INVESTIGATION OF AIRFLOW OVER AIR COOLED CONDENSER'S TUBE BUNDLE IN ORDER TO IMPROVE COOLING SYSTEM EFFICIENCY

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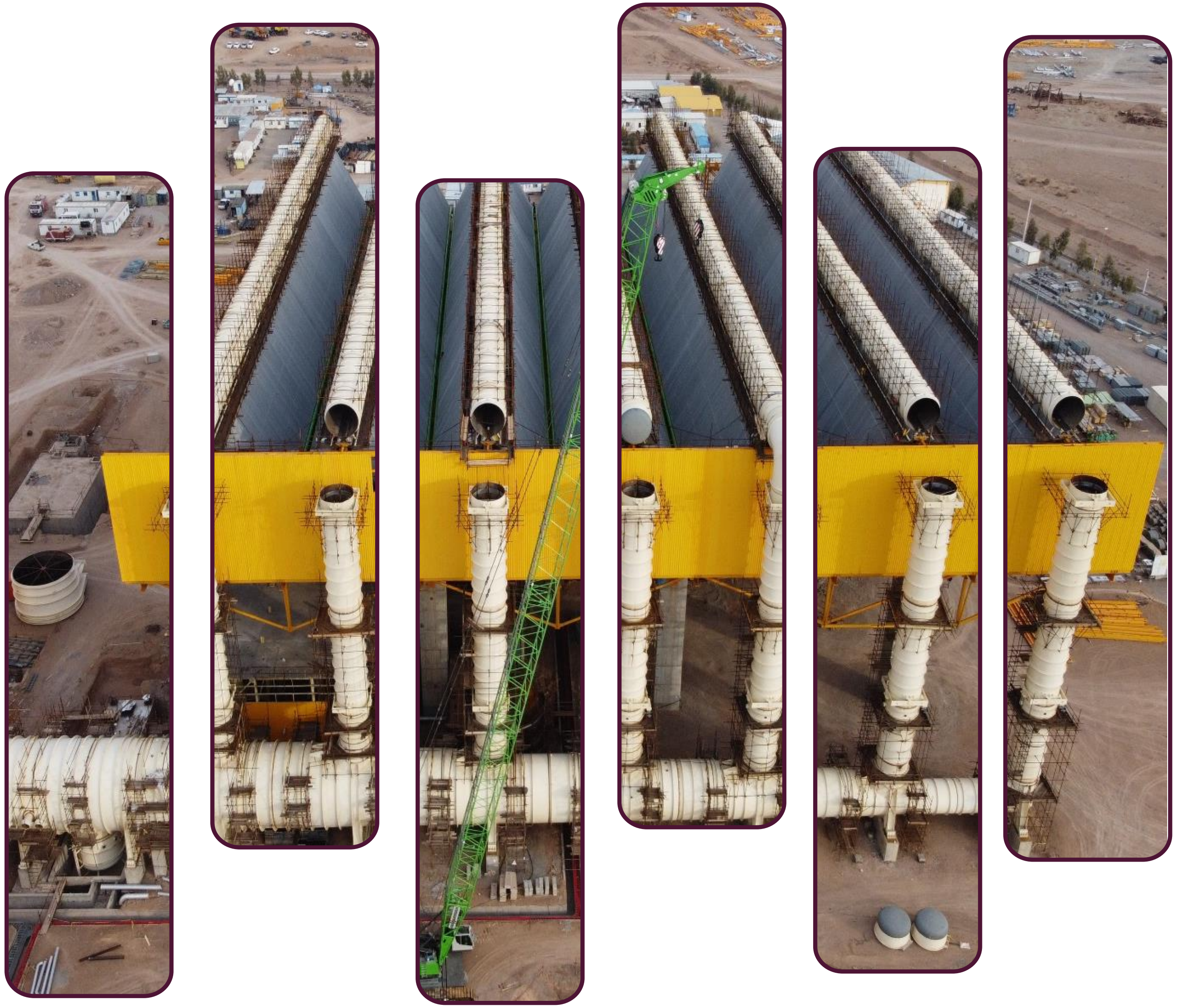

WHO WE ARE (MAPNA MD1-COOLING DEPARTMENT)

- **Plays an important role in combined cycle and steam power plants as well as process and industrial units.**

- **MAPNA-MD1 has acquired the knowledge and expertise in designing, supplying equipment, and implementing Heller Hybrid, ACC, and Once Through cooling.**

- **Provide technical and economic analyses for:**
  - **selection of cooling systems**
  - **changing different types of old wet cooling towers to dry ones**
  - **design, supply, and install cooling towers, condensers, pumps, fittings, piping, and control and protection equipment.**

Behbahan Power Plant

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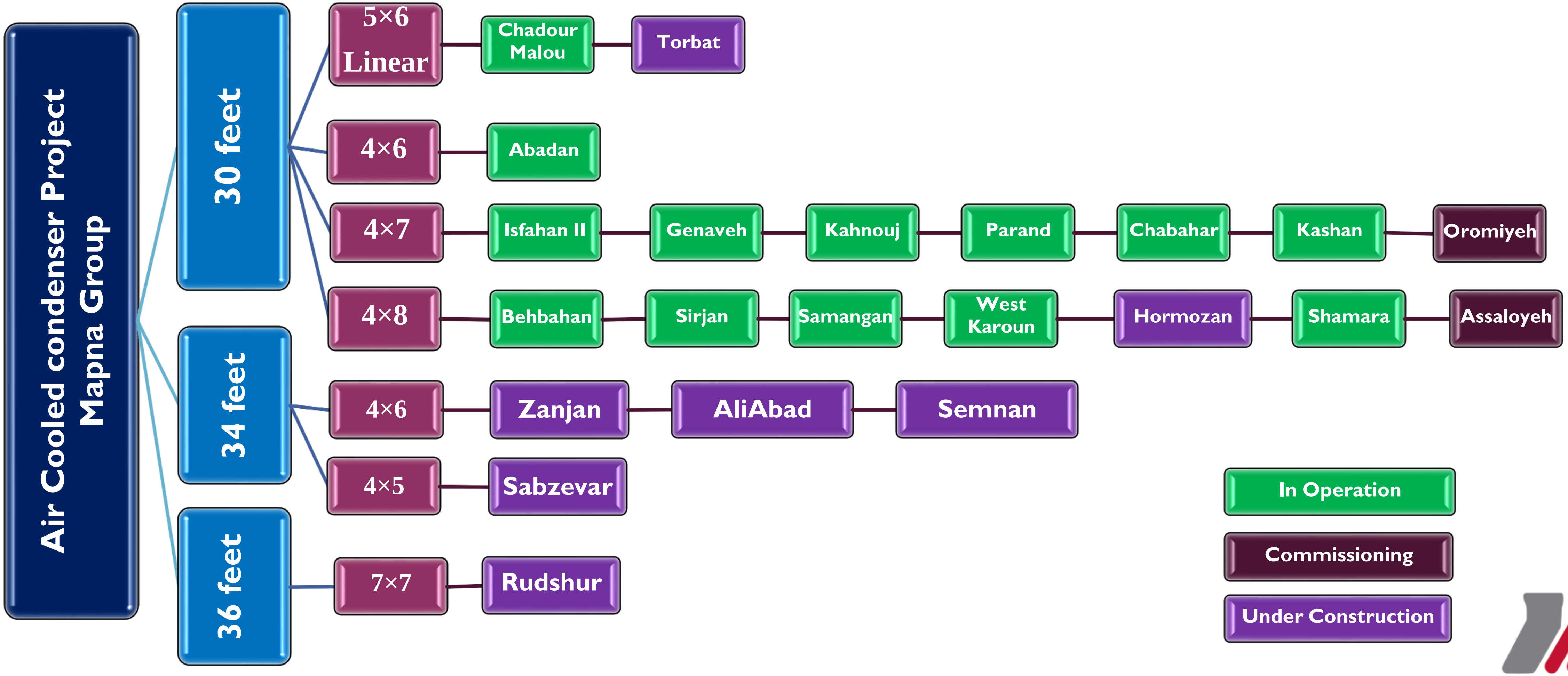
WHO WE ARE

