ASHRAE 1743-RP : Effect of Inlet Duct and Damper Design on Fan Performance and Static Pressure Measurements

Presented at ASHRAE TC-8.11;
Research committee meeting, Houston

PIs: Dr. Christian Bach, Dr. Omer San

Graduate research assistants:
Md Yeam Hossain *(Experimental Work)*
Romit Maulik *(CFD Work)*

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01/13/2019

Overall Agenda

- Review Action Items from last PMS meeting
- Experimental Update
- CFD Update
- Wrap-up/future work

Action items, from 12/06/2018

- No-cost extension: Eric to follow up with TC to request vote (last status: 2 votes missing)
- Analyzing data for different inlet plenum case and also for floor distance
  - Currently by varying floor distance, data is only from without plenum case
  - Need to think about varying the floor distance also for 8” and 16” plenum case
  - Discuss at TC in Atlanta
  - How does side flow affect fan power – show results from experimental tests!
- Send out book chapter (done, 12/10/18) and ASHRAE draft paper (done, 12/14/18)
- Follow up with Darryl on Unit selection (CTM vs ECM – what is more stable?)
  - Discussed about reducing plan to one 1.5-ton unit, either CTM or ECM
  - Need at least one draw through unit
  - Either 1.5 ton or 3 ton draw through for comparison with blow through
- Check into additional help for running tests – MAE 4010, RP1785 student to operate both rooms, etc. (currently repairing damage caused by other project’s student) (several students involved in repairs, one part-time UG student to support Yeam)
- Follow up with Vance next week on fan power/system resistance/measurement position (12/12/2018, no response, yet – government shutdown?)
  - CB check with Loren Cook – fan effects from different inlet flow field?
- How much does mean air velocity change for inlet flow area of units with different capacity?
  - Yeam- add data from unit selection table that included duct cross-section for different units

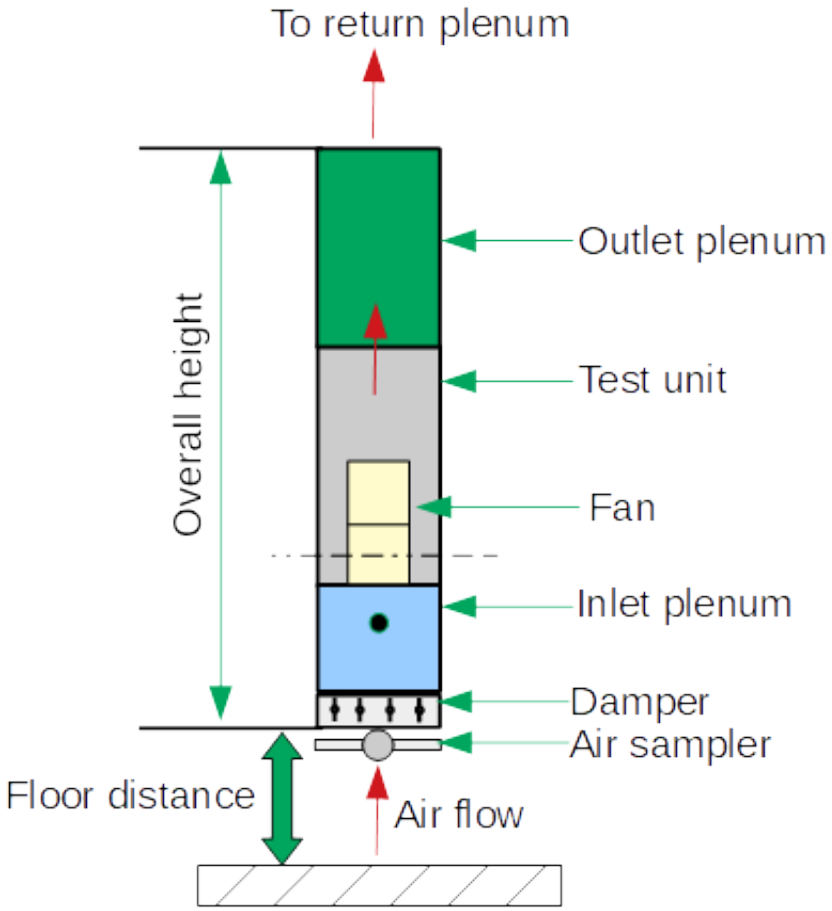
Agenda- Experimental part

- Project goals
- Test plan
- Results
- Summary and future work

Background and Project Goals

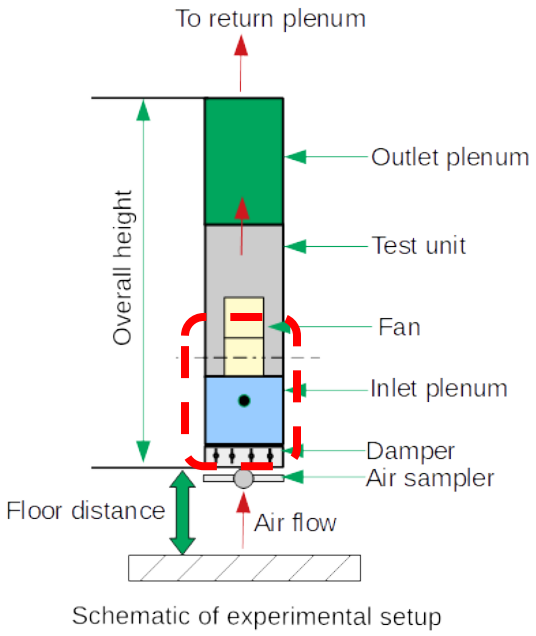
- Height limitations in existing testing facilities
  - Develop inlet duct work designs with reduced length
  - Reduce design space to configurations acceptable to the PMS
- Reduce the risk of false testing failures
  - Evaluate fan performance (power consumption, air flowrate) for proposed candidate designs
  - Acceptable inlet ductwork candidate designs should lead to similar performance as for the applicable reference design (e.g. 10 CFR Appendix M to Subpart B of Part 430)
    - Per PMS request for 3-ton AHU: ± 3W (preferred) and ±9W (acceptable)
- Develop inlet duct guideline for the AHRI and ASHRAE testing standards
- Develop guideline for duct CFD simulations (draft submitted to PMS for review F18)

Schematic of experimental setup

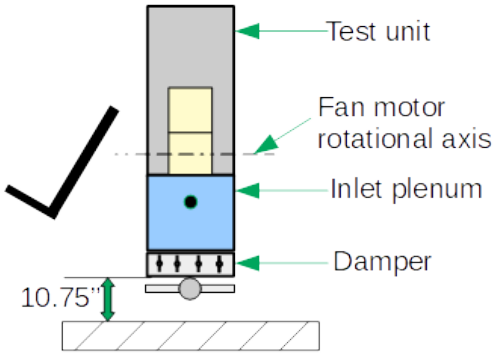


Schematic of experimental setup

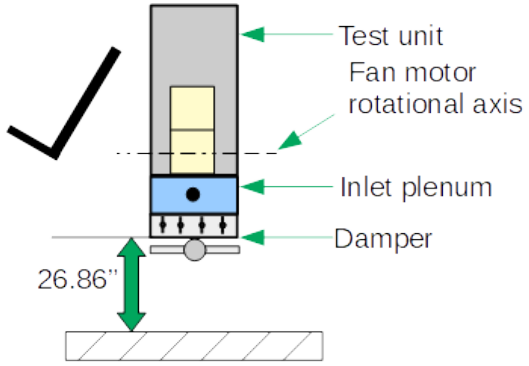
Test plan



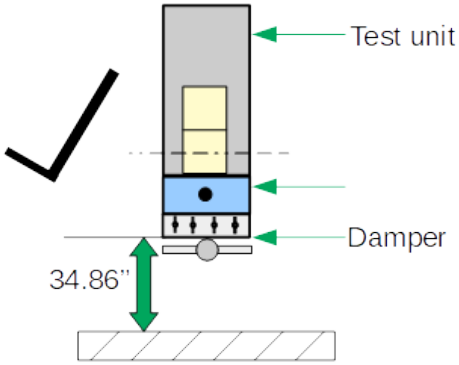
Schematic of experimental setup



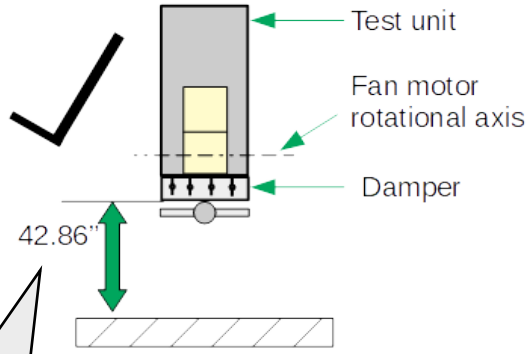
32.11" inlet plenum
(baseline test)



