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REPORT

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VIVIDAIR Z-CHILL - WESCO/ANIXTER SITE

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ENHANCING WAREHOUSE WORKING ENVIRONMENT WITH Z-Chill™ APPLICATION – A CASE STUDY

PREPARED FOR:
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I. EXECUTIVE SUMMARY

This case study is initiated to evaluate the effectiveness of VividAir Z-Chill™ application in a large volume space such as warehouses where full air conditioning is often impractical, cost prohibitive, or not permitted by energy codes without providing insulated envelope. To support this study, Wesco and VividAir granted unconditional permission to the engineer, waived any liability associated with this case study, and provided full access to the construction documents for a recently completed Wesco distribution facility in Avondale, Arizona.

Scope of Project included but not limited to the following:

a. Review existing design and construction documents.

b. Establish performance metrics, including heat energy (BTU/h) per square foot, airflow (CFM), temperature distribution and other relevant parameters.

c. Develop a computational fluid dynamics (CFD) model to evaluate temperature and air velocity profiles under Z-Chill™ units operation.

d. Analyze the performance of Z-Chill™ units with respect to:

   i) Effectiveness in tempering the overall environment within large warehouses.

   ii) Energy use comparison of Z-Chill™ combined with tempered air vs traditional ventilation/conditioning system.

   iii) Impact on human comfort as well as product/storage depending on commodity stored.

Z-Chill™ units can be considered a supercharged, enhanced ventilation system that combines spot cooling using equipment such as packaged DX rooftop units (RTUs) coupled with high airflow fans arranged as a Z-shape. This paper provides analytics, metrics, and discusses the benefits of using high-volume, low speed (HVLS) fans combined with tempered air to improve warehouse comfort and energy efficiency. This case study utilizes a recently completed and fully operational ventilation system serving a distribution center/warehouse in Arizona. Analyses were carried out using a CFD model for the building and the associated ventilation system.

Three ventilation scenarios were modeled, analyzed and compared to each other:

a. Scenario 1: 'As-Built' ventilation system (combination of Z-Chill™ units and tempered air).

b. Scenario 2: Tempered air only (spot cooling without fans).

c. Scenario 3: Additional cooling without fans (increased tonnage and airflow) to achieve temperatures comparable to Scenario '1'.

Key comparison metrics included:

a. Average space temperature.

b. Air velocity/air distribution (occupied zone at 5 ft above floor).

c. Energy consumption and Code compliance.

Scenario '1', demonstrated clear energy savings, improved temperature control, and enhanced air movement, directly improving worker comfort and productivity based on Operator's feedback as working in an 80 degrees F environment is much better than higher temperatures that can be common in AZ and range in the 90s to above 100 degrees F during summer months.

The 'as-designed' ventilation system provides consistent air circulation, reduces humidity levels, and enhances air quality within the occupied zone. It also allows for higher cooling thermostat setpoints in warm months and improves heat distribution in cold months, significantly reducing the overall energy load and cost.

Proper ventilation helps industrial facilities adhere to regulatory requirements regarding air quality and workplace safety set by bodies like OSHA.

II. INTRODUCTION

Warehouses are difficult environments to condition due to their large volume, tall ceilings, high activity levels, and dynamic occupancy patterns. Insufficient ventilation and elevated temperatures can result in:

- Reduced productivity: due to discomfort and poor air quality.
- Health and safety risks, including heat stress, dust accumulation, and respiratory irritants.

To address these challenges, VividAir and Syska Hennessy collaborated on a CFD-based study to evaluate the performance of the Z-Chill™ system at a Wesco distribution center in Phoenix, Arizona.

The Z-Tech™ HVLS fans*, based on patented aerodynamic technology, generate significantly greater thrust and airflow at lower rotational speeds compared to conventional HVLS fan designs. When paired with tempered air The combination of a fan and diffusers to provide tempered air is called Z-Chill™ Fan & Patented Diffuser* system, also a patented VividAir innovation.

<u>Wesco Distribution Center – Roosevelt Street, Phoenix, Arizona</u>

Wesco is a global leader in distributing electrical and industrial supplies, power distribution equipment and safety products. The company also provides advanced supply chain management and logistics services.

The Phoenix warehouse used in this study is approximately 390,000 SF and is served by:

- 12 (twelve) Z-Chill™ Fan & Diffuser units. Each unit is connected to a roof top packaged unit (RTU) via sheet metal ductwork; air supply and return ducts. The capacity of each RTU is 20 refrigeration tons and 8,000 CFM. The airflow rate of each Z-Tech™ fan is 178,000 CFM.
- 6 (six) Z-Tech™ Fan.

Figure 1 shows a floor plan of the distribution center, the locations of Z-Chill™ units are highlighted with yellow color, and the locations of Z-Tech™ fans are highlighted with blue color.

* The Z-Tech™ HVLS fan and the Z-Chill™ Fan are covered by one or more of the following U.S. Patents: 10428831, 10273964, 10527046, 11168703, 11698081, 12209595, D853553, D852943, D852944, D874639, D930815 and several pending patents.