MAPNA MD1 Projects



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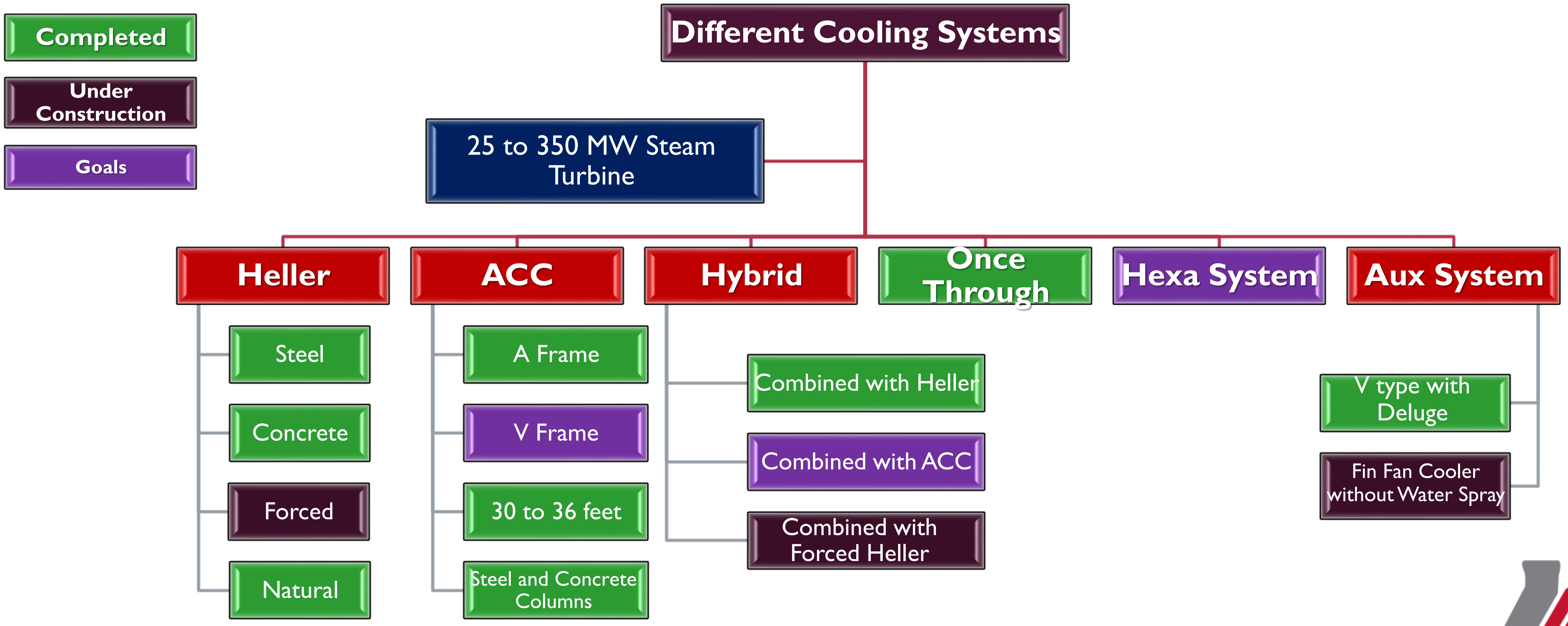
WHO WE ARE

MAPNA MD1 Different Cooling Systems



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OUTLINE

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Our Goal

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Including:

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Innovative Solution

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Including:

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Set-up structure

4

FUTURE WORK

Including:

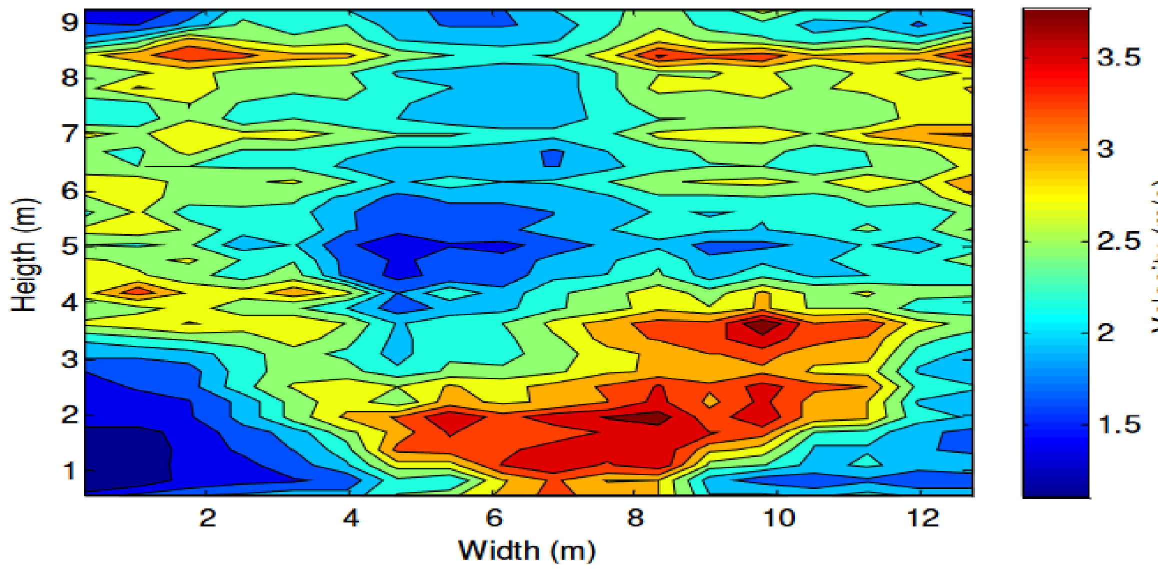
Next Step

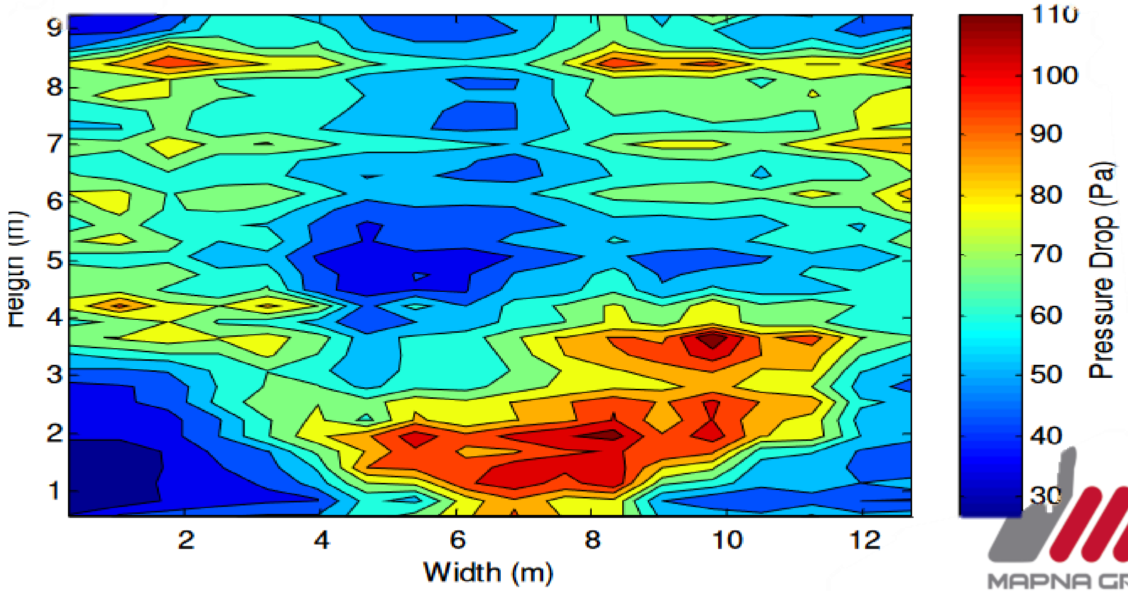
To find final Solution

INTRODUCTION

STUDY MOTIVATION

- **Insights from E.J.Walsh in “Flow Distribution Measurements from an Air-Cooled Condenser in a ~400MW Power Plant”, 2011:**
- The experimental study demonstrated the variation in flow distribution due to the interaction between the fan and the heat exchanger.
- Pressure and velocity distributions over the tube bundle revealed significant variations in fin efficiency, pressure drop, and local heat flux.
- These factors contribute to decreased ACC performance.





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GOAL

- Find new and innovative method to uniform air distribution over tube bundle.
- We know that the relation between fan power and rpm is:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

- So if we can uniform the flow distribution:
  - Fan power consumption decrease dramatically.

    or

  - Increase ACC Performance with the same fan power.