16" inlet plenum



8" inlet plenum

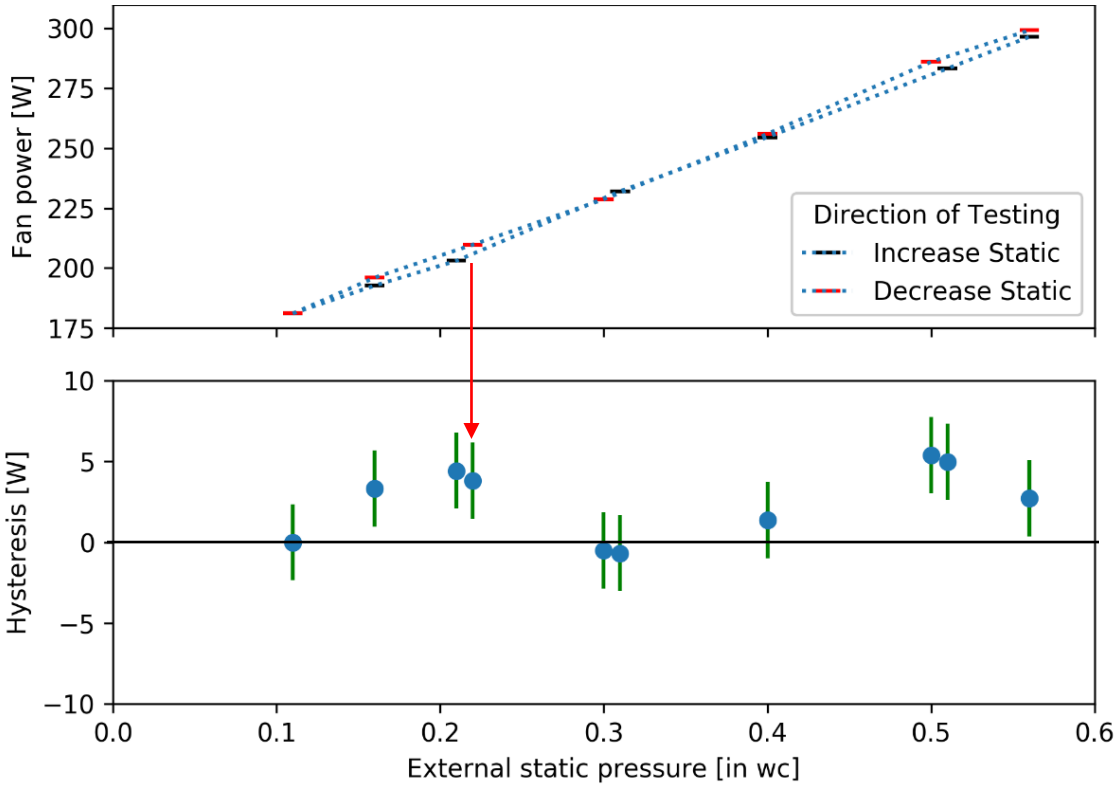


without inlet plenum

& 10.75" √

Hysteresis and uncertainty

- Measurement uncertainties are: $u_{power} \approx 1\ to\ 1.89\ [W], u_{\Delta P} = \pm 0.006$ [in WC]
- Hysteresis ≈ 0 to ≈ 10 [W] on direction of reversing static pressure direction
  - These values are for “interpolated” values between measurement points



Overall uncertainty calculations

- $average\ power = \frac{[power(increasing\ static) + power(decreasing\ static)]}{2}$
- $power\ meter\ uncertainty = 0.16\%\ MV + 0.04\%\ MR$
  - MV= measured value
  - MR=maximum range (max. voltage · max. current)
  - Maximum voltage = 400V, maximum current= 4.44 amps
- *Hysteresis*= $power(decreasing\ static)$- $power(increasing\ static)$

Overall uncertainty calculations

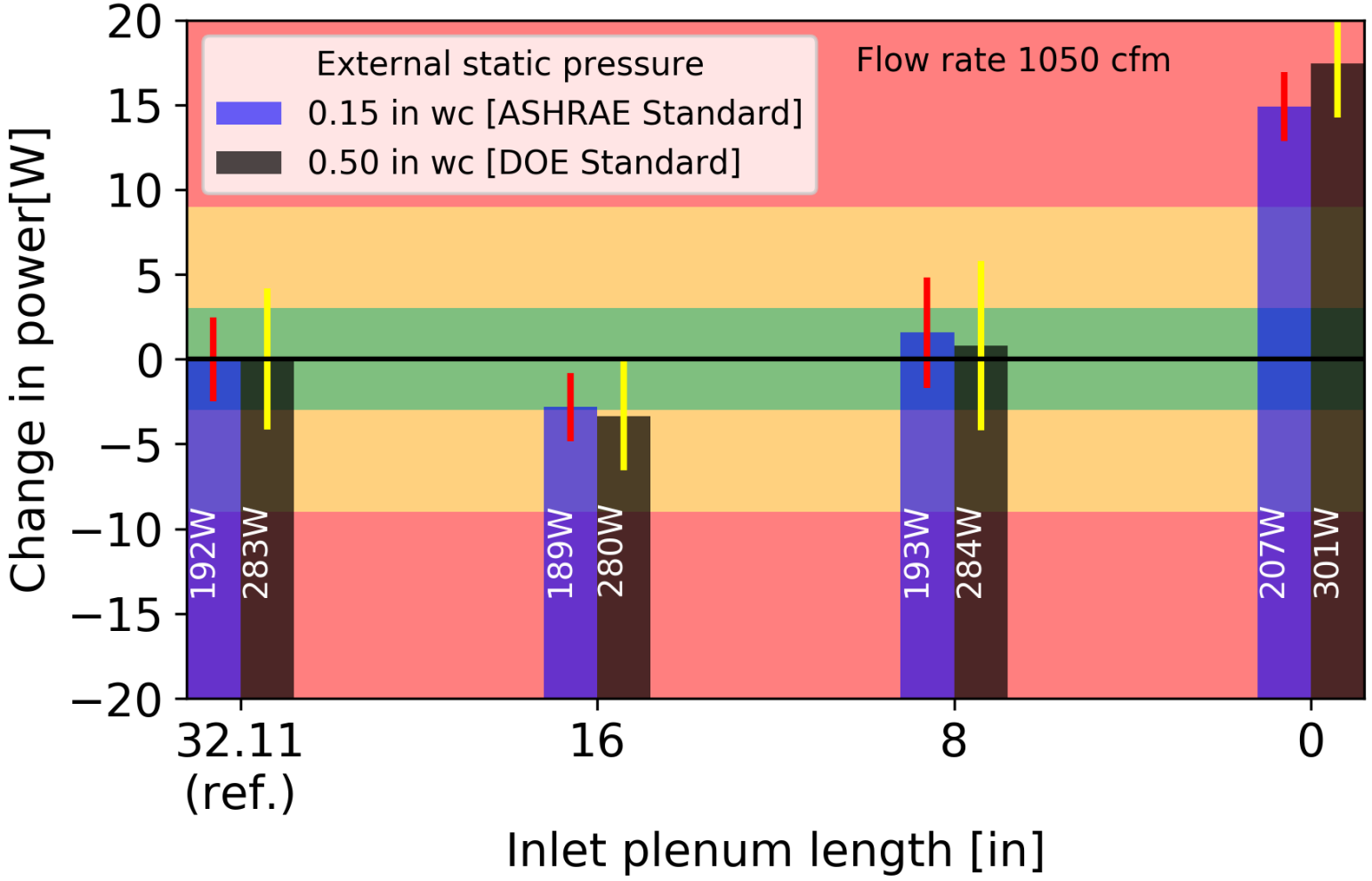
- *For each average power value:*
  - » *hysteresis adds uncertainty but is independent of power uncertainty*
  - » *power meter uncertainty (assuming perfect repeatability) will not be reduced by averaging the values for increasing and decreasing pressure) since same measurement device*
  - » *For fan power:*

