AIAA-2010-7675), Bidwell, C. S., "Super Cooled Large Droplet Analysis of Several Geometries Using LEWICE3D Version 3"

Drop Size (Microns)	%LWC
10.7792	0.0475
24.37238	0.0475
29.77389	0.0475
35.24709	0.0475
41.99855	0.0475
51.40099	0.0475
61.50823	0.0475
69.93255	0.0475
77.50246	0.0475
84.73027	0.0475
91.71088	0.0475
98.83237	0.0475
106.2296	0.0475
113.8977	0.0475
121.8354	0.0475
130.5719	0.0475
140.5805	0.0475
152.2594	0.0475
165.6468	0.0475
187.6024	0.0475
209.6167	0.01
226.1367	0.01
247.145	0.01
265.6669	0.005
290.3102	0.005
339.5112	0.005
391.7745	0.005

Experiment Details:

- MS-317 airfoil (chord 0.9 m)
- NLF(1)-0414 airfoil (chord 1.2 m)
- NACA 64A008 swept wing
- 3-element IRT airfoil model
- custom spray rig in IRT
- MVD 92 μm -- droplet distribution provided

Data Available:

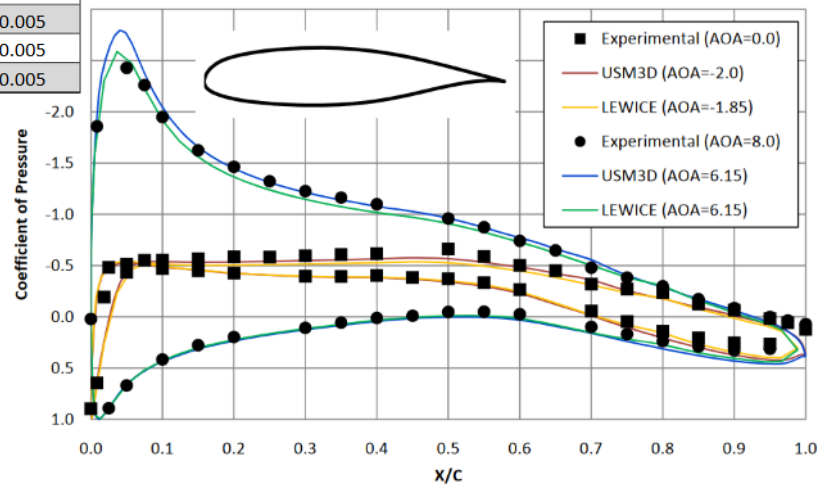
- surface pressure
- collection efficiency

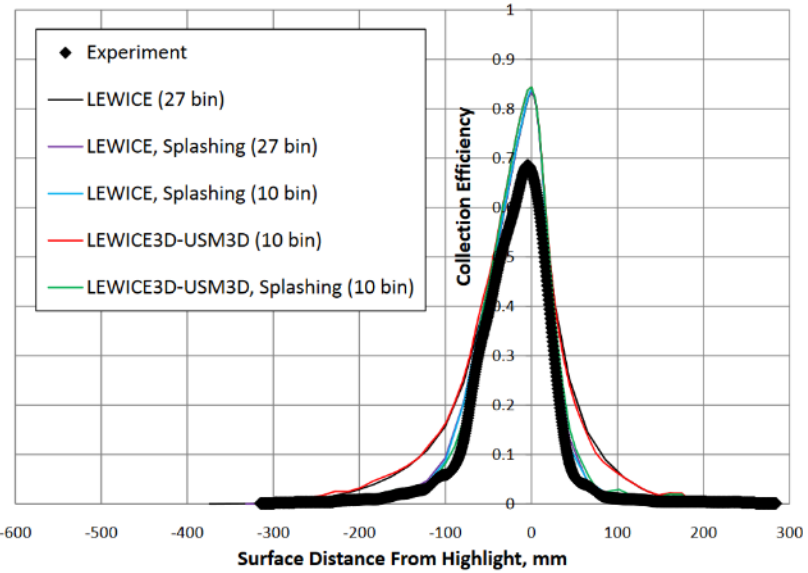
Advantages:

- cases include simple airfoil, multi-element airfoil, and swept wing
- surface pressures can be used to check air flow result quality

Concerns:

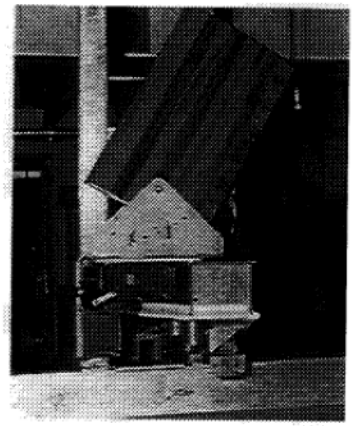
- splashing model was important for matching results
- Colin has retired from NASA – data availability?