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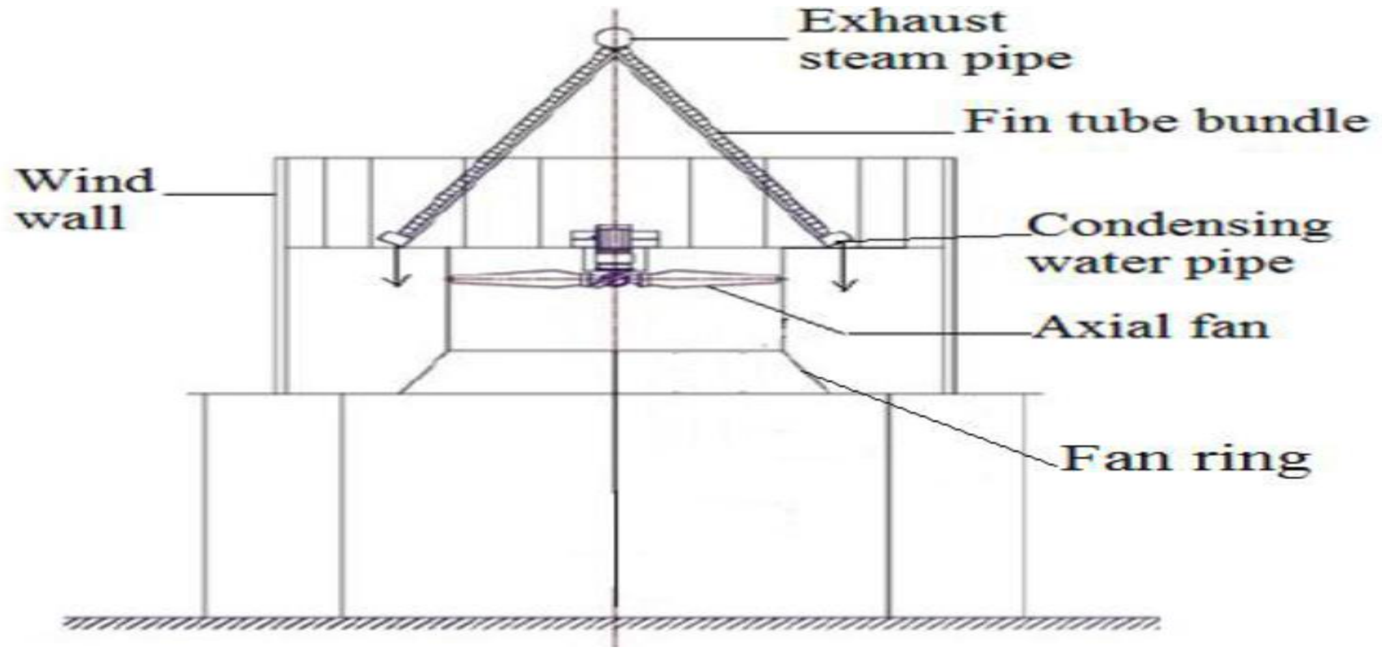
GEOMETRY (DOMAIN)

- One ACC Module.
  - Central Module is preferred to minimized ambient effect.



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NUMERICAL STUDY

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NUMERICAL STUDY STRATEGY

- Step 1 : Full Scale Modeling:
  - In the first step of this study, it is necessary to check whether flow disturbances exist in all cells of the ACC system.
  - The optimal approach is to model the full-scale CCPP power plant to capture all circumferential effects.
  - However, this involves an excessive amount of calculations.

- Step 2 : Single ACC Module Modeling:
  - As a more economical alternative, model only one ACC module.
  - Note that the results will be imprecise without incorporating the fan blade curve as domain input data.

- Step 3 : Fan Air Velocity profile:
  - Determine the fan air velocity profile for the same pressure difference (dP) and flow rate as the fan blade.
  - Refinement with Velocity Contour for main solution.

- Step 4 : Revisit step 2, using the velocity contour obtained in step 3 for more accurate results.

- Optimization: Innovative Solution:
  - Identify the optimal method to achieve a uniform flow pattern over the tube bundle, utilizing the domain from step 4.
  - Challenging question and revise our solution.

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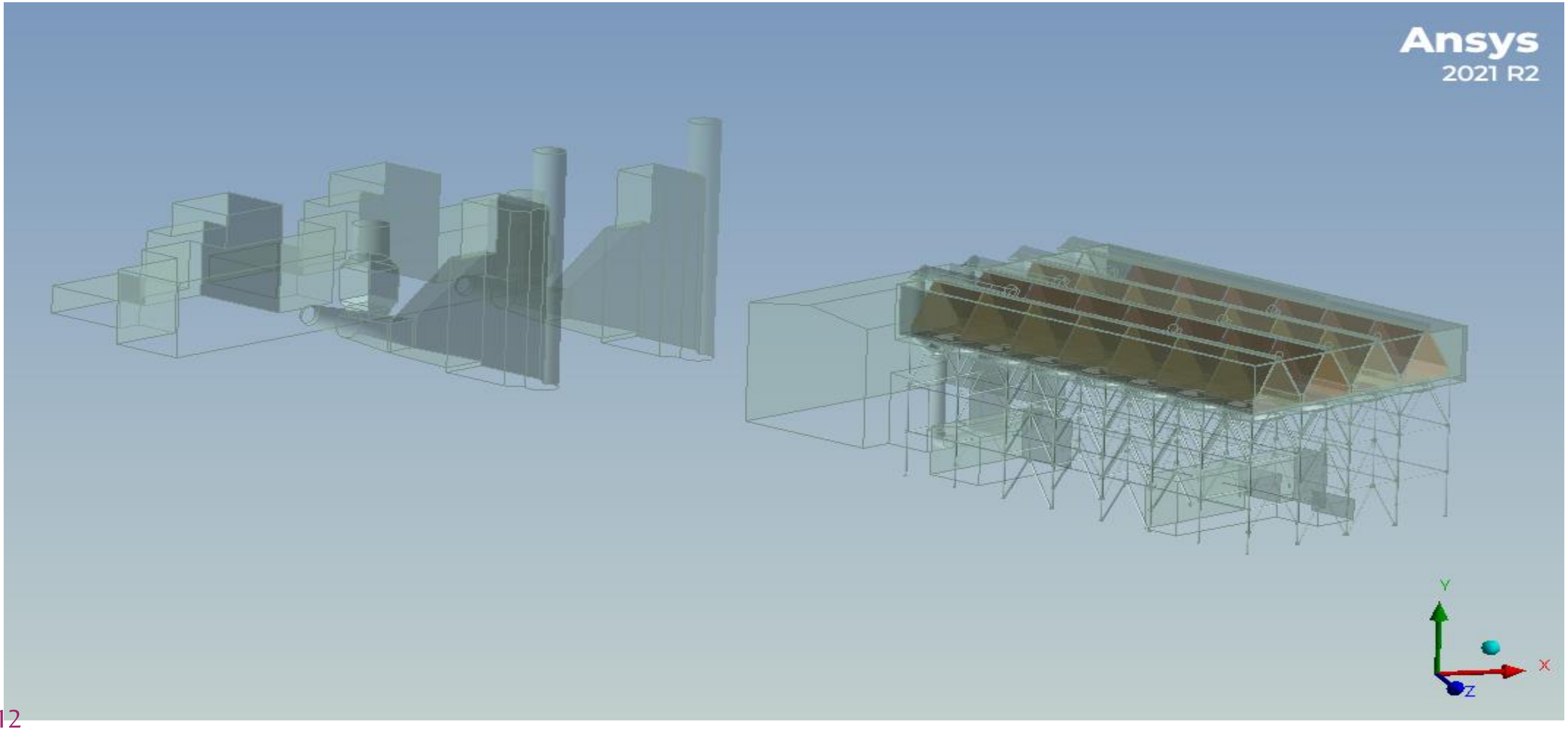
STEP 1 : FULL SCALE MODELING

- 3D DRAWING OF THE PLANT
  - (2 GAS TURBINES, 2 HRSGs, 1 STEAM TURBINE AND ONE ACC)



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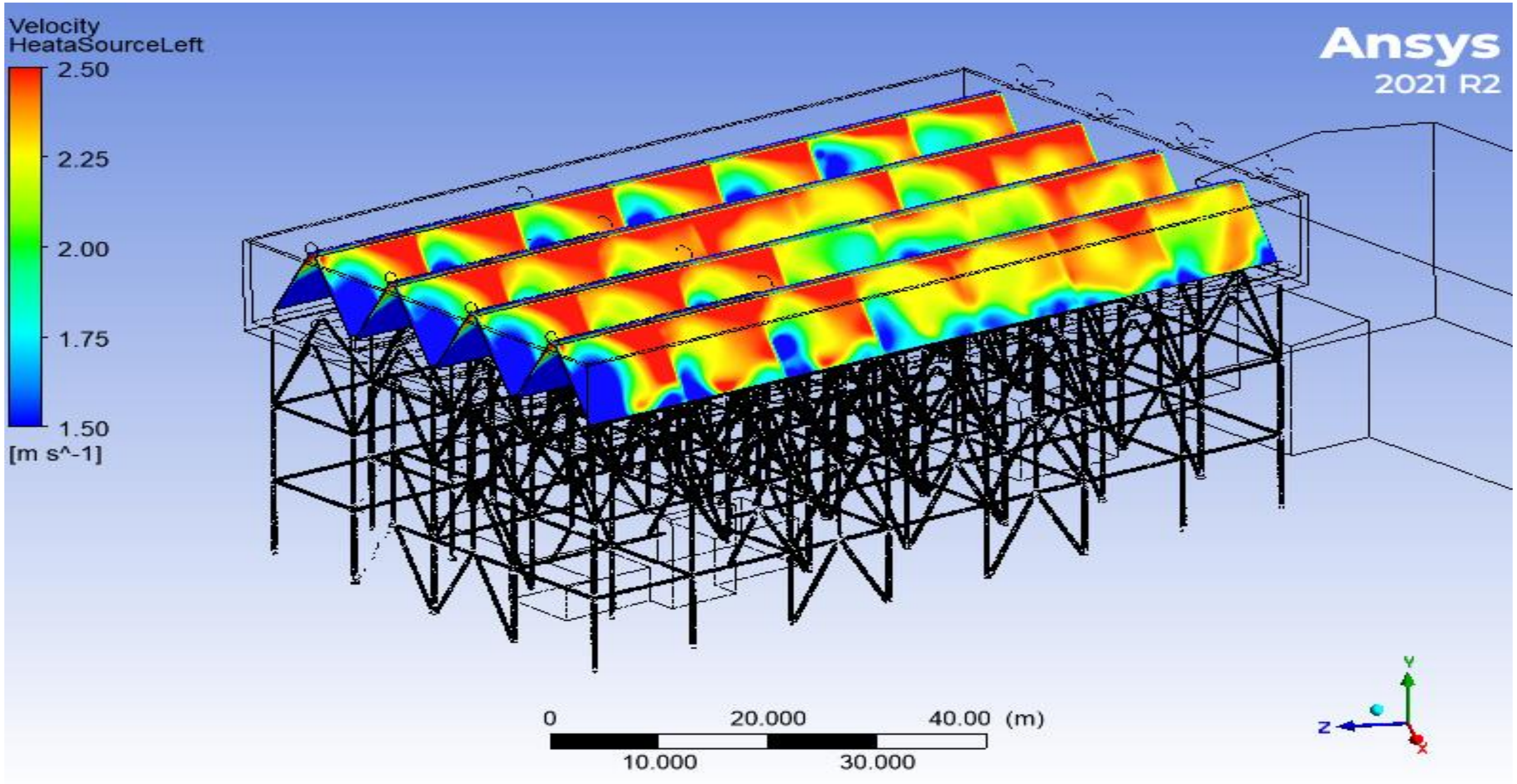
STEP 1 : MESH GENERATION AND RESULT

