DATA CENTER Frontier SPECIAL REPORT

Two-Phase Liquid in the Data Center

The Key Imperatives to Change the Game for AI and HPC

Report Compiled By: Bill Kleyman,
CEO and Co-Founder, Apolo.us
Contributing Editor, Data Center Frontier

brought to you by

OptiCool

Contents

Two-Phase Liquid in the Data Center

The Key Imperatives to Change the Game for AI and HPC

EXECUTIVE SUMMARY

Unless you've lived under a raised floor this past year or so, you probably noticed some GPT-level changes in the data center industry.

You're not alone. The impact of AI and HPC on critical infrastructure has been profound.

The type of infrastructure our data centers are being tasked with supporting is so different from the SQL and email servers we all grew up with. Greater density levels, new types of workloads like AI and cognitive systems, and a vast reliance on a massive boom in data have created a redesign mentality for data center leaders.

The challenge for many in this industry is how to leverage density and space more effectively while still being able to scale critical resources. Air cooling has led the industry in deployments for some time. However, our industry has reached the limits of how much heat an air-cooling system can dissipate. Liquid cooling has made significant strides to redefine density and next-generation computing capabilities.

Leaders in the space see the benefits of hybrid solutions, where liquid cooling can substantially impact critical workloads and support emerging AI use cases.

This paper will discuss the state of cooling in the data center, innovations in cooling, and understanding how to get started with a different cooling architecture approach. We will also discuss the limitations of traditional cooling methods, the early development stage of immersion and direct-to-chip cooling, and how two-phase liquid refrigerant heat extraction meets current demands. Additionally, we will address the history of refrigerant-based cooling, challenge misconceptions about its efficiency, and highlight how it can support some of the most advanced use cases in today's market.

Introduction

As we look out into the data center world, it's clear that a lot has changed. If 2023 taught us anything, we rely more on our digital infrastructure than ever. There are new demands around cloud computing, big data, and infrastructure power/cooling efficiency. Furthermore, this change in the data center is driven by more users, data, and reliance on the data center itself.

With cloud technologies and the rapid growth in AI (specifically generative AI) leading the way within many technological categories, working with the right data center optimization technologies has become more critical.

If you're a data center operator, it's key to note that modern advancements demand a rethink in how data centers are designed, particularly regarding cooling mechanisms. Traditional air and water-based cooling techniques are falling short of the current demands.

That's why we'll explore the shift from legacy data center designs to modern ones, emphasizing the role of two-phase liquid refrigerant cooling in meeting these new requirements. We will explore the advantages of rear door heat exchangers (RDx), key technological updates in heat rejection, and why now is the right time to adopt RDx.

This is where two-phase liquid cooling comes into play. While AI isn't necessarily a new technology, Generative AI certainly is. As a result, real-world generative AI and emerging machine learning use cases impact how we deploy entire systems into the data center.

This involves delivering liquid cooling to GPUs and supporting infrastructure. Remember, because of AI, the amount of power our systems require will only grow. In 2023, data centers across the globe consumed 7.4 GW of power, a 55% increase from the 4.9 Gigawatts in 2022, according to Cushman & Wakefield. That number is already forecast to grow significantly through 2030. Gartner estimates that ongoing power costs increase at least 10% per year due to increases in cost per kilowatt-hour (kwh) and underlying demand, especially for high-power density servers.

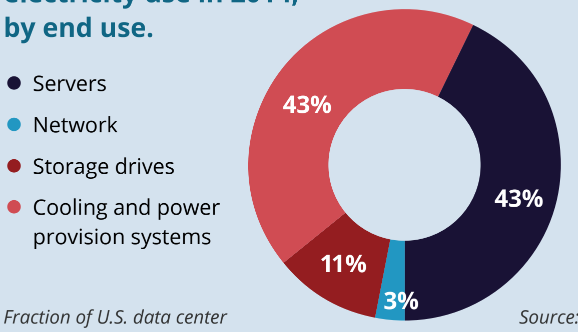
With AI in the mix, density, power, and cooling must all be considered from a new design perspective. Consider the following: In 2014, 43% of power usage went to cooling systems. Today, that number is at 50% and growing.

This means optimizing and cooling our data centers must also change and evolve.

So, what does this mean for you? Where should you look for liquid cooling solutions?

Let's examine the state of data center cooling to better understand how liquid cooling changes data center design. Most importantly, you'll see that today's liquid cooling solutions are much different than ever, making adoption far more feasible.

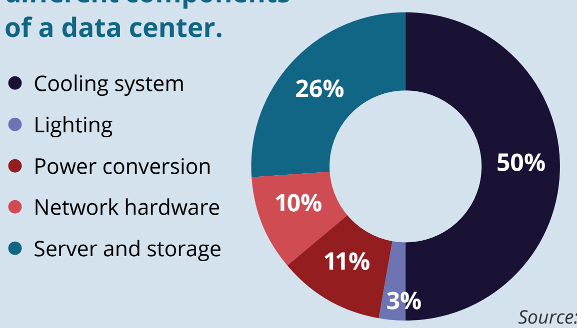
Fraction of U.S. data center electricity use in 2014, by end use.



Fraction of U.S. data center electricity use in 2014, by end use.

Source: Shehabi 2016.

A breakdown of energy consumption by different components of a data center.



