Nitrogen-Liquid Dual Mode Cooling Module

Abstract

Based on nitrogen cooling and liquid cooling dual-mode technology, this new model proposes a nitrogen cooling and liquid cooling dual-mode heat dissipation module with efficient cooling and energy optimization characteristics, which solves the problems of uneven GPU heat dissipation, excessive heat accumulation and insufficient energy efficiency in high-load AI servers. The module adopts a four-layer integrated structure design, which is layered from the inside out. It includes a cooling layer at the bottom with a cooling plate as the heat exchange hub between the liquid cooling and nitrogen cooling channels to achieve uniform diffusion of the heat source, a liquid cooling layer and its embedded serpentine liquid cooling channel in the middle to stably conduct heat through the circulating coolant, a nitrogen cooling layer on the top with an embedded serpentine nitrogen cooling channel, which introduces liquid nitrogen to quickly absorb high heat for deep cooling at a rate of 5°C/second, and a nitrogen evaporation layer on the top connected to the nitrogen cooling layer with a vertical evaporation channel to convert liquid nitrogen into gaseous nitrogen after absorbing heat, which is recycled and reused in the gaseous nitrogen collection area, increasing resource utilization by 40%. Each layer uses a 4:6, 3:7 or 5:5 space ratio optimization, and cooperates with the intelligent control device to dynamically switch the cooling mode (30%-40% switching frequency) to ensure that the GPU operates stably at 45°C±2°C. Compared with single-mode liquid cooling modules, this design increases the heat dissipation speed by 2.5 times and reduces energy consumption by 30%, making it particularly suitable for high-density computing scenarios in AI server data centers.

【Designated representative picture】 Figure 2

【A brief explanation of the symbols of the representative diagram】

1. Cooling plate

6. Nitrogen-liquid dual mode cooling module

7. Nitrogen cooling channel

8. Liquid cooling channel
9. Nitrogen evaporation channel
10. Cooling Layer
11. Liquid cooling Layer
12. Nitrogen cooling layer
13. Gaseous nitrogen collection area
14. Gaseous nitrogen outlet
15. Nitrogen evaporation layer
16. Liquid nitrogen inlet
17. Coolant inlet
18. Coolant outlet

Nitrogen-Liquid Dual Mode Cooling Module

Specification

【Technical field】

[0001] The present invention relates to the field of AI server heat dissipation technology, and more specifically, to a module based on a nitrogen-liquid dual mode structure for efficient cooling and energy optimization.

【Prior Art】

[0002] In the prior art, liquid cooling technology is widely used in servers due to its heat dissipation stability, but its heat dissipation speed has a bottleneck under high load conditions. Although nitrogen cooling technology has the characteristic of rapid cooling, it consumes a lot of energy, resulting in excessively high overall application costs. Therefore, the prior art lacks a dual mode cooling system that can take into account both the stability of liquid cooling and the efficiency of nitrogen cooling.

【New content】

[0003] The purpose of the present invention is to solve the problem of application limitations of liquid cooling systems in the prior art, and to achieve more efficient and energy-saving heat dissipation management in high-load server operation through a dual mode structural design of nitrogen cooling and liquid cooling. This new design is a nitrogen-liquid dual mode cooling module, which adopts a 4:6, 3:7 or 5:5 space ratio design, optimizes the combination of the liquid cooling part and the nitrogen cooling part in the physical structure, and introduces intelligent control technology to flexibly enable the nitrogen cooling mode according to the temperature changes of the server, ensuring the cooling speed while optimizing energy consumption.

The design of this new model is as follows:

Cooling layer: It is a heat exchange interface, set at the intersection of the two flow channels, to ensure that nitrogen cooling and liquid cooling act on the heat source at the same time and effectively transfer heat to the inside of the heat dissipation module.

Double flow channel design: The module is equipped with a first flow channel and a second flow channel, where:

The first flow channel is used to transmit liquid coolant (such as water or coolant) to provide a stable and large heat capacity liquid cooling heat dissipation effect.

The second flow channel is used to transport liquid nitrogen to provide a rapid nitrogen cooling effect.