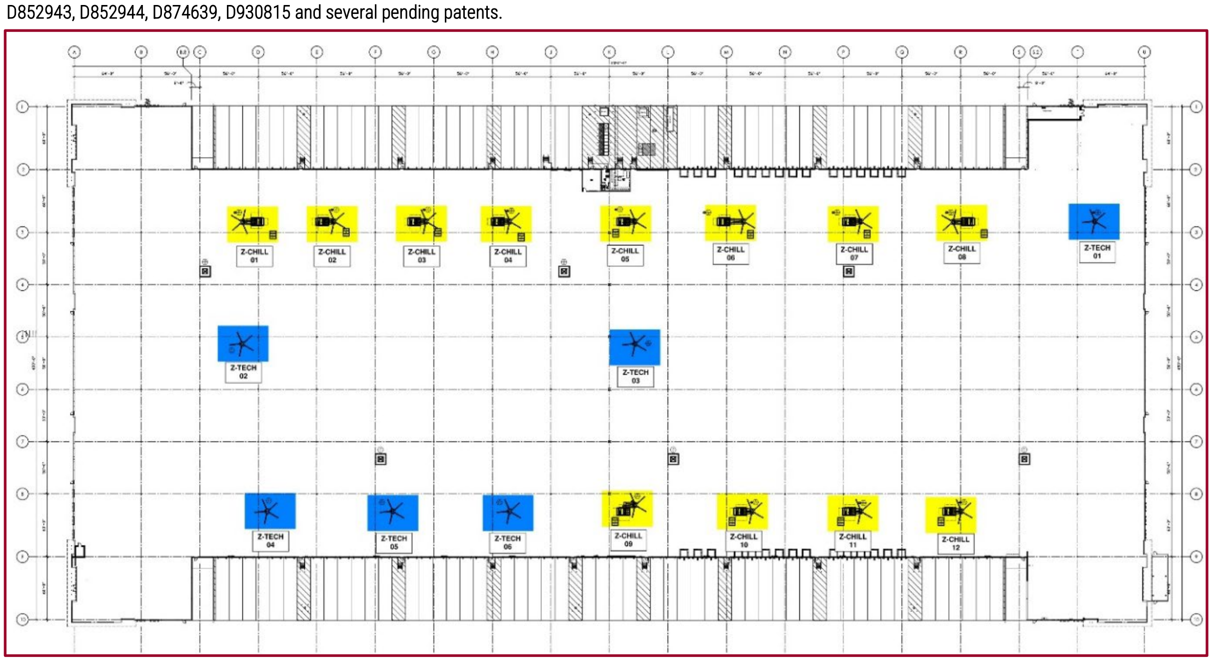

Figure 1: Wesco Distribution Center Floor Plan – Z-Chill™ and Z-Tech™ Locations

III. TECHNICAL OVERVIEW AND METHODOLOGY

1. Technical Overview

Industrial warehouses present unique ventilation challenges due to their large, open spaces and high ceilings. Traditional HVAC systems are often cost-prohibitive to install and operate in such environments. HVLS fans were specifically engineered to address these challenges.

The HVLS fans operate on the principle of moving large volumes of air at low rotational speeds, rather than the high-speed, turbulent airflow of smaller fans. This minimizes air turbulence while ensuring widespread air movement.

The ventilation system's core components (Figure 2):

- Z-Chill™ Fan & Patented Diffuser System
  - Patented Diffusers: The upper part of the Z-Chill™ unit comprises four return air diffusers. The bottom of the upper part is perforated to equally distributed tempered air over the blades.
  - Fan/Blades: Each unit has fan made of 5, two-piece extruded anodized aluminum blades.
  - Motor: High efficiency variable speed motor.
- Roof Top DX Cooling Units (RTU): the capacity of each unit is 20 refrigeration tons. The air supply and return ducts are from the bottom of the unit.
- Airflow Pattern: For each unit, the RTU supply tempered air over the fan, which pushes it across the floor in a broad, gentle column, covering a massive area and minimizing "dead zones".

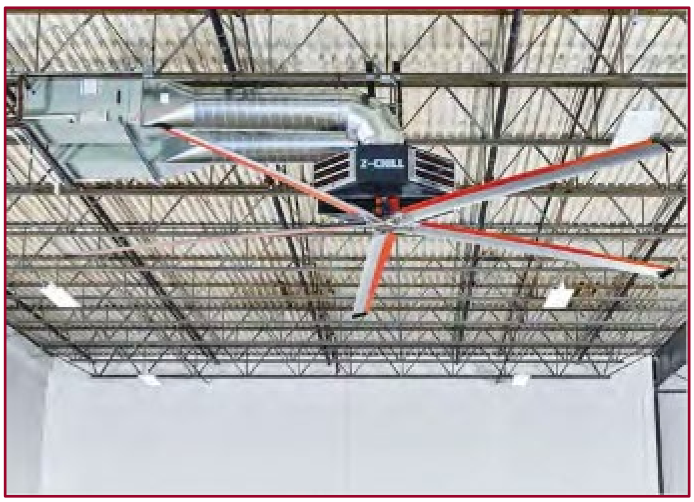

Figure 2: A Typical Z-Chill™ Fan and Supply and Return Air Ducts

2. Methodology

The study and analysis were carried out using a CFD model for the building and the ‘as-built’ ventilation system. A CFD model was developed to compare the ‘as-built’ ventilation system that comprises tempered air and HVSL with traditional cooling system.