Source: IEEE.org

Chapter 1: Liquid Cooling — Key Updates, Demands, and Trends

An interesting misconception in the digital infrastructure industry is that liquid cooling concepts are relatively new. Many believe that working with particular kinds of liquids designed for servers dates back to the past decade. However, as it relates specifically to liquid cooling, this technology has been around for quite some time, and it's battle-tested.

Between 1970 and 1995, most liquid cooling was done within mainframe systems. Then, in the 90s, we saw more gaming and custom-built PCs adopt liquid cooling for high-end performance requirements. Between 2005 and 2010, liquid cooling entered the data center with chilled doors. From there, looking into 2010 and beyond, liquid cooling was used in high-performance computing (HPC) environments and designs featuring direct contact and total immersion liquid cooling solutions.

Today, the conversation revolves around AI.

AI is Shaping How We Cool and Power Our Data Centers

Within the data center, specific shifts in modernization efforts and new requirements to support evolving digital solutions shape how we build tomorrow's digital infrastructure. Consider these key trends:

- **Cooling:** The advent of AI and HPC has significantly increased heat generation within data centers. Traditional air cooling systems struggle to dissipate this heat efficiently, leading to the adoption of advanced cooling solutions such as liquid cooling. Liquid cooling, particularly two-phase refrigerant, offers superior heat transfer capabilities, allowing data centers to maintain optimal operating temperatures even in high-density environments. This technology removes heat directly at the source, reducing the load on traditional cooling systems and improving overall energy efficiency.

- **Power:** As computational demands increase, so does data center power consumption. AI and HPC workloads require significant amounts of power, driving the need for more efficient power management solutions. Data centers optimize power usage to reduce operational costs and minimize environmental impact. This includes adopting energy-efficient hardware, implementing advanced power distribution systems, and utilizing renewable energy sources. Efficient cooling solutions also play a crucial role in power management by reducing the energy required for cooling infrastructure.

- **Cloud:** The rapid growth of cloud computing transformed data center operations. Cloud service providers must support vast amounts of data and various applications, from simple web hosting to complex AI computations. This shift requires scalable, flexible cooling solutions that adapt to varying workloads and server densities. With their modular and adaptable design, liquid cooling technologies are well-suited to meet the dynamic demands of cloud environments. They enable cloud data centers to efficiently manage heat, support higher densities, and ensure reliable performance.

- **Generative AI:** Generative AI, a subset of artificial intelligence focusing on creating new content, poses unique challenges for data center cooling. These workloads often involve processing large datasets and running complex algorithms, generating substantial heat. Traditional cooling methods are insufficient for these high-intensity tasks, necessitating advanced liquid cooling solutions. Two-phase refrigerant cooling, in particular, is effective in managing the heat generated by generative AI workloads. This technology provides efficient and reliable cooling, ensuring that data centers can support the growing demands of AI applications. These trends highlight the critical need for modern cooling solutions in today's data centers. By adopting advanced technologies such as liquid cooling, data centers can meet the demands of evolving digital solutions, optimize power usage, and support the growth of cloud and AI workloads.

With this in mind, let's pivot and understand the journey from legacy to modern data center design.

The Evolution of Data Center Cooling

Air cooling was the standard in data centers for decades, utilizing raised floor systems to deliver cold air to servers. However, this method has limitations in supporting high-density workloads and modern computing requirements. The shift to liquid cooling addresses these limitations by directly providing more efficient heat removal at the source.

The traditional raised floor cooling system uses perforated tiles to distribute cold air from the computer room air conditioner (CRAC) or computer room air handler (CRAH). While this method is effective for low-density environments, it struggles with higher densities and modern workloads. As server densities increase, the need for more effective cooling solutions becomes apparent. Liquid cooling, particularly two-phase refrigerant, offers superior heat transfer capabilities, making it an ideal choice for high-density data centers.

The Need for Better Cooling Solutions

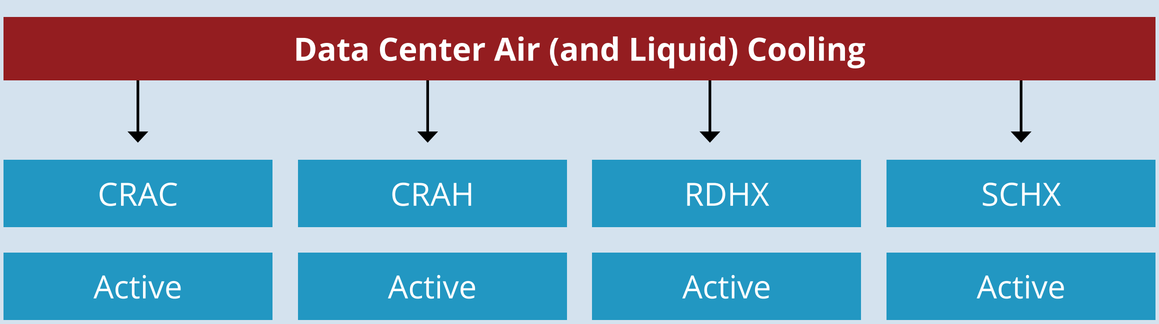
As server densities increase, so does the need for more effective cooling. Traditional air-cooling systems struggle to keep up with the thermal demands of modern servers, leading to inefficiencies and higher operational costs. Liquid cooling, particularly two-phase refrigerant cooling, offers a more efficient solution by leveraging the superior thermal properties of phase changing liquids compared to air and water.