NACA0012 swept-wing

C.S. Bidwell and S.R. Mohler, Jr , "Collection Efficiency and Ice Accretion Calculations for a Sphere, a Swept MS(1)-317 Wing, a Swept NACA-0012 Wing Tip, an Axisymmetric Inlet, and a Boeing 737-300 Inlet", AIAA-95-0755, 1995



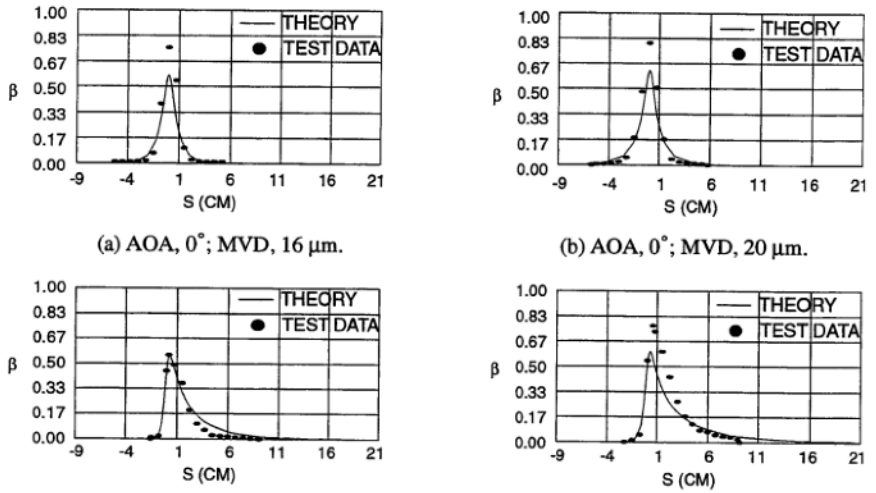
Chord length : 0,4399m

Sweep-angle : 0,15,30 or 45°. Unclear which value was used for the paper.

Test-matrix :

Model Description*	AOA (Degrees)	Engine Suction Flow (kg/s)	MVD (μm)
15.04 cm Sphere**	-	-	11.5, 16.7, 18.6
45.72 cm Sphere**	-	-	11.5, 14.7, 16.7, 18.6
Swept MS(1)-317 Wing ‡	0, 8	-	16.4, 20.4
Swept NACA-0012 Wing Tip ‡	0, 8	-	16.4, 20.4
Axisymmetric Engine Inlet †	0, 15	7.8, 10.4	16.4, 20.4
Boeing 737-300 Engine Inlet †, ‡	0, 15	7.8, 10.4	16.4, 20.4

* All tests were performed at a tunnel air temperature of approximately 10° C, and at an indicated airspeed of approximatley 73-78 m/s.
** Models tested in 1957.
† Models tested in September 1985
‡ Models tested in April 1989



(a) AOA, 0°; MVD, 16 μm. (b) AOA, 0°; MVD, 20 μm.

(c) AOA, 8°; MVD, 16 μm. (d) AOA, 8°; MVD, 20 μm.

gure 21. - Comparison of experimental and theoretical collection efficiency for the swept NACA-0012 wing tip. Airspeed, 75 m/s; static temperature, 7° C; static pressure 95840

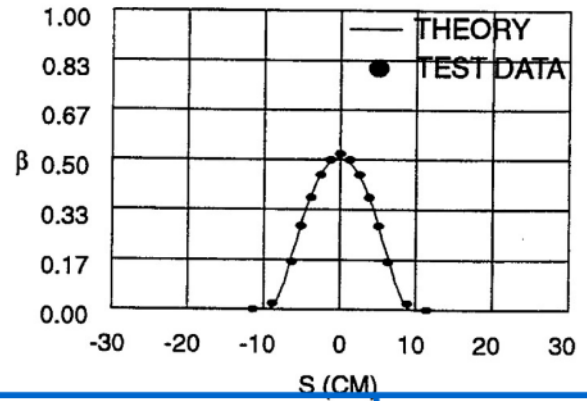
Experimental data available: collection efficiency

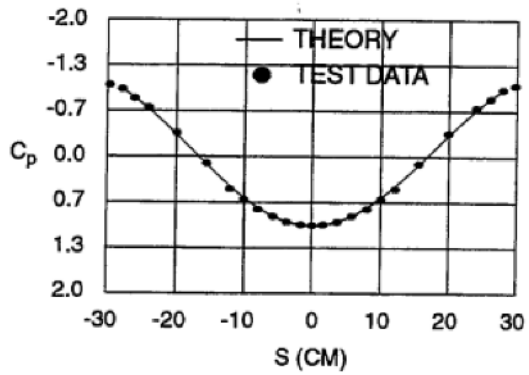
Link to be drawn with the AIAA 2014-2613 swept-wing test-case for which there are ice shapes but no collection efficiency measurements?

Impingement (and accretion) on a sphere

C.S. Bidwell and S.R. Mohler, Jr , "Collection Efficiency and Ice Accretion Calculations for a Sphere, a Swept MS(1)-317 Wing, a Swept NACA-0012 Wing Tip, an Axisymmetric Inlet, and a Boeing 737-300 Inlet", AIAA-95-0755, 1995

Experimental data available :
pressure, collection efficiency



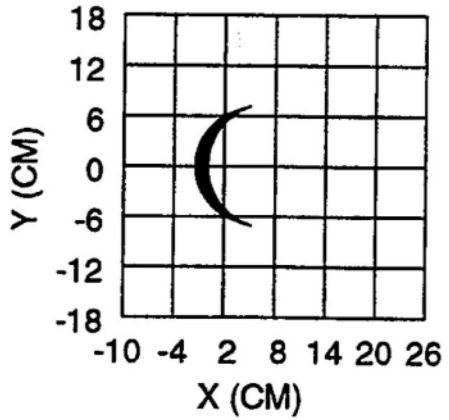


Test-matrix :