Dynamic switching system: The module is equipped with an automatic switching mechanism to dynamically enable nitrogen cooling, liquid cooling or dual-mode cooling mode according to the heat load requirements.

At low thermal loads, liquid cooling mode is prioritized.

Under high heat load, nitrogen cooling mode or dual-mode operation is automatically activated to accelerate heat dissipation efficiency.

Nitrogen recovery system: The residual gas after liquid nitrogen is cooled can be recycled through the recovery pipeline to reduce nitrogen consumption and usage costs.

Multi-layer structure design: The heat dissipation module includes multiple conductive layers and cooling channels to increase the contact area with the heat source and improve the heat conduction efficiency.

The overall system architecture of this new model is as follows:

The system includes multiple nitrogen-liquid dual mode cooling modules, which are configured above the GPU module of the server. Each module has two inlets, coolant and liquid nitrogen, at the liquid inlet end, and an electromagnetic valve is set at its contact point. Temperature sensors are configured at the contact surface of the GPU chip and the coolant and gaseous nitrogen outlets. The intelligent control device is configured to drive the electromagnetic valve to automatically switch between liquid cooling and nitrogen cooling modes according to the sensed data through the embedded control chip.

The system supports mechanical linkage structures between different cooling modes, triggers the electromagnetic valve switch through the temperature sensor, realizes the switching between liquid cooling and nitrogen cooling systems, and provides manual and automatic control parallel cooling management.

The intelligent control logic of this new type is as follows:

a. Control timing and dynamic actuation

Precise timing control:

1. Liquid cooling flow rate adjustment is completed within 10ms.

2. The cooling mode switching is completed within 100-300ms, and the stability and sensitivity reach 99.8%.

Dynamic action mode:

1. Through intelligent control technology, the startup frequency is adjusted by 10%-20%, achieving a cooling efficiency of 5°C per second and stabilizing the server at 45°C.

2. Dynamically adjust the liquid cooling and nitrogen cooling mode switching according to server load changes to ensure optimal cooling performance.

As shown in Figure 3, the system is equipped with an artificial intelligence smart control platform to achieve efficient operation mode switching:

Liquid cooling is the default operating mode, which runs stably under medium and low GPU load conditions and maintains the GPU temperature below 45°C. The startup frequency of nitrogen cooling mode is intelligently adjusted according to the GPU temperature, with a typical setting of 30%-40%. When the temperature rises rapidly or runs for a long time, the artificial intelligence smart control platform automatically triggers the nitrogen cooling mode to quickly cool down.

b. Dynamic cooling mode switching

Intelligent automatic switching mechanism:

1. When the heat load is low, liquid cooling mode is enabled first to improve energy efficiency.

2. When the GPU temperature exceeds 55°C, nitrogen cooling mode or dual-mode cooling mode will be automatically activated to ensure maximum cooling performance.

3. Achieve a cooling rate of 5°C/second to stabilize the server at 45°C.

Predictive Cooling and Adaptive Adjustment:

1. Real-time monitoring of GPU and server temperature and load to ensure timely adjustment of cooling strategies.

2. Analyze historical data and form the optimal cooling mode logic based on the heat load curve and cooling efficiency.

3. Predictive cooling: Based on the load fluctuation trend, high-efficiency cooling mode is started in advance to prevent excessive temperature from affecting operational stability.

4. Feedback optimization mechanism: According to the heat dissipation results, automatically correct the cooling parameters, optimize the cooling algorithm and improve efficiency.

c. Temperature control and monitoring system

Accurate monitoring:

1. Temperature monitoring error: ±0.1°C

2. Pressure monitoring error: ±0.02 MPa

Data analysis and performance reporting:

1. The data analysis tool can generate cooling performance reports within 5 seconds, improving system maintenance and adjustment efficiency.

d. Nitrogen cooling and liquid cooling recovery system

Improved recycling efficiency and energy efficiency:

1. Condensate tank recovery efficiency 60% (especially suitable for high temperature and high humidity environment).

2. The energy efficiency ratio of the nitrogen recovery system is improved by 15%, reducing resource consumption.

Compression adjustment control:

1. Nitrogen compression regulator pressure range: 0.8-2.5 MPa

2. Nitrogen flow range: 10-30 L/min

The recovery rate of the nitrogen-cooled part is 60%, and the recovery rate of the liquid-cooled part is 70%. The overall recovery efficiency of the dual-mode reaches 67%, which significantly reduces operating costs and has good sustainability. The nitrogen cooling mode is only started when necessary to reduce nitrogen consumption, thereby balancing the needs of high efficiency and energy saving.