- CFD-POST
- Non uniformity of air flow is obvious in all ACC modules.



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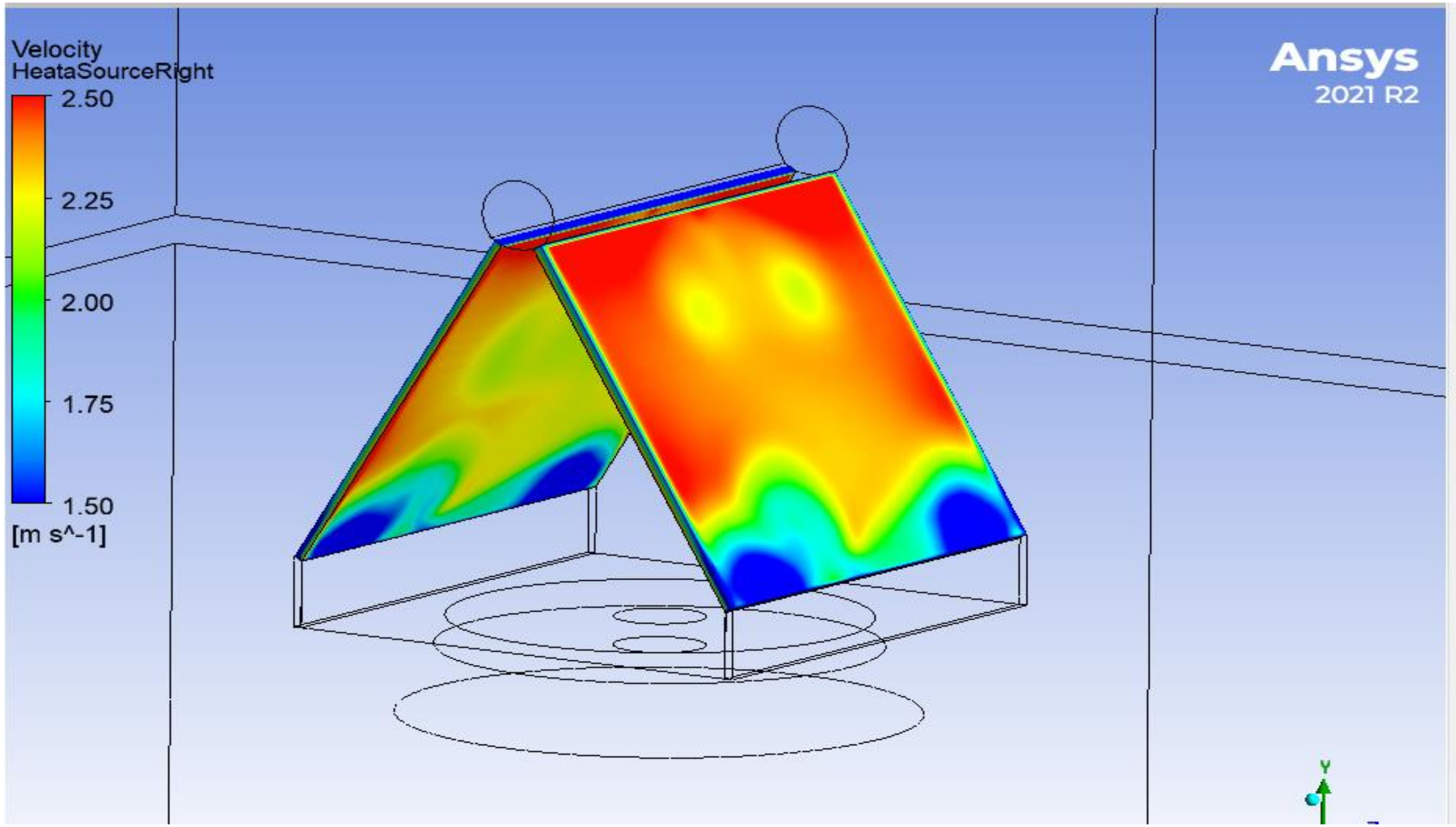
STEP 2 : SINGLE ACC MODULE AND MESH GENERATION AND RESULT

- CFD-Post
- The non-uniformity of airflow is evident in a single ACC module as well.
- This result was obtained without using the fan airflow profile. Instead, the fan curve was applied as a momentum source.



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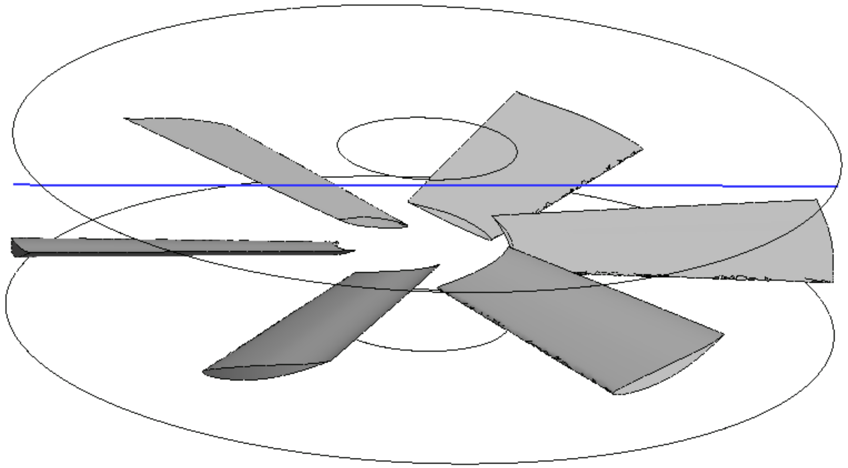
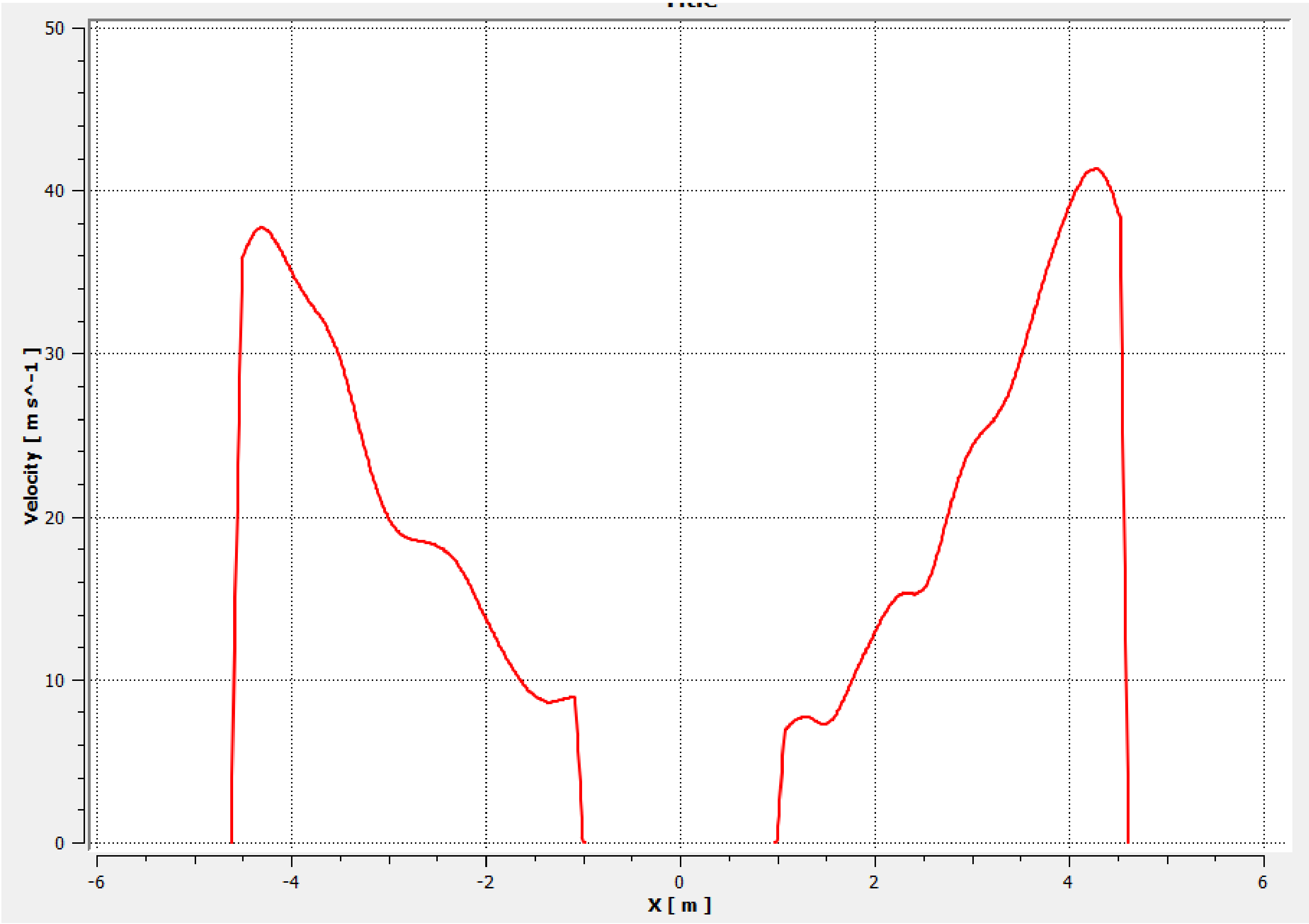
STEP 3: 3D MODEL OF FAN BLADE AND RESULT