Model Description*	AOA (Degrees)	Engine Suction Flow (kg/s)	MVD (μm)
15.04 cm Sphere**	-	-	11.5, 16.7, 18.6
45.72 cm Sphere**	-	-	11.5, 14.7, 16.7, 18.6
Swept MS(1)-317 Wing ‡	0, 8	-	16.4, 20.4
Swept NACA-0012 Wing Tip ‡	0, 8	-	16.4, 20.4
Axisymmetric Engine Inlet †	0, 15	7.8, 10.4	16.4, 20.4
Boeing 737-300 Engine Inlet †, ‡	0, 15	7.8, 10.4	16.4, 20.4

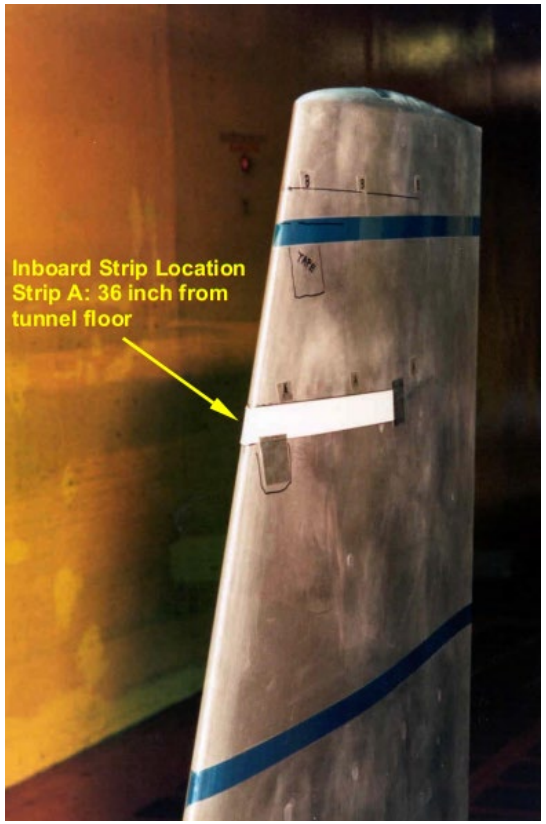
* All tests were performed at a tunnel air temperature of approximately 10° C, and at an indicated airspeed of approximatley 73-78 m/s.
** Models tested in 1957.
† Models tested in September 1985
‡ Models tested in April 1989

Some numerical results provided for the ice shape, HTC, ...



NACA 64A008 swept tail, at α = 6°

MVD = 21 microns
Speed = 176 mph
Mach = 0.23
Reynolds = 5.03
Static Temperature* = 291.2 K
Static Pressure* = 83025 Pa