【Simple explanation of the diagram】

【0004】

[Figure 1] Overall system structure diagram of this new model

[Figure 2] Internal structure design of this new model

[Figure 3 a & b] Operation logic diagram of the new intelligent control module

[Figure 4] Simulation test diagram of this new model

[Figure 5] Other test images of the new model

[Figure 6] Energy consumption comparison of this new model

[Figure 7] Application scenario diagram of the new model

【Implementation Method】

【0005】Referring to FIG. 2, the nitrogen-liquid dual mode cooling module 6 of the present invention is designed with a nitrogen-cooled and liquid-cooled space allocation ratio of 4:6. The overall structure of the module is from bottom to top. The cooling layer 10, wherein the bottom cooling plate 1 includes a liquid cooling channel 8 and a nitrogen cooling channel 7, transfers the heat source evenly to the upper structure to ensure effective heat dispersion. The liquid cooling layer 11, which is immediately

above the cooling layer 10, contains a liquid cooling channel 8, and transfers heat from the cooling layer 10 to the outside through a coolant. The nitrogen cooling layer 12, which is arranged above the liquid cooling layer 11, contains a nitrogen cooling channel 7, and uses liquid nitrogen to quickly absorb and take away high heat loads. The nitrogen evaporation layer 15 is located at the top of the module. , a nitrogen evaporation channel 9 and a gaseous nitrogen evaporation collection area 13 are provided, wherein the nitrogen evaporation channel 9 is connected to the nitrogen cooling channel 7 of the nitrogen cooling layer 12 in a plurality of vertical styles, and is responsible for converting liquid nitrogen into gaseous nitrogen and moving it to the gaseous nitrogen collection area 13, effectively improving the heat dissipation performance and reducing the occupied space, as a recovery and cycle, to ensure the maximum utilization of system resources.

【Explanation of symbols】

【0006】

1. Cooling plate

2. Intelligent nitrogen-liquid dual mode cooling system for AI servers

3. High frequency trading server

4. Liquid nitrogen cooling system

5. Liquid cooling system

6. Nitrogen-liquid dual mode cooling module

7. Nitrogen cooling channel

8. Liquid cooling channel

9. Nitrogen evaporation channel

10. Cooling Layer

11. Liquid cooling Layer

12. Nitrogen cooling layer

13. Gaseous nitrogen collection area

14. Gaseous nitrogen outlet

15. Nitrogen evaporation layer
16. Liquid nitrogen inlet
17. Coolant inlet
18. Coolant outlet
19. AI training cluster
20. Cloud Game Server
21. Military data analysis and satellite data processing server
22. Intelligent control equipment
23. Embedded control chip
24. Solenoid valve
25. Temperature sensor
26. GPU chip
27. Coolant tank
28. High efficiency fin heat exchanger
29. Mini nitrogen tank
30. Condensation tank

Nitrogen-Liquid Dual Mode Cooling Module

Claims

[Claim 1] A nitrogen-liquid dual mode cooling module, which is used in an AI server, and the structural includes:

The external dimensions of the module are 140 mm × 140 mm × 40 mm;

The internal layers from bottom to top include

The cooling layer is located at the bottom of the module and contains a cooling plate. As the intersection of the liquid cooling and nitrogen cooling channels, it is mainly used to evenly transfer the heat source to the upper structure to ensure effective heat dispersion;

The liquid cooling layer is located immediately above the cooling layer and contains liquid cooling channels, which stably transfer heat from the cooling layer to the outside through the coolant;

The nitrogen cooling layer is set above the liquid cooling layer and contains nitrogen cooling channels, which use liquid nitrogen to quickly absorb and carry away high heat loads;

The nitrogen evaporation layer is located at the top of the module and has an evaporation channel and a gaseous nitrogen collection area. The evaporation channel is connected to the nitrogen cooling channel of the nitrogen cooling layer in multiple vertical patterns. It is responsible for converting liquid nitrogen into gaseous nitrogen and moving it to the gaseous nitrogen collection area for recycling and circulation to ensure maximum utilization of system resources.