Three (3) ventilation scenarios were developed to assess cooling effectiveness, airflow, and energy performance:

1. Scenario 1: As-Built ventilation system (combination of Z-Chill™ units and tempered air):

   As-Built drawings were used to model the warehouse and the exact quantity and location of the Z-Chill™ units. The RTUs cooling capacity, air flow rates and Z-Chill™ fan size and speed were taken from the technical submittals and cut sheets provided by associated vendors:

RTU cooling capacity	20 R Tons
RTU airflow rate	8,000 CFM
Size of Z-Chill™ Fan	5-Blade, 24 feet diameter
Z-Chill™ Fan speed	56 RPM, 178,000 CFM

2. Scenario 2: Tempered air only (spot cooling without fans):

   The same model as Scenario 1 used but the Z-Chill™ fans were removed from under the RTUs. The RTUs supplied tempered air at high level to serve the warehouse.

3. Scenario 3: Additional cooling without Z-Chill™ fans:

   The main purpose of this scenario is to estimate the additional cooling capacity that will be required to achieve an average space temperature at 5 feet above floor level (occupied zone) comparable to the space temperature achieved in scenario 1 at the same height. This scenario also helps estimating energy savings because of using Z-Chill™ fans, that circulate air at relatively higher velocities within the occupied zone compared to the Scenario of RTUs only.

The three scenarios were compared to each other, and the key comparison metrics included:

a. Average space temperature at 5 feet above floor level, which is the occupied zone.

b. Temperature stratification.

c. Air velocity/air distribution at 5 feet above floor level.

d. Annual estimated energy consumption.

IV. CFD SIMULATION OUTCOME AND ANALYSIS

This section presents the key outcomes of the CFD simulations conducted to analyze the air temperatures and air velocities for different scenarios within the Wesco Warehouse in Pheonix, Arizona.

Scenario 1:

Figure 3 shows the temperature distribution across the floor at 5 feet above floor level (occupied zone).

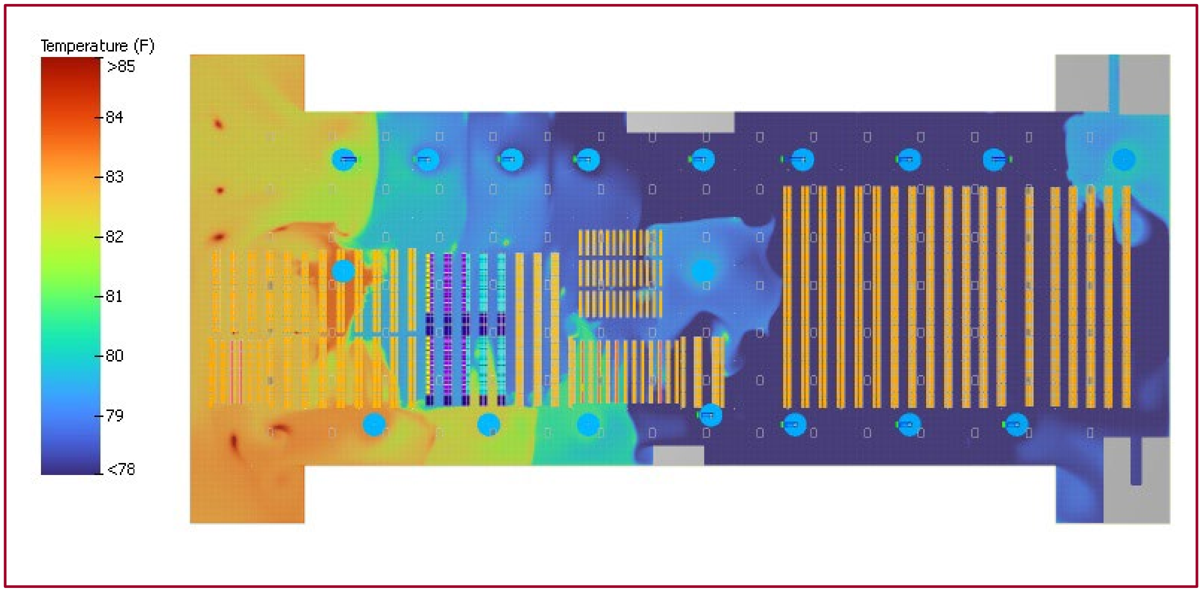

Figure 3: Space Temperature Distribution at 5 feet above Floor Level – Z-Chill™ Fan with Tempered Air

From Figure 3, the temperature within most of the occupied zone ranges between 78°F and 81°F. The only exception is the southwest area of the warehouse, where the temperatures are slightly higher and they get up to 83°F. This can be attributed to the lack of tempered air in that area that is served by four Z-Tech™ fans without connecting to RTUs.

For the middle area between the shelves, although it is served by a Z-Tech™ unit, the temperature is below 81°F. This can be explained by having two Z-Chill™ units, one to the north and a second to the south of it, that disperse tempered air.

Figure 4 shows the air velocity distribution across the floor at 5 feet above floor level.