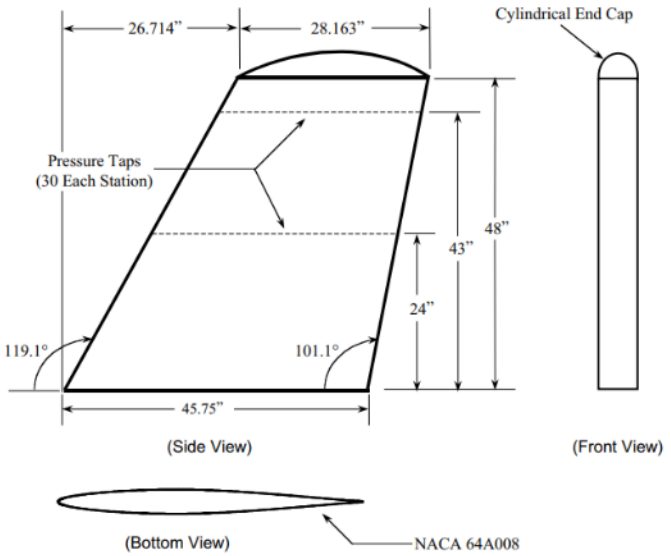
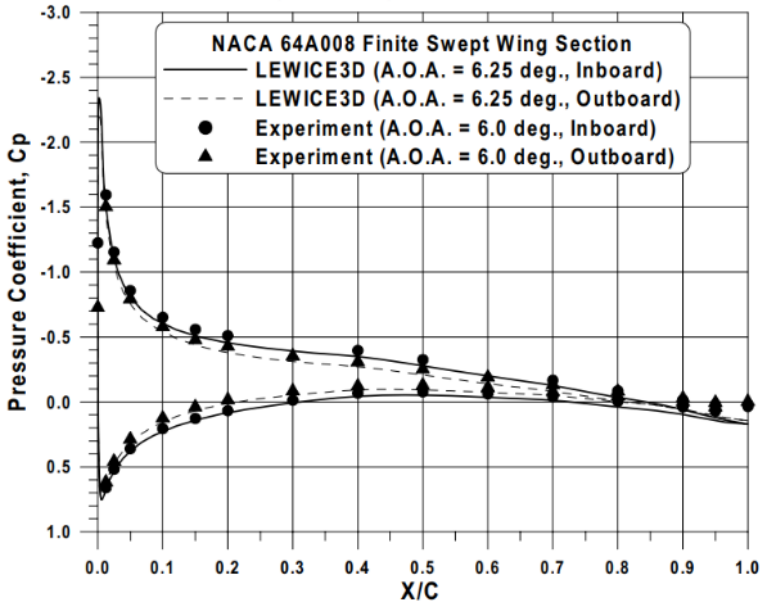
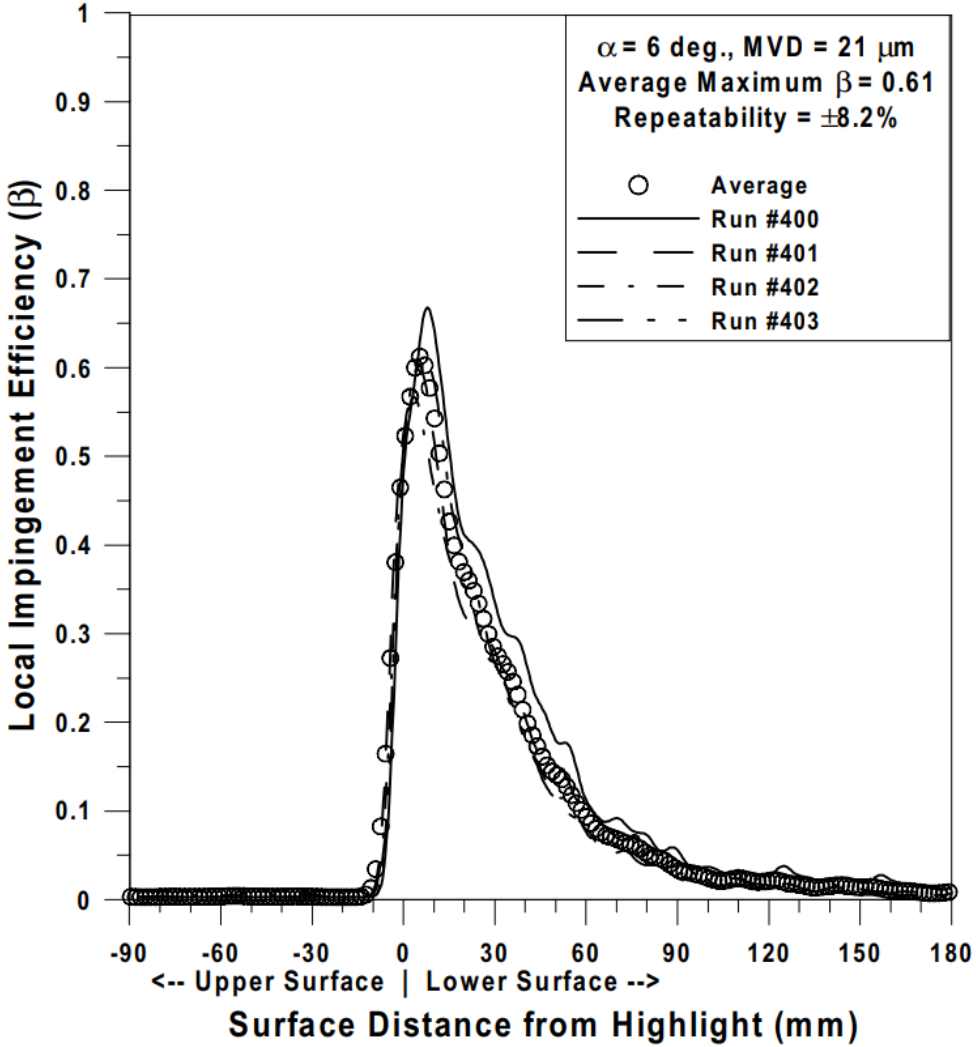


Fig. 14c NACA 64A008 swept tail (3-View Plot).



