



A PRACTICAL CASE STUDY ON CUSTOMIZED DATA CENTER COOLING SOLUTIONS

INDEX

INTRODUCTION	2
UNDERSTANDING DATA CENTERS	3
DATA CENTERS AS OF TODAY	4
THE IMPORTANCE OF THE RIGHT COOLING IN DATA CENTERS	5
THE IMPORTANCE OF DATA CENTER REDUNDANCY	6
CHALLENGES IN DESIGNING THE RIGHT COOLING SYSTEM OF A GENERATOR SET FOR A DATA CENTER	7
A SUCCESSFUL CASE STUDY ON CUSTOMIZED DATA CENTER COOLING SOLUTIONS	8
CONCLUSIONS	10

INTRODUCTION

In today's data-driven world, the role of data centers is crucial. They serve as the backbone of the global digital landscape, storing, processing, and distributing an enormous amount of data. From businesses to governments, every entity relies on data centers to keep their operations running smoothly. At the heart of these operations lies the IT infrastructure, a complex array of computer systems, networking infrastructure, and storage devices that make data accessibility possible.

The continuous evolution of data centers and their transition from private, on-site facilities to remote locations managed by cloud service providers reflects the rapid technological advancements. Not only are these establishments critical to storing and managing data, but they have also become an essential pillar for delivering various applications and services. This article delves into the intricate world of data centers, tracing their evolution, understanding their present-day significance, and exploring the challenges and solutions involved in their design and maintenance, with a spotlight on a case study between NRF and Company X.



UNDERSTANDING DATA CENTERS

According to IBM “A data center is a physical room, building or facility that houses IT infrastructure for building, running, and delivering applications and services, and for storing and managing the data associated with those applications and services.

Data centers have evolved in recent years from privately-owned, tightly controlled on-premises facilities housing traditional IT infrastructure for the exclusive use of one company, to remote facilities or networks of facilities owned by cloud service providers housing virtualized IT infrastructure for the shared use of multiple companies and customers.”¹

Data centers are integral components in the digital age, functioning as the primary infrastructure for contemporary information storage and processing. These meticulously designed establishments contain a wide array of computer systems, networking infrastructure, and storage, thereby providing organizations with the capabilities to store, manage, and disseminate copious quantities of data. Essentially, data centers function as the essential core for businesses, facilitating continuous accessibility to vital information and applications.

Data Centers can be understood by a tier classification system used for their categorization. This system evaluates a data center’s readiness and error tolerance capabilities based on its infrastructure and redundancy. In this system, Tier 1 corresponds to the basic infrastructure needed, while Tier 4 signifies the pinnacle of reliability.²³

The power density in contemporary data centers varies significantly, ranging from mere kilowatts per rack to several hundred kilowatts per rack. This fluctuation hinges on the computational needs and the infrastructure design of the data center. While greater power densities lead to more effective space and resource utilization, they also introduce added complexities in aspects such as cooling and power distribution.⁴⁵