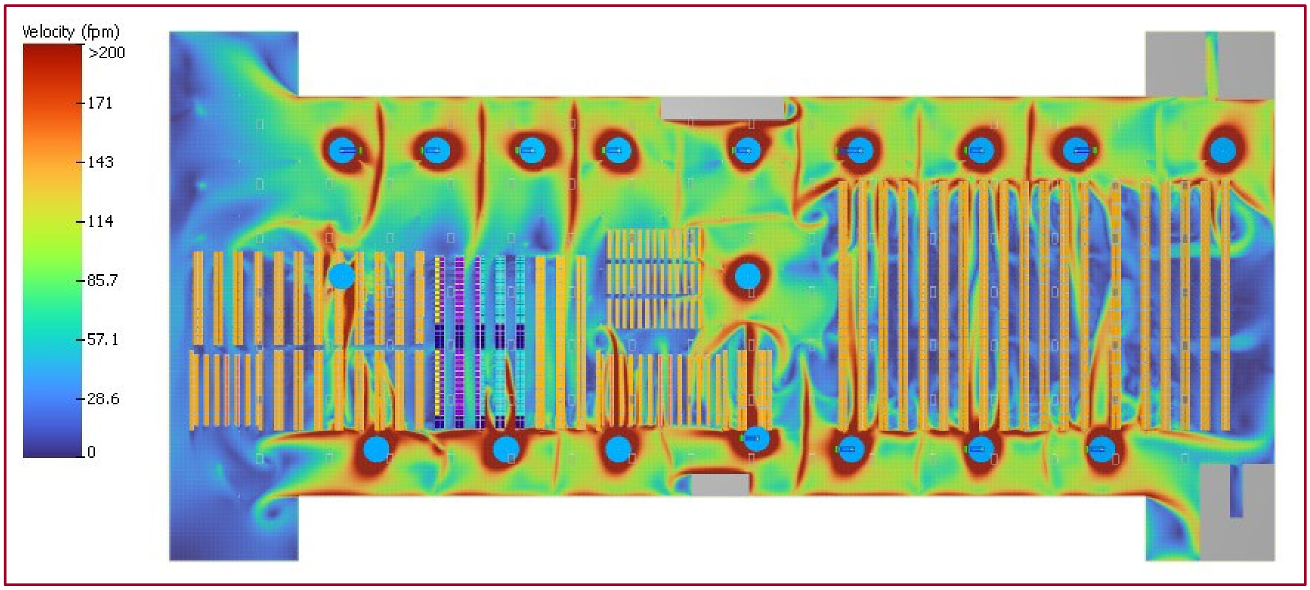

Figure 4: Air Velocity at 5 feet above Floor Level

It is apparent from Figure 4 that there is good air movement within the occupied zone. The air velocities under the Z-Chill™ and Z-Tech™ fans range between 80 fpm to 120 fpm. As per the manufacturer's published specification, the 24 feet long blades fans cover up to 25,000 SF, however, for this installation the fans are covering relatively smaller area and it ranges between 6,000 SF to 16,000 SF and this can be attributed to various design parameters such as the height of fans, proximity to walls, proximity to each other and also the surroundings (i.e. shelves) that can obstruct and impact the air distribution/coverage.

Figure 4 also shows that in certain areas, particularly between fan zones and at walls close to fans, the air velocity is higher, and it can get to above 160 fpm. The reason for these higher velocities is the collision of two adjacent airstreams or airstream with the wall at low level, as illustrated in Figure 5 below. This information, in addition to temperature distribution, helps to fine-tune the design by strategically placing the Z-Chill™ systems and adjusting the speed of associated fans.

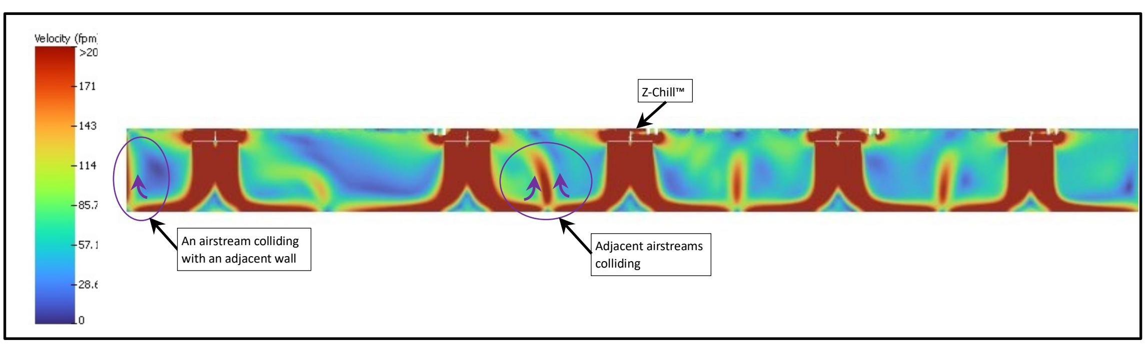

Figure 5: East/West Section – Air Velocity Profile

Figures 6 and 7 are east-west and north-south sections that show the temperature stratification for the height of the warehouse. This is a further illustration of the impact of Z-Chill™/Z-Tech™ fans as they push the tempered air to the occupied zone and achieve a temperature in the range of 78°F - 80°F.