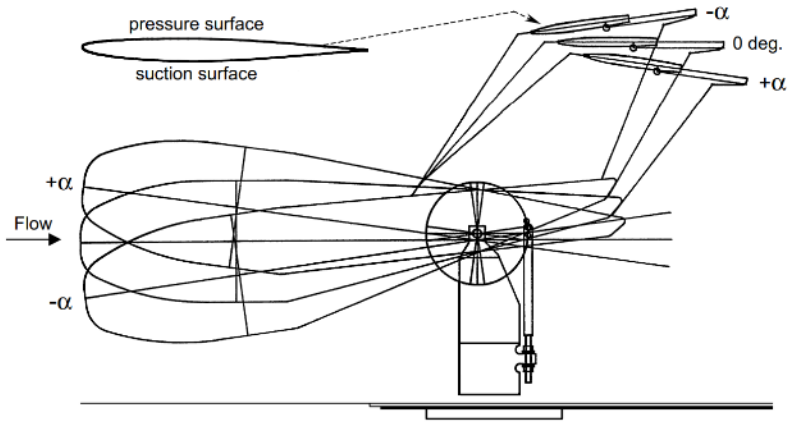
b. α = 6°, M = 0.23, Re = 5.03 million

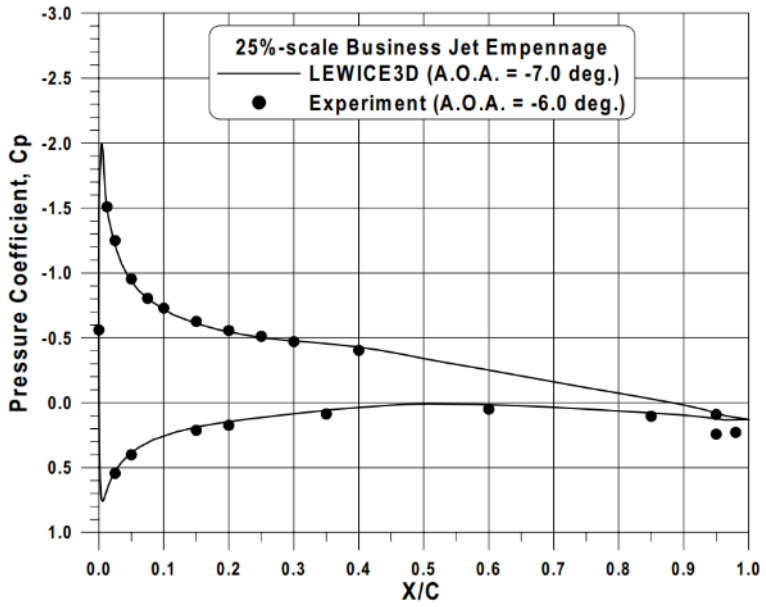


NASA TM 2002-211700 / NASA-TM-2005-213653

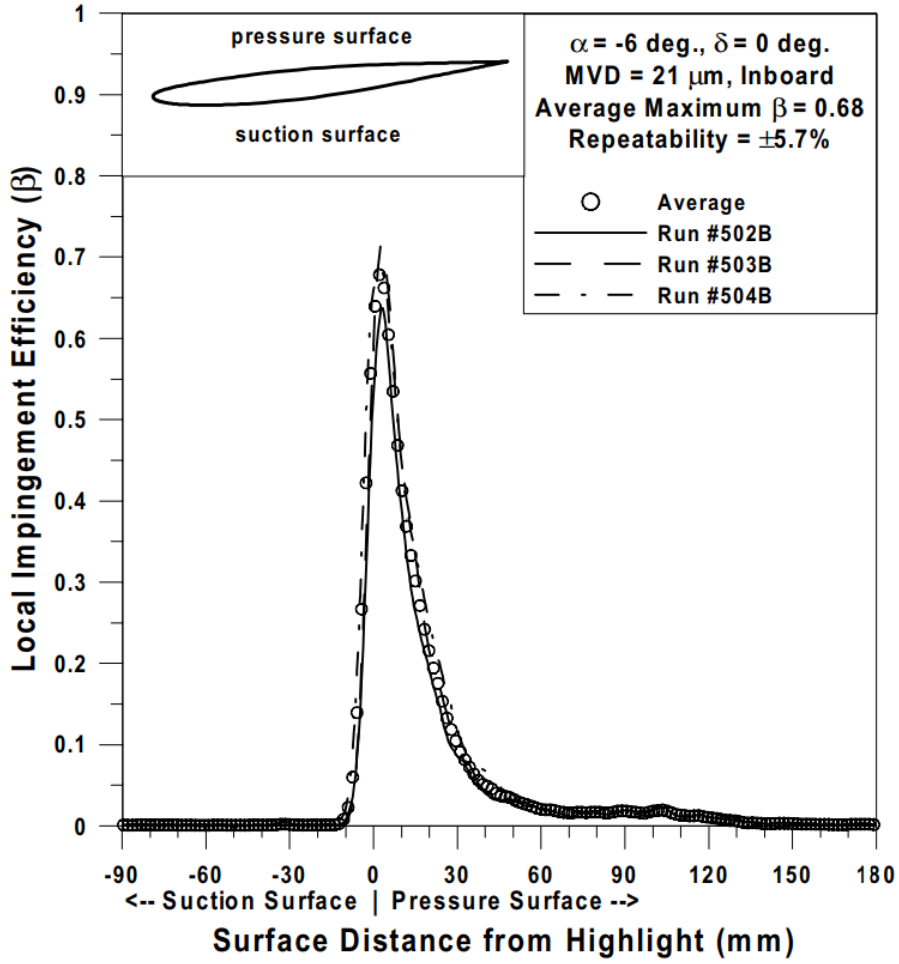
25%-scale business jet empennage horizontal tail, at α = -6°

MVD = 21 microns
Speed = 176 mph
Mach = 0.23
Reynolds = 1.49
Static Temperature* = 291.2 K
Static Pressure* = 91400 Pa