- CFD-Post / FAN BLADE CURVE
- It will be used as input data for step 4.





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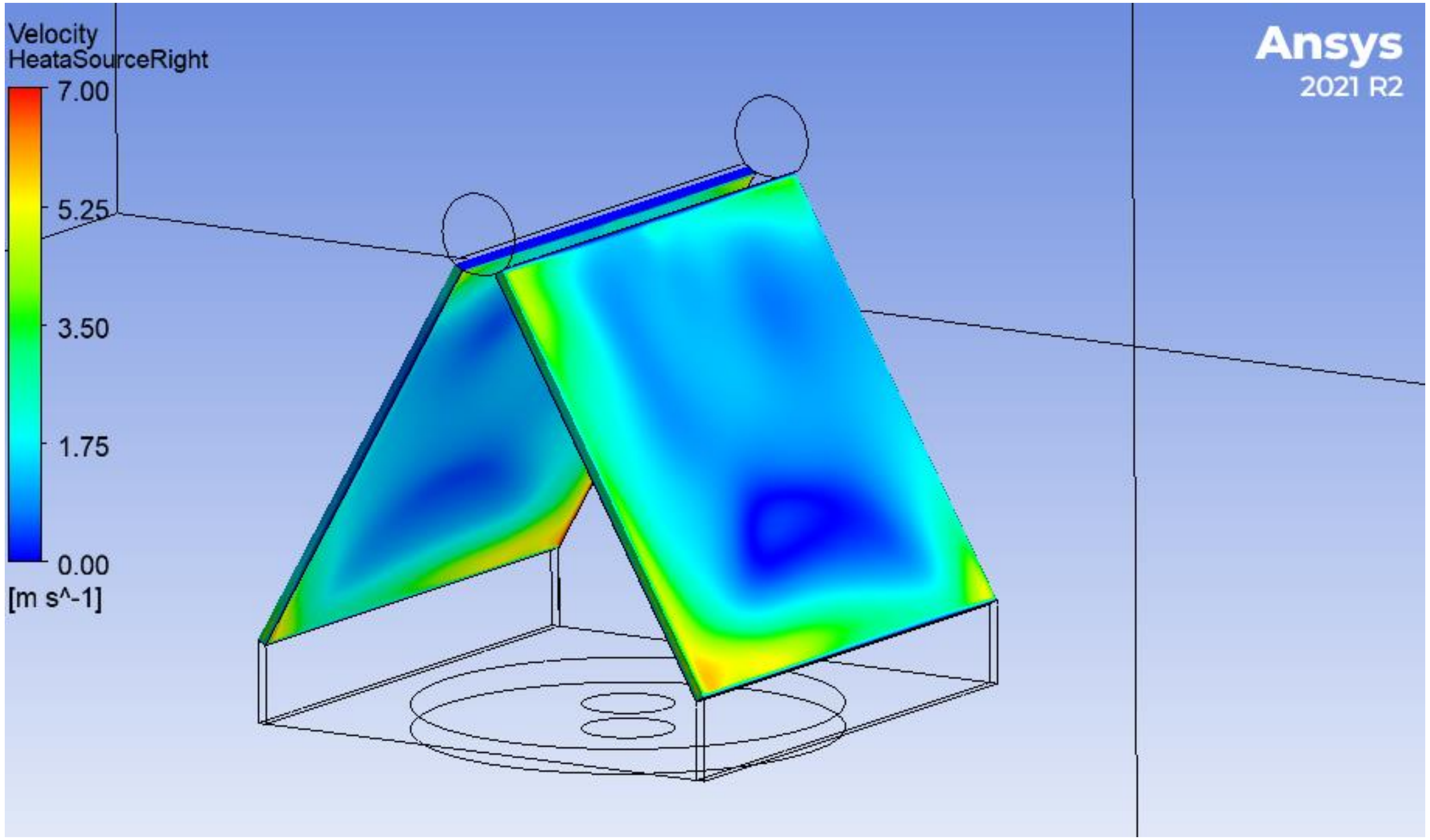
STEP 4: REVISE STEP 2 AND RESULT

- CFD-Post / Velocity Vector
- Non-uniformity flow profile over tube bundle surface is visible.



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INNOVATIVE SOLUTION

MAPNA SPECIFIC METHOD

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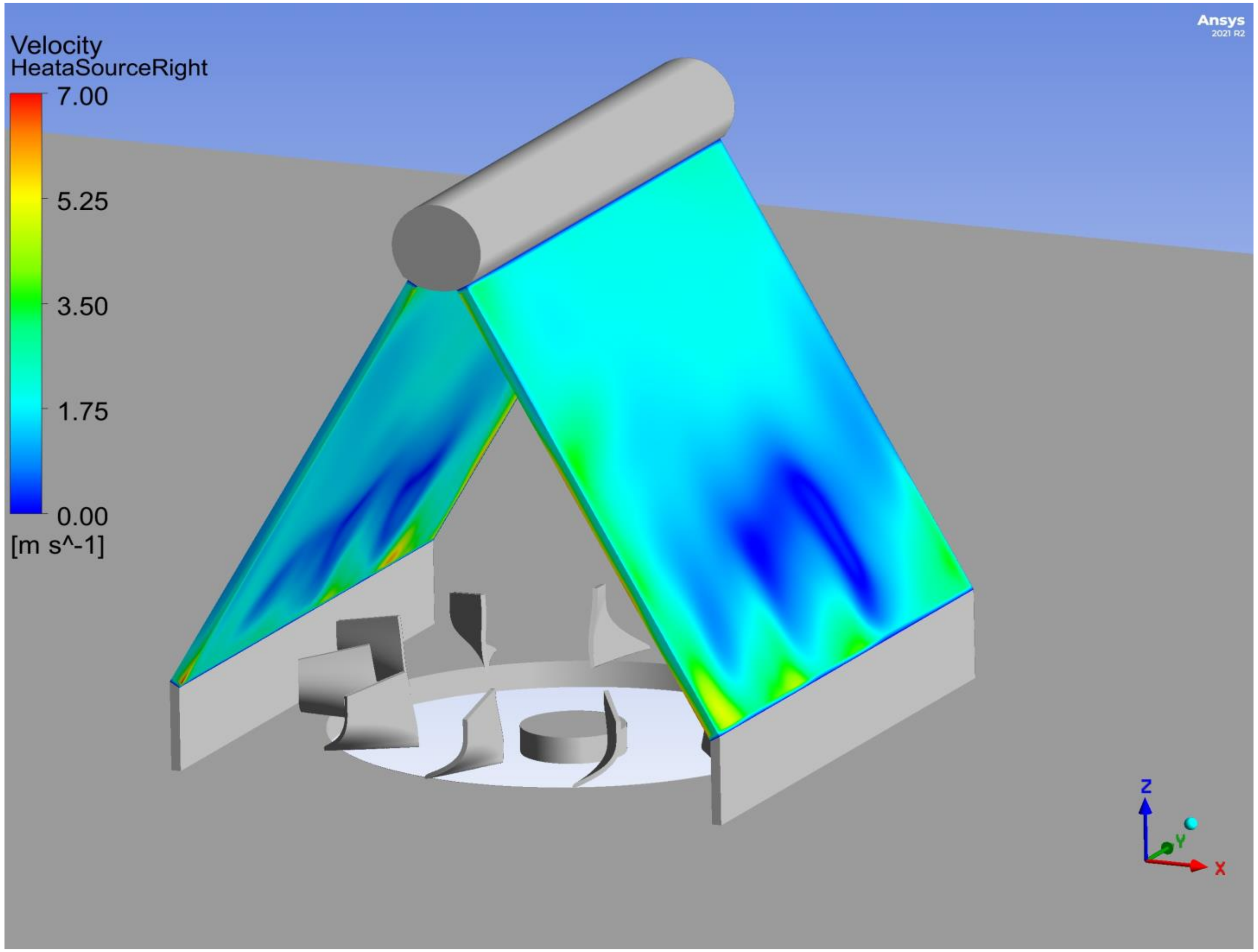
SOLUTION: USING STATOR BLADE/RESULT

- Much more uniform flow pattern than before!



