DTE Energy, Fermi 2 Turbine Building Ventilation (TBHVAC) Fan Failures

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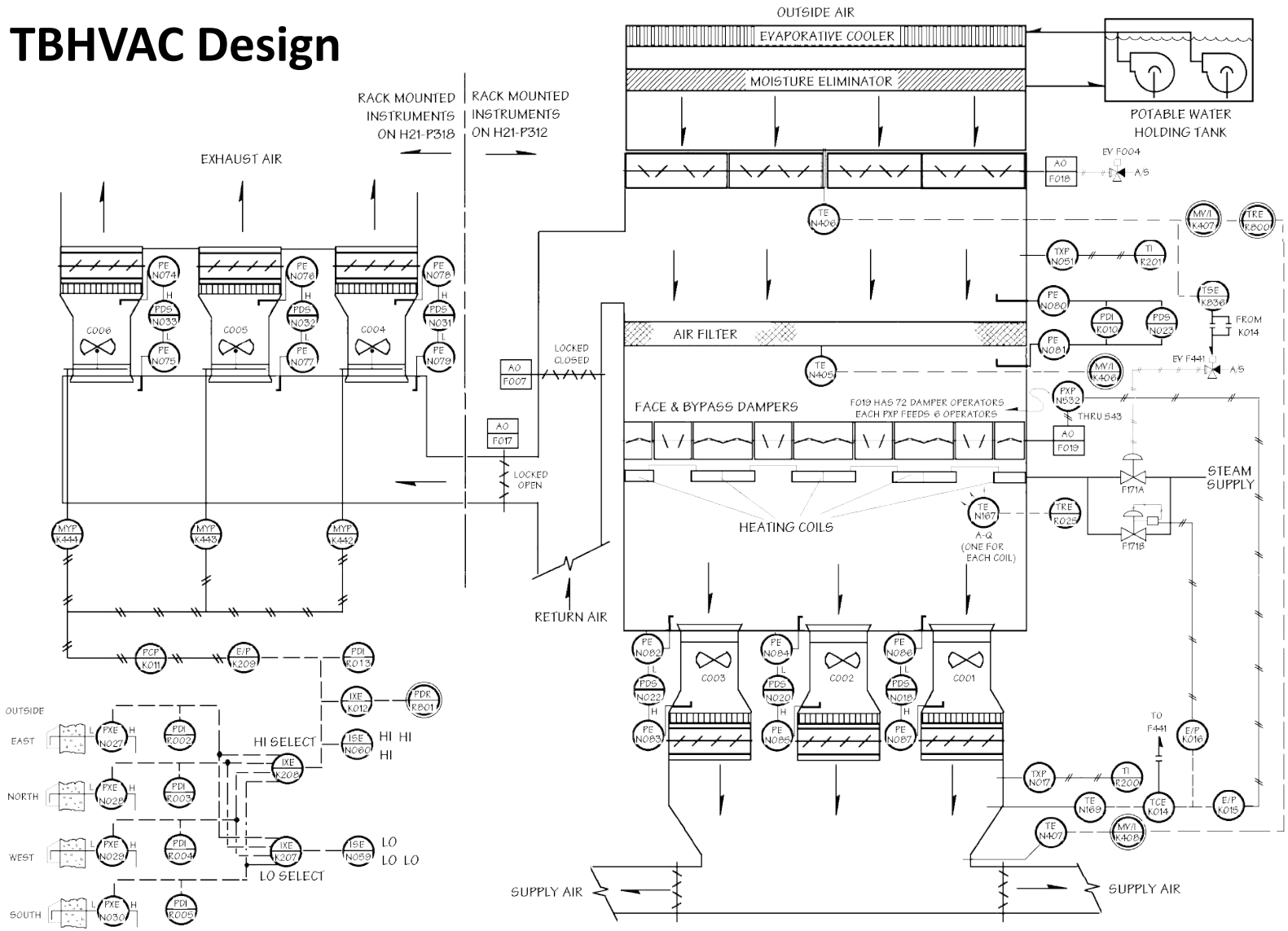
Presentation Objectives

- TBHVAC Basic Design
- Problem Description and Causes
- Actions Taken to Preclude Catastrophic Fan Failures
- TBHVAC Exhaust Inlet Plenum Computer Modeling
- TBHVAC Fan Blade Strain Gauge Testing
- Pre-mod and Post-mod Monitoring

TBHVAC Design



Exhaust Fans
Vaneaxial (3), 50% capacity, 215000 cfm @ 4.5 in. w.c. 250 HP

Supply Fans
Vaneaxial (3), 50% capacity, 205000 cfm @ 5.54 in. w.c. 250 HP

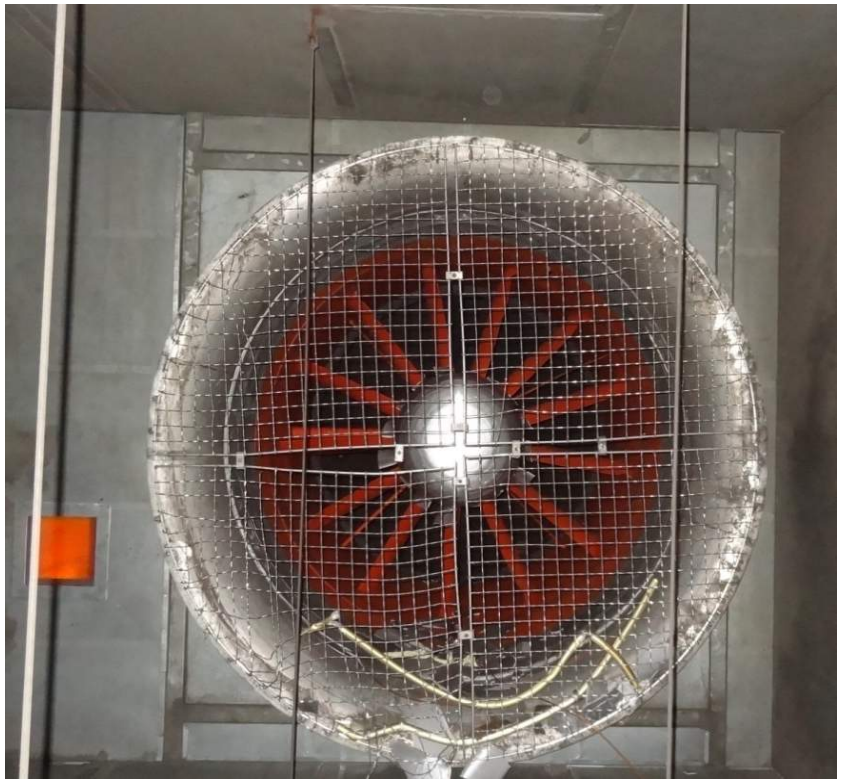
Issue Description

Since initial plant startup, the Turbine Building HVAC Exhaust fans experienced multiple catastrophic blade failures.

- The Center TBHVAC Exhaust fan experienced six (6) failures.
- The North TBHVAC Exhaust fan experienced six (6) failures.
- The South TBHVAC Exhaust fan experienced zero (0) failures.
- The Supply fans only experienced one catastrophic failure due to material intrusion.

Catastrophic Fan Failures

Catastrophic Fan Failures



Cause

Root Causes:

- The exhaust fan controllable pitch fan blades were pitched too high resulting in fan stall.

- The exhaust inlet plenum design less than adequate resulting in non-uniform airflow causing high stress fatigue failures of the fan blades.

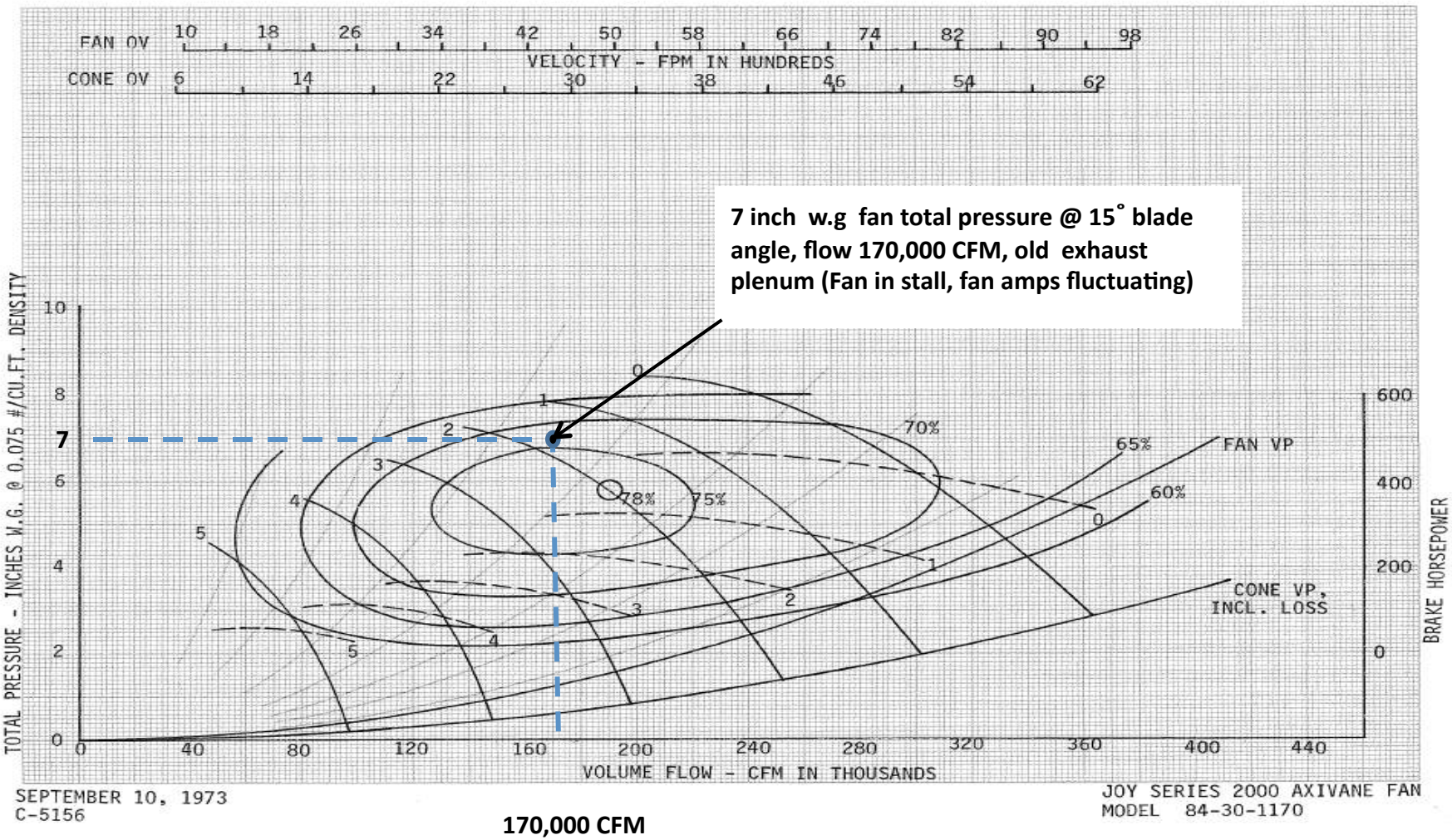
Actions Completed

1. All TBHVAC Exhaust Fans converted from controllable (variable pitch) to adjustable (fixed pitch) fans at a lower pitch setting.

2. The exhaust inlet plenum was reconfigured with extended fan inlets based on CFD modeling performed by Airflow Sciences, complete 2014.