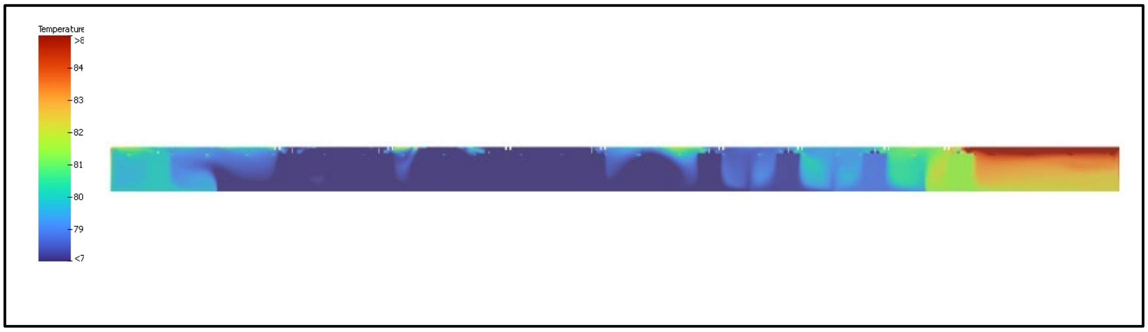

Figure 6: East/West Section - Temperature Stratification

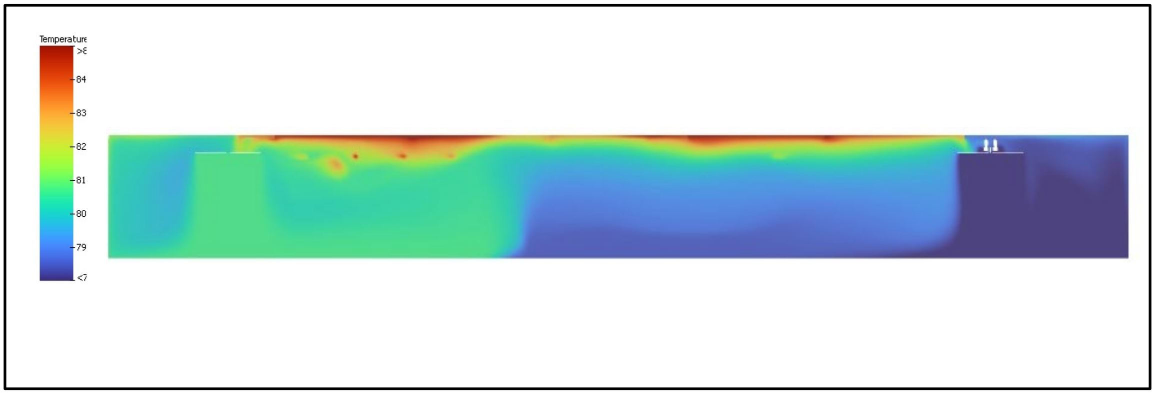

Figure 7: North/South Section - Temperature Stratification

<u>Scenario 2:</u>

The purpose of this Scenario is to compare it with Scenario 1 and show the advantages of having high volume low speed fans (Z-Tech™ fans) in warehouse settings. The RTUs weren't changed from Scenario 1.

Figure 8 shows the temperature distribution across the floor at 5 feet above floor level (occupied zone).

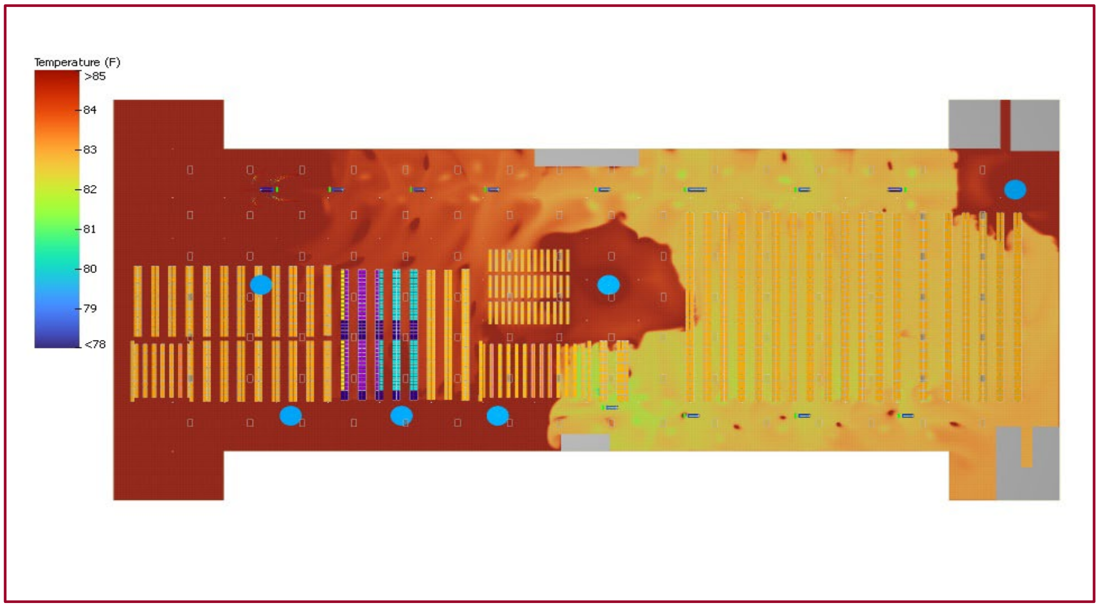

Figure 8: Space Temperature Distribution at 5 feet above Floor Level – Tempered Air without Z-Chill™ Fan

Although the same cooling capacity is still serving the warehouse, sufficient cooler air didn't get to the occupied zone because of the height of the warehouse and the cooler air mixing with the warmer air rising to high levels. From Figure 8, the space temperature across the floor is between 83°F and 85°F.

Figure 9 shows the air velocity at 5 feet above floor level, where air velocity does not exceed 80-85fpm.