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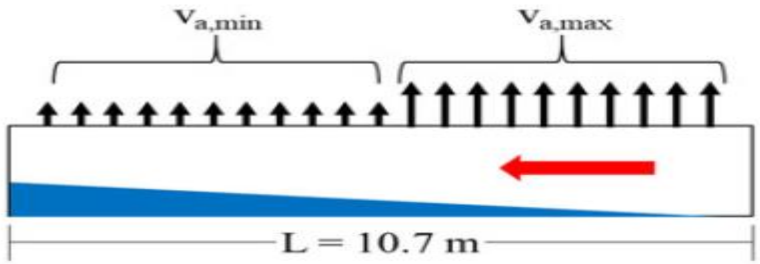
CHALLENGING QUESTION

- **Which airflow profile is more efficient?**
  - **Uniform flow profile** over the entire tube bundle surface

  Or

  - **Stratified flow profile** (e.g., more airflow at the upper or lower part of the tube bundle surface)

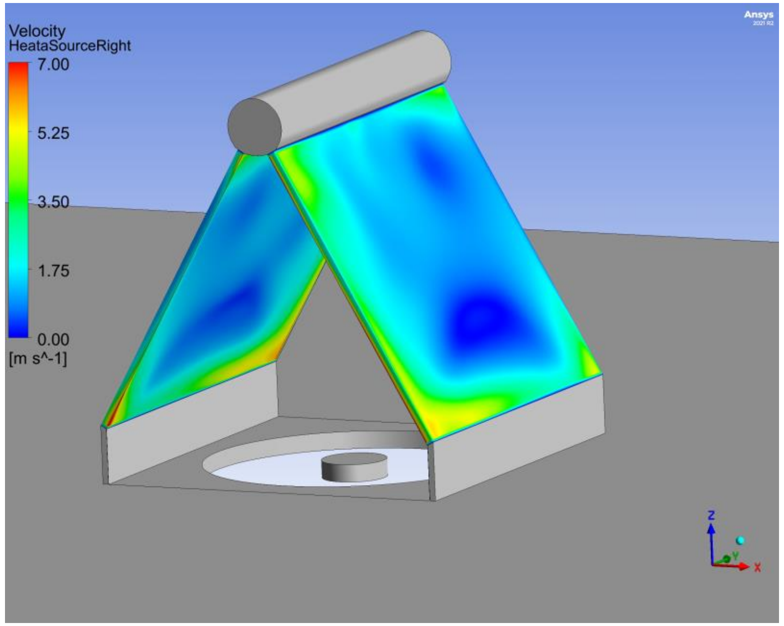
- **Insights from William Davis in "Effects of Airflow Profile and Condensation Pressure on Performance of Air-Cooled Condensers"**:
  - *A tested **non-uniform velocity profile** (stratified) in a 10.7m tube showed a **3.1% increase in capacity** compared to a uniform velocity profile.*
  - *Reversing the airflow direction (more airflow at the upper part) resulted in a **3.5% increase in condenser capacity***



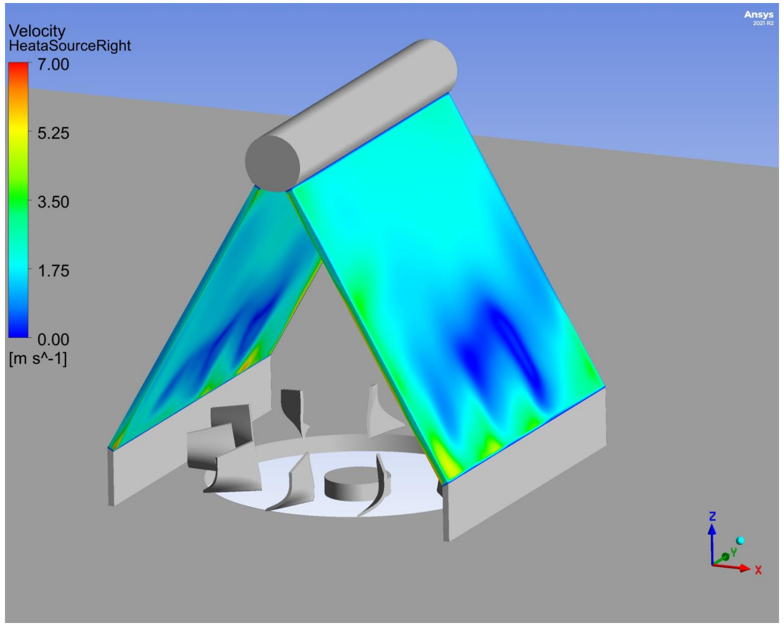
- **Important Note**:
  - The primary purpose of the ACC is steam condensation, not cooling the condensate water.
  - Therefore, airflow should be directed to the upper part of the tube bundle where there is more steam, rather than the lower part.

SOLUTION (STATOR WITH SHROUD): RESULT COMPARISON

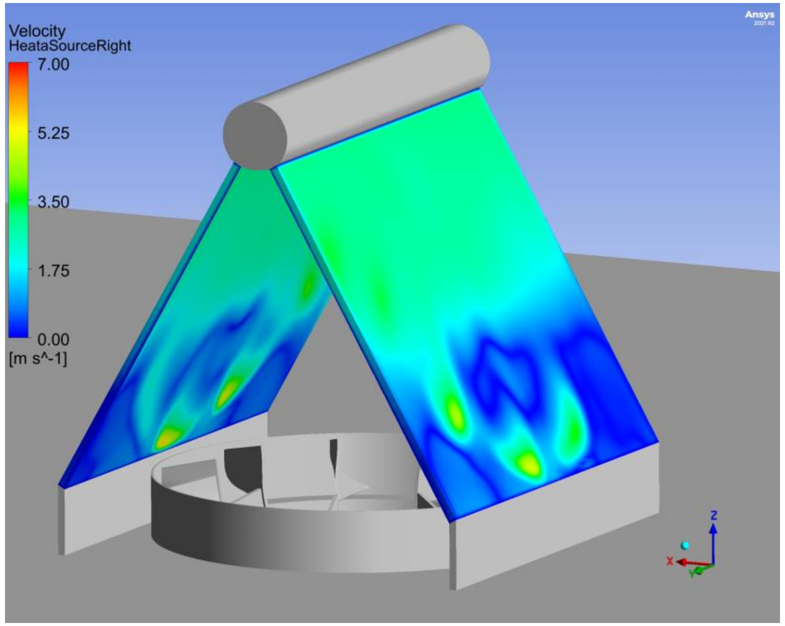
- As you can see, using stator blades (middle picture) results in a more uniform flow compared to the classic case.
- When stator blades are combined with a shroud, the flow becomes even more uniform, with a significantly greater amount concentrated in the upper part, compared to the other two cases.