Fan Curve

North Exhaust Fan Operating with South Exhaust Fan, Before Improvements



170,000 CFM

Action 1, Fans Converted to Adjustable Pitch

Controllable Pitch Fans, 52 Moving Parts

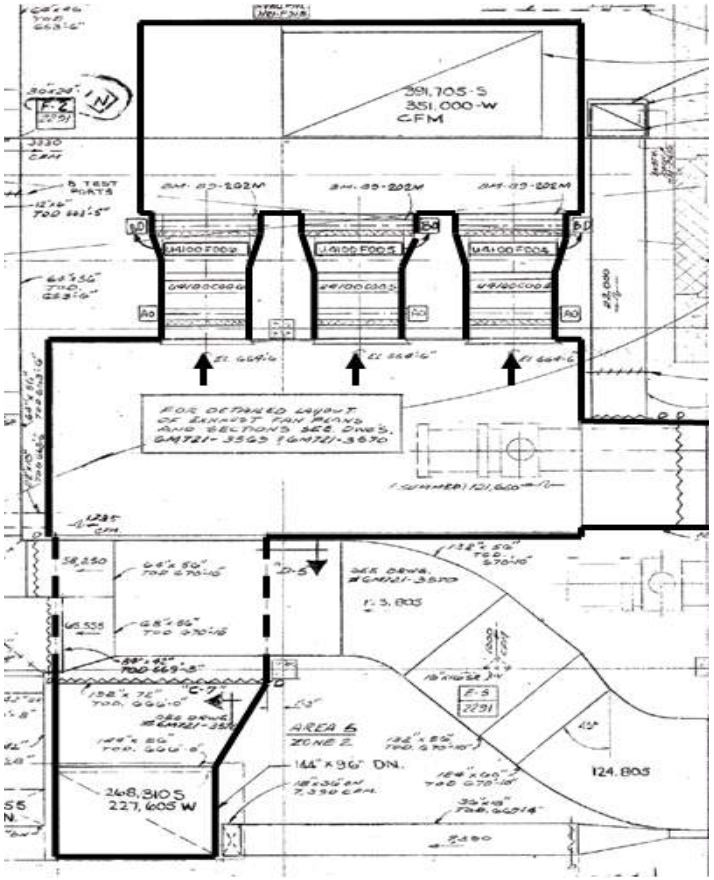
Converted To →

Adjustable Pitch Fans, More Robust, One relative moving Part

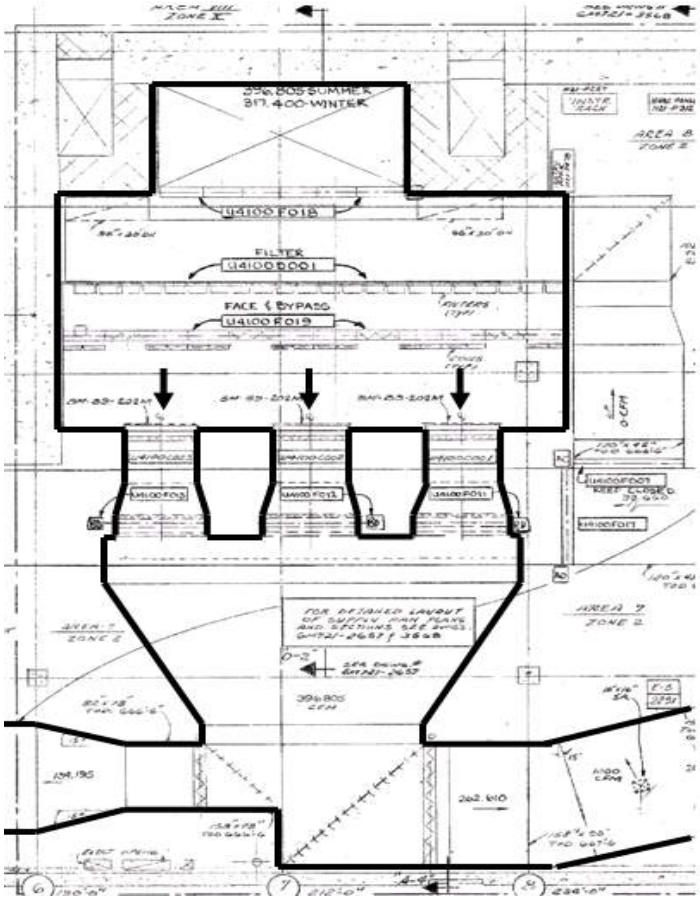
Action 2, Exhaust Plenum Reconfigured

Exhaust and Supply Plenum Comparison

Previous Exhaust Inlet Plenum, Inadequate Approach to Fans



Existing Supply Inlet Plenum, Adequate Approach to Fans



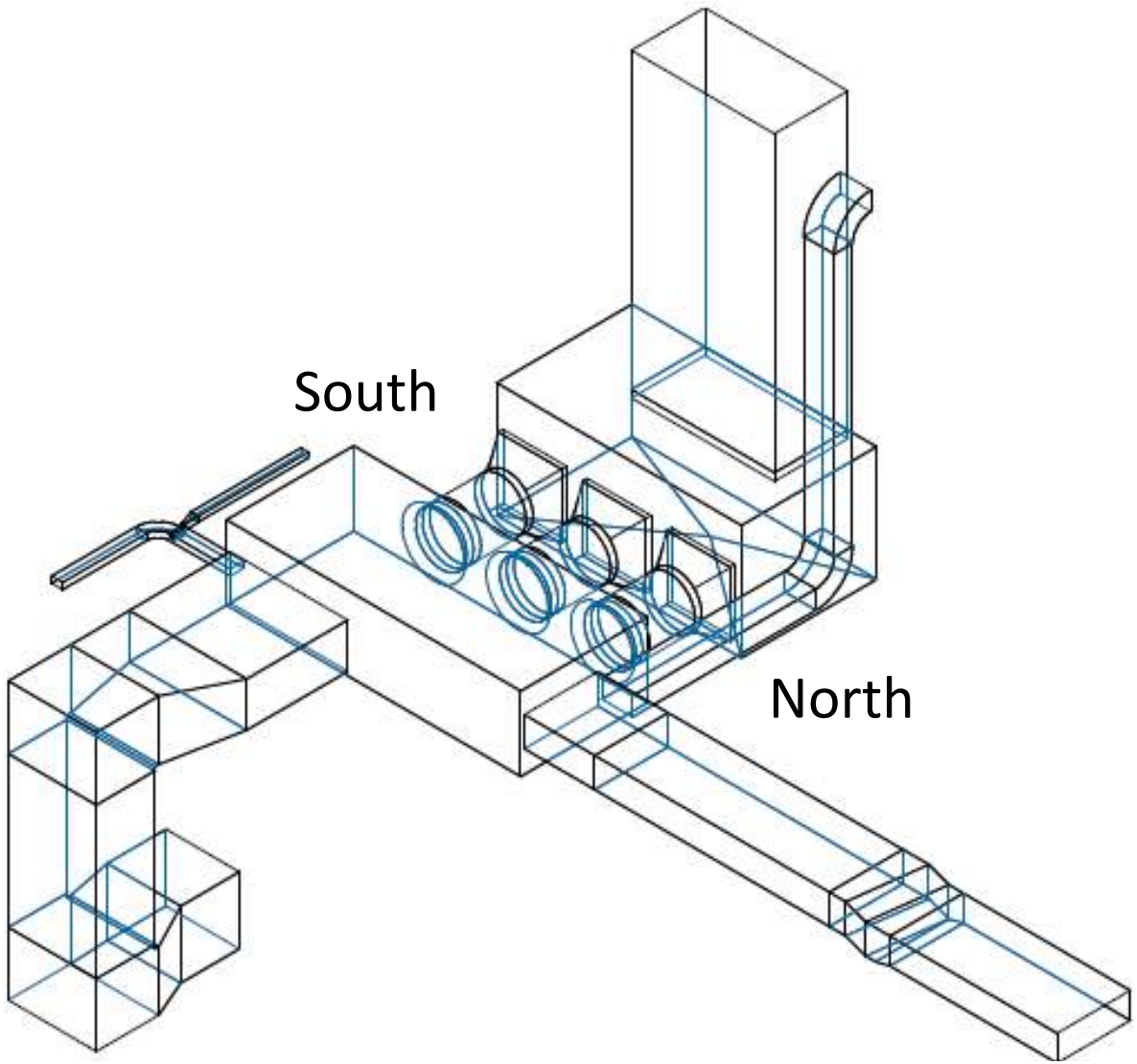
TBHVAC Air Flow Investigation by Airflow Sciences Corporation:

- 3-D Velocity Testing
  - Knowledge of Actual Flow
  - Sparse Data
- CFD (Computational Fluid Dynamics) Modeling
  - Complete Flow Field
  - Modeling Assumptions

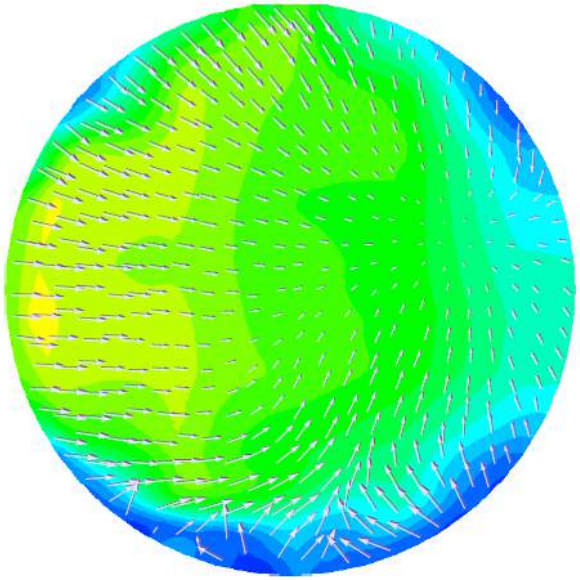
3-D Velocity Testing

- 3-D Velocity Probe
  - 3 Velocity Components
  - Pressure / Temperature
- 3-D Data Acquisition System (3DDAS™)
  - Automated Data Collection, Leak Detection & Report Generation
  - Accurate & Repeatable Measurements
  - Compliant with EPA Method Procedures

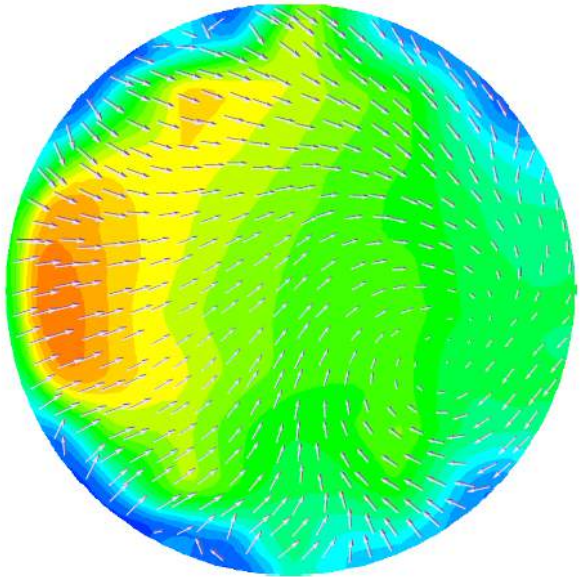
Previous Exhaust Inlet / Outlet Plenums



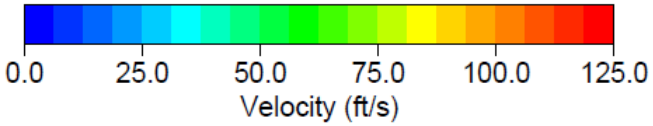
Previous Exhaust Inlet Plenum, North and South Inlet Velocity Profile, 2010 Testing