Both the liquid cooling system and the nitrogen cooling system are equipped with independent inlet and outlet pipelines, and the cooling mode can be dynamically switched through intelligent control equipment.

[Claim 2] The nitrogen-liquid dual mode cooling module described in Claim 1 has a multi-layer structure made of high thermal conductivity material to improve heat conduction efficiency, includes liquid-cooled cooling channels and nitrogen-cooled cooling channels, and has micro-channels inside, which are designed with a symmetrical grid distribution to

achieve low pressure drop and high flow rate, thereby further improving cooling efficiency.

[Claim 3] The nitrogen-liquid dual mode cooling module according to Claim 1, wherein the cooling layer

The cooling plate is made of copper-aluminum composite material and has a wavy groove structure on the surface to increase the heat conduction area.

[Claim 4] The nitrogen-liquid dual mode cooling module according to Claim 1 has a double-layer insulation design for its inlet and outlet pipes, with the outer layer being a corrosion-resistant alloy and the inner layer being a ceramic coating, and is equipped with quick connectors to accommodate server rack installation.

[Claim 5] A nitrogen-liquid dual mode cooling module according to Claim 1, wherein the inner wall of the evaporation channel of the nitrogen evaporation layer is coated with a hydrophobic coating to prevent liquid nitrogen residue from affecting the gaseous nitrogen recovery efficiency.

[Claim 6] According to the nitrogen-liquid dual mode cooling module described in Claim 1, an elastic thermally conductive gasket is provided between the cooling layer and the liquid cooling layer to fill the gap between the layers to improve the heat conduction efficiency.

[Claim 7] According to Claim 1, the intelligent nitrogen-liquid dual mode thermal management system for AI servers, comprising the nitrogen-liquid dual mode cooling module, wherein the nitrogen cooling mode is capable of providing:

A plurality of nitrogen-liquid dual mode cooling modules, disposed above each GPU module of the server;

Each module has two inlets for coolant and liquid nitrogen at the liquid inlet end, and an electromagnetic valve is set at the contact point;

Temperature sensors are arranged at the GPU wafer contact surface and the coolant and gaseous nitrogen outlets;

Equipped with intelligent control equipment, the embedded control chip drives the electromagnetic valve to automatically switch between liquid cooling and nitrogen cooling modes according to the sensing data;

The system supports mechanical linkage between different cooling modes. The temperature sensor triggers the electromagnetic valve switch to switch between liquid cooling and nitrogen cooling system channels, and provides manual and automatic control in parallel.

Equipped with intelligent control equipment, including temperature sensor array, electromagnetic valve and embedded control chip. The temperature sensor is arranged on the GPU contact surface, and the electromagnetic valve is driven by the chip to switch the liquid cooling and nitrogen cooling channels;

The nitrogen cooling mode is equipped with a delay protection function to avoid frequent switching affecting stability and efficiency reduction;

The overall system can dynamically switch between 30%-40% of the frequency to perform optimized switching, reduce the risk of system overcooling and improve energy efficiency to comply with the temperature curve adjustment mechanism.

Supports dynamic adjustment mode of server temperature curve to drive liquid nitrogen valve opening and closing, reducing the risk of overcooling and ensuring stability and energy efficiency.

[Claim 8] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system, the nitrogen cooling mode can provide:

Highly efficient cooling performance of 5°C/second for high heat load scenarios;

The compression regulator stabilizes the gas pressure and flow;

The nitrogen cooling system automatically activates the cooling frequency when the server operating load reaches its peak to ensure efficient cooling performance.

[Claim 9] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system, the resource recovery design of the nitrogen cooling part includes:

The gaseous nitrogen recovery rate reaches 60%, effectively reducing coolant consumption and costs;

Built-in compression regulator to stabilize gas pressure and flow;

The cooling pipe is designed with anti-frost material to avoid condensation affecting efficiency;

Supports built-in recycling device to improve resource utilization.