$$u_{total} \approx \pm\sqrt{(hystereis/2)^2 + (power\ meter\ uncertainty)^2}$$

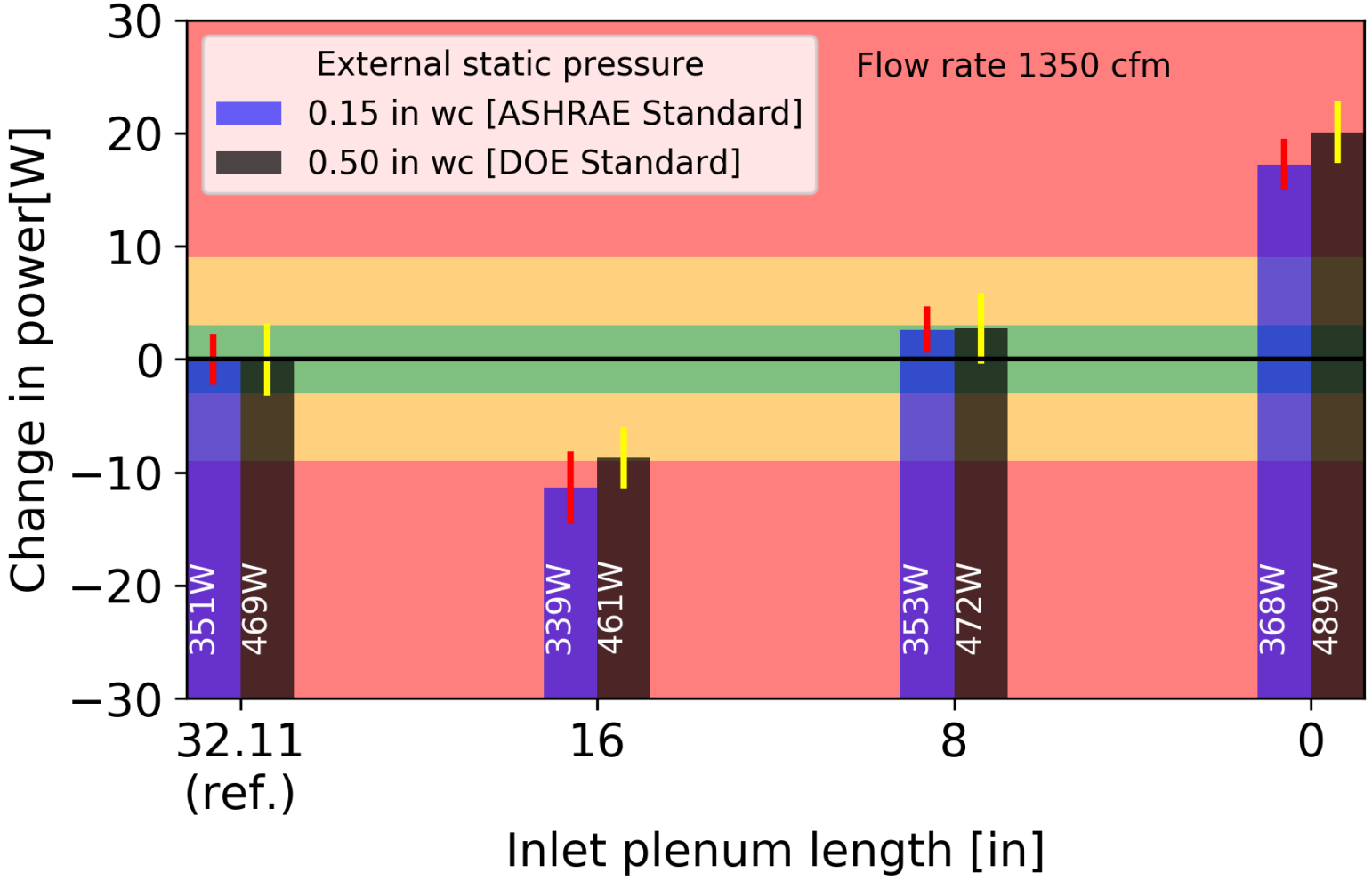
  - » For changes in fan power

$$\Delta u_{difference} \approx \pm\sqrt{u_{total,A}^2 + u_{total,B}^2}$$

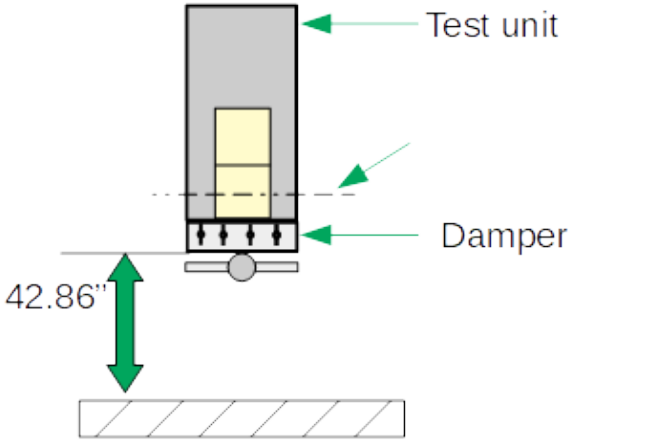
Effect of Inlet Plenum Length (1050 CFM)

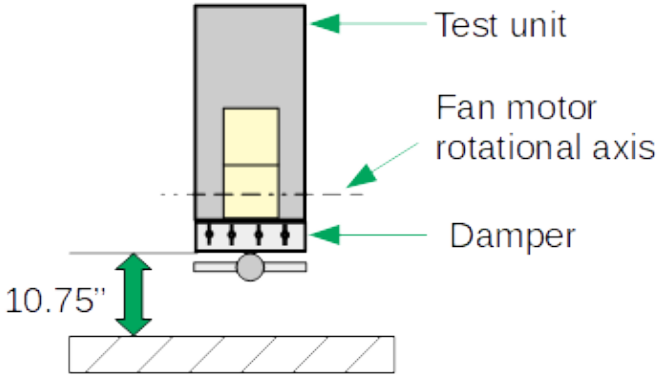


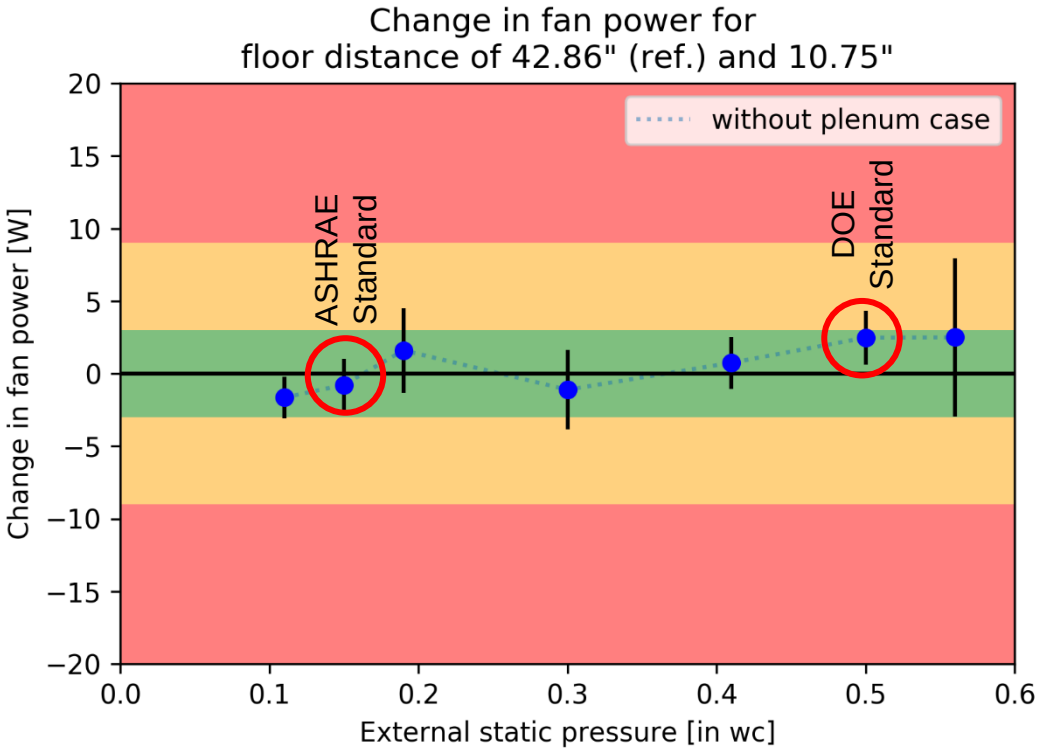
Effect of Inlet Plenum Length (1350 CFM)



Change in fan power with floor distance (1050 cfm): Sensitivity to static pressure (no plenum case)