South
RMS = 21.7%



North
RMS = 31.9%

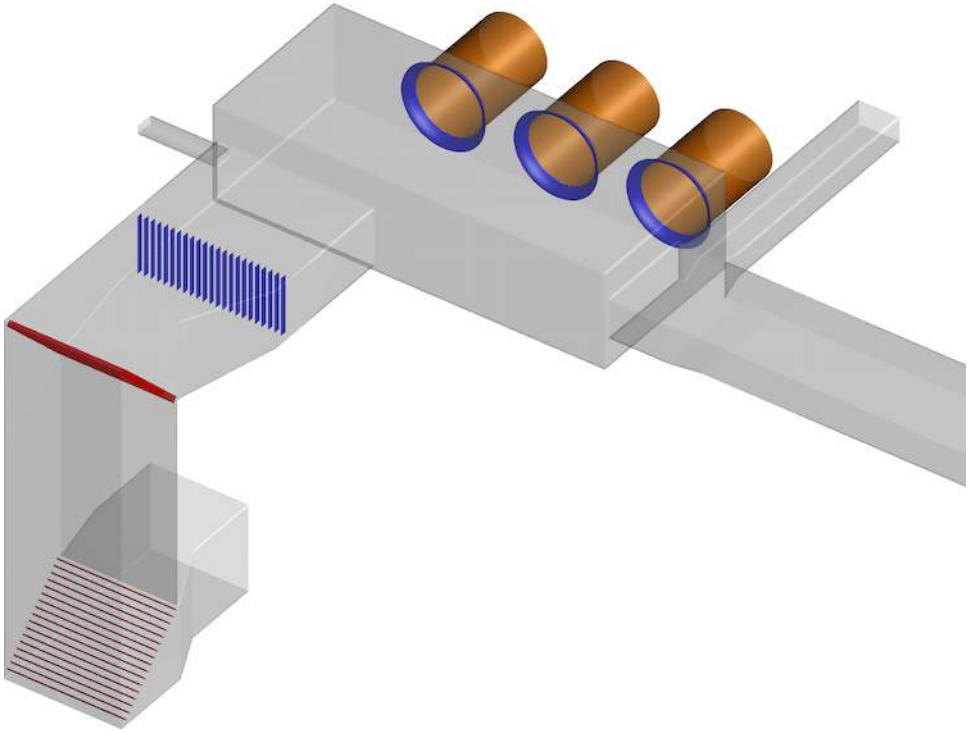


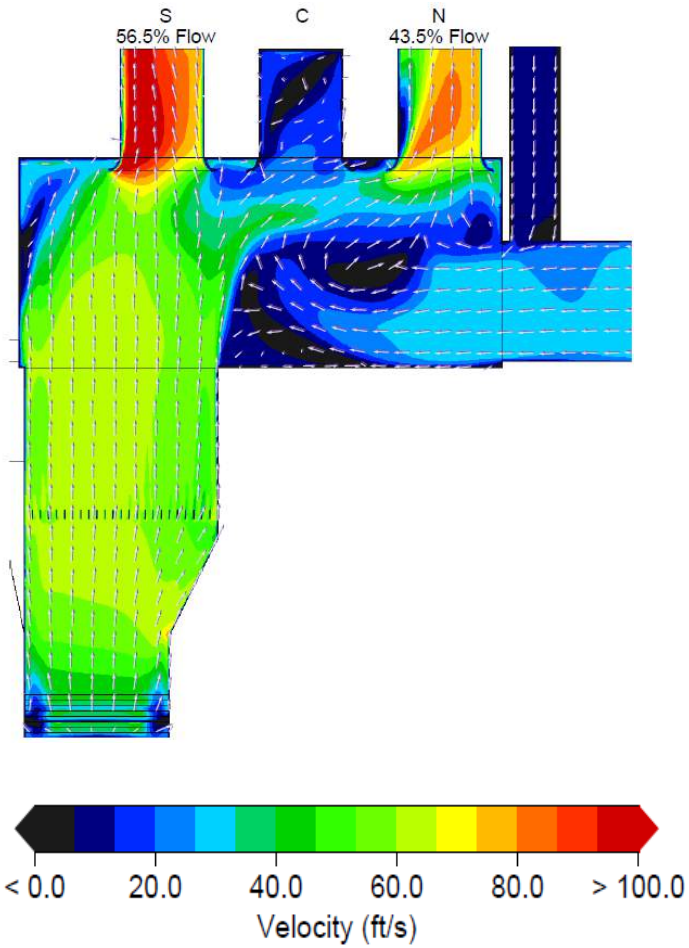
- Velocity RMS is the measure of the velocity uniformity at the plane of interest
  - Lower values are better
- AMCA 803 recommends velocity RMS of < 10% at the fan inlets

CFD Modeling
(Computational Fluid Dynamics)

- Divide 3-D domain into millions of small cells (approx 1.5”)
- Solve equations of fluid motion on individual cells
- Boundary conditions at walls / inlets / exits
- Steady state → turbulence model
- Results: Time-average velocity & pressure fields

Previous Exhaust Inlet Plenum, North and South Fans in Service





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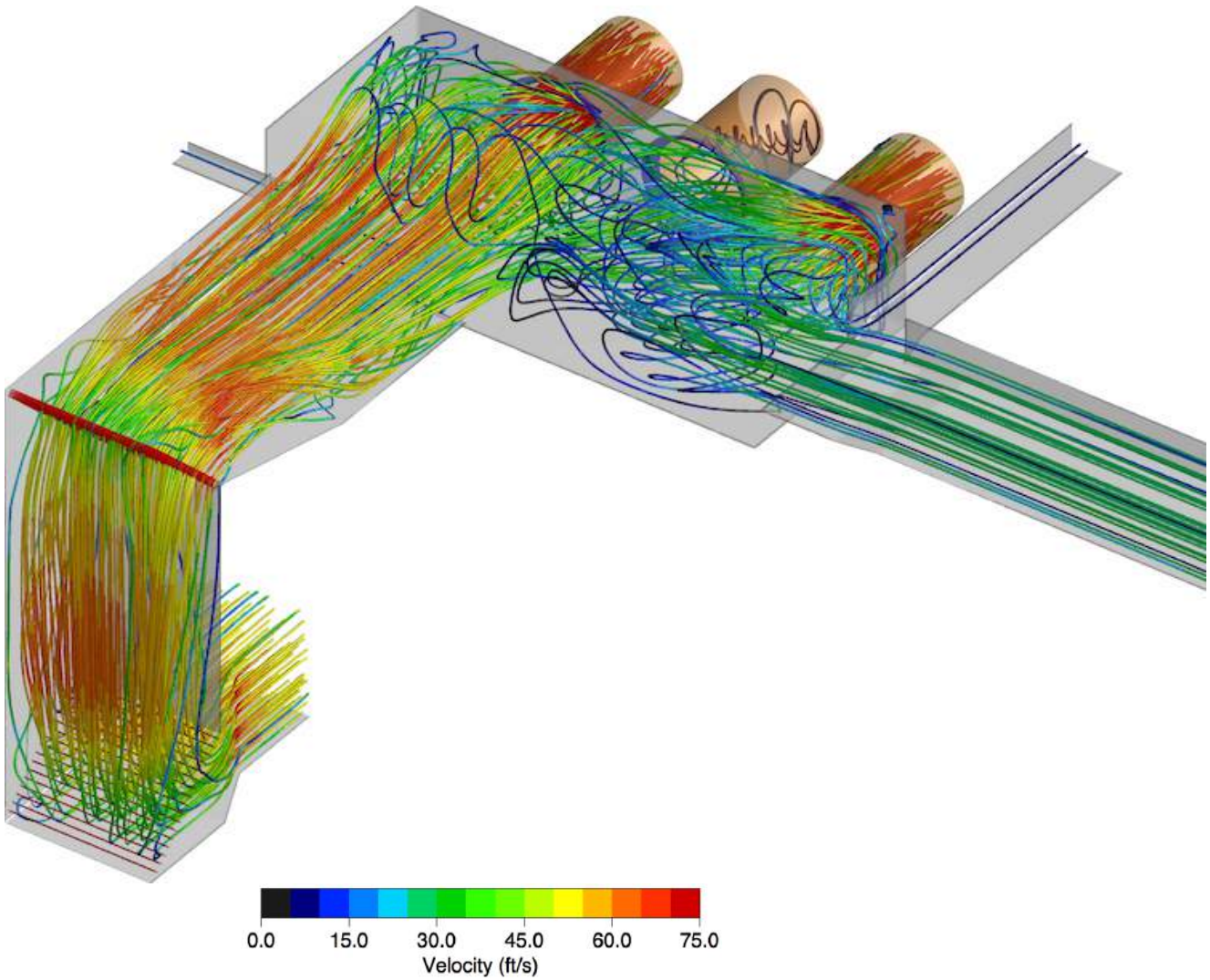
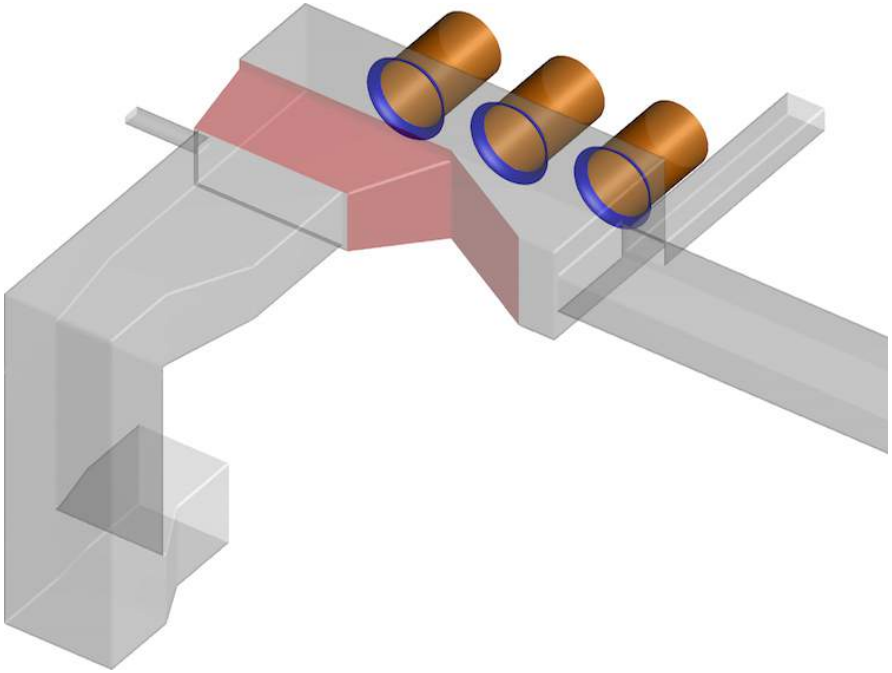


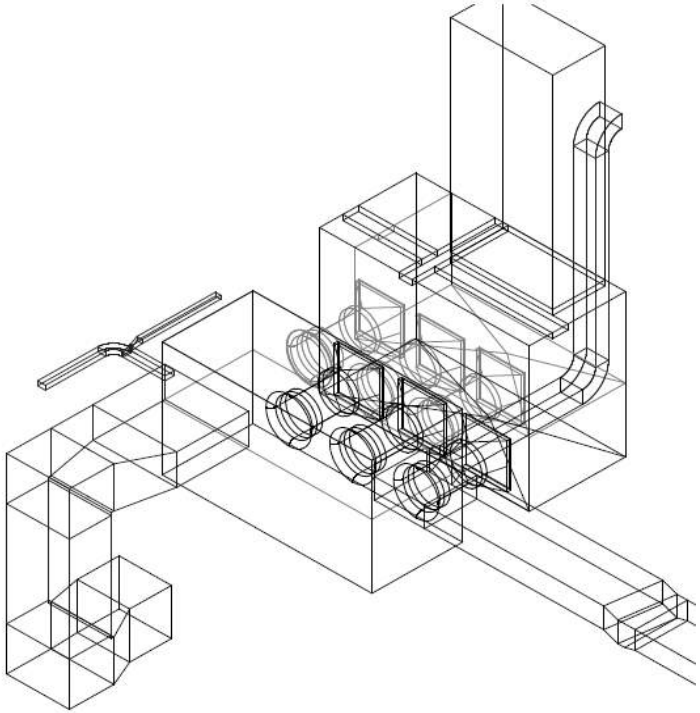
Plenum Design Objectives

- Reduce RMS at Fan Inlets (< 10% per AMCA)
  - Gas Flow Straight into Fans
  - Less Recirculation in Plenum
- Allow for Any Combination of Fans
- Reduce Pressure Losses
- Constructability