Comparing Figures 8 & 9 with Figures 3 & 4 for Scenario 1, the advantage of adding Z-Tech™ fan is obvious. The temperature is less, and the air velocity is higher within the occupied zone. For Scenario 1, although the average temperature is around 80°F, but higher air velocities within the occupied zone increase the rate of convection heat from human body, causing it to feel cooler, primarily by continuously replacing the warm, moist air near the skin with cooler, drier air. A perceived temperature reduction can be between 1-2°F.

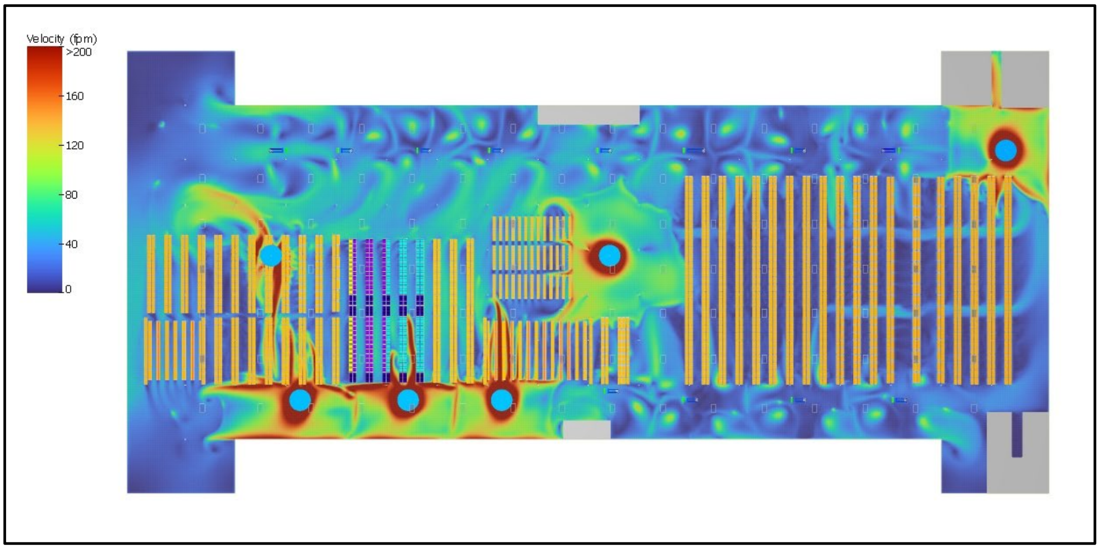

Figure 9: Air Velocity at 5 feet above Floor Level

Scenario 3:

The main purpose of Scenario 3 is to understand the additional cooling capacity that will be required to achieve an average space temperature of 80°F at 5 feet above floor level, so we can compare it with Scenario 1 taking into consideration the estimated energy consumption and compliance with Code. The energy analysis is included in the next section.

Figure 10 below shows the temperatures across the floor. The Temperatures range is between 79°F -81°F, which close to the average temperature achieved in Scenario 1.

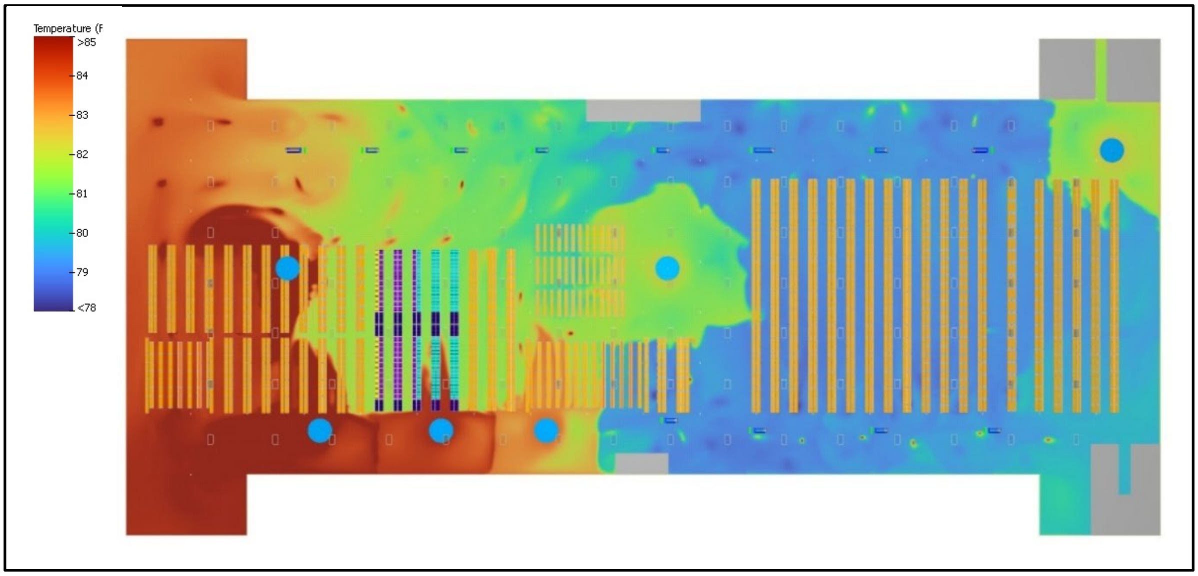

Figure 10: Space Temperature Distribution at 5 feet above Floor Level – Cooling without Z-Chill™ Fans

From Figure 10, there are some areas, especially the southwest corner of the warehouse, where the temperatures are above 82°F because there are no RTUs on the roof to supply conditioned air. For this Scenario, the locations of cooling equipment and air supply are the same as Scenario 1 but we reduce air supply temperature and increased airflow rate to estimate the additional cooling demand required.

The air velocities across the floor for this Scenario except the areas under the Z-Tech™ fans, ranges between 20 fpm to 85 fpm as shown in Figure 11. These are lower velocities compared to Figure 4 of Scenario 1.

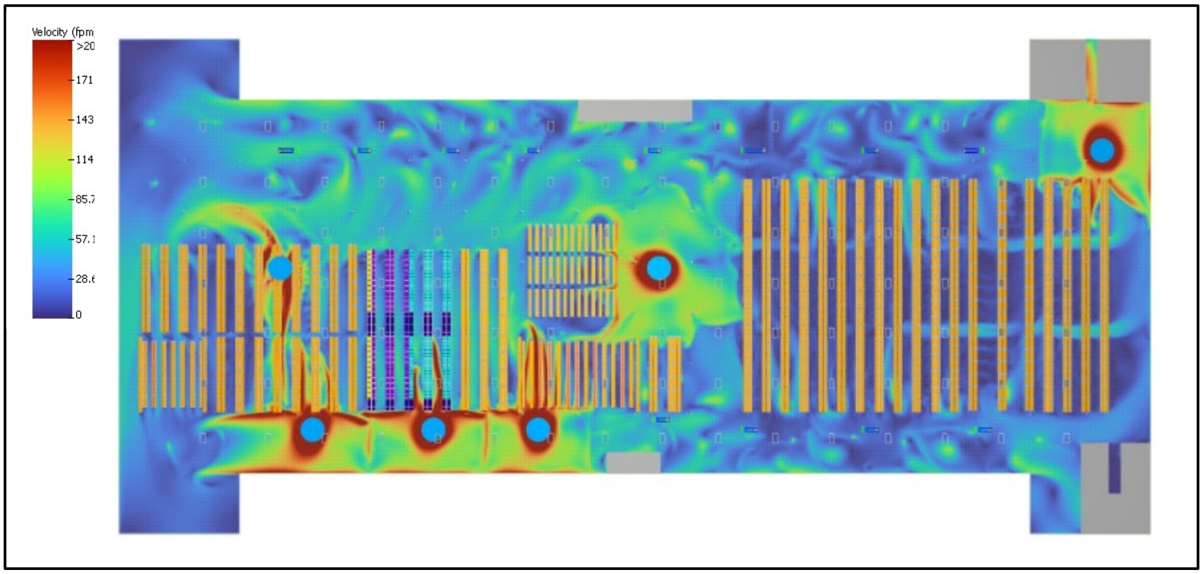

Figure 11: Air Velocity at 5 feet above Floor Level

Figures 12 and 13 are east-west and north-south sections that show the temperature stratification for the height of the warehouse. The conditioned air that is supplied to the warehouse mixes with warm air at higher level before it gets to the occupied zone and this explains the additional cooling capacity required to achieve the setpoint temperature within the occupied zone.

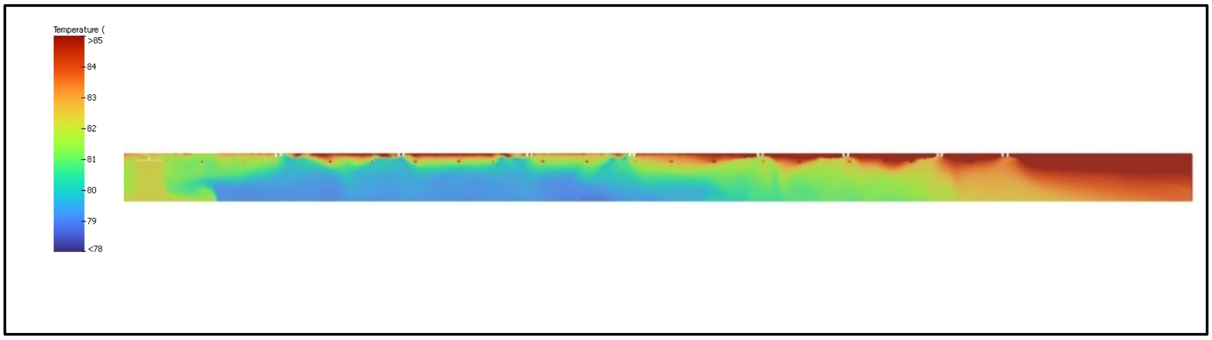

Figure 12: East/West Section - Temperature Stratification

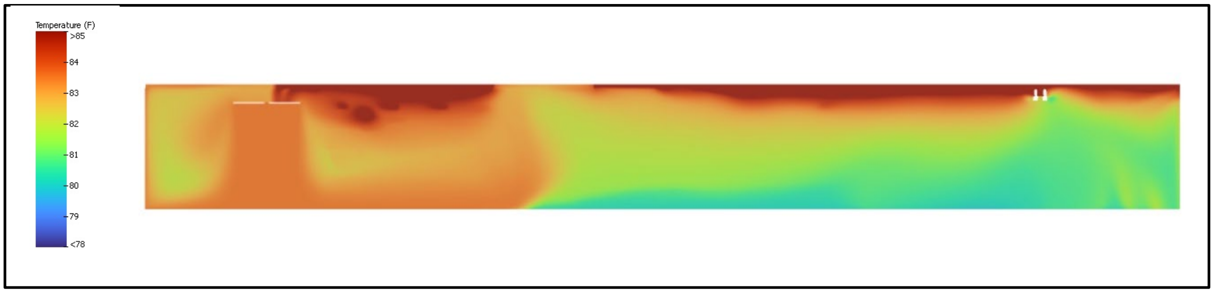

Figure 13: North/South Section - Temperature Stratification

V. COMPARATIVE ENERGY ANALYSIS

This section evaluates the relative energy performance of Scenario 1 and Scenario 3. The comparison aims to highlight potential reductions in annual energy use realized by the introduction of the Z-Chill™ HVLS fans. This comparison aims to evaluate two systems in which the average temperature at 5ft is approximately 80°F (+/-5%) at peak conditions. Scenario 2 was excluded from the energy evaluation because this design does not achieve the 80°F setpoint at peak conditions.

Scenario Descriptions:

Assumptions:

a. 6am - 6pm operation
b. Economization threshold: 70°F (subject to local climate as high humidity will limit economization significantly)

Scenario 1:

a. Twelve (12) 20-ton RTUs
b. Twelve (12) Z-Chill™ system
c. Supply air temperature: 59.1°F
d. Return air temperature: 85°F
e. RTU Fan air flow rate: 8,000 CFM

Scenario 3:

a. Twelve (12) 28 -ton RTUs
b. no Z-Chill™ system
c. Supply air temperature (avg): 59.1°F
d. Return air temperature: 85°F
e. RTU Fan air flow rate: 11,000 CFM

Energy analysis was conducted via Bin calculations using TMY3 weather data. The weather data provides annual hourly 30-year normalized ambient temperatures for the Phoenix Metropolitan Area.

The estimated theoretical annual energy consumption and associated cost are shown in Table 1 below for both scenarios; Scenario 1 and Scenario 3.

Table 1: Estimated annual energy consumption and cost

	Cooling and Fan Energy (kWh)	Cooling and Fan Energy Costs ($)
Scenario 1	1,719,575.08	$156,481.33
Scenario 3	2,090,038.34	$190,193.49
Savings	370,463.26	$33,712.16

Note/Qualification: Estimated Energy costs are calculated using IES and intended to provide a comparison example only. It is critical to note that Actual Energy Consumption and Cost may vary significantly as they are a function of multiple variables such as actual operation hours, temperature control set points and any reset, weather condition, building envelope type, leakages and maintenance and cost of electricity.

Scenario 1 results in an approximate estimated theoretical energy cost savings of 370,463 kWh or $33,712 in energy costs annually based on 12 hours of operation. Results for 24/7 operation will vary.

Scenario 3 may require the envelope to be insulated, especially if the energy usage associated with this option exceeds the percentage allowed by the State Energy Code based on warehouse size. Furthermore, the addition of insulation not only will reduce energy costs but will also improve space comfort. Refer to below for more discussion as to Energy Codes.

Return on Investment (ROI):

Various factors are required to determine the ROI, however the intent of this study is to provide a simple approximation of potential payback/ROI for the case study project in Phoenix, AZ where Z-Chill was implemented approximately a year ago. Towards this goal, we took Scenario 1, Owner's provided cost of installed RTUs with Z-Chill and applied the same cost metric ($/ton) of Air Conditioning to Scenario 3 to have straight forward and reasonable comparison.

Based on the above cost metric, and using estimated energy usage, the ROI is approximately 4.2 years.

In general, any investment with approximately 5-year payback or less is considered a viable investment.

Code Interpretations:

The Case Study Project for the Phoenix Warehouse was governed under 2015 Internal Energy Conservation Code (IECC) and qualified as a low - energy building according to section C402.1.1 of the 2015 IECC, Scenario 1 can be classified as a low-energy building. A low-energy building is a building in which the peak design energy usage for space conditioning is less than 3.4 Btu/h/SF. For the Phoenix Warehouse, the calculated peak design energy usage for space conditioning is 1.85 Btu/h/SF. A low-energy building is exempted from the building thermal envelope provisions of IECC 2015 Section C402.

For Scenario 3, on the other hand, the peak design energy usage for space exceeds the low energy threshold and may require insulation of the envelope based on governing energy code at time of Permit.

Projects that are governed under International Energy Code may qualify as low-energy buildings as long as the energy usage is below IECC, however it is important to validate State and City officials' acceptance.

Projects in States having their own Energy Codes may not qualify as Low-energy buildings. For instance, California is governed by California Energy Code and do not offer any qualifications for low-energy exemption. Similarly for Oregon, Washington and various other states that do have strict energy requirements do not allow low energy exemption. As such, it is extremely critical to assess the feasibility of implementing Z-Chill with the respective State and City Energy Code requirements to avoid having issues during Permit or Installation Phases.

VI. CONCLUSIONS

Based on our analysis, Z-Chill may be a viable solution to provide tempered air resulting in industrial warehouse applications, however it should be analyzed based on project specific and Owner's Requirements. Z-Chill may address some of the operational challenges in these large spaces by providing ventilation on steroids (higher air velocity / somewhat turbulent) to generate sufficient air movement and effective ventilation at somewhat suitable temperatures that contribute to improving the warehouse working environment while using minimal energy and reducing annual energy consumption and related costs.