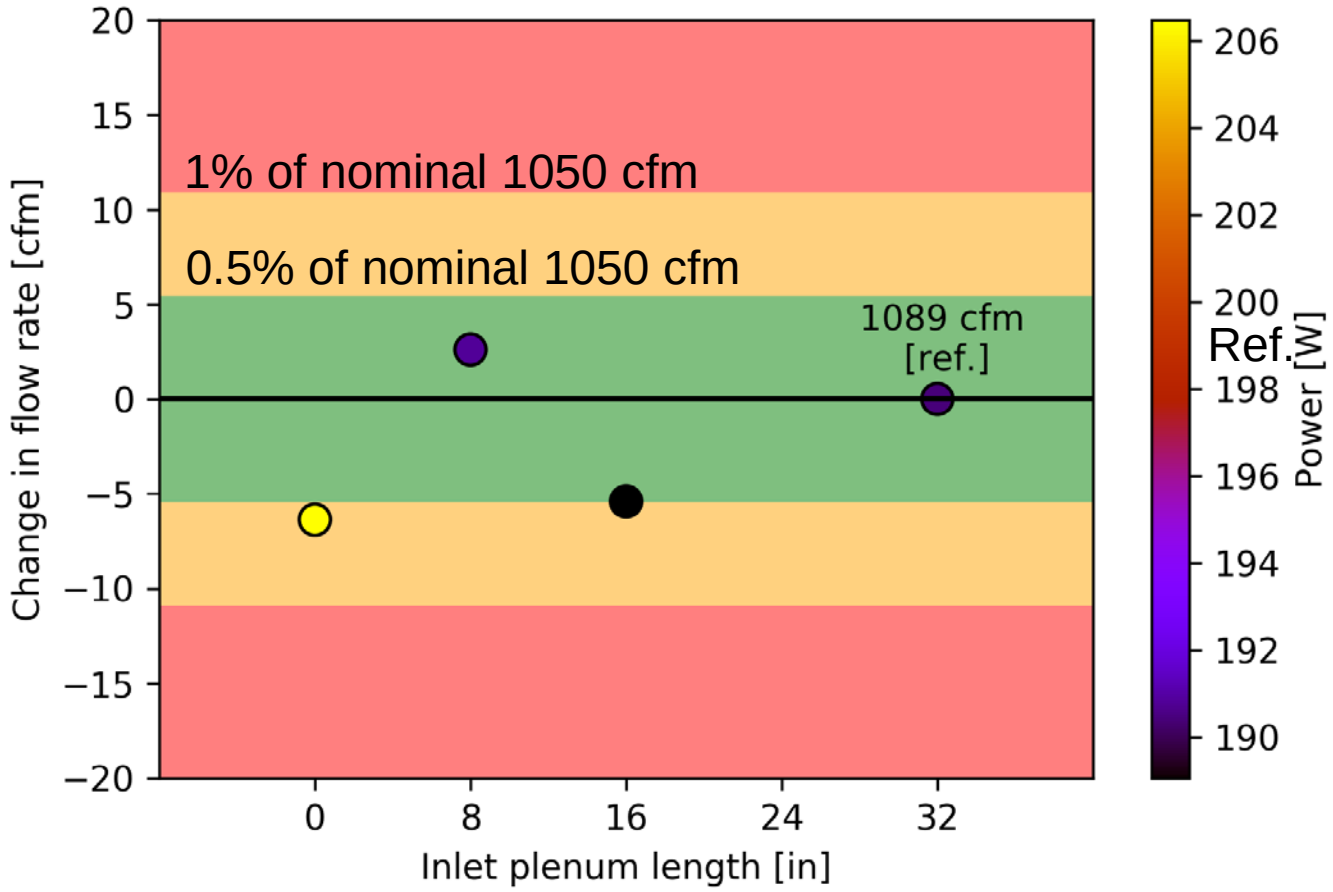




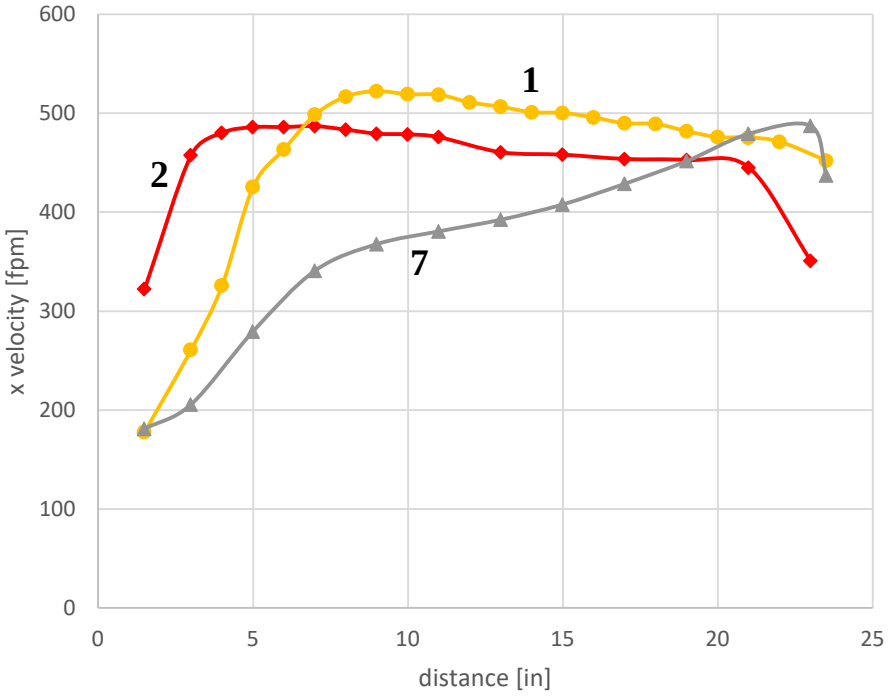


Note: External static pressure is measured from exit plenum to ambient since no static pressure ports at inlet.

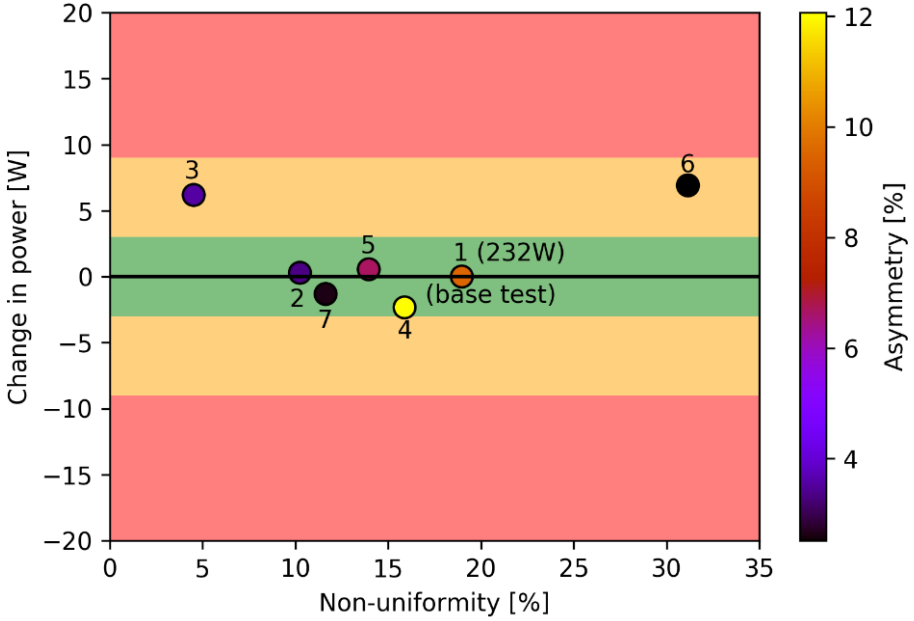
Flow rate vs plenum length at 0.15” wc (nominal 1050 cfm)



Effect of velocity profile



config.	inlet configurations (all with standard plenum)
1	conditioning bays on (baseline test)
2	conditioning bays off
3	air sampler and cardboard extension
4	config. 4 with side flow
5	config. 4 with conditioning bays on and reduced floor distance
6	air sampler, damper and conditioning bays on
7	air straightener, side flow and cardboard surrounding



Summary of the experimental subproject

- Quick recap of tested cases
- Test results
  - Varying the inlet plenum length, include side flow to determine effect
  - Varying floor distance for without plenum case
  - Hysteresis on increasing/decreasing pressure prior to measurement
    - same order of magnitude as PMS suggested acceptable range for power change
- Re-establish facility and setup operation (target: 03/11/2019)
  - Repair damage of psychrometric rooms and experimental setup
  - Investigate hysteresis further
    - duct leakage test (started prior to winter break)
    - fan wheel speed sensor (purchased)
- Varying the floor distance for other plenum length cases (16”, 8”)
- Overall progress
  - New target with second no-cost extension: February 29, 2020

ASHRAE RP-1743

CFD assessments for vertical duct design

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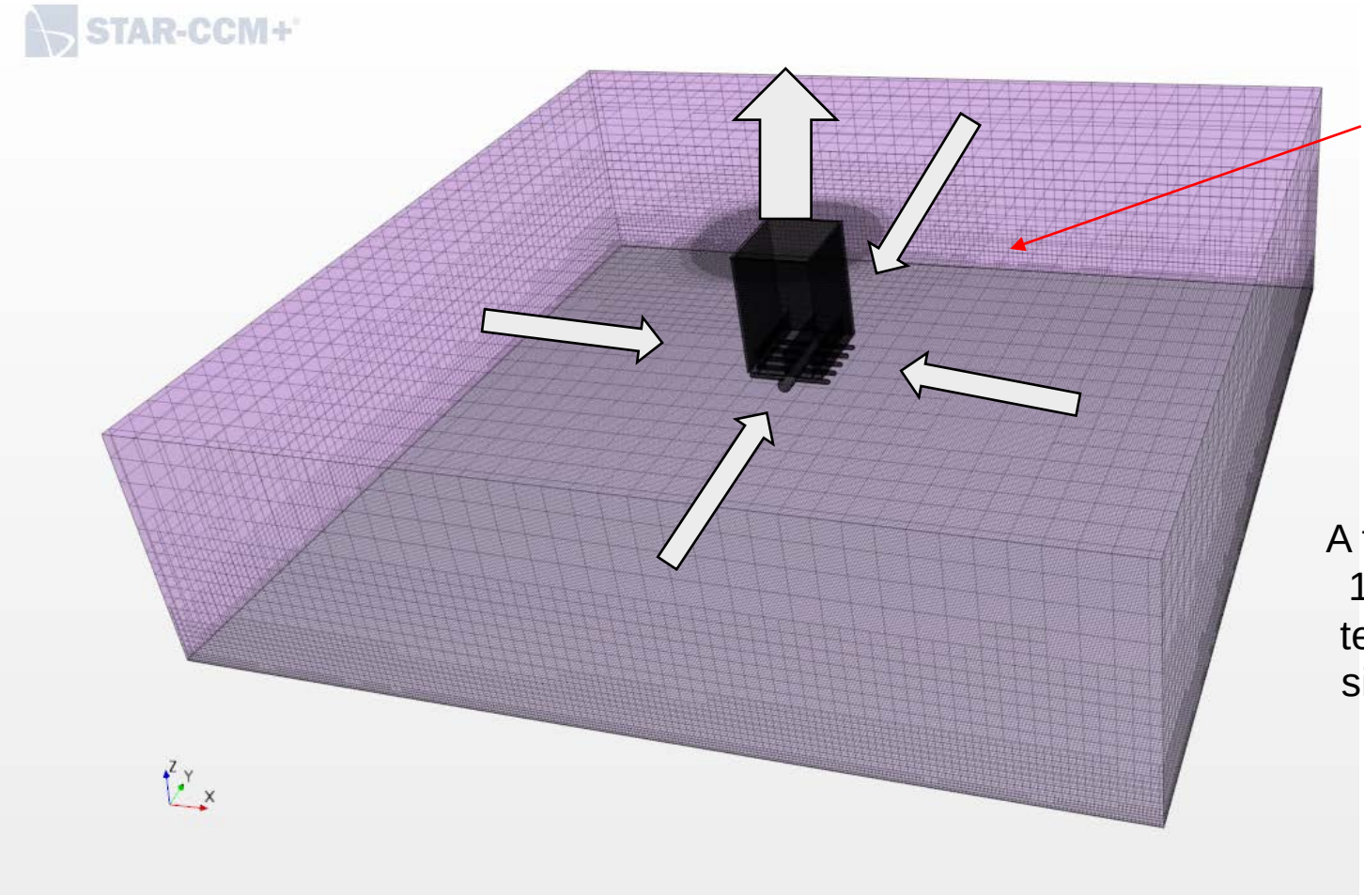
** Co-PI, Oklahoma State University

Agenda

1. Introduction
   I. Computational domain
   II. Modeling strategy
2. Results
   I. Without side-flow
   II. With side-flow
3. Conclusion and Future Work
   I. Conclusion
   II. Future work