CFD Modeling Performed on Different Design Concepts

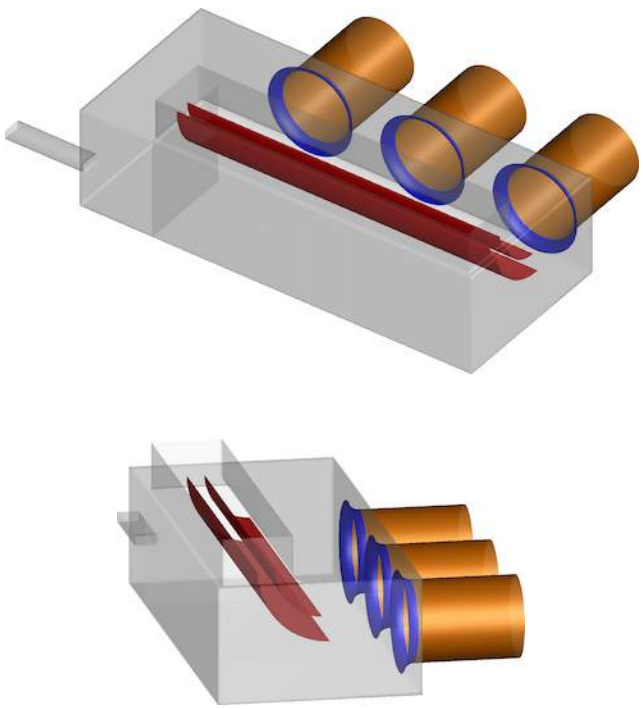


Minor duct modifications with internal Baffles/Turning Vanes

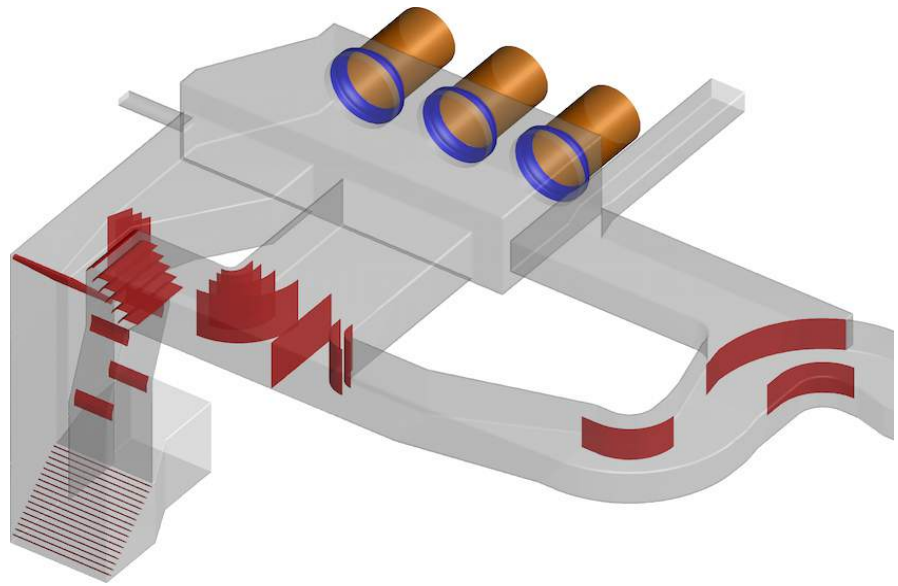


Extend Plenums and fans to the floor

CFD Modeling Performed on Different Design Concepts

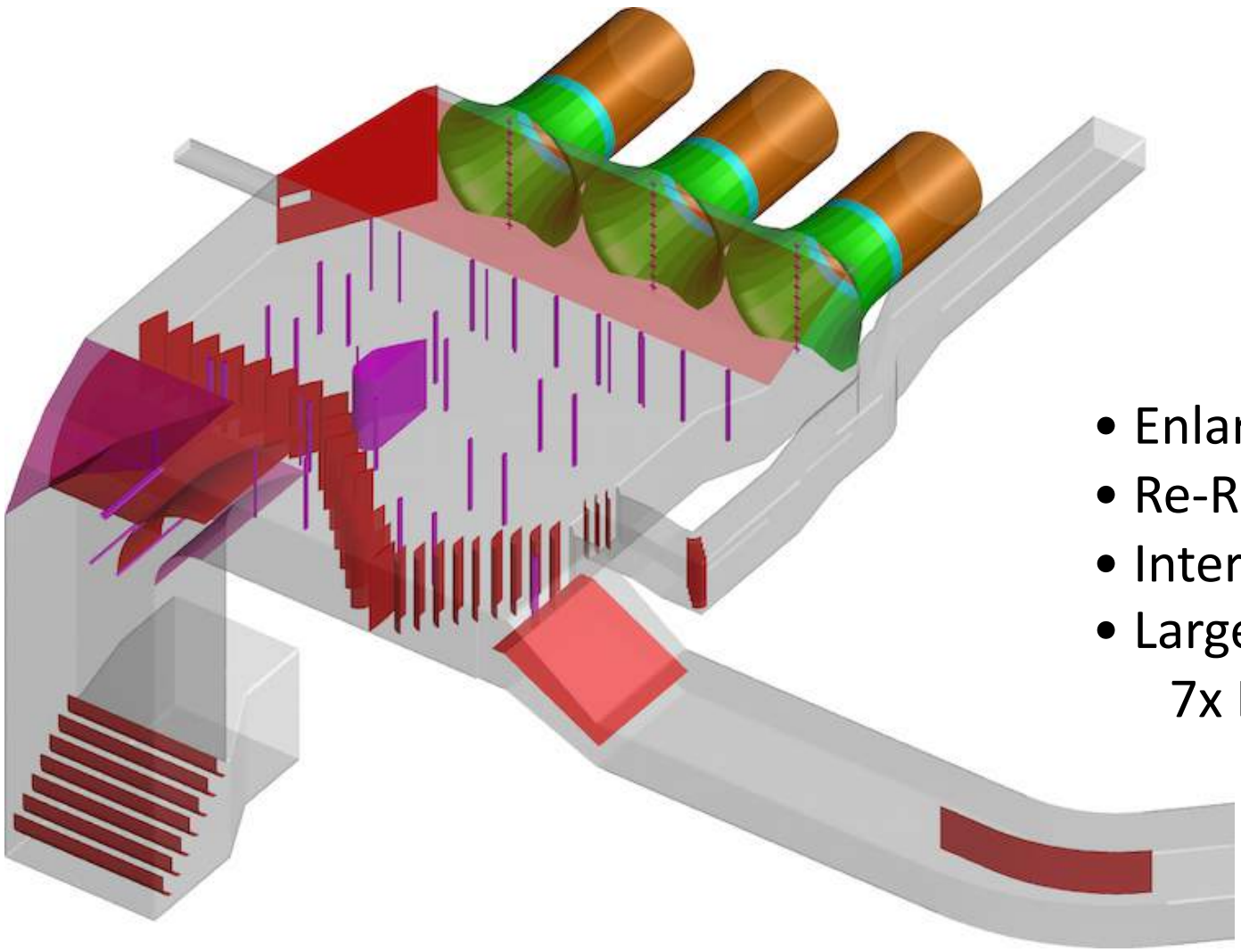


Route exhaust ducts through the roof and enter through the top of the plenum



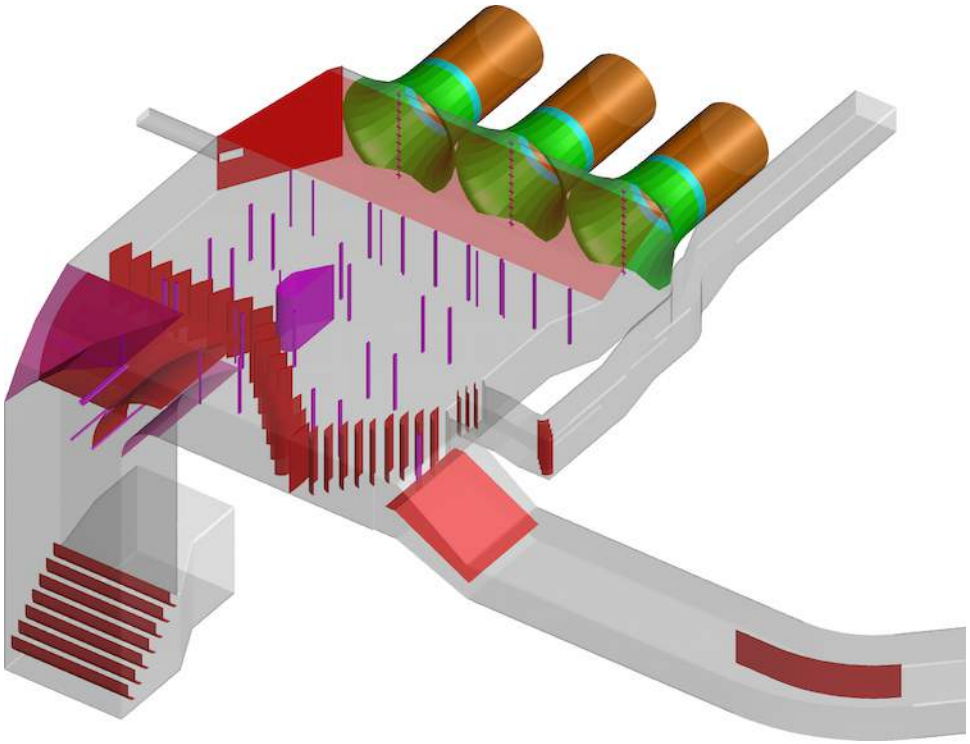
Split the main riser into 2 ducts for better inlet conditions to the North fan