Without Stator



Stator without Shroud



Stator with Shroud

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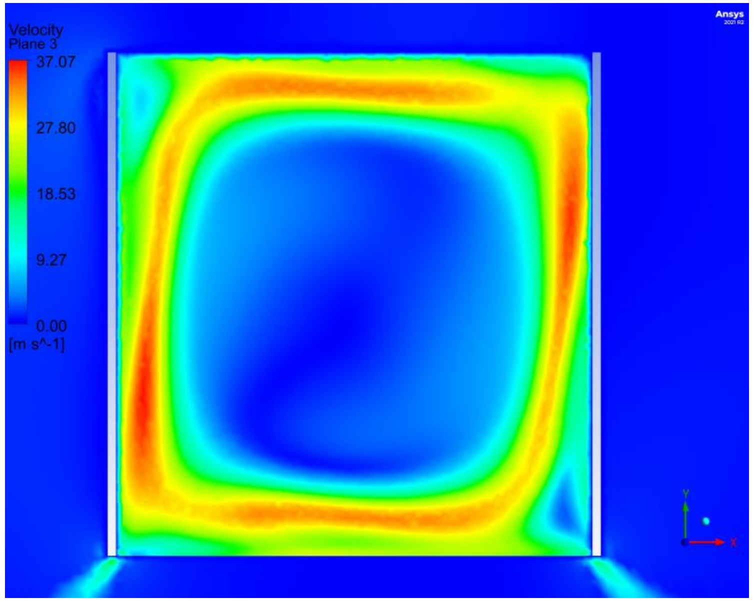
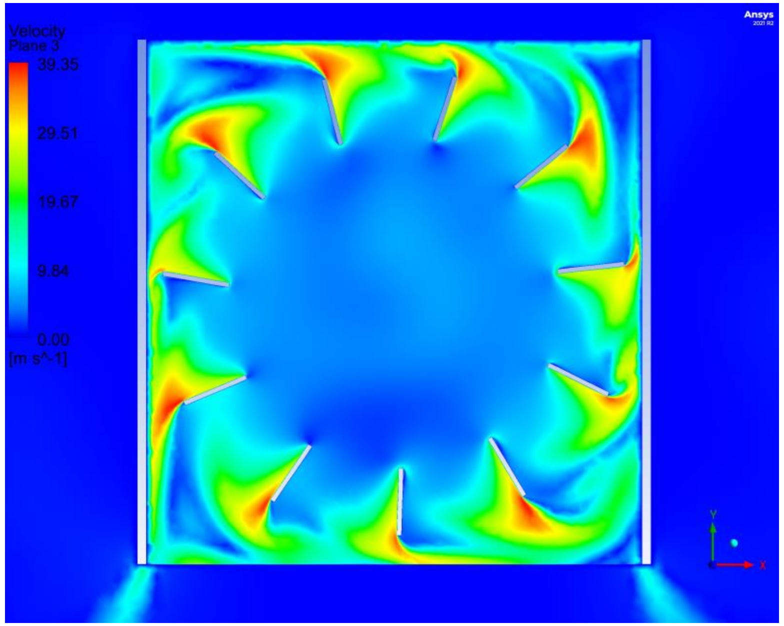
SOLUTION: RESULT COMPARISON

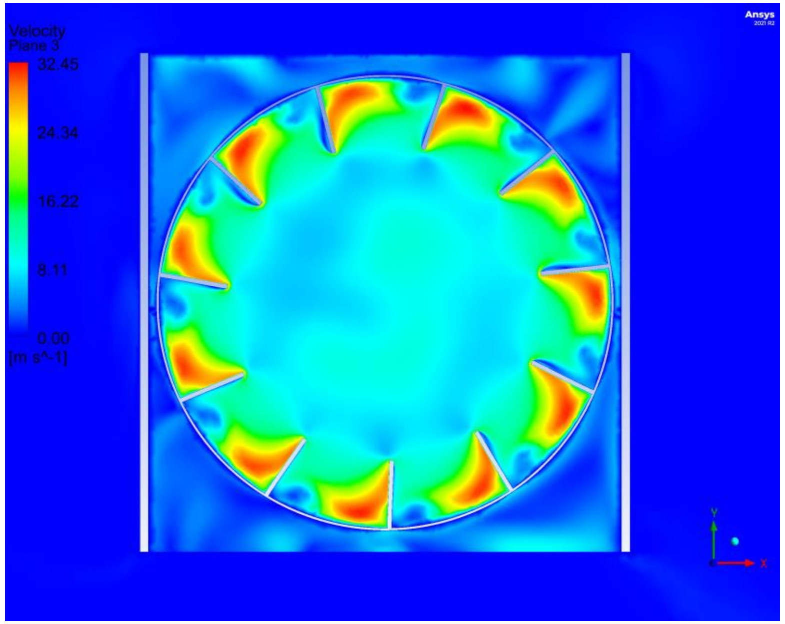
- As seen in the slide, in the middle image, using stator blades results greater upward airflow compared to the case without stator blades (left image).
- Moreover, with the addition of a shroud (right image), not only is this effect enhanced, but it also prevents the airflow from being directed towards the corners, which is ineffective.



Without Stator



Stator without Shroud



Stator with Shroud

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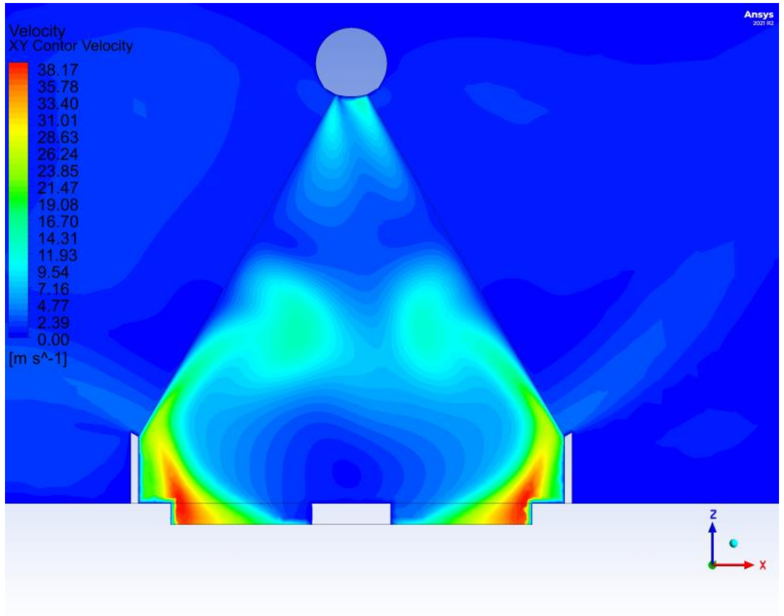
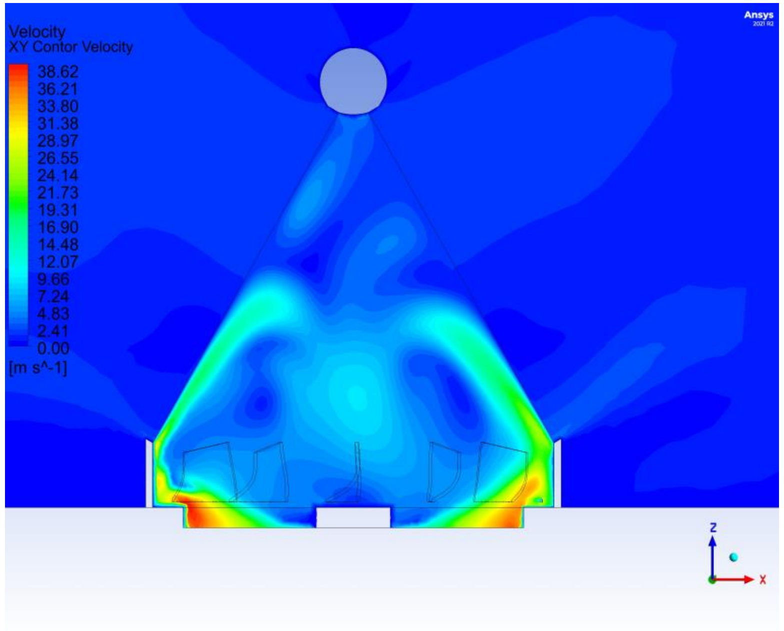
SOLUTION: RESULT COMPARISON

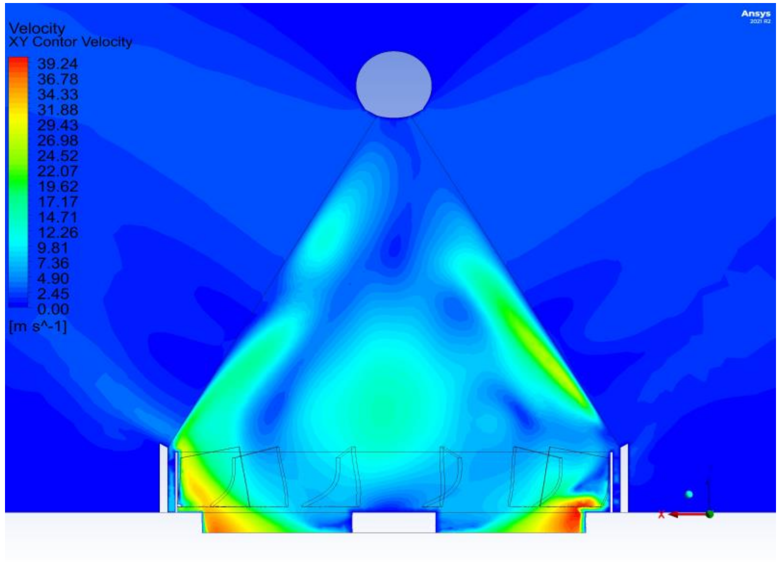
- The use of stator blades and a shroud has improved the upward flow guidance. Additionally, the air at higher elevations gains more energy to pass through the tube bundle.
- The increased velocity of air passing through the tube bundles indicates that energy losses within the cell have been prevented, resulting in improved heat exchange without altering the technical specifications of the fan.



Without Stator



Stator without Shroud



Stator with Shroud

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SOLUTION: RESULT COMPARISON

- In this slide, it can be observed that the use of a stator with a shroud has led to approximately a 10% increase in the average velocity over the tube bundle. Additionally, the use of a stator and shroud has reduced the deviation of maximum velocity relative to the average speed.
- This means that the combination of a stator and shroud produces a more uniform velocity profile and increases the average velocity.