Computational domain



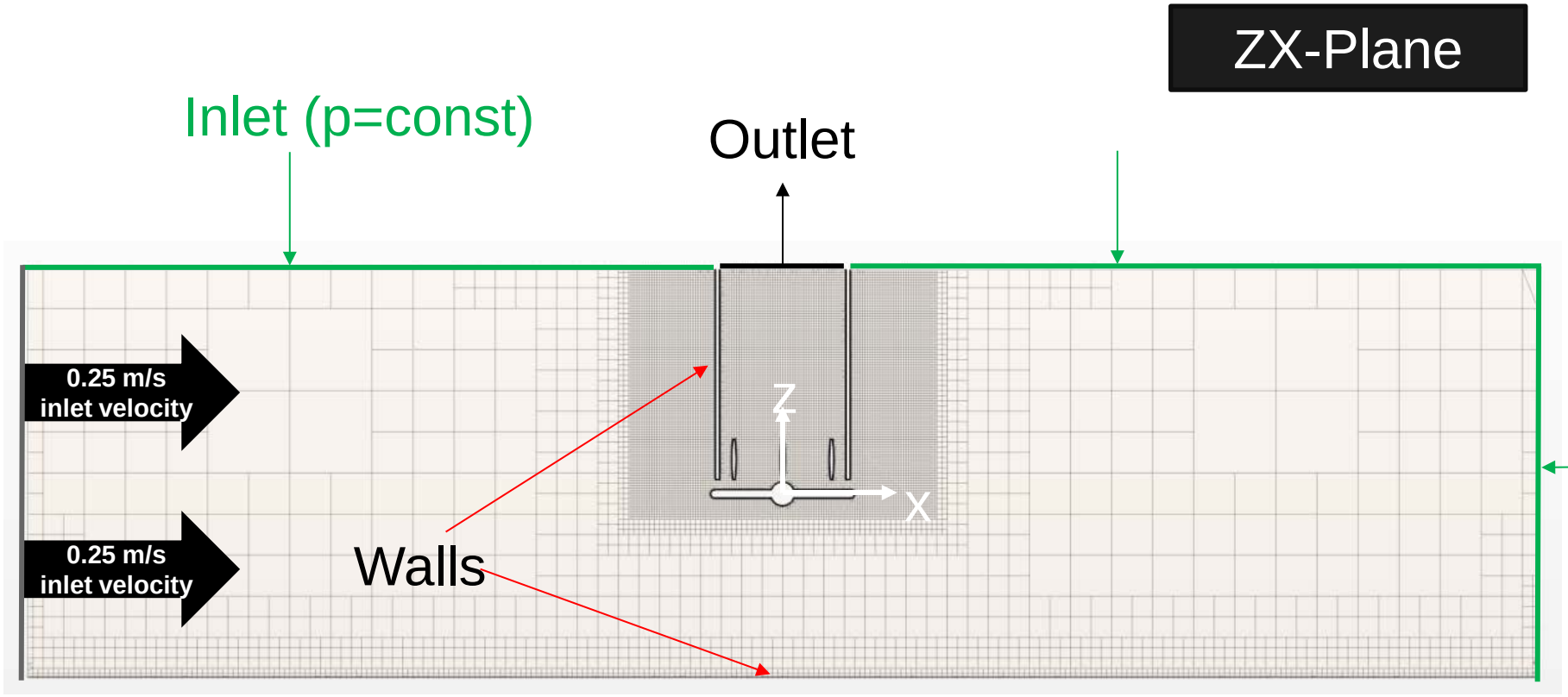
Flow has high curvature

A flow rate of 1050 CFM tested in all simulations

Computational modeling

- Steady state simulations of the computational domain using StarCCM+
- Utilizes k-omega turbulence model – appropriate for high rotation in flow (but requires very fine near wall mesh).
- Uses trimmed cell mesh – i.e. a mesh that utilizes on hexahedral elements (suitable for relatively small domains)