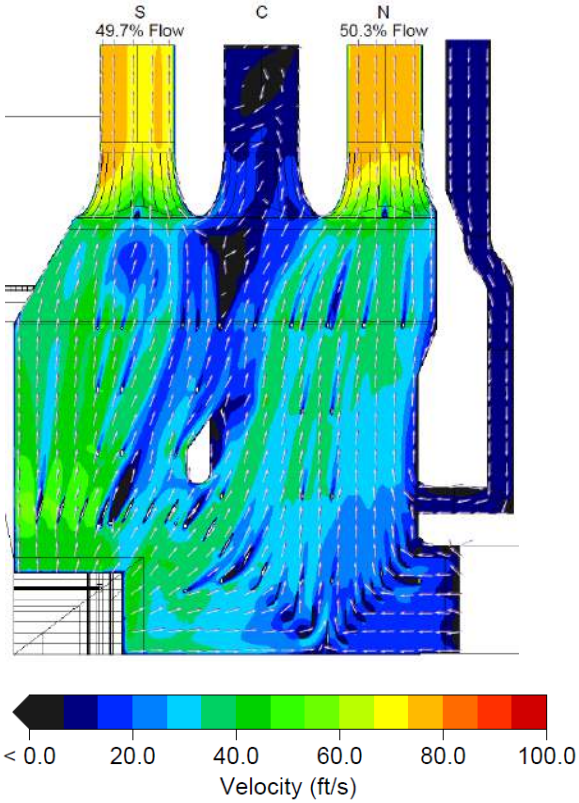
Final Exhaust Inlet Plenum Design



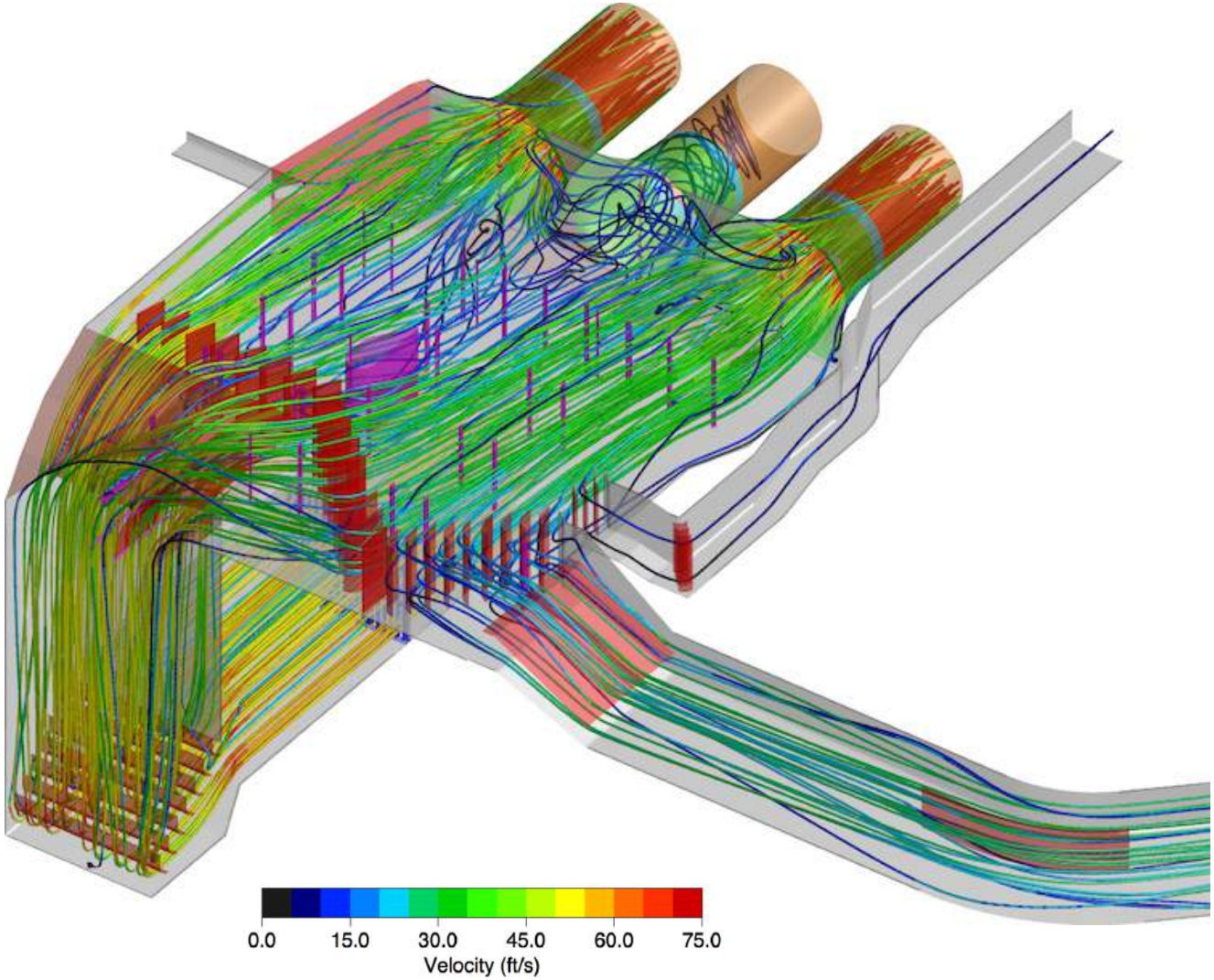
- Enlarged Plenum
- Re-Route Ducts
- Internal Vanes
- Larger Bellmouths
  7x Longer

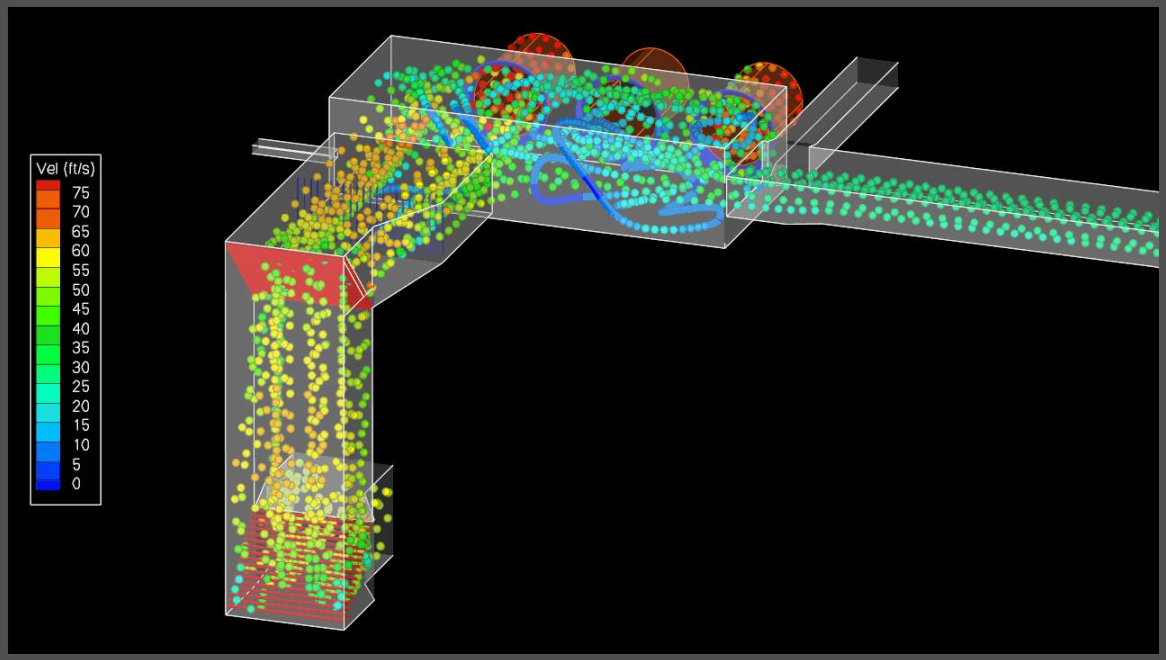
Final Exhaust Inlet Plenum Design, With Internal Geometry, North and South Fans in Service



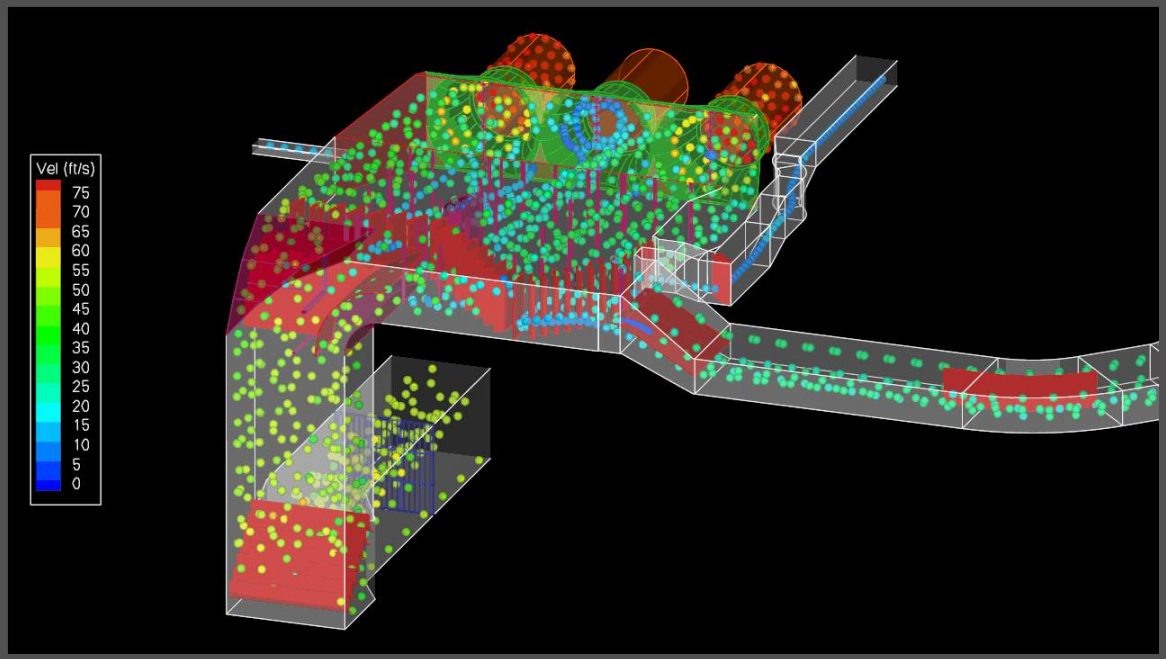


Final Exhaust Inlet Plenum Design, With Internal Geometry, North and South Fans in Service





Previous Exhaust Inlet Plenum, North and South Fans in Service



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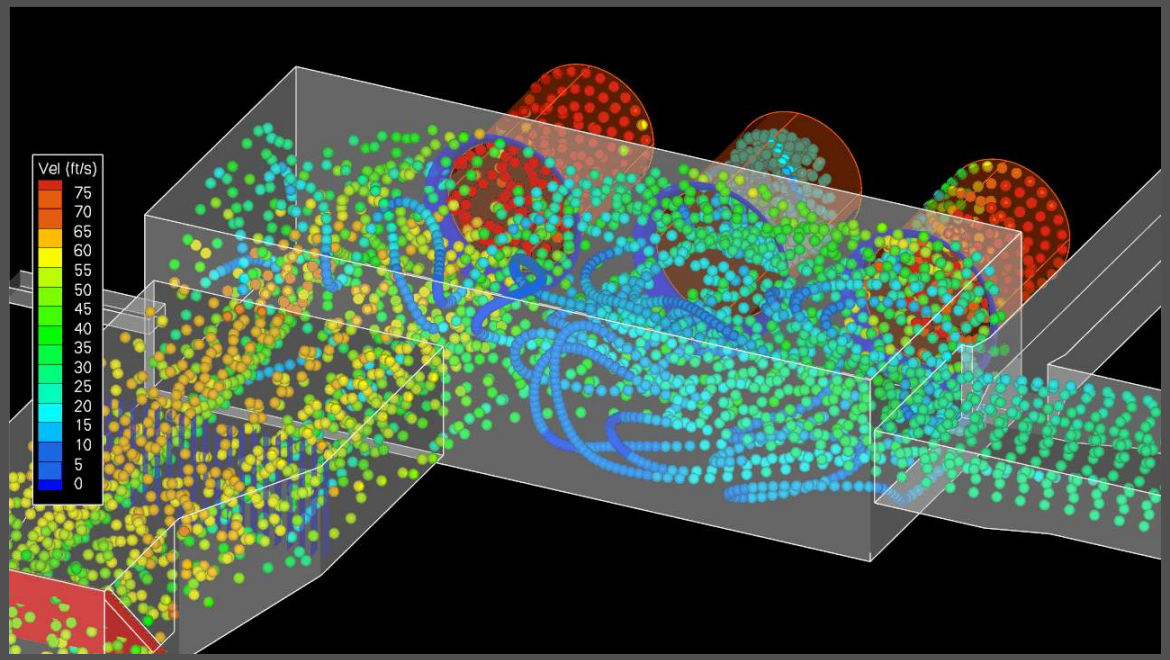