[Claim 10] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system, the liquid cooling system further comprises:

Liquid cooling coolant flow rate can be automatically adjusted according to the load to optimize energy efficiency;

Equipped with high-efficiency fin heat exchanger to improve heat conduction performance;

Liquid cooling coolant supports high-efficiency and environmentally friendly formulas to adapt to a variety of server operating environments;

The cooling pipe adopts a layered design. The inner layer optimizes heat dissipation uniformity, while the outer layer uses multiple layers of protective materials, such as anti-corrosion and anti-frost, to extend the system life and improve operational stability.

[Claim 11] According to the nitrogen-cooled liquid-cooled dual-mode heat dissipation module described in claim 7, the intelligent nitrogen-cooled liquid-cooled AI server dual-mode heat dissipation system is further suitable for large-scale server data center applications, and its features include:

Supports 1,000 to 10,000 server cabinet configurations;

The overall cooling performance simulation evaluation function is used to plan the data center cooling solution;

Supports dynamic energy consumption assessment and provides optimization suggestions based on data center load.

[Claim 12] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system has a built-in intelligent control device:

Temperature and pressure sensors provide accurate monitoring of heat dissipation effects;

Data logging capabilities to track long-term operating performance and provide optimization recommendations;

Supports recording and analysis of energy consumption data for operation optimization.

[Claim 13] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system has application scenarios including:

High-frequency trading servers to achieve ultra-low latency cooling requirements;

Artificial intelligence training cluster to ensure stable and efficient heat dissipation;

Cloud gaming servers to meet cooling requirements for long-term operation;

Military data analysis and satellite data processing servers provide optimized heat dissipation for special high-heat environments.

[Claim 14] According to the nitrogen-cooled liquid-cooled dual-mode heat dissipation module described in Claim 7, the intelligent nitrogen-cooled liquid-cooled AI server dual-mode heat dissipation system is equipped with an intelligent cooling management function, an optimization algorithm built into the intelligent control device, and realizes dynamic adjustment and cabinet-level collaborative control logic through the linkage of temperature sensors and flow valves. The algorithm includes :

The real-time data monitoring part uses temperature sensors, pressure sensors, and load sensors to obtain real-time cooling demand data of GPUs and servers during operation;

The historical data analysis part integrates long-term operation data, performs big data analysis based on heat load curve and cooling efficiency, and forms the corresponding logic of the optimal cooling mode;

The adaptive dynamic adjustment part dynamically switches between liquid cooling and nitrogen cooling modes according to real-time data and preset cooling models, and automatically adjusts the liquid cooling flow rate, nitrogen pressure and flow rate to optimize energy consumption and cooling performance;

The temperature sensor is linked to the nitrogen cooling valve. When it detects that the temperature rise rate exceeds the threshold, the nitrogen cooling valve is automatically opened in advance.

The feedback optimization mechanism automatically corrects cooling parameters based on the heat dissipation result data, gradually optimizes the algorithm model, and improves the overall heat dissipation efficiency of the system.

[Claim 15] According to the nitrogen-cooled and liquid-cooled dual-mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode cooling system, its intelligent control device further includes a redundant valve structure, which automatically activates the backup valve when the main valve fails to ensure that the cold switching function is not interrupted.

[Claim 16] According to the nitrogen-liquid dual mode cooling module described in Claim 7, the intelligent nitrogen-cooled and liquid-cooled AI server dual-mode heat dissipation system further integrates heat dissipation fins in its electromagnetic valve to prevent valve overheating and actuation failure.

Nitrogen-Liquid Dual Mode Cooling Module

Figure

Figure 1.