Variable	No Guide		Stator without Shroud		Stator with Shroud	
	Heat Source Left	Heat Source Right	Heat Source Left	Heat Source Right	Heat Source Left	Heat Source Right
ave Velocity (m/s)	1.78	1.81	1.81	1.80	1.99	1.95
maxVal Velocity (m/s)	10.67	12.64	6.88	9.00	5.54	5.39
minVal Velocity (m/s)	0.07	0.04	0.04	0.03	0.02	0.03
maxVal - ave (m/s)	8.89	10.83	5.07	7.19	3.56	3.44
	Average velocity change percentage relative to the case without stator (%)		1.92	-0.18	11.71	8.18
			0.87		9.95	

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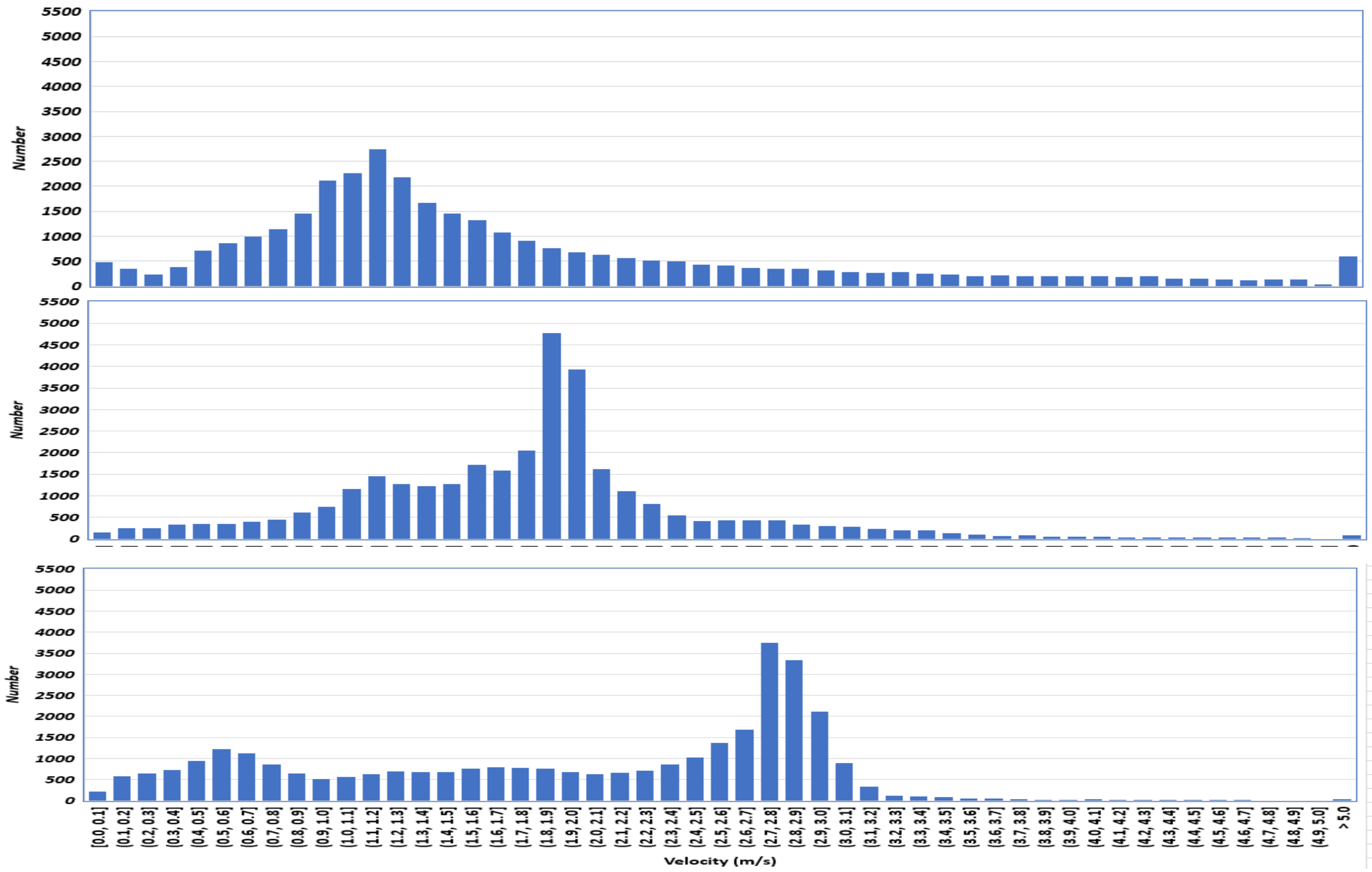
SOLUTION: RESULT COMPARISON

- This slide displays the histogram of velocity frequencies over the tube bundles for different cases.
- The use of a stator and shroud has increased the frequency of higher velocity, shifting the histogram to the right.

Without Stator

Stator without Shroud

Stator with Shroud



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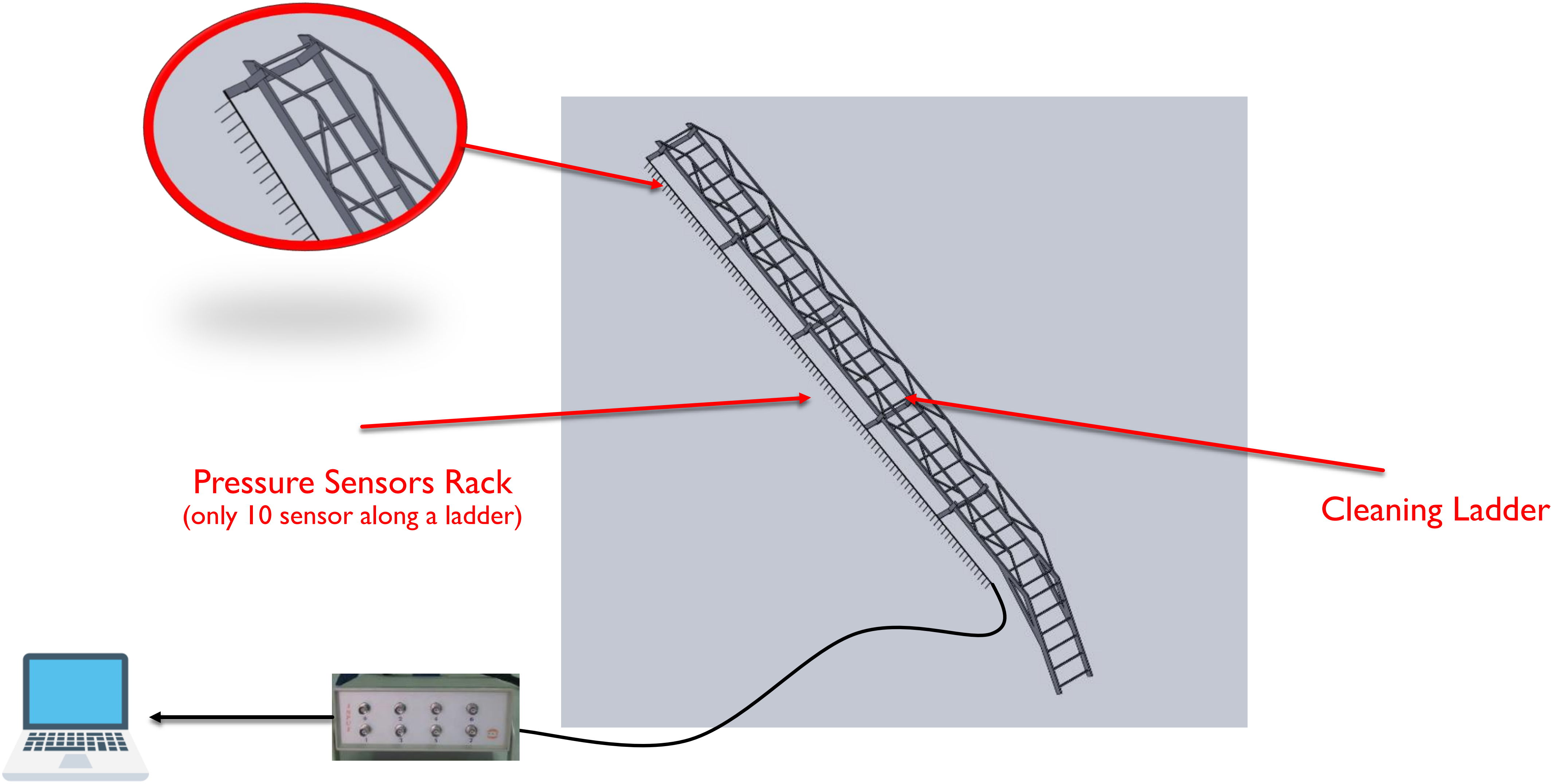
EXPERIMENT STUDY

DATA GATHERING SET-UP STRUCTURE



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FUTURE STUDY

FUTURE STUDY

- **First Step:**
  - Complete the experimental study in one of our power plants.
  - Validate the findings from our numerical study.

- **Next Steps:**
  - Design and construct stator blades.
  - Install the stator blades in one ACC module.
  - Conduct the experimental study again.
  - Record the results and analyze the findings.

- **Final Steps:**
  - Perform a cost analysis to identify the most effective solution with minimal cost impact.

FIND OUR TEAM AT:

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Thank you

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