b. α = -6°, M = 0.23, Re = 1.49 million



NASA TM 2002-211700 / NASA-TM-2005-213653

Axisymmetric inlet at α = 15°

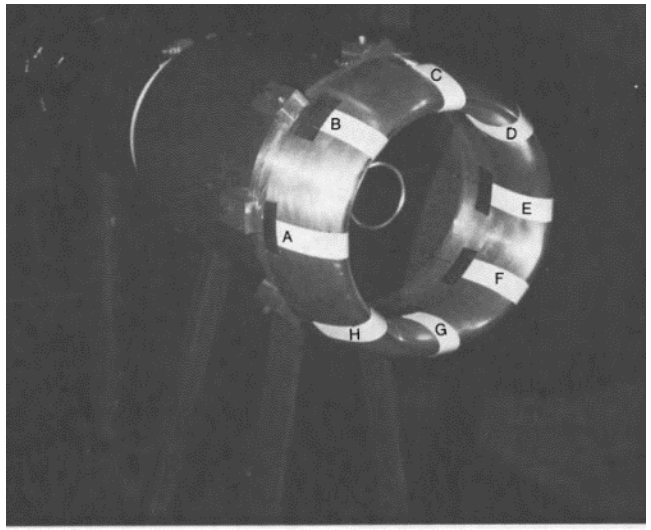
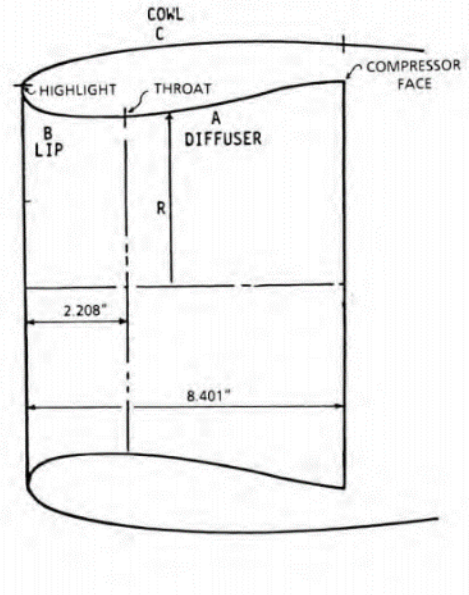


FIGURE 3.22

BLOTTER STRIP LOCATIONS ON AXISYMMETRIC INLET FOR α = 15°.

MVD = 20.36 microns
Speed = 168.9 mph
Mach = 0.2328



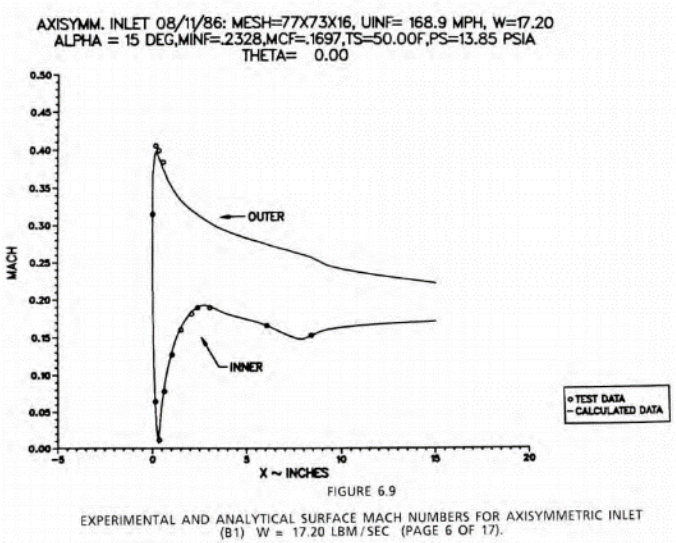
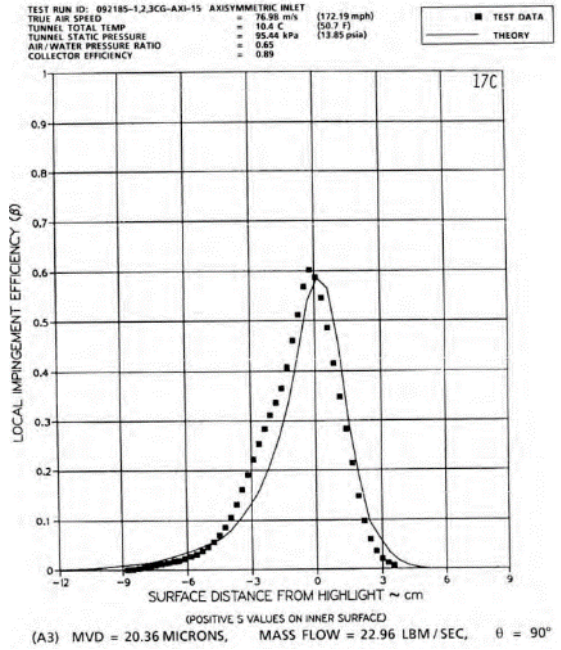
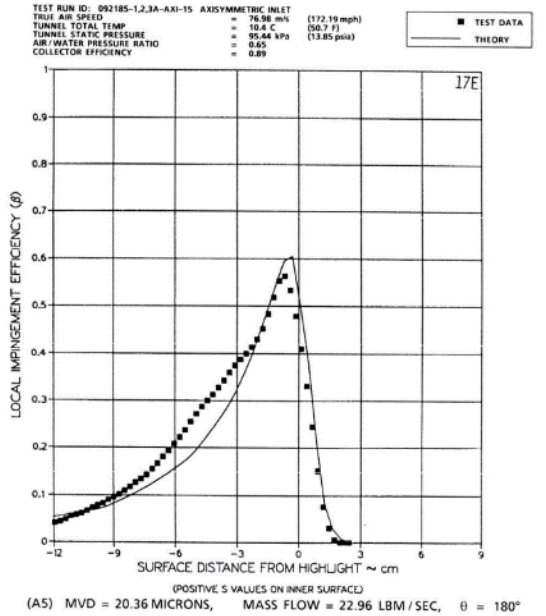