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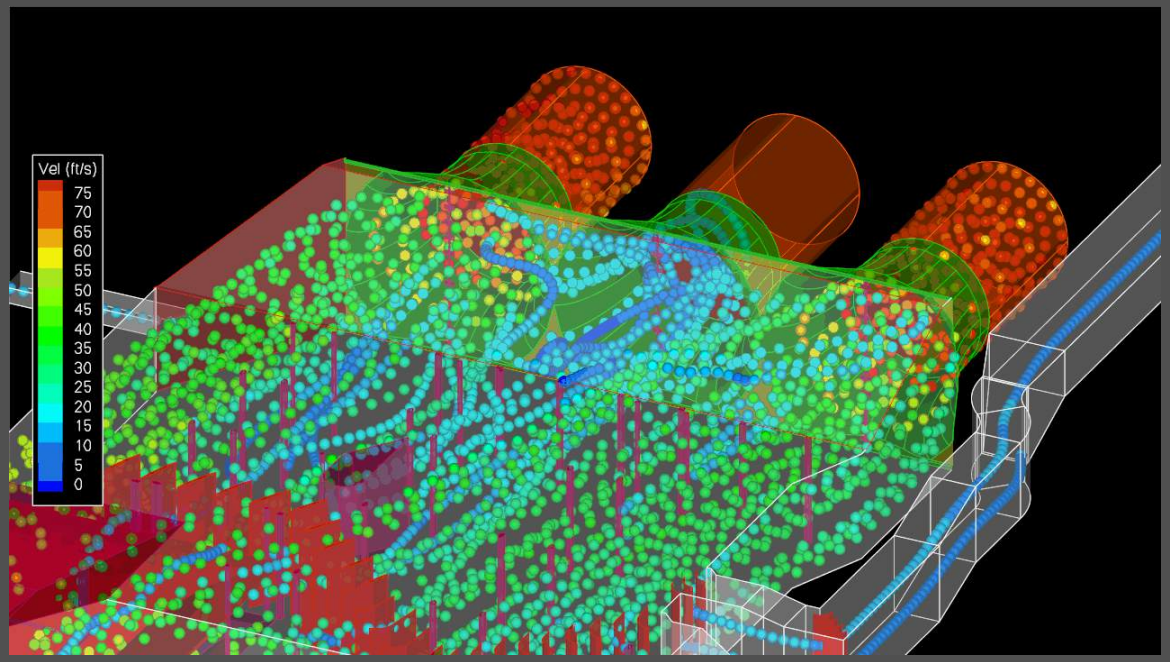

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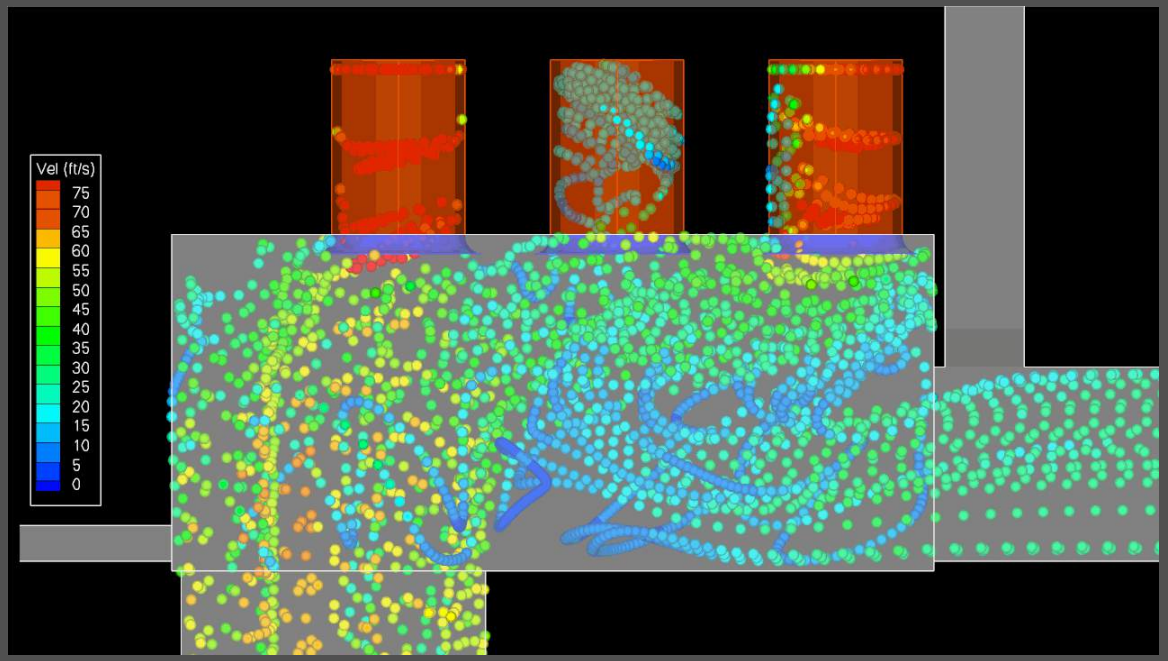
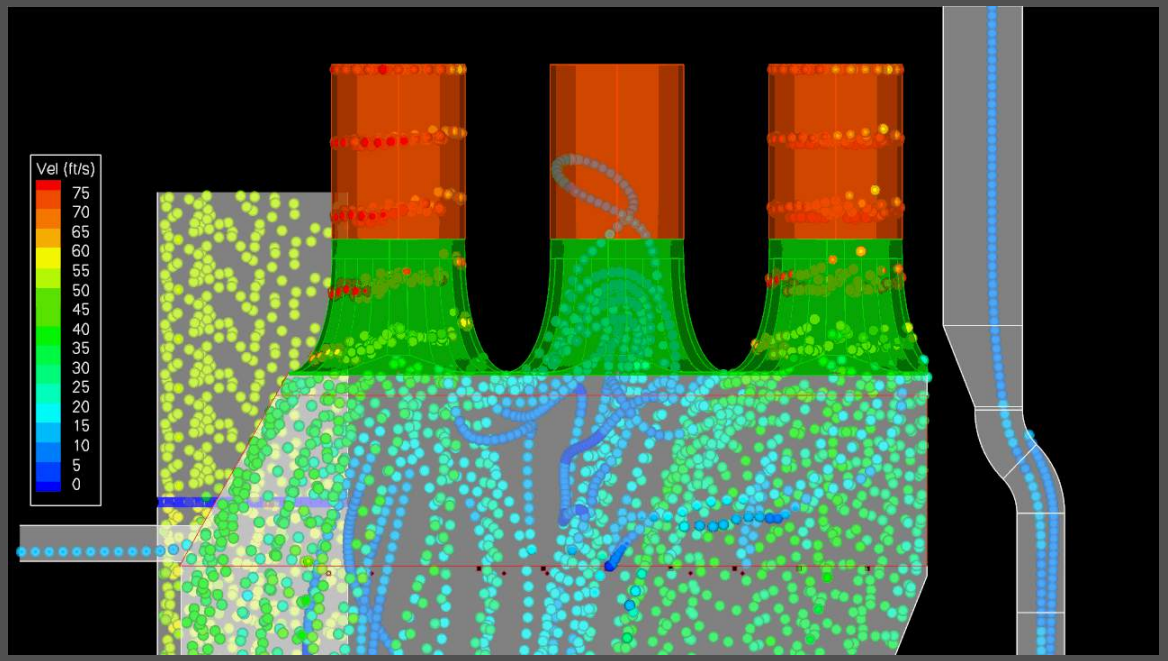


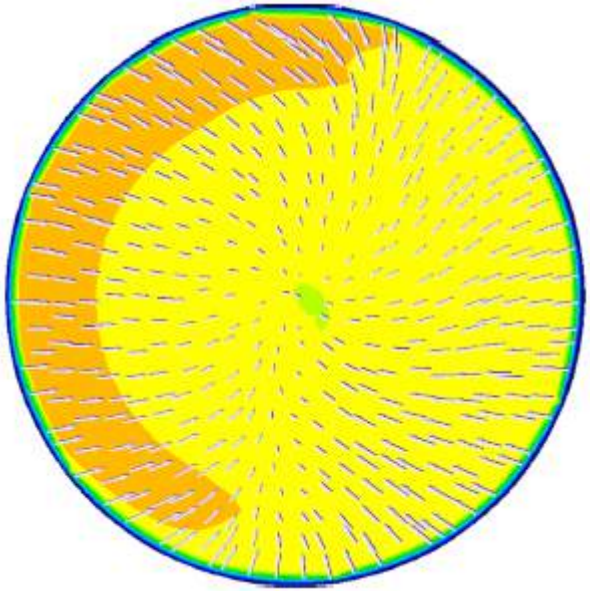
Previous Exhaust Inlet Plenum, North and South Fans in Service



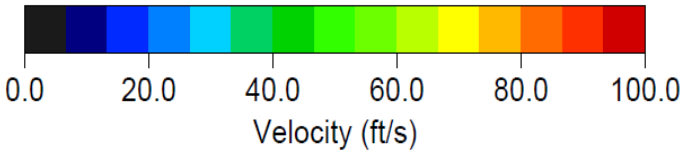
Final Exhaust Inlet Plenum, North and South Fans in Service

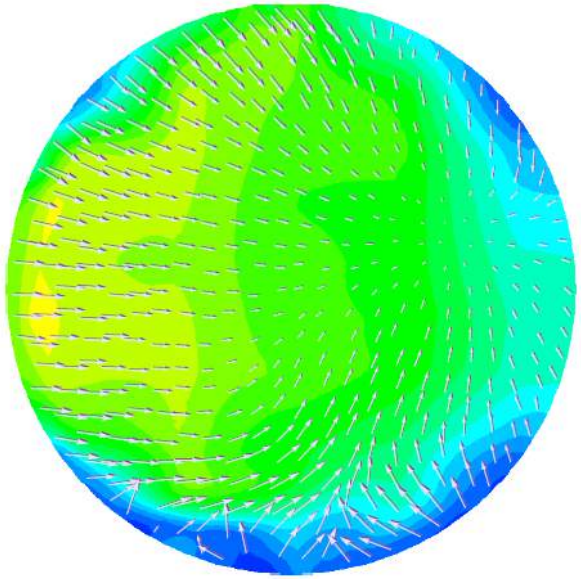
New Exhaust Inlet Plenum

Previous South Fan Inlet Velocity Profile Compared to Modified (Operating with The North Exhaust Fan)

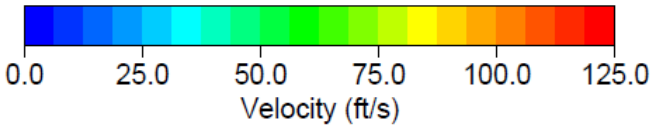


Modified Plenum, South Fan
RMS = 4.3%



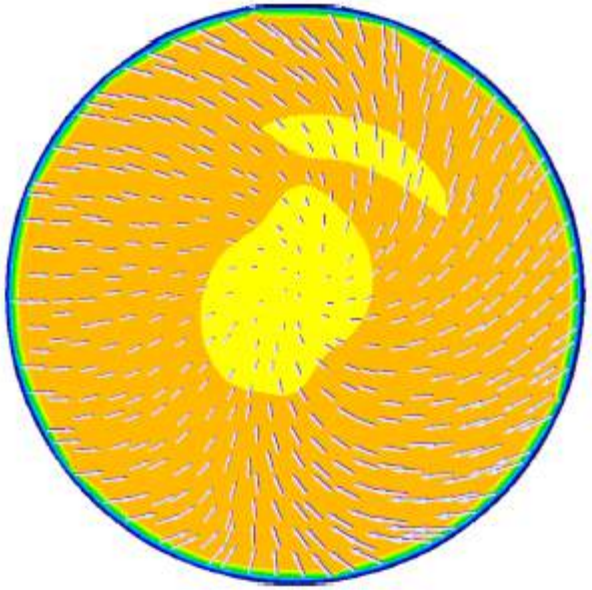


Previous Plenum, South Fan
RMS = 21.7%

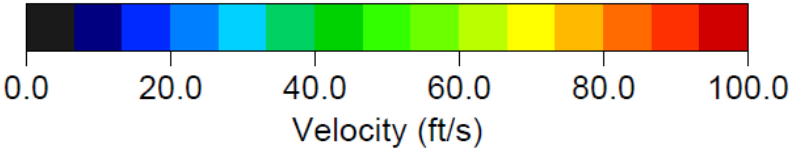


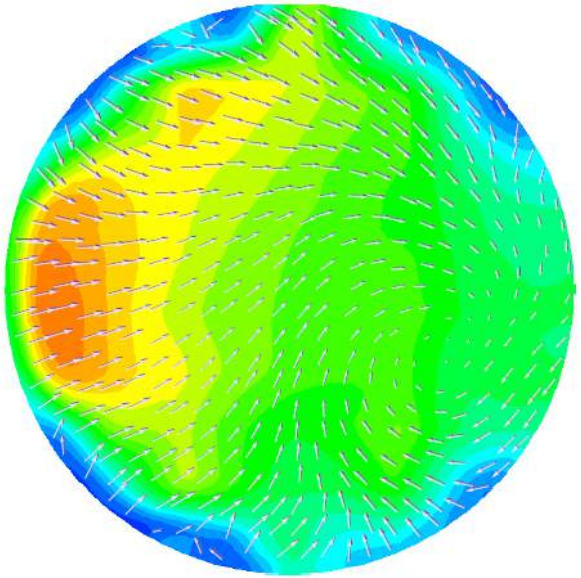
New Exhaust Inlet Plenum

Previous North Fan Inlet Velocity Profile Compared to Modified (Operating with The South Exhaust Fan)