High-density environments, such as those required for AI and HPC workloads, generate substantial heat. Air cooling systems, which rely on cold air circulation, are often insufficient to effectively dissipate this heat, resulting in hotspots and reduced performance. With its higher heat capacity and thermal conductivity, liquid cooling can remove heat more efficiently, ensuring that servers operate within optimal temperature ranges.

With this in mind, it's important to note that there are several different types of cooling solutions. Consider this chart.

In the next few sections, the limitations of air cooling will be discussed, as well as how liquid cooling overcomes those limitations.

Data Center Cooling Classifications Chart



Challenges in Air Cooling Specific Workloads

Q = m × c × ΔT: This is the basic formula for calculating heat transfer or sensible cooling/heating, where **Q** is the amount of heat, **m** is the mass, c is the specific heat of the mass, and **ΔT** is the temperature change. When it comes to air cooling, the challenge lies in the fact that air is not very dense (low **m**) and has a low specific heat (low **c**). As a result, significantly more air needs to be moved to achieve the same cooling or heating effect that would require far less water. This inherent inefficiency makes air cooling less effective, especially in high-density data center environments where substantial heat needs to be dissipated.

Moreover, refrigerant-based systems are five times more efficient at moving heat than water, making them a far superior option for managing the thermal demands of modern data centers.

Although there is nothing wrong with air-cooled solutions, it's more important than ever to understand the workloads and use cases leveraging a specific type of cooling. As it relates to air-cooled designs, a significant challenge in supporting emerging use cases revolves around five key factors:

1. DENSITY AND CAPACITY

- **Density:** Modern workloads, particularly those involving AI and HPC, require high-density server configurations. Air cooling systems often struggle to dissipate the heat generated by densely packed servers. As server density increases, the ability of air cooling to effectively manage heat diminishes, leading to hotspots and reduced performance.

- **Capacity:** The thermal capacity of air is significantly lower than that of liquid, meaning air-cooled systems must move large volumes of air to remove the same amount of heat. This limitation becomes increasingly problematic as data centers scale up, necessitating more powerful and energy-intensive cooling systems to maintain adequate temperatures.

2. SCALE

- **Scalability:** Air cooling systems face challenges when scaling to support larger data centers or increased computational loads. As data centers expand, the infrastructure required to support air cooling—such as raised floors, extensive ductwork, and large CRAC units—becomes more complex and costly to implement and maintain. This complexity can hinder the ability to quickly scale operations in response to growing demand.

- **Adaptability:** Air cooling systems are less adaptable to changing server configurations and densities. On the other hand, liquid cooling solutions offer greater flexibility, allowing data centers to easily reconfigure cooling infrastructure to match evolving requirements without extensive physical modifications.

3. EFFICIENCY

- **Energy Efficiency:** Air cooling systems are generally less energy-efficient than liquid cooling solutions. The energy required to move and condition large volumes of air can significantly increase operational costs. Additionally, air cooling systems often struggle to achieve the same thermal management level as liquid cooling, leading to higher energy consumption.

- **Thermal Efficiency:** Liquids have a much higher thermal conductivity and heat capacity than air, making liquid cooling systems more efficient at capturing, transferring and dissipating heat. This efficiency translates into lower energy consumption and more effective temperature management in high-density environments.

4. PERFORMANCE

- **Thermal Performance:** The performance of air-cooled systems can degrade under high thermal loads, leading to thermal throttling of servers and reduced computational performance. In contrast, liquid cooling systems provide consistent and reliable cooling, maintaining optimal operating temperatures even under peak loads.

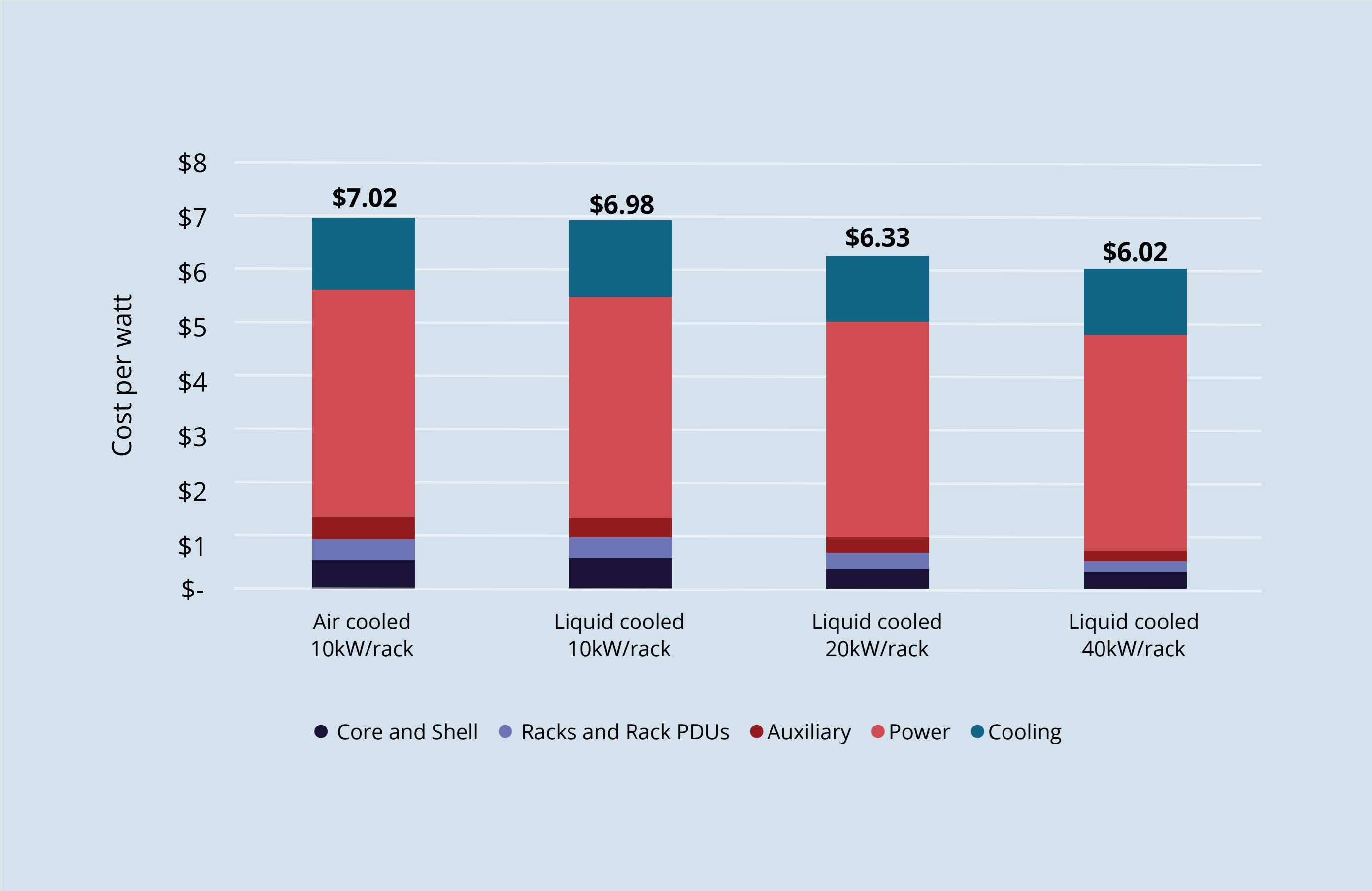
- **Reliability:** Air cooling systems are more susceptible to ambient temperature and humidity fluctuations, which can affect their performance and reliability. Liquid cooling systems offer more stable and predictable cooling performance with their closed-loop designs and advanced control mechanisms.