FIGURE 6.9

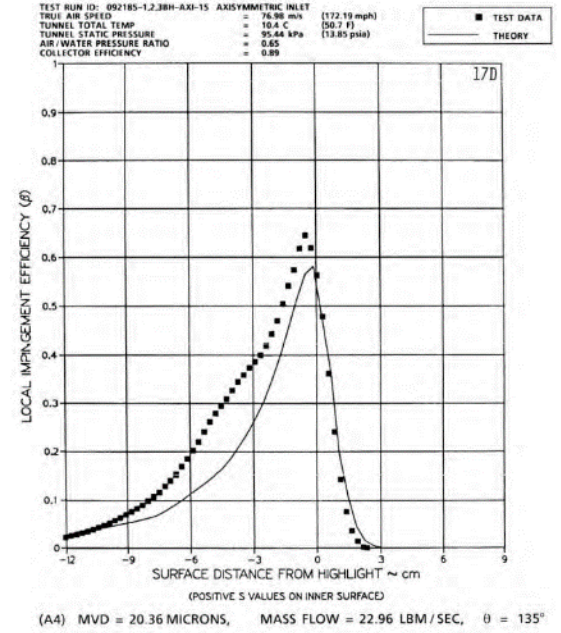
EXPERIMENTAL AND ANALYTICAL SURFACE MACH NUMBERS FOR AXISYMMETRIC INLET (B1) W = 17.20 LBM/SEC (PAGE 6 OF 17).



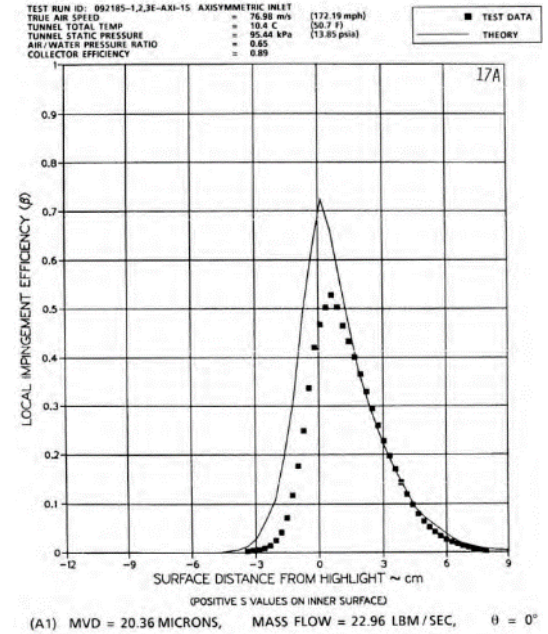
(A3) MVD = 20.36 MICRONS, MASS FLOW = 22.96 LBM/SEC, θ = 90°



(A5) MVD = 20.36 MICRONS, MASS FLOW = 22.96 LBM/SEC, θ = 180°



(A4) MVD = 20.36 MICRONS, MASS FLOW = 22.96 LBM/SEC, θ = 135°



(A1) MVD = 20.36 MICRONS, MASS FLOW = 22.96 LBM/SEC, θ = 0°

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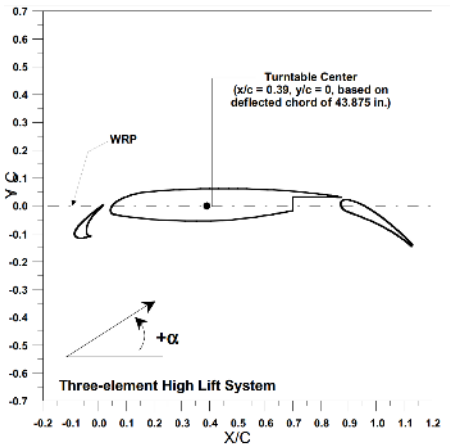
Three-element airfoil at α = 0°

MVD = 21 microns
Speed = 176 mph
Mach = 0.23
Reynolds = 4.9M (deflected chord?)
Static Temperature* = 291.2 K
Static Pressure* = 84337 Pa