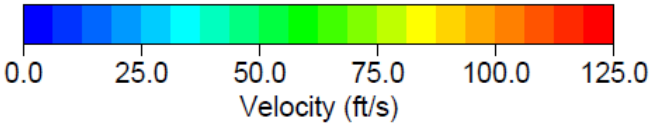


Modified Plenum, North Fan
RMS = 2.5%





Previous Plenum, North Fan
RMS = 31.9%



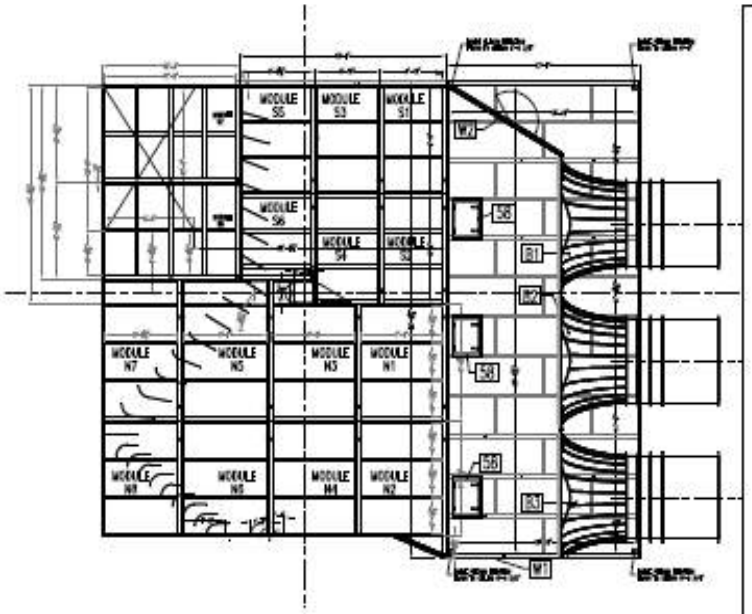
Summary of Final Inlet Plenum Design Results

- **Significantly Better (Lower RMS) for All Fan Combinations**

RMS Summary and Comparison

	2010 As-Found Baseline		2014 Post Modification	
Two Fan N + S	South	North	South	North
Axial Velocity RMS %	21.7%	31.9%	4.3%	2.5%
Two Fan N + C	Center	North	Center	North
Axial Velocity RMS %	29.0%	14.5%	6.6%	2.9%
Two Fan S + C	South	Center	South	Center
Axial Velocity RMS %	24.1%	20.2%	4.6%	3.5%
Single Fan North	North		North	
Axial Velocity RMS %	18.5%		3.7%	
Single Fan Center	Center		Center	
Axial Velocity RMS %	19.2%		3.7%	
Single Fan South	South		South	
Axial Velocity RMS %	20.0%		3.5%	

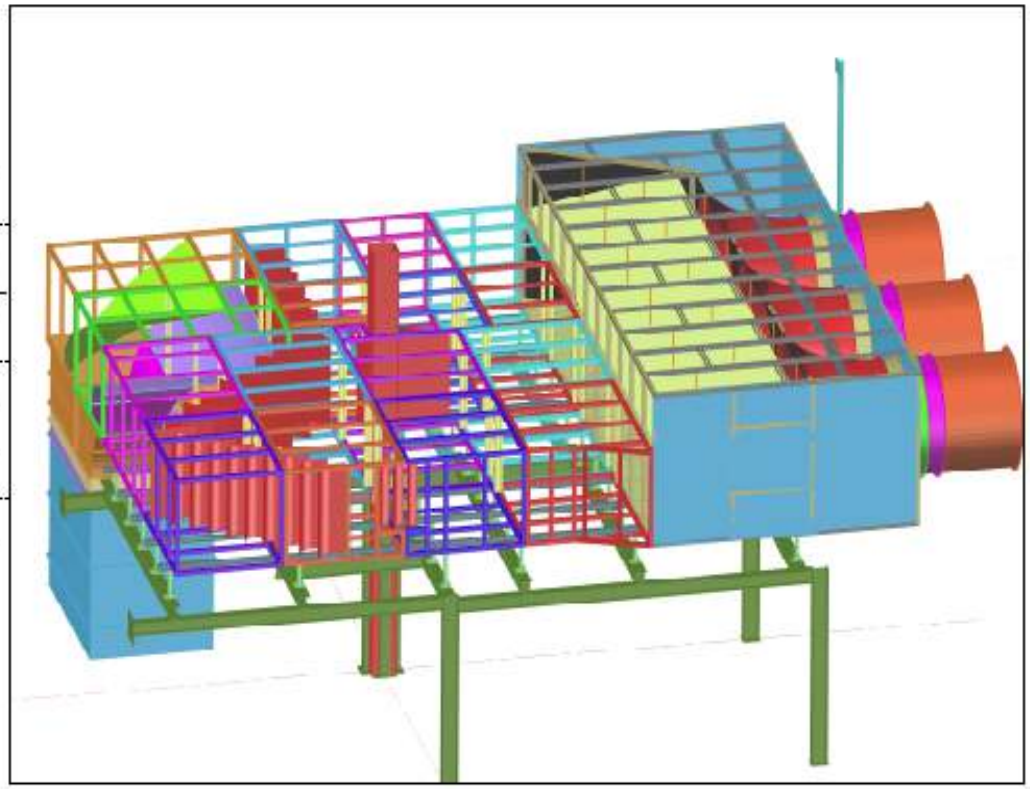
Isometric of Modules



HVAC MODULE FLOOR PLAN

SCALE: 1/4" = 1'-0"