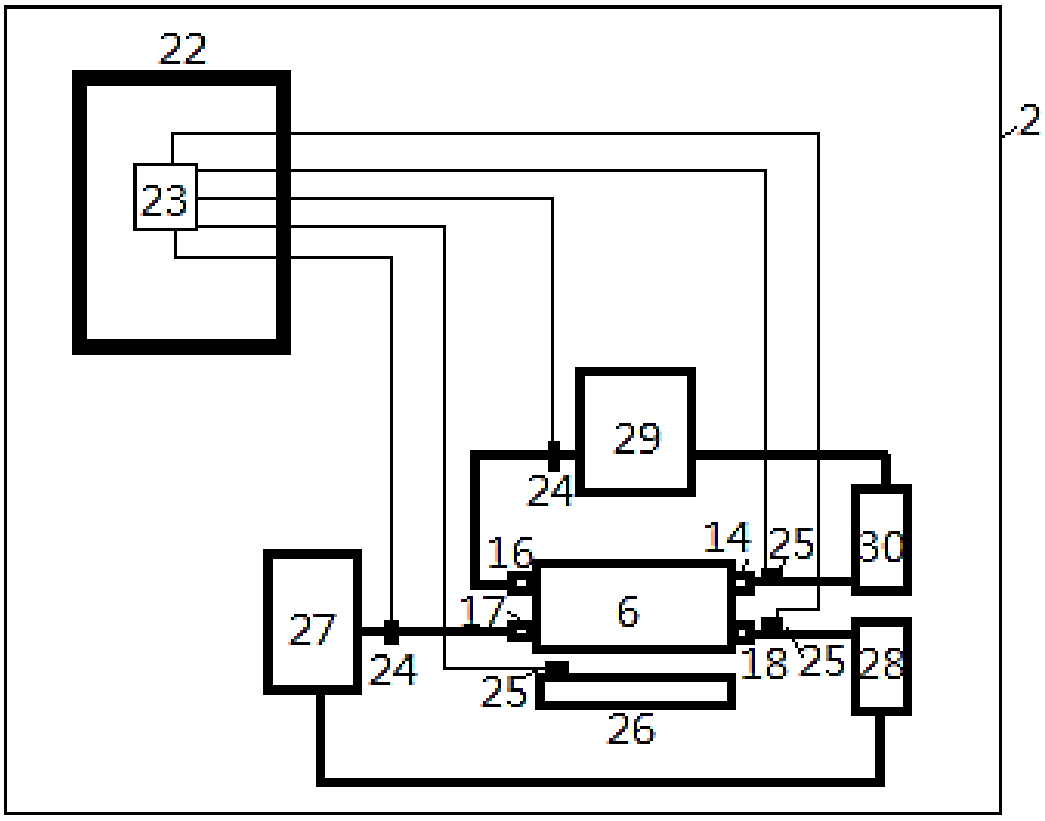

Figure 2.