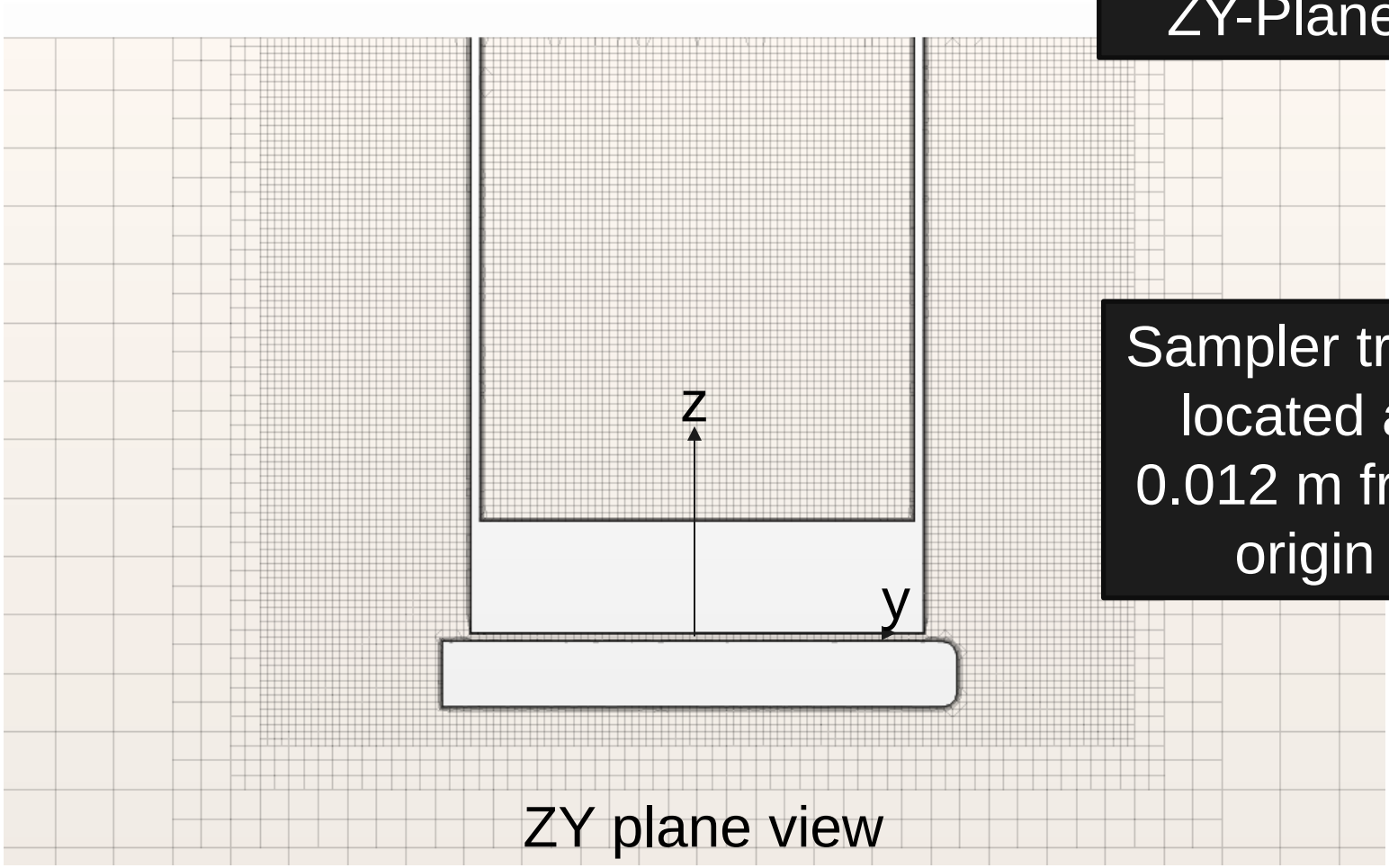
Domain cross-section, side flow



Baseline BCs

Domain cross-section

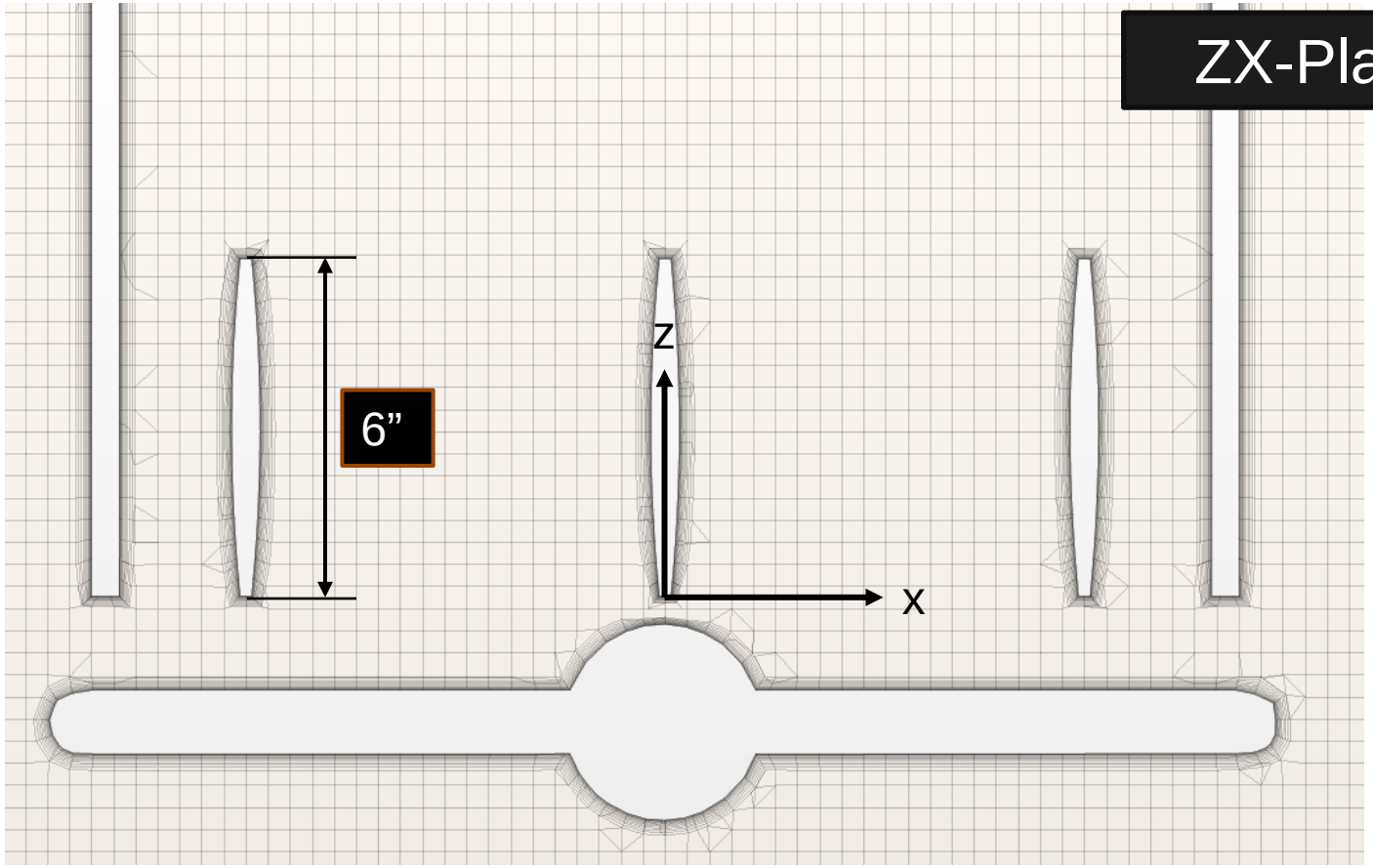
ZY-Plane



ZY plane view

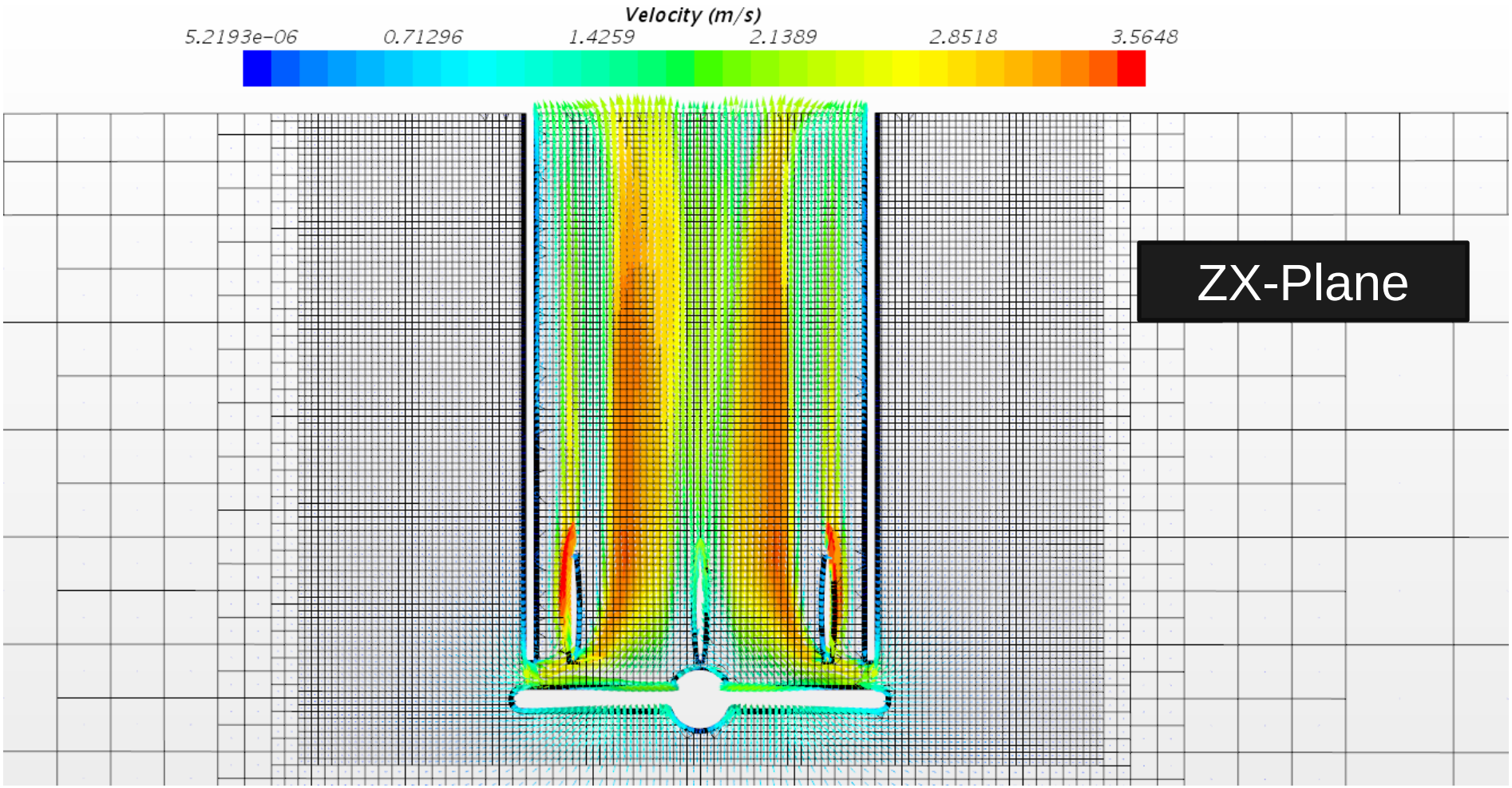
Sampler trunk located at 0.012 m from origin

Damper close-up

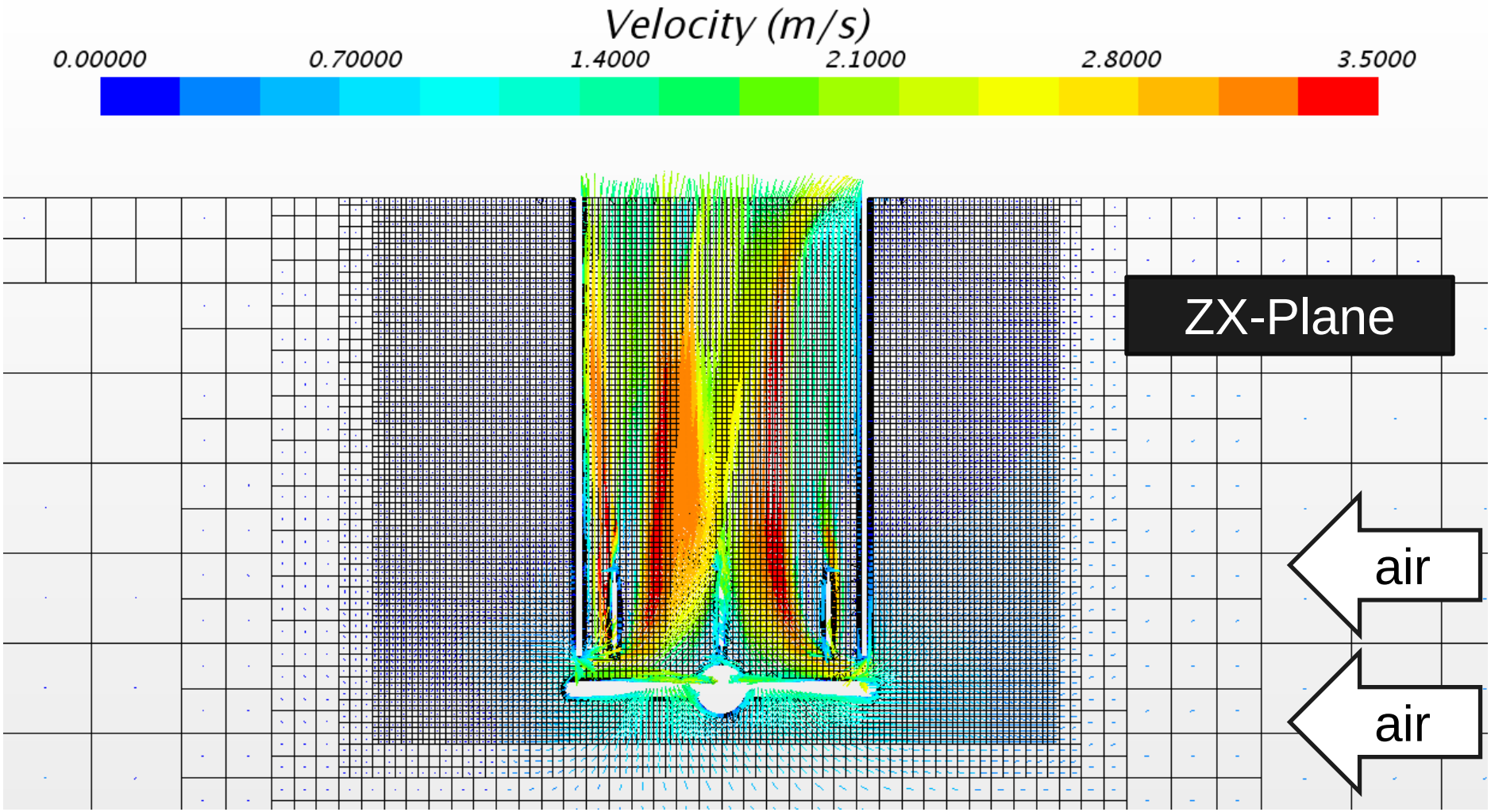


Curved dampers (thickness 0.5” at center and 0.2” at edges)

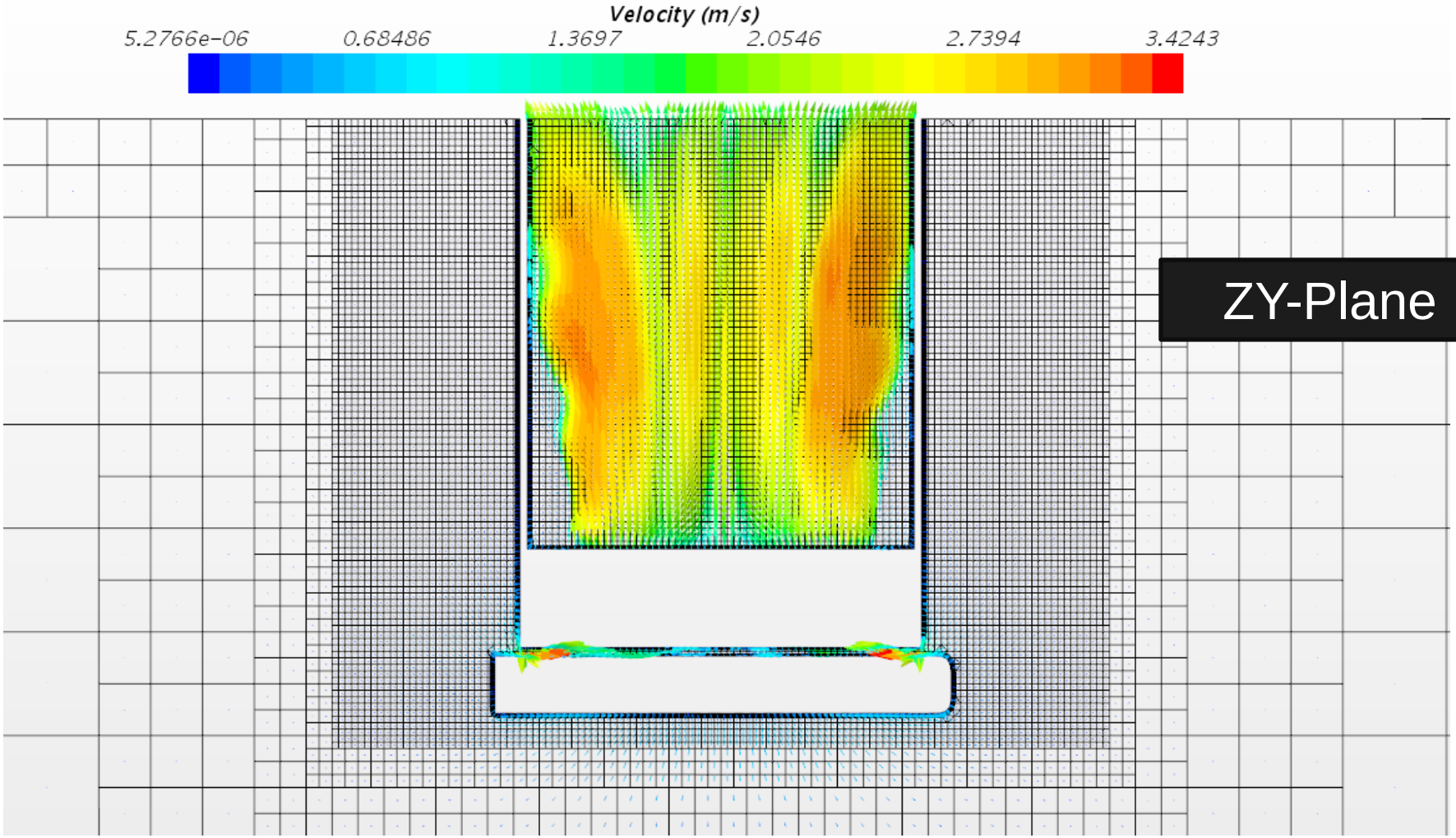
Velocity Contours – no Side Flow



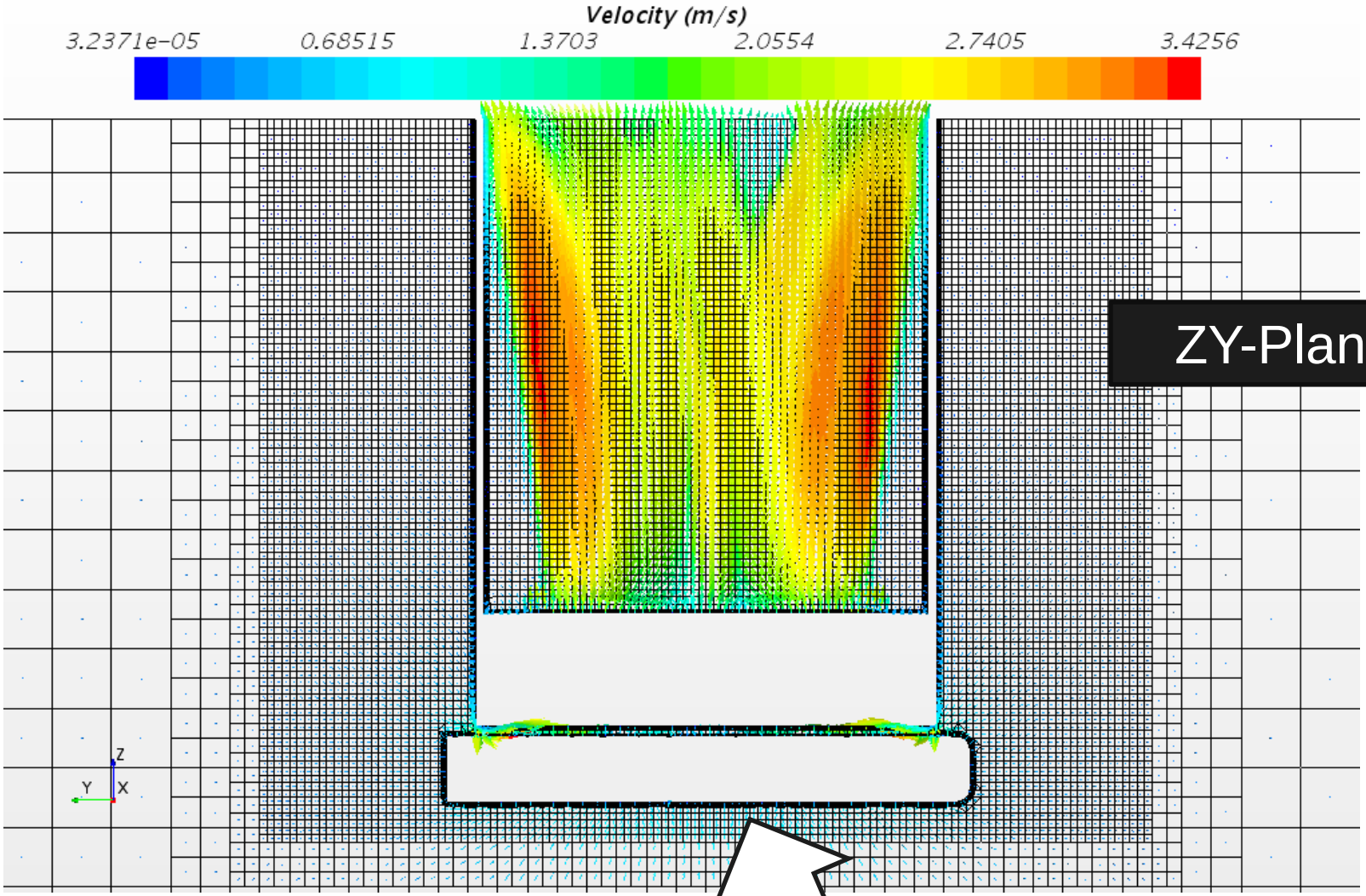
Velocity Contours – with Side Flow



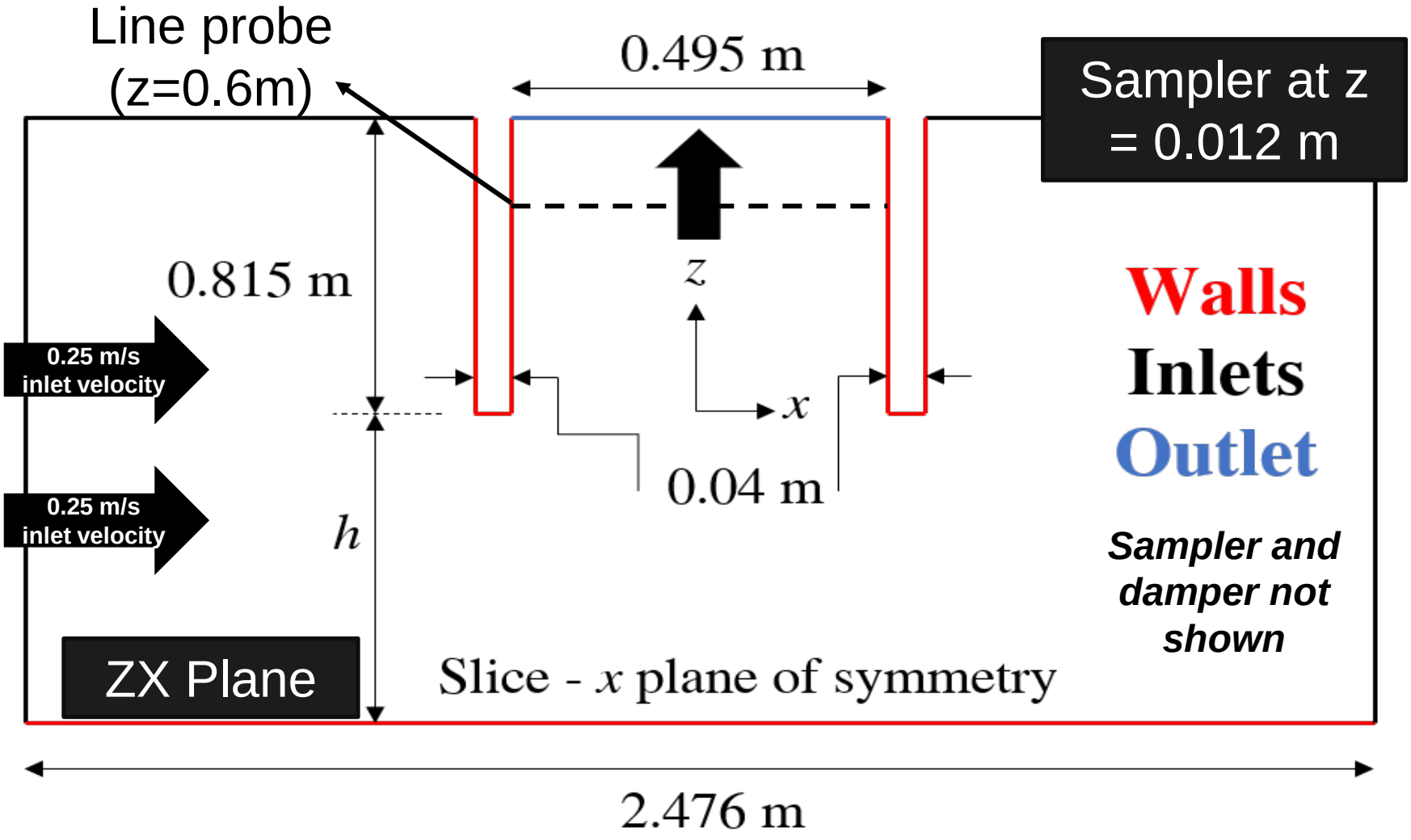
Velocity Contours – no Side Flow



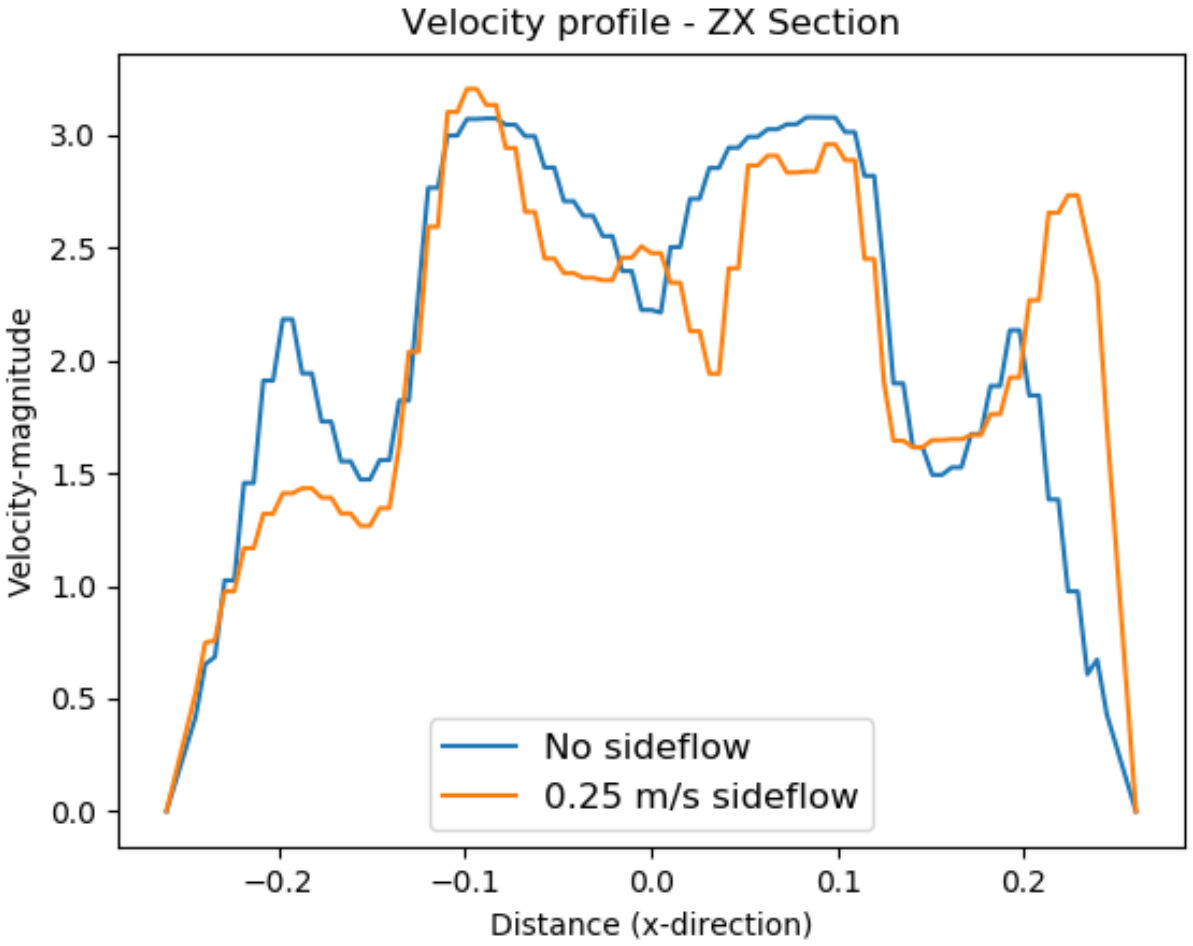
Velocity Contours – with Side Flow



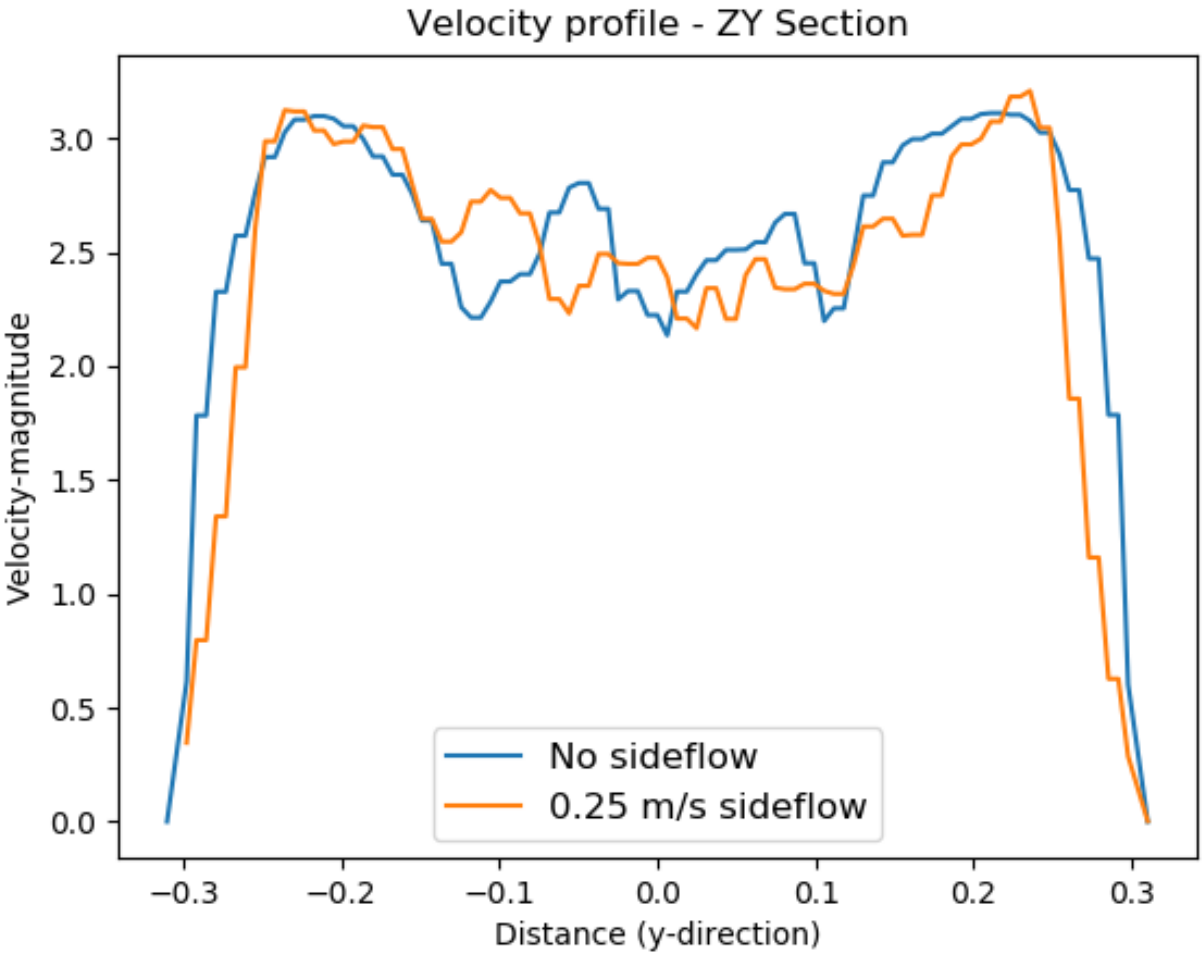
Quantitative comparisons



ZX Plane velocity comparisons



ZY Plane velocity comparisons



Conclusions & Future work

- Conclusions:
  - » Side flow perturbs velocity magnitudes in flow direction.
  - » Increases separation zone within the duct side facing the inlet.
- Future work
  - » The effects of side flow onto fan power were investigated in the experimental part of the study
    - – Assessment in CFD is too complex
- Publications
  - » CFD Guideline was sent to PMS as part of October meeting invite (10/22/2018)
  - » Received some feedback for ASHRAE summer 19 conference paper (12/14/2018)
  - » We are working on a draft for a paper for the International Congress for Refrigeration, to be shared with the PMS soon