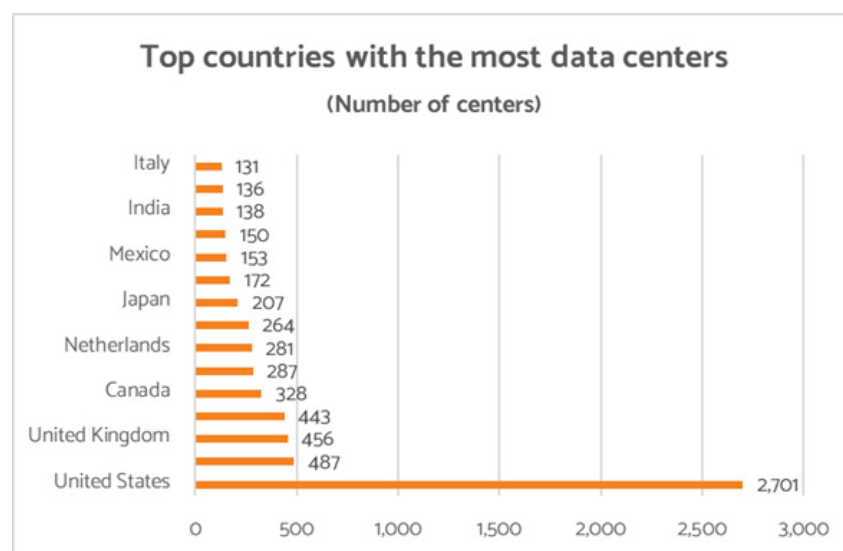
1. What is a data center?. IBM. (n.d.). <https://www.ibm.com/topics/data-centers>
2. Cooling methods employed in data centers vary depending on the facility design and layout. Raised floor cooling, overhead cooling, and in-row cooling are some of the common techniques used. These methods aim to efficiently distribute cooled air to the IT equipment while efficiently removing the hot air generated by the servers and other devices.
3. George, A. S. (n.d.). Tier classification system. Uptime Institute. <https://uptimeinstitute.com/tiers/>
4. TechTarget. (2022, April 25). What is a Data Center? - Definition from TechTarget.com. <https://www.techtarget.com/definition/data-center>
5. Humidity regulation is also crucial in data centers. Controlling the humidity levels helps prevent electrostatic discharge and equipment corrosion. Precise humidity control is achieved through the integration of humidification and dehumidification systems within the cooling infrastructure.

DATA CENTERS AS OF TODAY

Over the course of the last four decades, the market for data centers has witnessed substantial transformation. Modern data centers have progressively become more advanced and intricate with the incorporation of pioneering technologies including virtualization, cloud computing, and software-defined data centers. The market has concurrently experienced a transition towards data centers that are more energy-conserving and environmentally considerate, as illustrated by the embracing of green data center technologies.

Most of these data centers are in North America, Europe, and Asia. In North America, the United States is the largest market for data centers, followed by Canada and Mexico. In Europe, the United Kingdom, Germany, and France are the largest markets. In Asia, China, Japan, and India are the largest markets. The US alone has 2,701 data centers, followed by Germany with 487 and the UK with 456.⁶ In the future, these numbers will keep on growing thanks to the growing demand.

Over the previous decade, there has been an increase in the demand for cloud-based solutions in data centers. This trend has stimulated the evolution of innovative technologies and solutions, including Data Center Infrastructure Management (DCIM) software, designed to empower organizations in optimizing their data center management. In 2022, the DCIM market clocked in at a considerable €1.8 Billion, with predictions indicating a potential surge to €5.2 Billion by 2032.⁷ This market is expected to continue to grow in the coming years thanks to the increasing demand for cloud computing, the rise of big data, and the need for efficient data management.



6. 15 crucial data center statistics to know in 2023. Techjury. (n.d.). [https://techjury.net/blog/data-center-statistics/#:-:text=The%20US%2C%20Germany%2C%20UK%2C,the%20largest%20data%20center%20number.&text=The%20US%20has%202%2C701%20data,%2C%20and%20Canada%20\(328\).](https://techjury.net/blog/data-center-statistics/#:-:text=The%20US%2C%20Germany%2C%20UK%2C,the%20largest%20data%20center%20number.&text=The%20US%20has%202%2C701%20data,%2C%20and%20Canada%20(328).)
7. Emergen Research, <https://www.emergenresearch.com/>. (n.d.). Data Center Infrastructure Management Market Size, share: Industry forecast by 2032. Data Center Infrastructure Management Market Size, Share | Industry Forecast by 2032. <https://www.emergenresearch.com/industry-report/data-center-infrastructure-management-market>

THE IMPORTANCE OF THE RIGHT COOLING IN DATA CENTERS

Within the complex ecosystem of a data center, efficient cooling is paramount to maintaining optimal performance and safeguarding the integrity of sensitive equipment. As data centers are densely populated with high-performance servers, networking devices, and storage systems, the generated heat becomes a significant concern. Excessive heat can cause equipment malfunction, data loss, and even physical damage.

To counteract this, data centers employ sophisticated cooling systems to regulate the temperature and humidity levels. Refrigeration plays a critical role in this process by effectively removing the excess heat generated by the IT infrastructure. By using precision air conditioning units, heat exchangers, and cooling towers, data centers can ensure a controlled environment that promotes optimal performance and reliability.

Cooling methods employed in data centers vary depending on the facility design and layout. The Chilled Water System is a data center cooling system commonly used in mid-to-large-sized data centers. It uses heated water to cool air that is brought in by air handlers (CRAHs). The water is supplied by a chiller plant located somewhere in the facility. The chilled water system method of cooling data centers is a more efficient and effective way of cooling compared to traditional air-cooling systems. The chilled water system works by circulating cold water through pipes that run through the data center. The cold water absorbs the heat generated by the IT equipment and is then pumped back to the chiller plant to be cooled again. This process is repeated continuously to maintain a consistent temperature in the data center.⁸



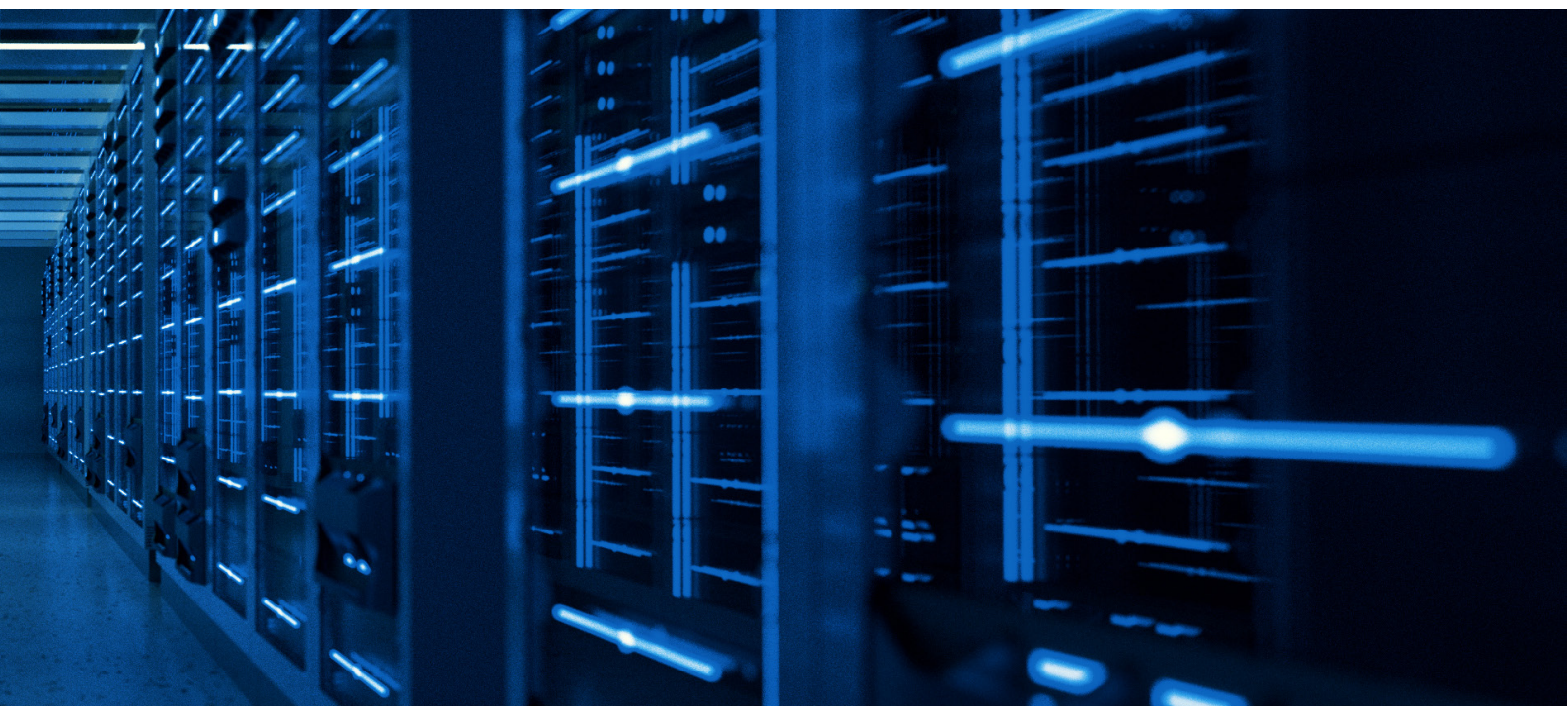
8. 42U. (2016, October 6). Free cooling webinar. 42U. <https://www.42u.com/webinars/free-cooling-economizer.htm>

THE IMPORTANCE OF DATA CENTER REDUNDANCY

Having a backup power generator is a critical component in safeguarding a data center's operational integrity. Its significance cannot be understated, as generator failure is among the primary causes of data center downtime.

Generators hold an indispensable role in data center redundancy due to a plethora of factors. Firstly, they act as an alternate power supply, which is crucial for ensuring continuity in operations during instances of primary power failures. Moreover, their role is pivotal in maintaining uptime, which is vital in preventing data loss that could be detrimental if power interruptions occur. Additionally, generators serve as a shield against power surges that have the potential to cause severe damage to data center equipment. Furthermore, compliance with various regulatory standards is often dependent on the incorporation of reliable backup power solutions, a role which generators adeptly fulfill. Finally, by bolstering the resilience of data centers, generators play an instrumental role in contributing to the overall robustness of these centers, allowing them to efficiently counter various challenges.

In light of these factors, it is imperative that data centers incorporate a dependable backup power generator within their redundancy planning. Given the potentially high costs associated with data center downtime, a reliable backup power generator is an invaluable investment in ensuring uninterrupted operations in the event of power outages.⁹



9. GenServe. (2022a, September 7). Why are generators important for data center redundancy?. GenServe. <https://genserveinc.com/2022/09/07/why-are-generators-important-for-data-center-redundancy/>

CHALLENGES IN DESIGNING THE RIGHT COOLING SYSTEM OF A GENERATOR SET FOR A DATA CENTER

Developing and designing the cooling module of a generator set for data centers presents a unique set of challenges for engineers to meet the specific requirements of their clients.

NRF, a company known for its expertise in developing, designing and manufacturing cooling solutions for totally different business segments, faced the challenge of creating a tailor-made solution for a prominent Data Center Company. The size of the cooling unit must be carefully matched to the specific genset's power output and operating requirements. Several factors and considerations contribute to the significant variation in genset cooling system sizes. These challenges include:

Failing of a piece: One of the main challenges that data centers face is the failing of a piece in their generator set. This can be addressed by designing a backup into the unit. In this example Company X requested a design with 4 fans since this would mean less wiring, more cost-effective, reduced assembly time, lower total power required for the fans, and decreased noise generated by the system. Nonetheless NRF found that this solution had a big problem: in the event that one fan fails, 25% of the heat exchange surface, would be lost. For a Data Center this was an unacceptable threshold. That is why the NRF team suggested the use of 9 fans in total. It was determined that there wasn't much difference in power consumption, price, and noise. This, in turn, represented an advantage. If one of the fans fails, only 11% of the heat exchange surface is lost, providing with an acceptable heat dissipation so the genset could keep working and thus the Data Center.

Size: It's important to select a cooling unit that is appropriately sized for the specific genset's power output and operating requirements. The genset manufacturer's guidelines and specifications have to be consulted to ensure the proper cooling capacity and sizing for reliable and efficient operation.

Genset cooling systems can vary significantly in size due to several factors and considerations:

- **Power Output, Efficiency and Heat Dissipation Requirements:** the cooling unit needs to be sized appropriately to handle the heat load and maintain optimal operating temperatures. Larger generator sets typically requires larger cooling units.
- **Cooling Technology:** air-cooled units tend to be smaller, as they utilize fans and heat sinks for dissipation. Water-cooled units rely on radiators, pumps and coolant circulation.
- **Application and Environment:** Gensets used in mobile applications, such as recreational vehicles or portable generators, may have smaller cooling units to ensure compactness and portability. On the other hand, industrial or data center gensets operating in demanding environments may require larger cooling units to handle higher heat loads and maintain reliable performance.

A SUCCESSFUL CASE STUDY ON CUSTOMIZED DATA CENTER COOLING SOLUTIONS

For a Diesel Generator Set model 20V4000 MTU, NRF has designed a water-cooling system that measures approximately 3 meters in width and 3 meters in height. With such a sizable unit, the design challenges become more prominent. One of the crucial factors to consider is the thermal expansion of the coolers.

Thermal expansion refers to the tendency of materials, including aluminum, to expand or contract in response to temperature changes. When heated, aluminum and other materials expand, and when cooled, they contract. Therefore, it is essential to account for the thermal expansion of aluminum coolers during the design and installation process. This consideration becomes particularly important when connecting the coolers to other components or structures.

To accommodate the dimensional changes that may occur due to thermal expansion, proper clearances, flexible mounting techniques, and the use of slotted mounting holes are incorporated. These design features help to manage the thermal expansion effectively and prevent any damage or stress on the coolers or the surrounding structure.

In addition to the thermal expansion design features, NRF offers modularity as a key advantage in their design approach. The incorporation of modular cooling units allows for scalability, simplified installation processes, and enhanced reliability. By utilizing multiple cooling modules, the system can continue to operate even if one module fails or requires maintenance. This redundancy ensures uninterrupted cooling for the genset, minimizing the risk of overheating and downtime.

A cooling unit designed for a genset usually comprises substantial components like heat exchangers, fans, and accompanying piping. It is crucial for the support structure to possess the strength and stability necessary to withstand the weight and load exerted by these components without experiencing deformation or failure.



Figure 1. NRF Genset Cooling Unit. Three cooling modules.

Through mechanical simulation, NRF engineers are able to analyze and optimize the design of the support structure for the genset cooling unit. This simulation process plays a pivotal role in enhancing the structural integrity of the unit, mitigating potential risks, and ensuring long-term performance and reliability. By subjecting the support structure to virtual tests and simulations, engineers can validate the design, identify any potential issues or weak points, and make informed engineering decisions that contribute to the creation of a robust and highly efficient cooling system for the genset.



Figure 2. Mechanical Study of the NRF Genset Cooling Unit Structure.

As well as for the critical structures, mechanical simulation of expansion tanks in a genset cooling unit helps verify structural integrity, assess pressure variations, evaluate fatigue life, prevent leakage, and ensure the overall safety and reliability of the system. It allows NRF engineers to optimize the tank design, select appropriate materials, and make informed decisions to create a robust and efficient cooling solution.

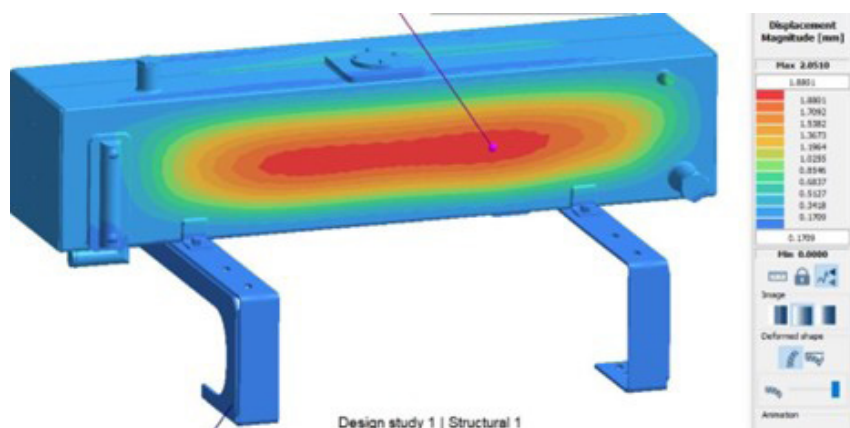


Figure 3. Mechanical Simulation of the NRF Genset Cooling Unit Expansion Vessel

CONCLUSIONS

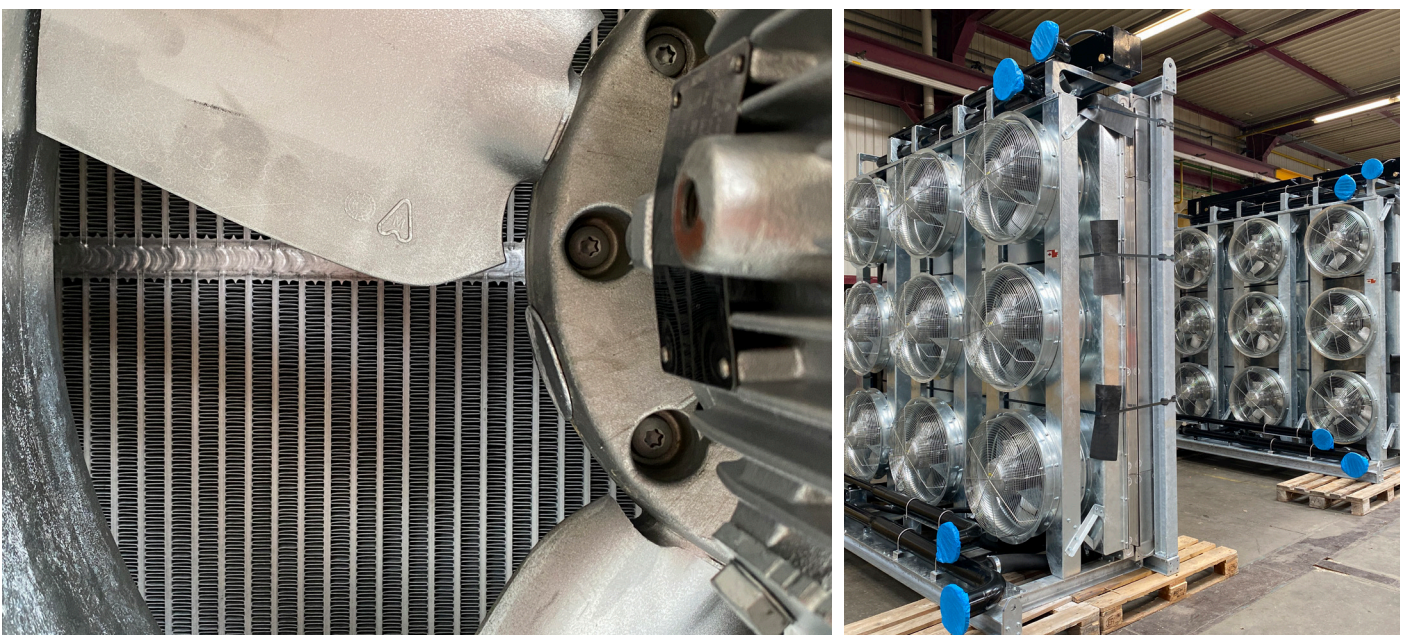
Data centers have emerged as the lifeblood of the modern digital ecosystem, hosting the quintessential resources for managing, storing, and processing data. As we have seen throughout this article, data centers are complex structures with intricate systems and components. The optimization of data center infrastructure is critical for achieving not just operational efficiency but also reliability and environmental sustainability.

One of the crucial aspects highlighted in this article is a case study between NRF and an unnamed prominent Data Center Company, referred to as Company X. This case study exemplifies the multifaceted engineering challenges and innovative solutions in designing genset cooling systems for data centers. NRF, renowned for its expertise in tailor made cooling solutions in many market segments, navigated through multiple challenges including selecting the right cooling unit, addressing the issue of part failure, and accommodating thermal expansion.

NRF's solution to use a total of 9 fans in the cooling unit is noteworthy. It not only enhanced the redundancy but also assured that in the event of a fan failure, the loss of heat exchange surface was minimal, ensuring continuous operation even in relatively high-temperature environments. This solution showcased a perfect blend of cost-effectiveness and operational reliability.

Furthermore, the case study highlighted how important it is to take into consideration the thermal expansion, modular design, and structural integrity. Through mechanical simulation, NRF optimized the support structure and expansion tanks of the genset cooling unit, contributing to a robust and efficient cooling solution.

This case study between NRF and Company X demonstrates the paramount importance of tailored engineering solutions in the context of data center operations. Customized designs help data centers run smoothly and handle problems better.





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