5. COST

- **Capital Expenditure (CapEx):** Implementing and scaling air cooling systems can require significant upfront investment in infrastructure, including CRAC units, raised floors, and extensive ductwork. These costs can be prohibitive for data centers looking to expand or upgrade their cooling capabilities.
- **Operational Expenditure (OpEx):** The ongoing operational costs of air cooling systems, including energy consumption, maintenance, and potential downtime due to cooling inefficiencies, can be high. Liquid cooling solutions, while potentially requiring higher initial investment, often result in lower operational costs due to their higher efficiency and reduced energy consumption.

These challenges highlight the limitations of air cooling systems in supporting the high-density, high-performance workloads common in modern data centers. By understanding these limitations, data center operators can make informed decisions about adopting more advanced cooling technologies, such as liquid cooling, to meet their evolving needs.

Let's stay on this topic for a minute. With AI and HPC at the top of everyone's list, how are new use cases dominating the market?



New Use Cases Dominating the Market

SERVERS ARE NO LONGER PIZZA BOXES

The architecture of servers has evolved significantly. Modern servers are no longer the simple, low-density “pizza boxes” of the past. They are now highly sophisticated, densely packed systems requiring advanced cooling solutions to manage the increased heat load.

Modern servers are designed to support complex workloads, including AI, machine learning, and big data analytics. These applications require significant computational power, resulting in higher heat generation. The traditional “pizza box” server design is inadequate for these demands. Instead, modern servers are densely packed with high-performance components, necessitating advanced cooling solutions like liquid cooling.

LIMITS TO AIRFLOW — THE PHYSICS

The fundamental physics of air cooling imposes limits on its effectiveness. Air has a much lower heat-carrying capacity than liquids, making it less efficient for cooling high-density server environments. This chapter will explore the physical limitations of air cooling and how liquid cooling technologies overcome these barriers.

Air cooling relies on the movement of air to dissipate heat. However, air has a lower heat capacity and thermal conductivity than liquids. This means that air cooling systems must circulate large volumes of air to manage heat, which becomes impractical in high-density environments. With its higher heat capacity and thermal conductivity, liquid cooling can remove heat more efficiently, reducing the need for extensive air-handling infrastructure.

The challenge is designing an infrastructure to support these new and emerging use cases. Let’s explore some critical design considerations.

Data Center Design Considerations

Air cooling has been the preferred method in data centers, and it is still a viable option. Given low electronic densities and affordable energy prices, blowing cold air across electronics generally works. However, data center and computing solutions have become more compact. High equipment densities are also more common, making better cooling methods imperative.

Chapter 2: RDx to the Rescue — The Modernization of Legacy Data Centers

RDx (Rear Door heat exchanger) systems represent a significant advancement in data center cooling technology. They offer a scalable and efficient solution for modernizing legacy data centers, providing targeted cooling directly at the server level. RDx systems eliminate the need for extensive air handling infrastructure, reducing complexity and improving energy efficiency.

RDx systems work by incorporating heat exchangers into the rear doors of server racks. These heat exchangers extract heat directly from the servers, preventing it from entering the data center environment. This targeted cooling approach ensures that servers remain within optimal temperature ranges, enhancing performance and reliability.

Benefits of RDx

RDx systems provide numerous benefits, including improved cooling efficiency, reduced energy consumption, and greater flexibility in data center design. They are particularly effective in high-density environments where traditional air cooling falls short.

The benefits of RDx systems extend beyond cooling efficiency. By removing heat directly at the source, RDx systems reduce the load on CRAC/CRAH units, lowering energy consumption and operational costs. Additionally, RDx systems offer greater flexibility in data center design, allowing for higher densities and more efficient use of space.

Real-World Case Study: Victory Technology Center, The Pursuit of ROI

Real-world case studies provide valuable insights into the benefits of RDx systems. For example, Victory Technology Center of Buffalo, NY, was initially designed as a dedicated data center to support Catholic Health, Western New York's second-largest multi-hospital healthcare system. The design firm MDC Solutions was brought on to retrofit a recently closed hospital into a data center to meet the healthcare system's rising technology demands.

Mike DiGiore, President of MDC Solutions, recalls the first phase of construction,

"At the time, traditional forced-air was the mainstay of data center cooling. So, the first suite was designed using these methods."

With this traditional design came the traditional obstacles of ductwork, raised floors, humidity control, and a host of other maintenance issues.

ENTER THE OPTICOOL SOLUTION

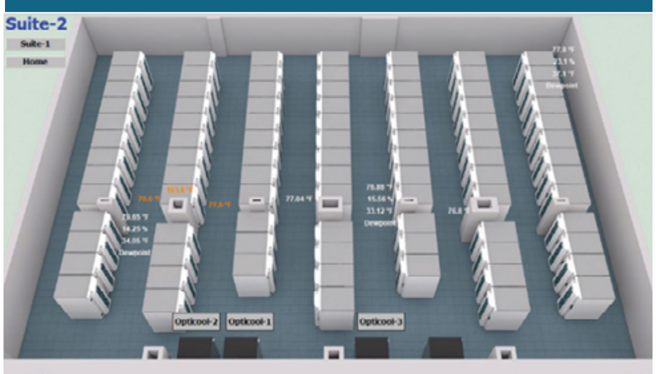
"At the time of Phase I construction, OptiCool Technologies' refrigerant-based cooling system had not yet been perfected," said James Pluta, Director of Facilities. "Luckily, by the time of the Phase II design, the planets essentially aligned for us," added Mike DiGiore. With the availability of OptiCool's cooling solution, construction of the new colocation footprint centered around the innovative new design.

Suite 1 Traditional Cooling

1 OptiCool Pump = 3 Traditional CRAC Units.
A side by side comparison.

Use of Valuable Floor Space
Each CRAC unit 6' wide x 3' deep x 5' tall = **54 total ft²**

Suite 2 OptiCool System



One OptiCool pump is 2½' wide by 2' deep x5' tall = **5 total ft²**

Total floor space saved = 49 ft² / $185,000 Savings
(dollar value based on colocation revenue)

OptiCool's refrigerant-based cooling dramatically transformed the design and efficiency of subsequent VTC suites. Elegant simplicity is the key. Unlike airflow cooling, OptiCool provides close-coupled cooling at the heat source, providing a wealth of advantages, including **energy usage reduction by up to 90%.**

"The OptiCool solution is far superior to any that I've ever encountered," said James Pluta. "Our Service Techs are saying 'this can't be that simple!' and yet it truly is." From a single cabinet in a shared colocation environment to a dedicated hard-walled suite, VTC is dedicated to offering custom solutions to its clients. "The OptiCool solution has become a major component in doing just that," said DiGiore.

The average life span of a typical CRAC unit is 15 years. VTC is currently in its 10th year.

"We anticipate retrofitting suite one to OptiCool in about five years," said DiGiore. "The future of data center cooling is here today, and with great confidence, we have put our future in the hands of OptiCool."

Key Technology Updates — Bringing Experience to the Forefront

That said, rear door heat exchange-type systems have been around for quite some time. However, substantial updates and advancements have occurred over the past few years.

ADVANCES IN HEAT REJECTION TECHNOLOGIES

Recent advancements in heat rejection technologies have significantly improved the efficiency of liquid cooling systems. These innovations include enhanced heat exchangers, more efficient refrigerants, and advanced control systems. In this section, we'll detail these technological updates and their impact on data center cooling.

Enhanced heat exchangers and more efficient refrigerants are key advancements in heat rejection technologies. These innovations improve the efficiency of liquid cooling systems, enabling them to remove heat more effectively. Advanced control systems also play a crucial role, allowing for precise monitoring and adjustment of cooling parameters to ensure optimal performance.

Beyond heat rejection, there have been other important advancements as well. Let's explore the top three:

1. INCREASED COOLING EFFICIENCY AND CAPACITY

- **Advancement:** Modern two phased RDx systems have significantly improved their ability to efficiently remove heat directly at the source. These systems can handle higher heat loads at lower air discharge temperatures, crucial for supporting high-density and high-performance computing environments.

- **Impact:** This advancement enables data centers to target and maintain optimal ASHREA recommended operating temperatures for densely packed servers, ensuring consistent performance and reliability while reducing the overall energy consumption required for cooling.

2. MODULAR AND SCALABLE DESIGN

- **Advancement:** RDx systems have evolved to offer modular and scalable designs, allowing data centers to easily expand its cooling capacity as needed. This flexibility is vital for modern data centers that need to adapt quickly to changing workloads and increasing server densities.

- **Impact:** The modular nature of RDx systems reduces the complexity and cost of scaling up cooling infrastructure. Data centers can add or remove cooling units based on current demands without significant modifications to the existing setup, ensuring efficient use of space and resources.

3. ENHANCED CONTROL AND MONITORING CAPABILITIES

- **Advancement:** Integration of advanced control and monitoring technologies into RDx systems has greatly enhanced their performance and reliability. Features such as real-time environmental monitoring, adaptive load balancing, and integration with building management systems (BMS) are now common.

- **Impact:** These capabilities allow for precise control over the cooling environment, optimizing energy use and ensuring that adaptive heat extraction is delivered exactly where and when needed. Improved monitoring also helps in the early detection of potential issues, reducing downtime and maintenance costs.

FABLES AND MISCONCEPTIONS

One common misconception is that refrigerant-based cooling is inefficient and unreliable. However, evidence shows that pumped two-phase liquid refrigerant heat extraction is highly efficient and can remove more heat per unit of energy consumed than air cooling. Additionally, refrigerant-based cooling systems are designed to be reliable, with advanced control systems ensuring stable and consistent performance.

There are other misconceptions as well. Let's review a few:

1. MISCONCEPTION: LIQUID COOLING IS TOO RISKY AND PRONE TO LEAKS

- **Reality:** Modern two-phase liquid cooling systems, including RDx, are designed with robust safety features to minimize the risk of leaks. These systems use non-conductive, non-corrosive, and non-toxic refrigerants, reducing potential damage in the unlikely event of a leak. Additionally, advanced quick-connect couplers and redundant seals ensure secure and leak-free connections.

- **Impact:** This misconception often prevents data centers from adopting highly efficient liquid cooling technologies that significantly improve cooling performance and energy efficiency.

2. MISCONCEPTION: LIQUID COOLING IS EXPENSIVE AND NOT COST-EFFECTIVE

- **Reality:** While the initial capital expenditure (CapEx) for liquid cooling systems may be slightly higher than traditional air cooling solutions, the total cost of ownership (TCO) is often lower. Liquid cooling systems are more energy-efficient, reducing operational expenditure (OpEx) over time. They also provide superior cooling for high-density environments, which can reduce the need for additional infrastructure and extend the lifespan of equipment.

- **Impact:** This misconception leads to short-term decision-making focused on upfront costs rather than long-term savings and operational benefits, hindering the adoption of more efficient cooling solutions.

3. MISCONCEPTION: REAR DOOR HEAT EXCHANGERS ARE NOT SCALABLE OR FLEXIBLE

- **Reality:** RDx systems are designed to be modular and scalable, making them highly adaptable to different data center configurations and growth requirements. They can be easily integrated into existing data centers and expanded as cooling needs increase. The modular design allows for incremental investment and deployment, aligning with modern data centers' dynamic nature.

- **Impact:** This misconception can result in data centers overlooking RDx solutions, missing out on the flexibility and scalability needed to efficiently manage increasing cooling demands as data center workloads grow.

So far, we've discussed the impact of modern cooling solutions and reviewed misconceptions and myths about the technology. With that out of the way, let's find out why so many are deploying RDx systems to support emerging technologies.

Chapter 3: Why RDx, and Why Now

Deploying Rear Door Heat Exchanger (RDx) systems in data centers is crucial now more than ever. RDx systems offer superior cooling efficiency by capturing and removing heat directly at the source, improving server performance and reliability. They reduce reliance on traditional, energy-intensive air conditioning, significantly saving operational costs. Their modular and scalable design allows data centers to incrementally add cooling capacity as computational needs grow, ensuring adaptability to rapid technological advancements.

With the rise of AI, HPC, and other advanced technologies generating substantial heat, traditional air cooling systems are no longer sufficient. RDx systems enhance energy efficiency, supporting sustainability goals and compliance with environmental regulations. Furthermore, RDx systems provide a cost-effective modernization solution, extending the lifespan of existing data center infrastructure. By adopting RDx technology, data centers can meet increasing demands, improve efficiency, and remain competitive in a rapidly evolving industry.

The Urgency of Modernizing Cooling Solutions

The increasing power and cooling demands of modern data centers necessitate immediate action. RDx systems provide a timely solution to these challenges, offering a path to modernizing cooling infrastructure without extensive overhauls.

The urgency of modernizing cooling solutions cannot be overstated. As data centers continue to support more demanding workloads, the limitations of traditional cooling methods become increasingly apparent. RDx systems offer a practical and effective solution, enabling data centers to meet current and future cooling demands without significant infrastructure changes.

The Competitive Advantage

Adopting RDx systems can provide a significant competitive advantage by improving energy efficiency and reducing operational costs while supporting higher-density workloads. This chapter will explore the strategic benefits of RDx adoption for data center operators.

Data center operators who adopt RDx systems can gain a competitive edge by improving cooling efficiency and reducing energy costs. RDx systems enable higher densities, supporting more powerful and efficient computing environments. This competitive advantage can translate into better performance, lower operational costs, and increased capacity to support emerging technologies like AI and HPC.

Moving Forward with Confidence

The transition to modern cooling solutions like RDx is crucial for meeting the evolving demands of data centers. Traditional air cooling methods, such as Hot Aisle/Cold Aisle configurations, attempt to manage heat by mechanically forcing large volumes of air through the data center. This approach, while somewhat effective, is inherently inefficient and can lead to significant challenges:

- **Hot Spots and Inefficient Air Movement:** Hot spots in data centers create significant problems because air doesn't move willingly. The Hot Aisle/Cold Aisle setup seeks to address this by using a mechanical solution to force air (which has low mass m and specific heat c) to travel long distances. This method aims to reduce the overall temperature (**ΔT**), but the process is inefficient due to the low capacity of air to carry and dissipate heat. The result is excessive energy use, with large amounts of power consumed to move air through the data center, which is both low-density and difficult to control.
- **Energy Waste and Inefficiency:** Traditional air cooling methods waste electricity by requiring extensive mechanical systems to move air from hot spots through colder air and eventually to the heat exchanger. This process is energy-intensive and inefficient, particularly as data center densities increase and the heat load becomes more challenging to manage.

In contrast, RDx solutions offer a more targeted and efficient approach:

- **Direct Cooling at the Heat Source:** RDx systems place heat exchangers directly at the heat source, ensuring that cold liquid is delivered precisely where needed. This approach reduces the need for extensive air movement, minimizing the energy wasted on inefficient air cooling processes. By directly targeting the heat source, RDx systems optimize cooling efficiency and significantly reduce the electricity required for cooling.
- **Reduced Energy Consumption:** RDx systems eliminate the inefficiencies of traditional air cooling by focusing on liquid-based cooling at the heat source. The cold liquid efficiently absorbs and removes heat at the point of generation, lowering overall energy consumption and enhancing the data center's cooling performance.

By adopting these advanced technologies, data centers can improve efficiency, reduce costs, and support the next generation of high-performance computing workloads. RDx systems represent a practical and effective way to address the limitations of traditional air cooling methods, providing a future-proof solution that aligns with the growing needs of modern data centers.

Let's explore the leaders bringing modern RDx solutions to the market.

Chapter 4: RDx in Action — Understanding the OptiCool Advantage

Working with partners at the forefront of designing and manufacturing precision liquid cooling solutions for data centers and other mission-critical environments is critical. Partners like OptiCool offer a range of innovative cooling products designed to meet the evolving needs of modern data centers. With a commitment to research and development, OptiCool has developed state-of-the-art cooling systems that are efficient, reliable, and scalable.

Key Features of OptiCool's RDx Systems

1. **Efficient Heat Removal:** OptiCool's RDX systems are designed to remove heat directly from the servers, preventing them from entering the data center environment. This targeted approach ensures that servers remain within optimal temperature ranges, enhancing performance and reliability.
2. **Scalable and Modular Design:** OptiCool's RDx solutions are scalable and modular, allowing data centers to easily expand and adapt to changing cooling requirements. The systems can be customized to fit various server rack configurations and densities.
3. **Energy Efficiency:** OptiCool's RDx systems reduce the load on traditional air cooling systems by removing heat at the source, lowering energy consumption and operational costs. Two-phase refrigerant cooling further enhances efficiency by leveraging the superior thermal properties of liquids compared to air.
4. **Reliability and Redundancy:** OptiCool's RDx systems are built with reliability in mind. They feature redundant components and advanced control systems that ensure stable and consistent performance. The systems are also designed to be maintenance-friendly, with quick-connect couplers and hot-swappable components.
5. **Electronics-Friendly Refrigerant:** OptiCool systems use non-conductive and non-corrosive refrigerants in the white space of data centers, making them intrinsically safe for electronics compared to water-based cooling systems, which use electrically conductive water that can damage servers in the event of a leak. Additionally, OptiCool equipment utilizes liquid-to-vapor latent heat to reject heat, leading to a flow rate that is **more than five times less** required than that of water-based cooling systems. This reduces the risks associated with leaks and enhances cooling efficiency, making OptiCool systems a safer and more effective solution for modern data centers.

Now, here's the really cool part. These systems are already being deployed in some real-world applications.

Real-World RDx Applications

OptiCool's RDx solutions have been successfully implemented in various data centers, demonstrating their effectiveness in addressing modern cooling challenges. Here are a few examples:

1. **AI Workloads:** A data center supporting AI workloads implemented OptiCool's RDx systems to manage the increased heat generated by high-density servers. The result was a significant reduction in energy consumption and improved cooling efficiency. The other good news is that they did not have to rip out their existing infrastructure. Rather, it integrated very well with existing air-cooled systems.

2. **High-Performance Computing:** An HPC facility adopted OptiCool's RDx solutions to support their demanding computational tasks. The RDx systems provided reliable and efficient cooling, allowing the facility to perform optimally.

3. **Cloud Data Centers:** A cloud service provider integrated OptiCool's RDx systems into its data centers to enhance cooling efficiency and support higher densities. The RDx systems' scalable and modular design allowed for seamless expansion as the provider's cooling needs grew.

Final Thoughts and an RDx Checklist to Get Started

The landscape of data center cooling is rapidly evolving, driven by the demands of AI, HPC, and other emerging technologies. Traditional air and water-based cooling methods are no longer sufficient to meet these demands. Two-phase liquid refrigerant cooling, particularly RDx systems, offers a viable solution for modernizing legacy data centers and supporting high-density workloads. By understanding the benefits of these advanced cooling technologies and adopting them strategically, data center operators can ensure their facilities are ready to meet the challenges of tomorrow.

Sometimes, getting started can be challenging. Consider this brief checklist as a bit of a guide.

Checklist to Get Started with RDx Technology

Implementing Rear Door Heat Exchanger (RDx) systems in a data center requires careful planning and consideration of various factors to ensure efficient operation and long-term reliability. This checklist covers key areas such as maintenance, capacity sizing, infrastructure requirements, and environmental considerations to help you effectively get started with RDx technology.