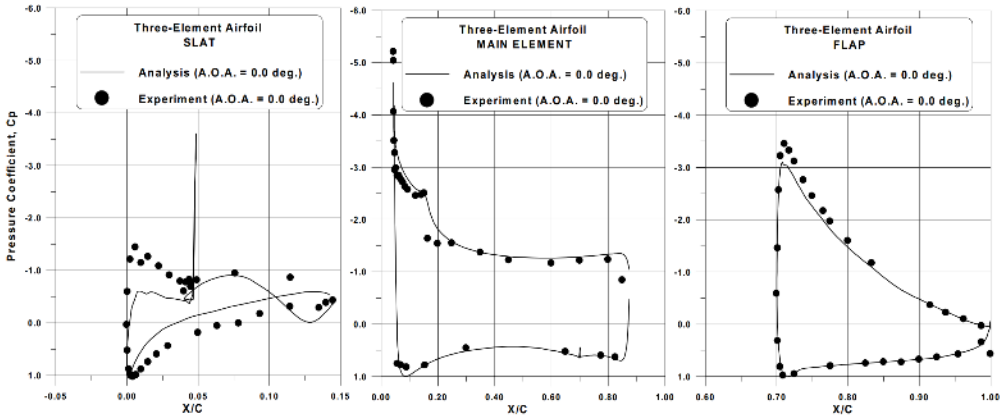
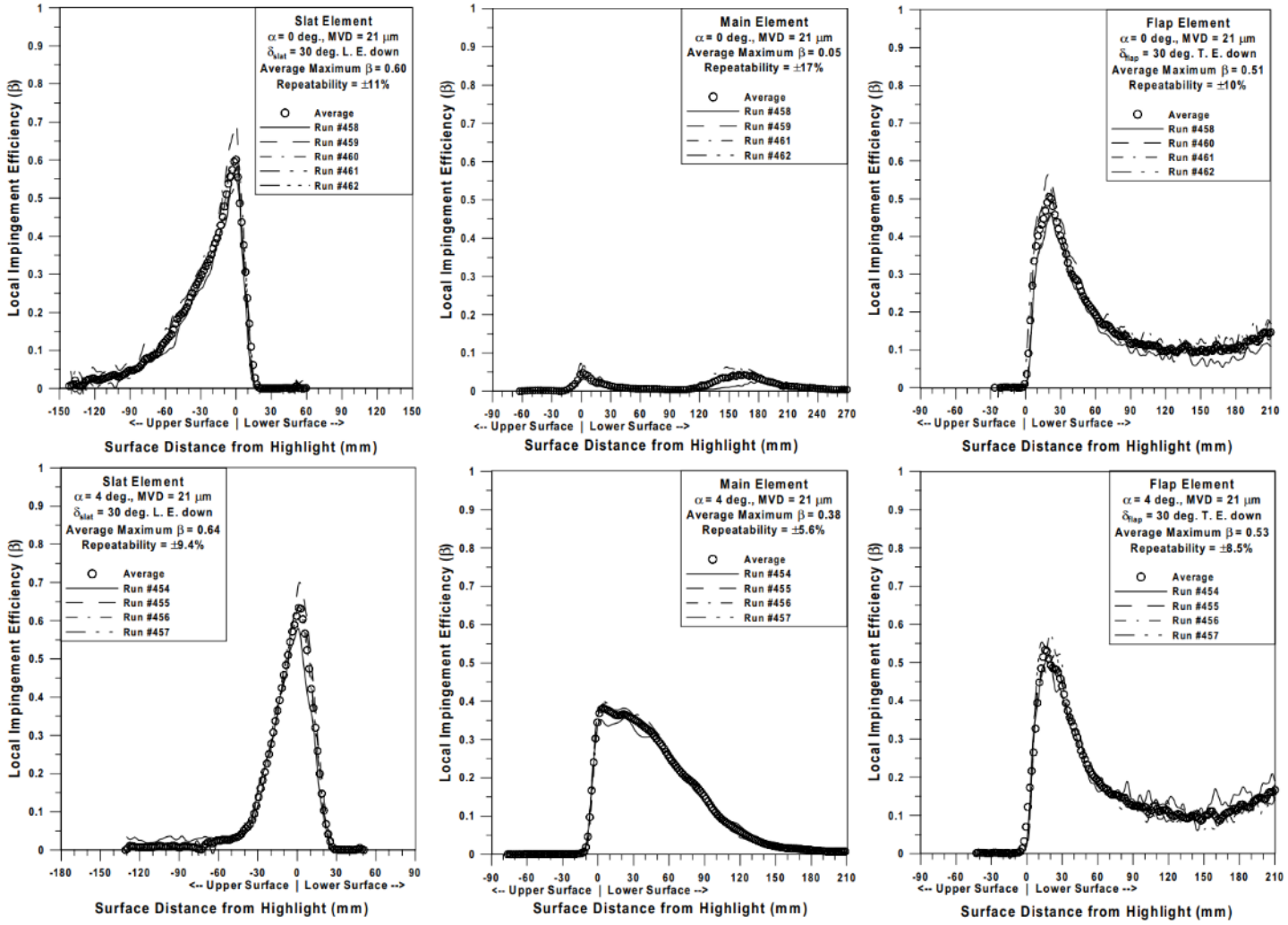


Fig. 81 Comparison of experimental and INS2D pressure distributions for the three-element high lift system; α = 0°, M = 0.23, Re = 4.9 million, landing configuration, slat deflection 30 deg., flap deflection 30 deg.



NASA TM 2002-211700

IPW Standard for Results

Plot Lists for Results Template

14 May 2020

Rev 1

Plot List for Each Experimental Case

Code-to-Experiment

- CP vs. X/C plot
  - From clean geometry (no ice)
  - Along row of pressure taps
  - Whole chord
  - (pressures from artificial ice shapes out of scope)
- Ice Geometry and Clean Geometry plot
  - Cut normal to leading edge (usually)
  - Tracing or cut through MCCS from scan
  - Plot CPmax point from experiment and stagnation point from ice code on Clean Geometry
  - Plot line showing max thickness and location with thickness value and angle value callout from experiment and code
- Ice Mass/span value from experiment (if measured)
- Collection Efficiency vs. Arc Length from code and experiment (if measured from dye strips)

Code-to-Code

Multi-iteration codes must plot first/last iteration as appropriate but have option to include other iterations.

Parameters plotted vs. arc length on cut normal to leading edge:

- CP
- Convective Heat Transfer Coefficient
- Freezing Fraction (agree on definition for this workshop)
- Film/Ice Temperature (surface temperature)
- Roughness (k)
- Ice Density (code input setting or code output)
- Ice Thickness
- Ice Mass/span value at cut from code

An Idea for Template Structure

Experimental Case

Two pages of plots created per code for each experimental comparison case: