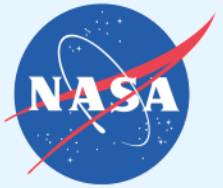
Flow Quality Surveys in the Settling Chamber of the NASA Glenn Icing Research Tunnel (2011 Tests)

In 2011, the heat exchanger and refrigeration plant for NASA Glenn Research Center's Icing Research Tunnel (IRT) were upgraded. Flow quality surveys were performed in the settling chamber of the IRT in order to understand the e_ect that the new heat exchanger had on the ow quality upstream of the spray bars. Measurements were made of the total pressure, static pressure, total temperature, airspeed, and ow angle (pitch and yaw). These measurements were directly compared to measurements taken in 2000, after the previous heat exchanger was installed. In general, the ow quality appears to have improved with the new heat exchanger.



IRT 2011-12 Cooling System Upgrade

Flow Quality Surveys in the Settling Chamber of the NASA Glenn Icing Research Tunnel (2011 Tests)

Laura E. Steen / Sierra Lobo, Inc.
Judith Foss Van Zante, Ph.D. / Sierra Lobo, Inc.
Andy P. Broeren / NASA Glenn
Mark J. Kubiak / Gilcrest

Session Summary

Time	Topic	Presenter
0800 – 0900	IRT Upgrade and Cloud Cal	Van Zante / NASA-SLI
0900 – 0930	IRT Test Section Aero-Thermal Cal	Pastor-Barsi / NASA-SLI
0930 – 1000	**IRT Plenum Aero-Thermal Cal**	**Steen / NASA-SLI**
1000 – 1030	VIRT: Air Flow and Liquid Water Concentration Simulations	Clark / UVa
1030 – 1100	VIRT: Drop Concentration and Flux on Aerodynamic Surfaces	Triphahn / UIUC
1100 – 1130	3D Laser Scanner in IRT	Lee / NASA-ASRC

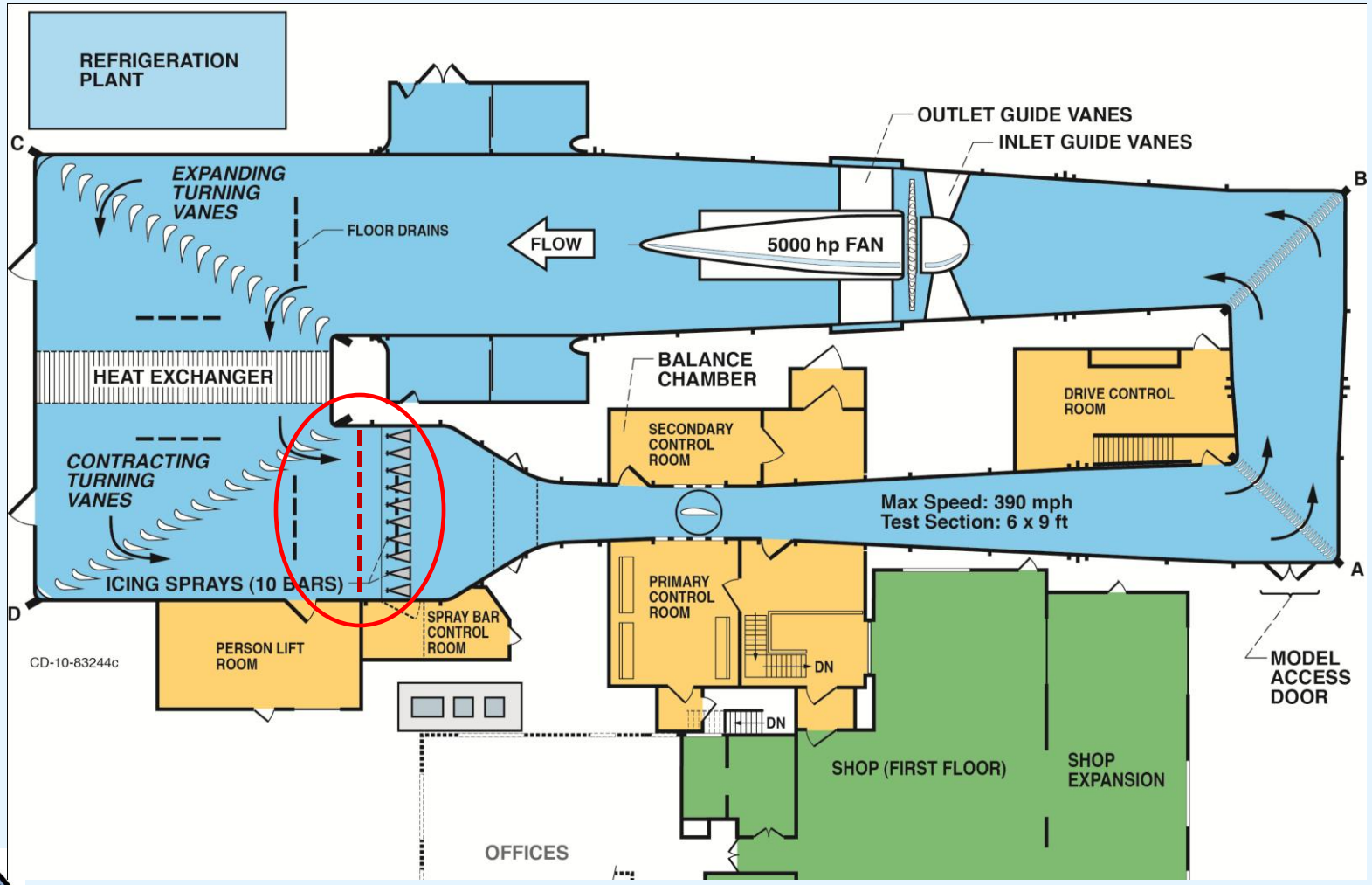
Goals for Settling Chamber Surveys

- These were the first tests conducted in the IRT after the upgrades
- Acceptance Test Criteria required that the standard deviation of velocity measured in the settling chamber not exceed 6.6% of the mean velocity
- This was meant to be a “first hash” of how the heat exchanger changed the flow field: Surveyed downstream of heat exchanger & upstream of the spray bars
- Repeating tests that were performed in 2000:
  3 vertical & 3 horizontal profile locations

Outline

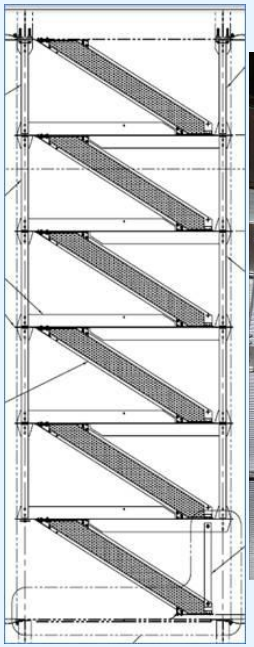
1. Brief restatement of Icing Research Tunnel (IRT) Modifications
2. Test and Instrumentation Description
3. Test results: velocity and flow-angle profiles (pitch & yaw) in the settling chamber

2012 Icing Research Tunnel



Upgrades to the IRT Heat Exchanger & Refrigeration Plant

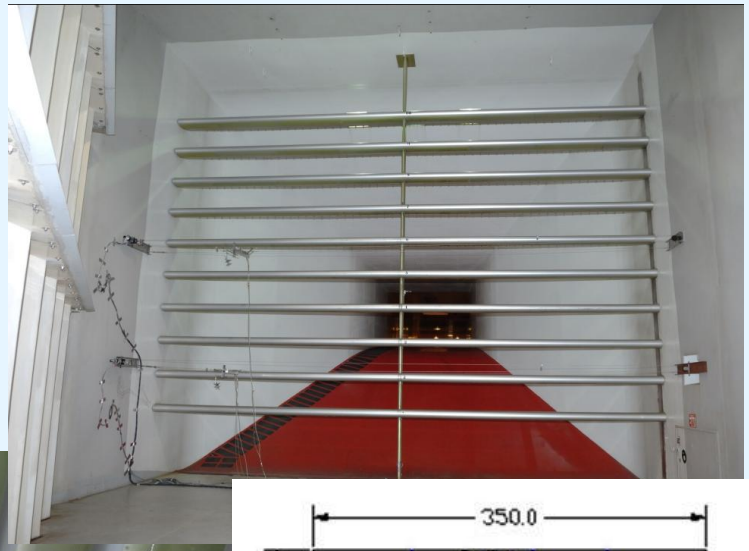
- Heat exchanger and refrigeration plant upgraded in 2011
- Profile changed to a Z-chevron with 6 segments

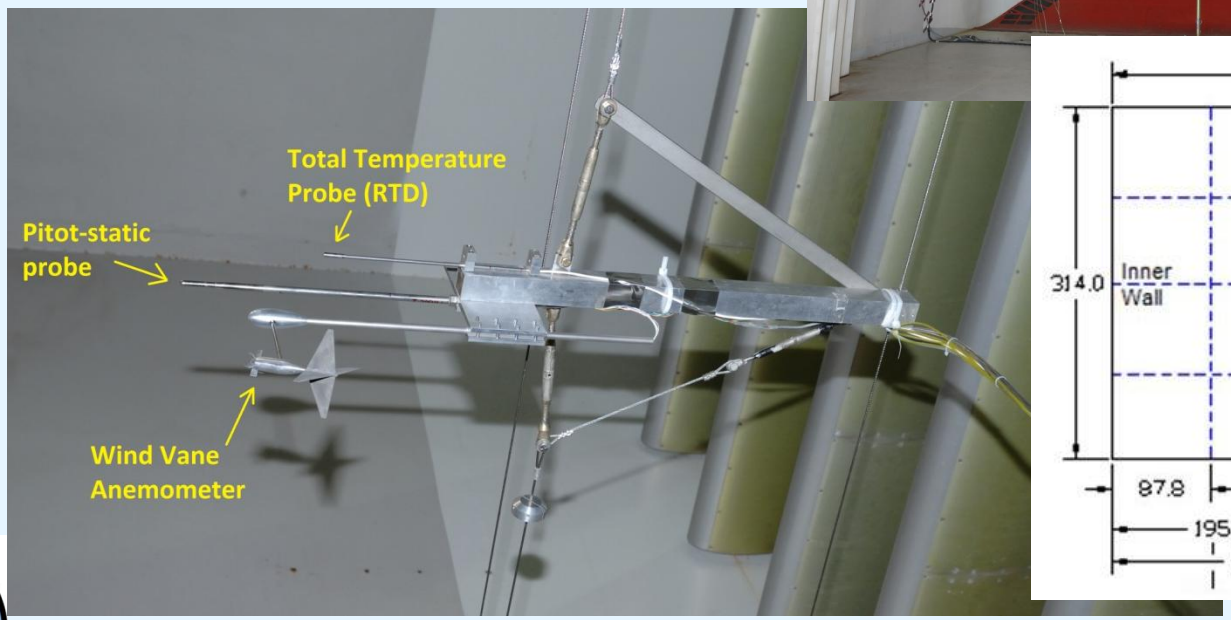


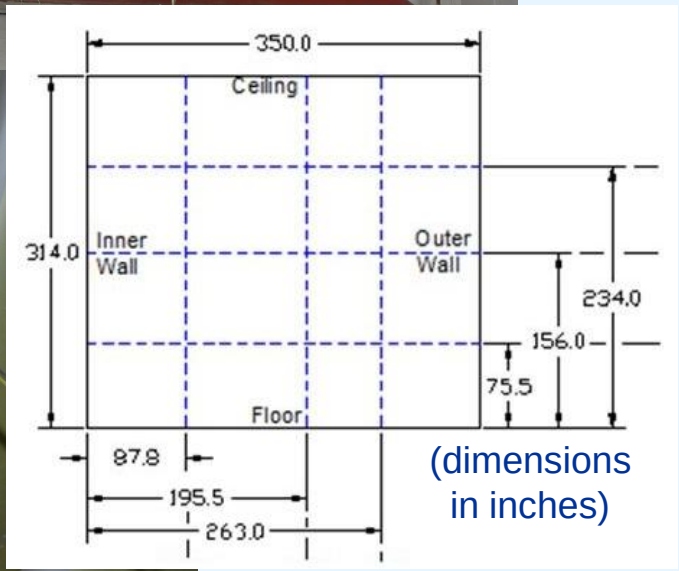
Instrumentation

2 traversing platforms, each instrumented with:

- Pitot-static probe (total & static pressure)
- Resistance Temperature Detector (RTD) (total temperature)
- Wind vane Anemometer (pitch & yaw angle, airspeed)







Test Conditions

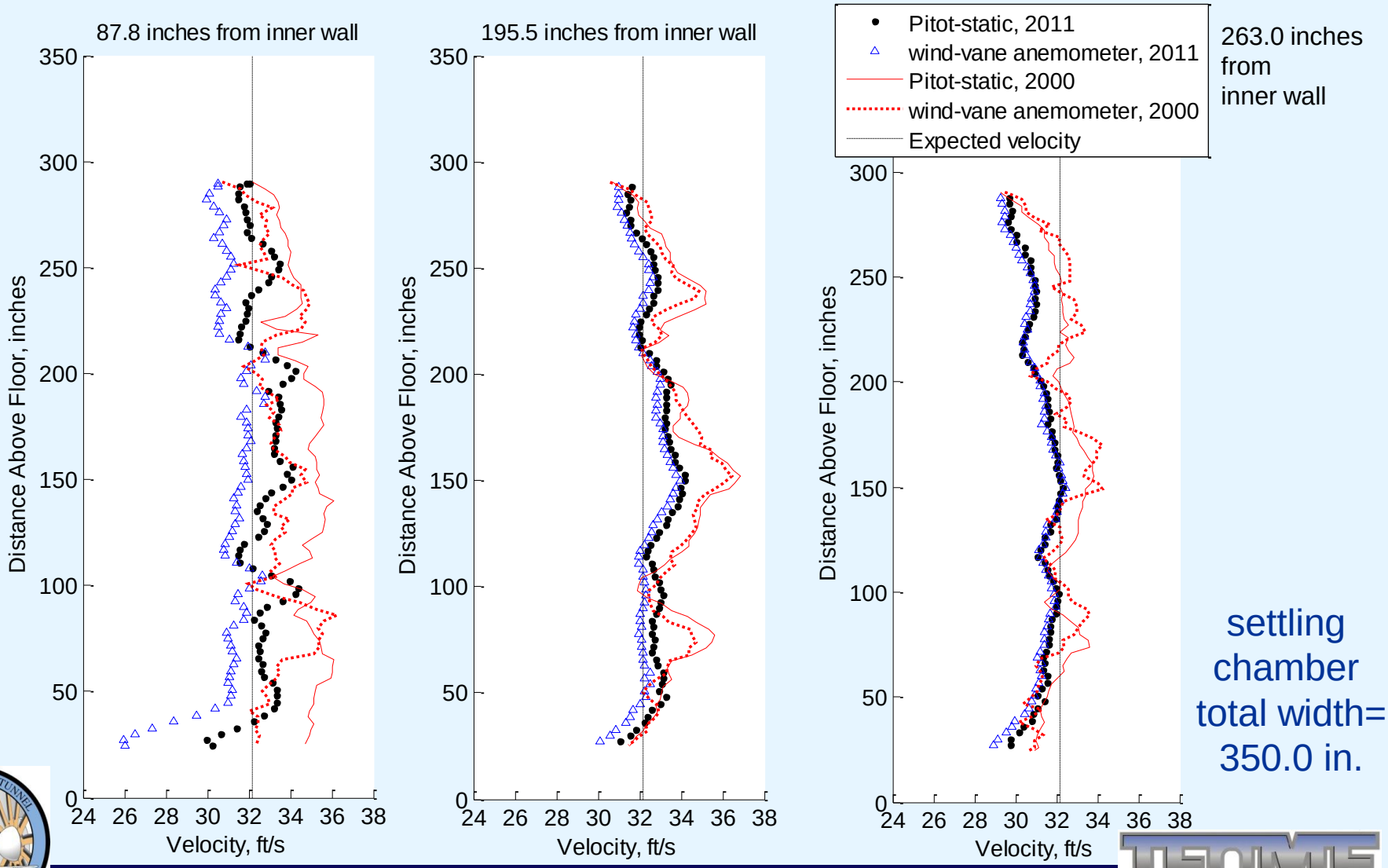
Test Section Conditions:

- Test Section Velocity = 300 knots (350 mph, 506 ft/s)
  Expected settling-chamber velocity ≈ 32 ft/s
- Total Temperature = 18^{o}C, ± 5^{o}C
  The temperature control system was still being perfected when these tests were conducted (Oct. 2011), & temperature survey results will not be presented.

Taking Data:

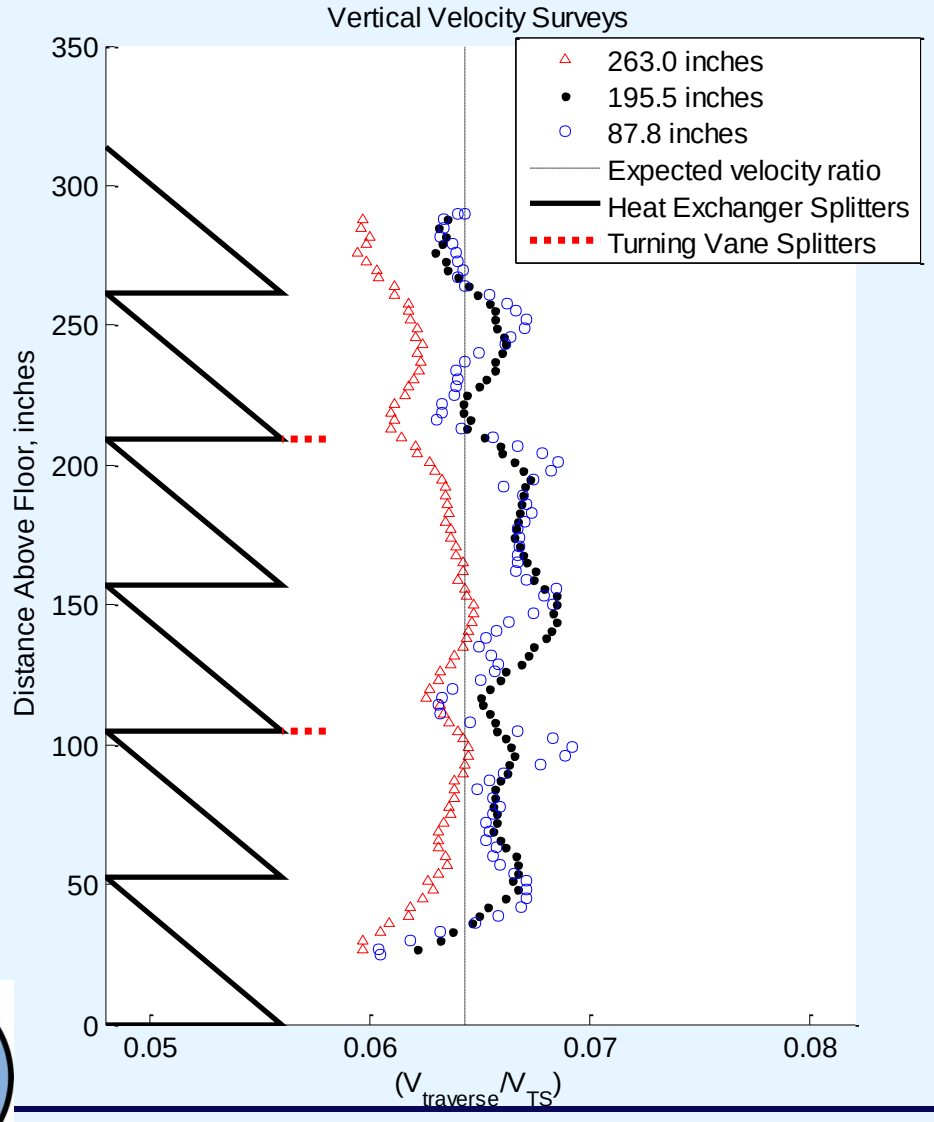
- Sampling rate of 1 Hz, 20-second average for every data point (20-sample avg.)
- 10 seconds of settling time before each recording
- Measure every 3 inches on outbound survey, every 12 inches on return survey

Velocity Results: Vertical Surveys



settling chamber total width= 350.0 in.

Pitot-Static Velocity Results: 2011 Vertical Surveys



- Vertical survey results, non-dimensionalized by the test section velocity
- includes a visual of the heat exchanger vertical profile and the turning-vane splitters upstream
- Legend indicates distance from the inner wall

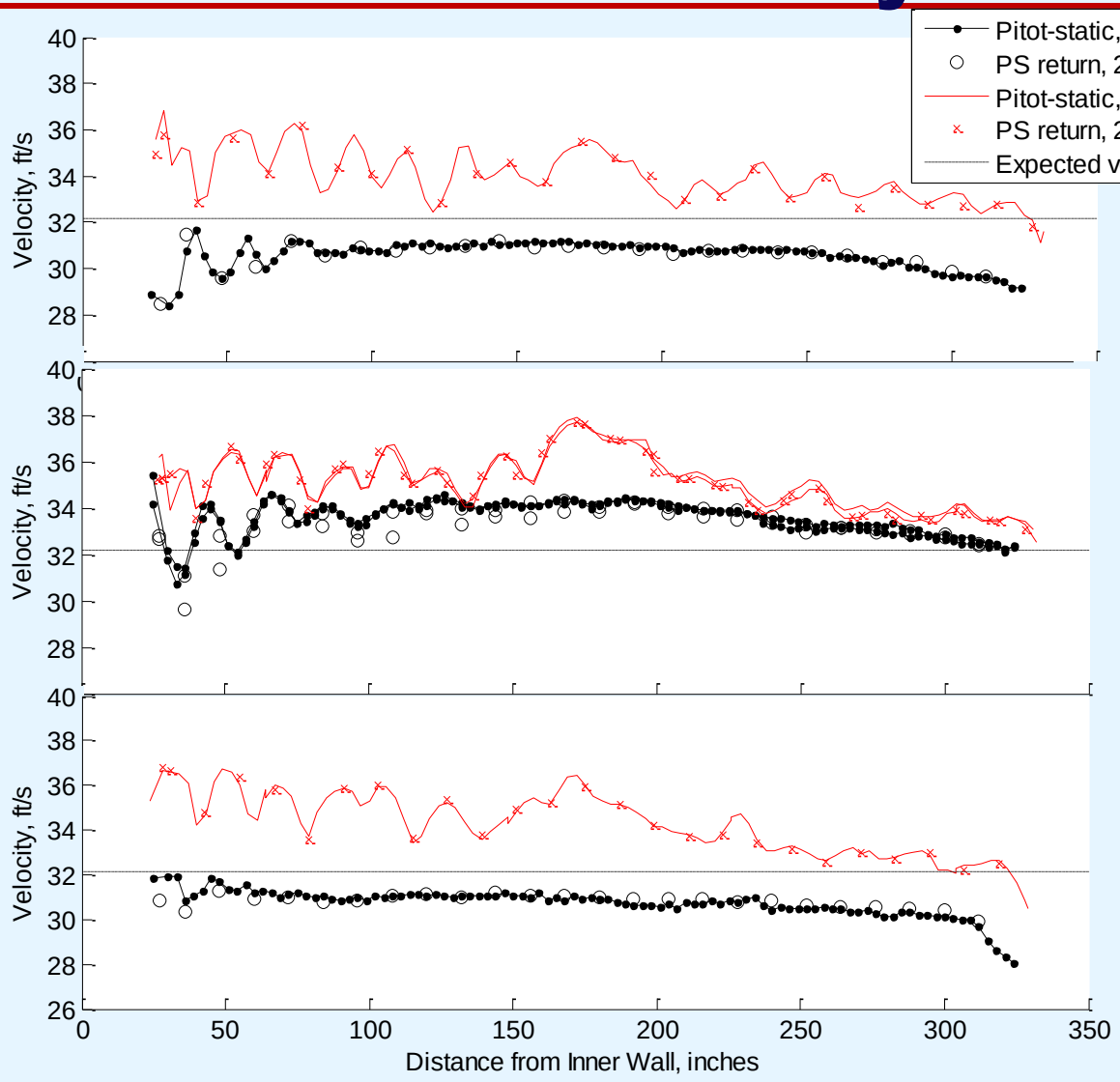
Pitot-Static Velocity Results: Horizontal Surveys

Distance Above Floor:

234.0 in.

156.0 in.

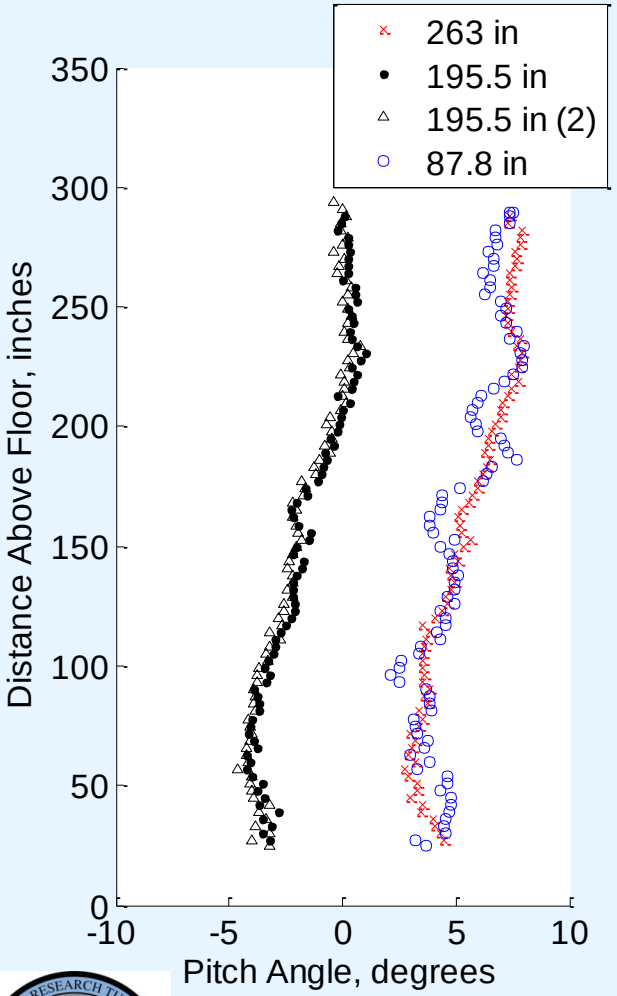
75.5 in.

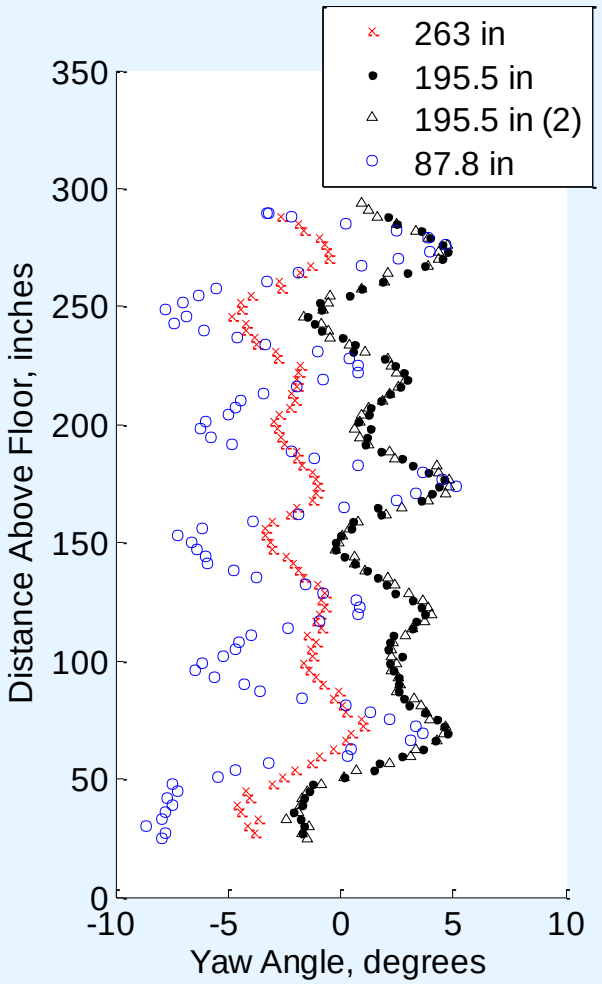


settling chamber total height= 314.0 in.

Note: The repeatability characteristics in these plots are nearly the same as the rest of the data in this presentation

Angle Results: Vertical Surveys

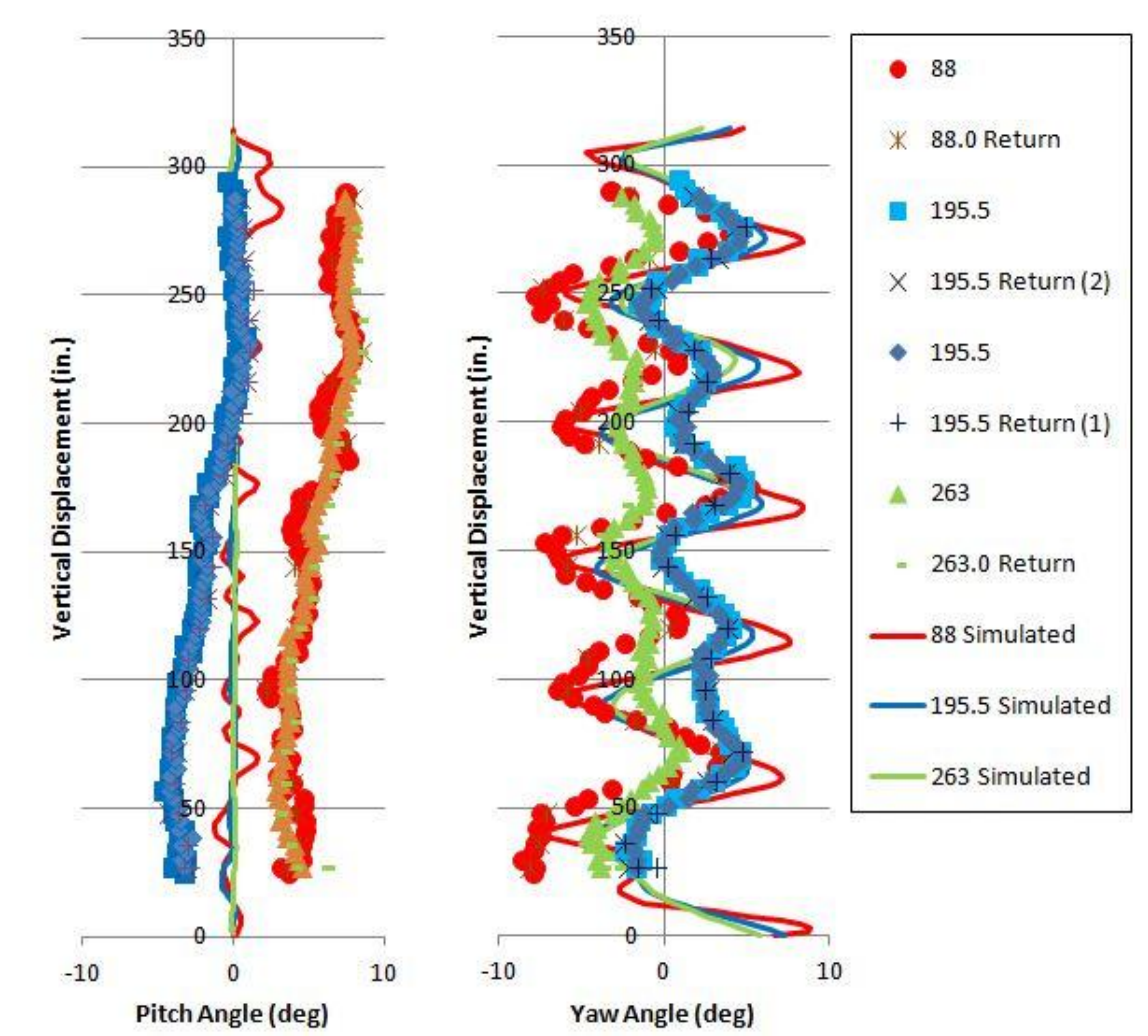




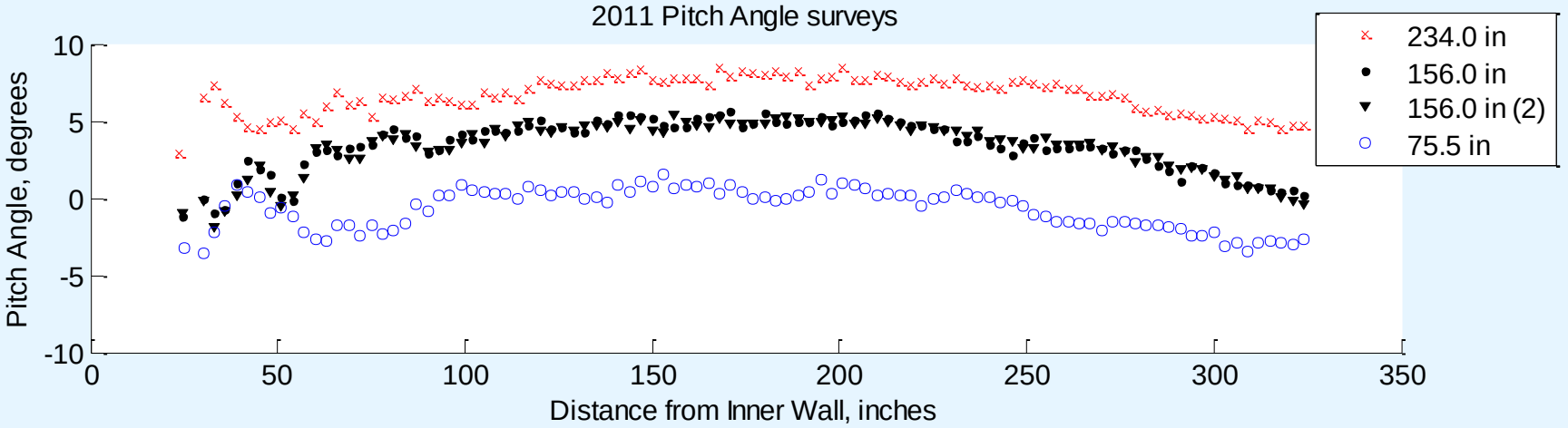
- Legend indicates distance above floor, (2) indicates repeat survey
- These plots are to be used for trend identification ONLY, not numerical values.

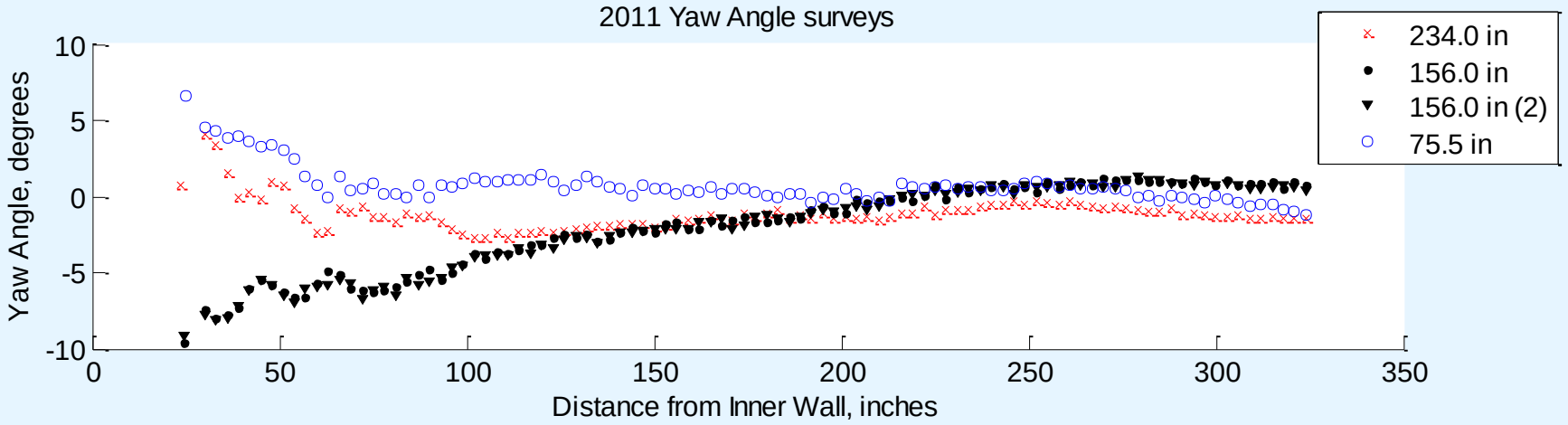
Angle Comparison with Virtual Icing Research Tunnel at U. of Virginia

- Computations done at University of Virginia by Kevin Clark, and Prof. Eric Loth
- Only showing vertical surveys
- Legend indicates distance from inner wall, (1) and (2) are initial and repeat surveys at center loc.



Angle Results: Horizontal Surveys





- Legend indicates distance above floor, (2) indicates repeat survey
- These plots are to be used for trend identification ONLY, not numerical values

Results Summary

- Overall, the settling chamber airflow improved as compared to the 2000 heat exchanger.

Velocity Surveys: *(standard deviation) / (average velocity)* =

2000 Tests	2000 Tests	2011 Tests
Vertical, inner	2.5%	2.7%
Vertical “center”	4.0%	2.1%
Vertical outer	2.9%	2.3%
Horizontal, lower	4.0%	2.0%
Horizontal “center”	3.4%	2.2%
Horizontal, upper	3.2%	2.1%

- Vertical spatial variations in pitch have improved, and vertical variations in yaw have degraded. Computational work done at U.VA confirms that the trends that were seen can be expected

Acknowledgements

Collaboration with University of Virginia:

- Kevin Clark, Eric Loth

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