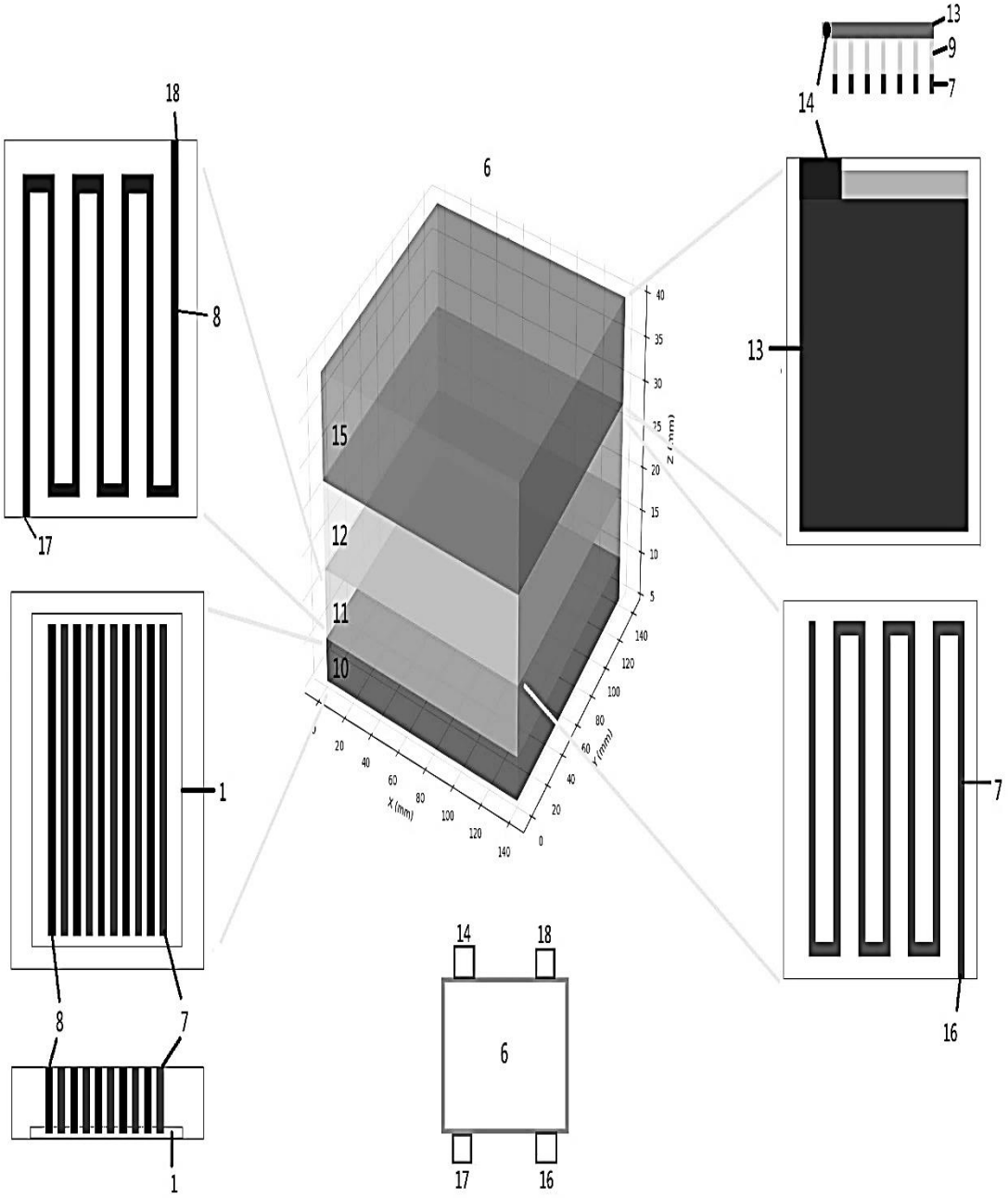

Figure 3.a

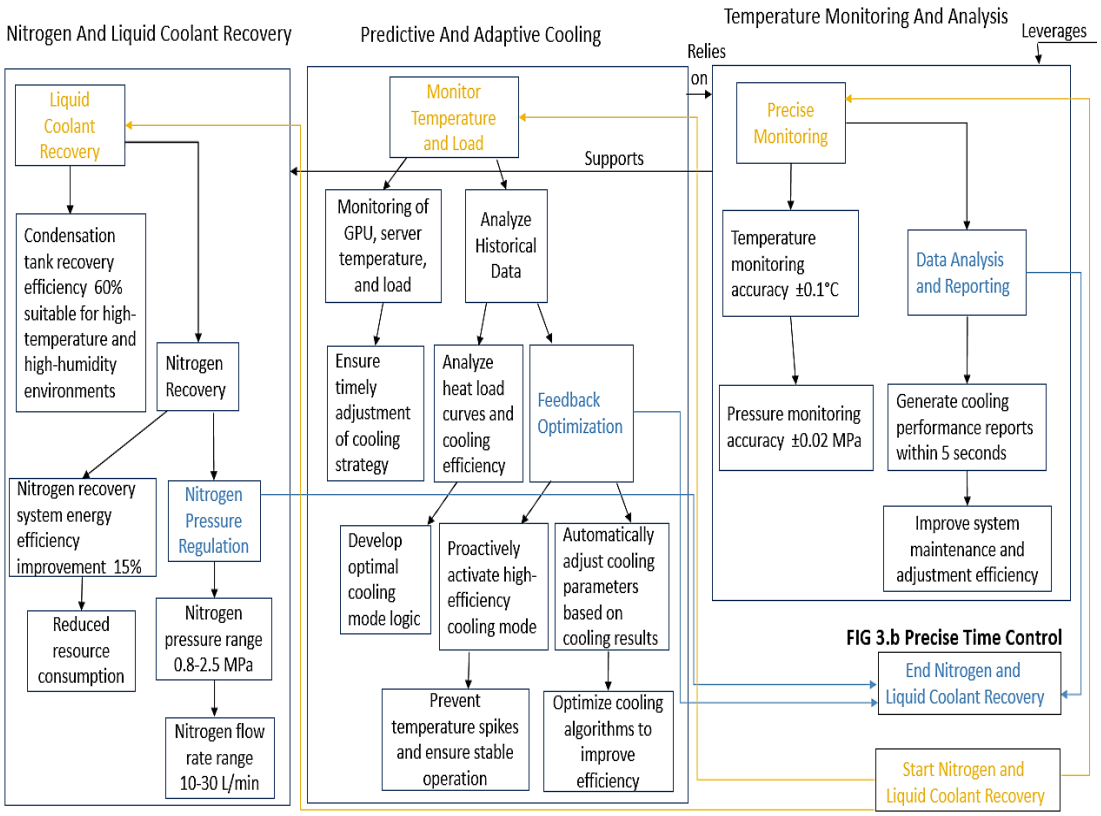