PLANNING OVERVIEW

Before implementing RDx systems, it's essential to conduct a thorough assessment of your current cooling infrastructure and identify areas where RDx can provide immediate benefits. Planning should include:

- **Needs Assessment:** Evaluate your current cooling capabilities and determine the specific cooling demands based on server density, heat load, and future scalability.

- **Infrastructure Review:** Assess existing infrastructure to identify potential challenges, such as space constraints, compatibility with existing cooling systems, and the need for retrofitting.

- **Compliance with Standards:** Ensure the planning process aligns with ASHRAE guidelines, particularly the Thermal Guidelines for Data Processing Environments and Liquid Cooling Guidelines for Datacom Equipment Centers.

CAPACITY SIZING

Proper capacity sizing is crucial for the effective operation of RDx systems:

- **Flow Rate Determination:** Calculate the required coolant flow rate to handle the heat load, considering the coolant's inlet and outlet temperatures. Flow rates typically range from 4 to over 15 gallons per minute (GPM) per door.

- **Heat Load Calculation:** Use the heat load data to determine the appropriate number of RDx units needed to meet your data center's cooling requirements. Ensure that each RDx unit can sufficiently reduce the server outlet air temperature to prevent hot spots.

INFRASTRUCTURE REQUIREMENTS

Successful RDx implementation requires specific infrastructure considerations:

- **Cooling Water Supply:** RDx systems need a reliable supply of coolant, which may come from a chiller plant or a cooling tower. Ensure that your facility's cooling water system can maintain the necessary flow rate and temperature within ASHRAE's recommended guidelines.

- **Piping and Connections:** Plan the installation of flexible hoses and quick-disconnect fittings to ensure easy maintenance and operation. Consider overhead or underfloor piping based on your data center's layout.

- **Weight and Space Considerations:** Verify that the data center floor can support the weight of RDx units, especially when filled with coolant. The layout should accommodate the RDx units without obstructing access to server racks or other equipment.

IMPLEMENTATION

The installation of RDx systems involves several steps:

- **Site Preparation:** Ensure the site is ready for installation by clearing any obstructions and verifying that the floor can support the weight of the RDx units. Install any necessary support structures, such as brackets or frames, to secure the RDx units.

- **System Integration:** Connect the RDx units to the cooling water supply and ensure proper alignment and secure connections. Perform a pressure test on the piping system to check for leaks before full operation.

- **Commissioning:** Commission the RDx system by calibrating the coolant flow rates, verifying temperature differentials, and ensuring all sensors and monitoring systems function correctly. Commissioning should include thoroughly checking air and coolant flow rates to optimize performance.

MAINTENANCE

Maintenance is crucial for the long-term reliability of RDx systems:

- **Regular Cleaning:** Schedule regular cleaning of the RDx coils to remove dust and debris, which can accumulate and reduce efficiency. Periodic inspection of the coolant for any signs of contamination is also recommended.

- **Water-Side Maintenance:** Maintaining water quality according to ASHRAE standards, ensuring proper filtration and treatment to prevent scaling, corrosion, or biological growth in the coolant system.

- **Leak Detection:** Implement regular checks for leaks, particularly at connection points and valves. Where possible, utilize electronic leak detection systems to monitor for any signs of coolant leakage.

SITE PREPARATION AND COMMISSIONING

Proper site preparation and commissioning are critical to the success of RDx installation:

- **Chiller and Cooling Tower Evaluation:** Ensure your chiller and cooling tower systems have sufficient capacity to handle the additional load from the RDx units. This may involve upgrading existing systems or installing additional capacity.

- **Temperature and Flow Monitoring:** Install temperature sensors and flow meters to continuously monitor the RDx system's performance. Ensure these systems are calibrated correctly during commissioning to provide accurate data for ongoing operations.

- **Pressure Testing:** Before bringing the system online, conduct a pressure test on the entire cooling loop to ensure there are no leaks or weak points that could cause system failure.

METERING AND MONITORING

Effective metering and monitoring are essential for optimizing the performance of RDx systems:

- **Energy Monitoring:** Implement an Energy Monitoring and Control System (EMCS) to track the energy consumption of the RDx units. This system should provide real-time data and allow for adjustments to improve efficiency.

- **Temperature and Humidity Control:** Continuously monitor air and coolant temperatures and humidity levels to ensure the RDx system operates within optimal parameters. Based on real-time data, adjust setpoints as necessary.

ENVIRONMENTAL CONSIDERATIONS

Environmental factors play a significant role in the operation and efficiency of RDx systems:

- **ASHRAE Guidelines Compliance:** Ensure that the RDx system's operation is within the environmental conditions outlined by ASHRAE, including acceptable temperature ranges and water quality standards.

- **Condensation Management:** Design the RDx system to minimize the risk of condensation, which can occur if the coolant temperature drops below the dew point. Ensure that the system includes provisions for condensation management, such as drip trays or insulation.

The journey from legacy to modern data center designs involves embracing new cooling technologies that offer superior performance and efficiency. RDx systems represent a significant step forward, providing targeted cooling solutions that meet the demands of today's high-density computing environments. By adopting RDx systems, data centers can achieve greater efficiency, reduce operational costs, and support the next generation of high-performance computing workloads.

The evolution of data center cooling is about meeting current demands and preparing for the future. As AI and HPC continue to drive technological advancements, the need for efficient and effective cooling solutions will only grow. RDx systems offer a scalable and adaptable solution, ensuring that data centers can keep pace with the rapid evolution of technology.