NORTH

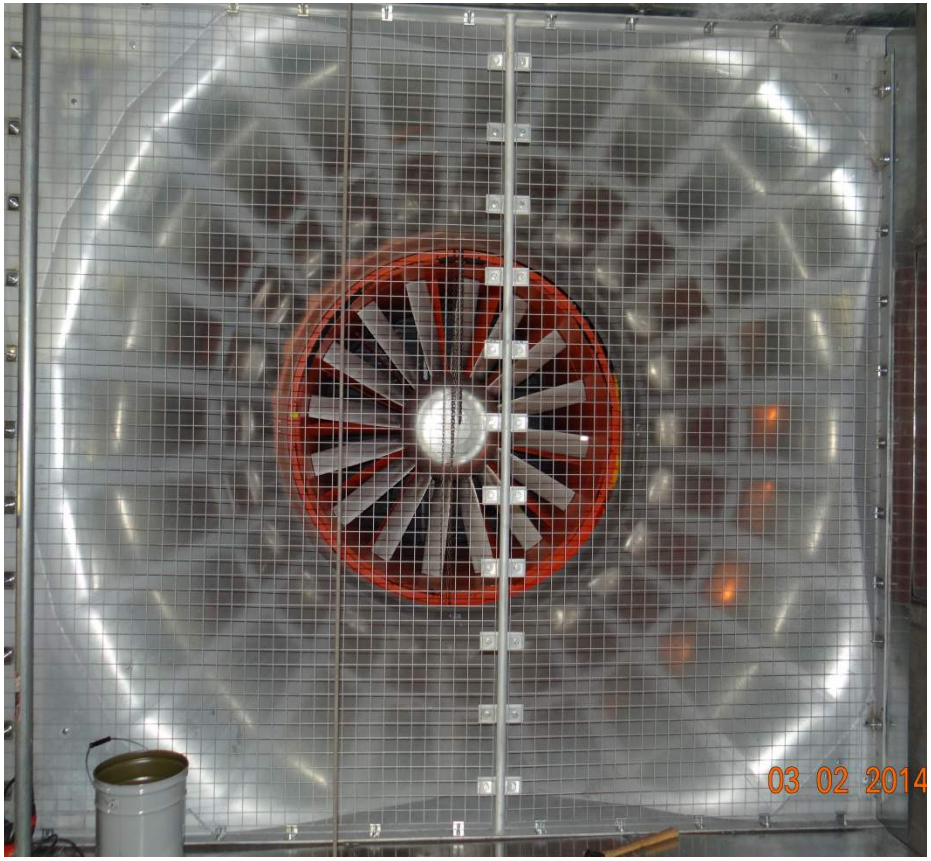


HVAC MODULES ISOMETRIC VIEW

NOT TO SCALE

NORTH

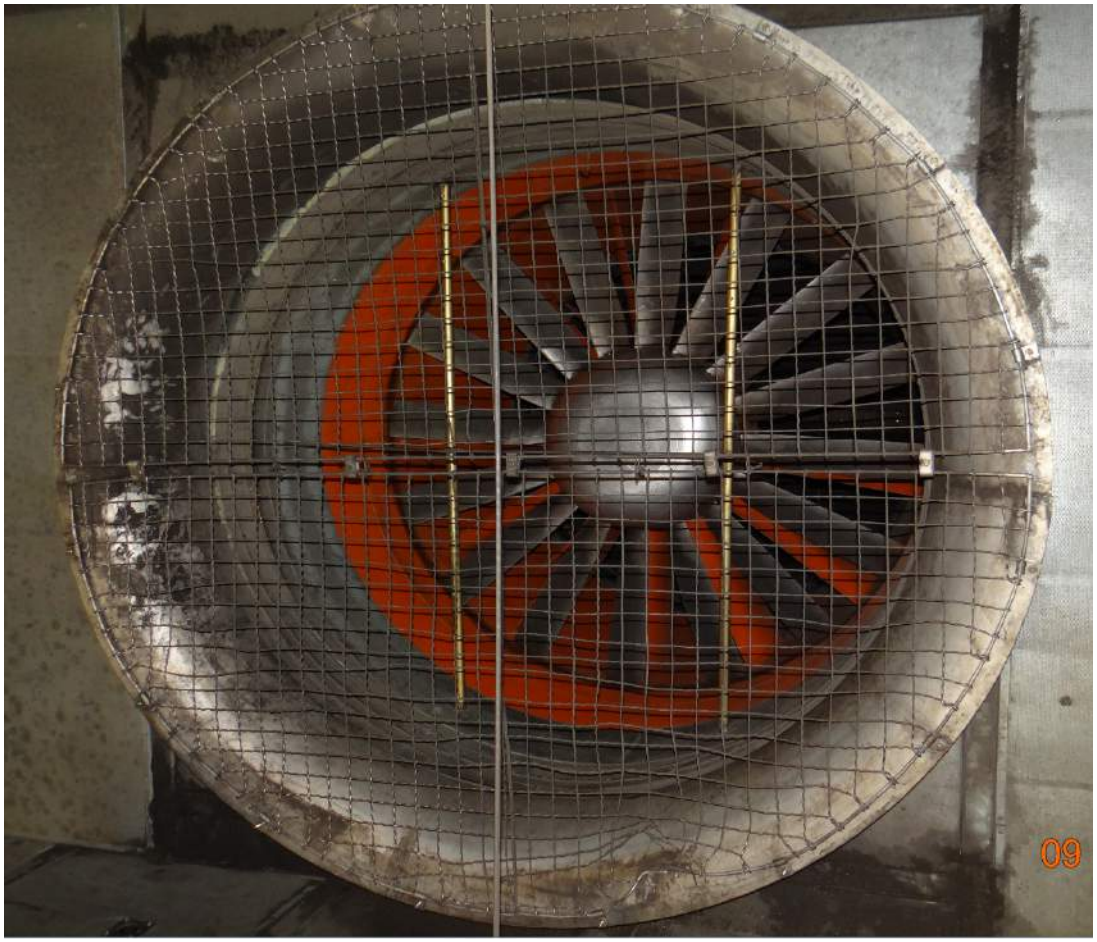
New Extended Fan Inlet Bell-mouth



Internal Inlet Bell-mouth

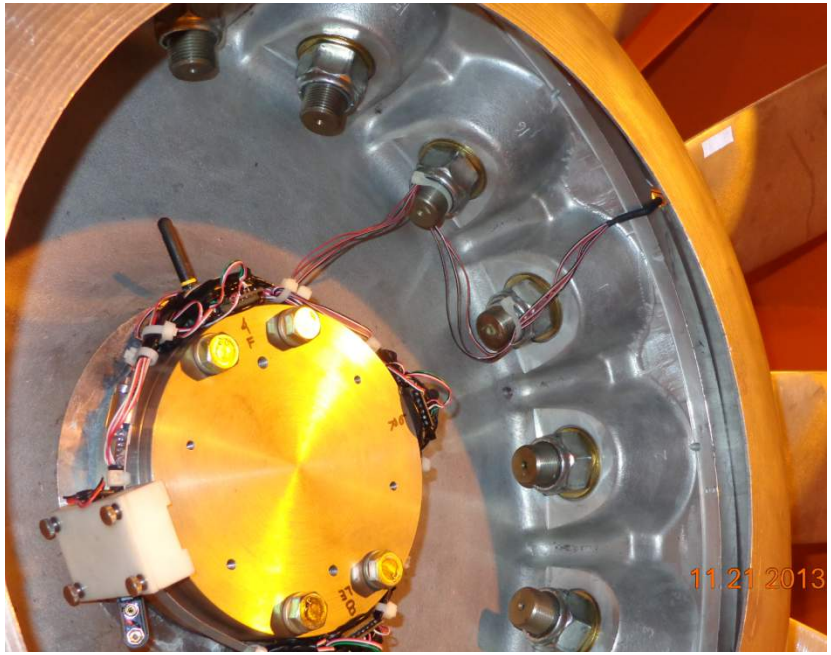
External Inlet Bell-mouth

Old Fan Inlet Bell-mouth



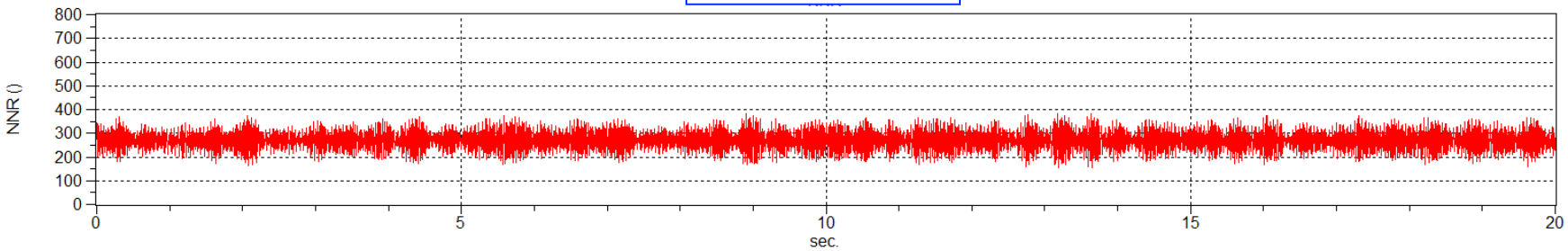
Internal Inlet Bell-mouth

Fan Blade Strain Gauge Testing

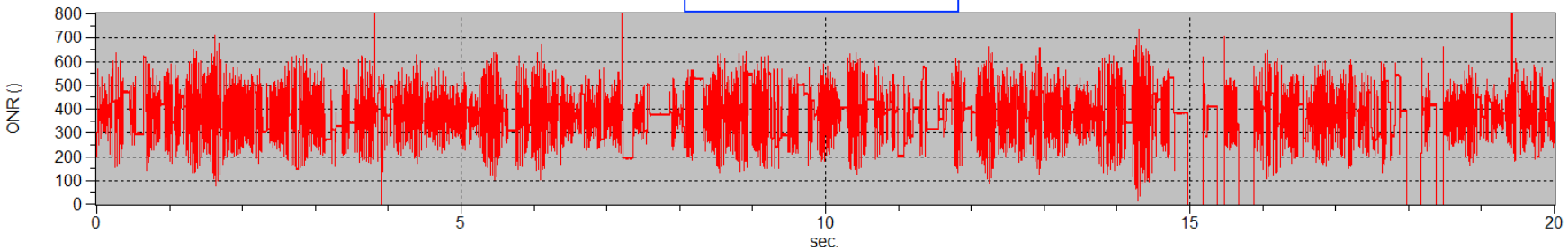


Strain Gauge Comparison to Old Data – Rear Position – Both Fans Before and After Exhaust Plenum Modification

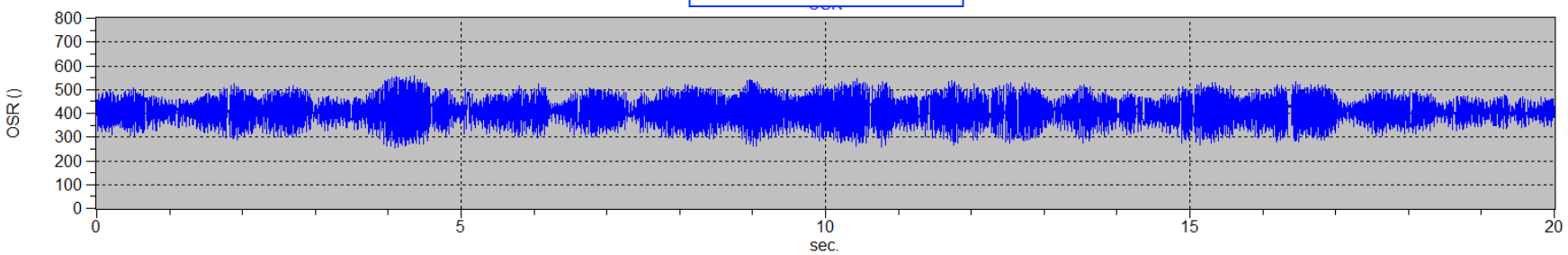
NEW NORTH REAR



OLD NORTH REAR



OLD SOUTH REAR



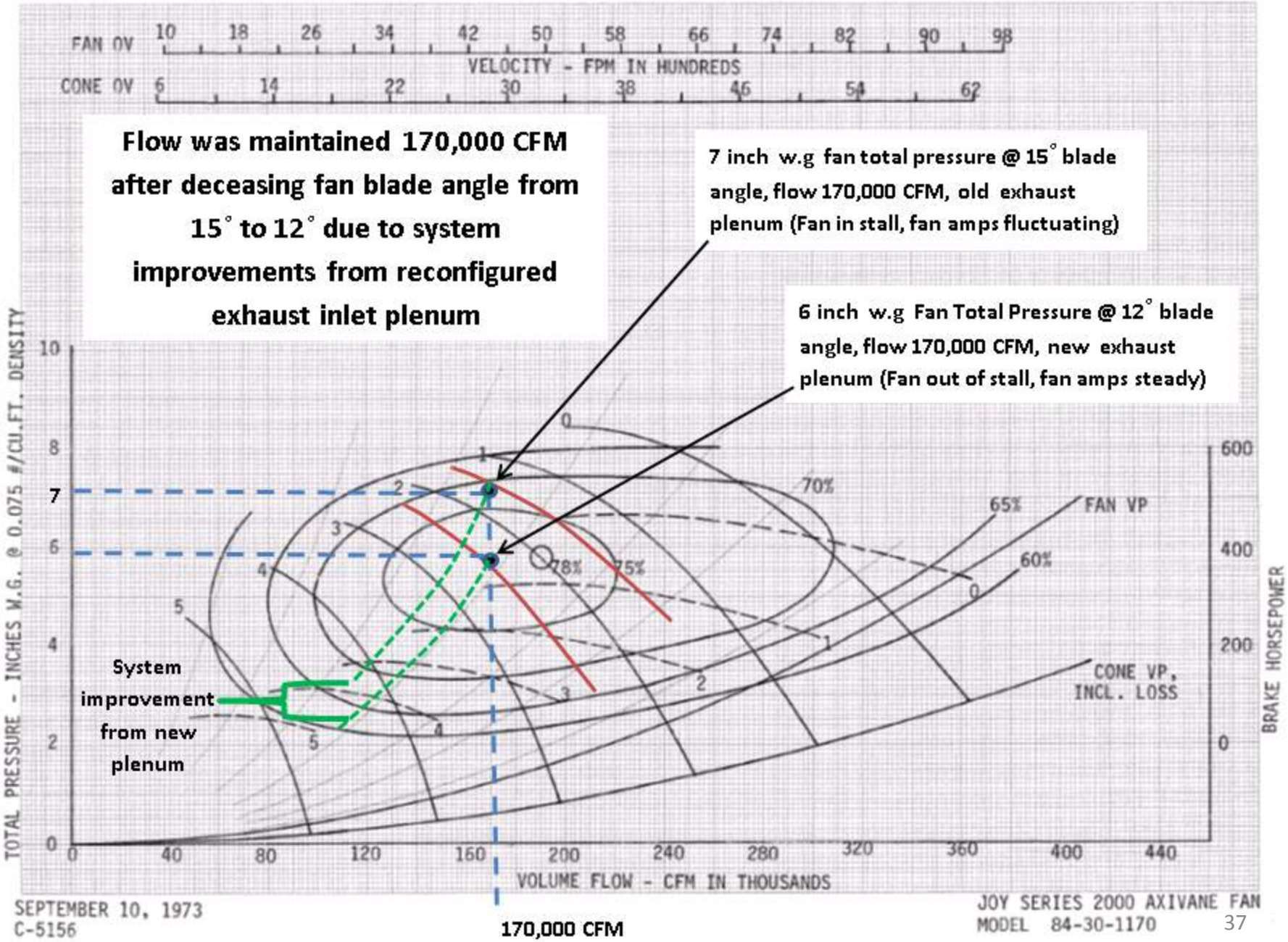
Monitoring

VELOCITY PRESSURE (IN. W.C.) TO FLOW (CFM)

VELOCITY PRESSURE (IN. W.C.)	FLOW (CFM)	VELOCITY PRESSURE (IN. W.C.)	FLOW (CFM)
0.1	48740	1.6	194961
0.2	68929	1.7	200962
0.3	84421	1.8	206788
0.4	97481	1.9	212454
0.5	108987	2	217973
0.6	119389	2.1	223356
0.7	128955	2.2	228612
0.8	137858	2.3	233750
0.9	146221	2.4	238778
1	154130	2.5	243702
1.1	161653	2.6	248528
1.2	168841	2.7	253262
1.3	175736	2.8	257910
1.4	182370	2.9	262475
1.5	188770	3	266962

Installed VOLU-probes for Airflow and Total Pressure Monitoring

North Exhaust Fan Operating with South Exhaust Fan, Before and After Improvements



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