Figure 3.b

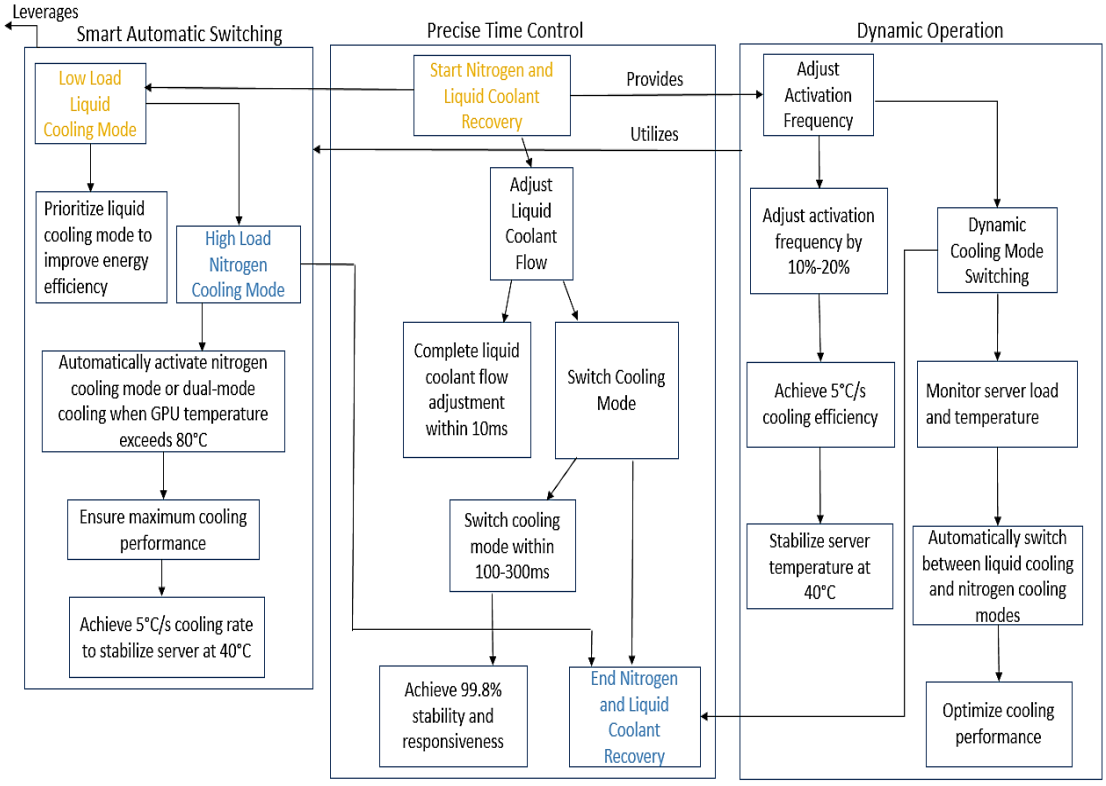

Figure 4.

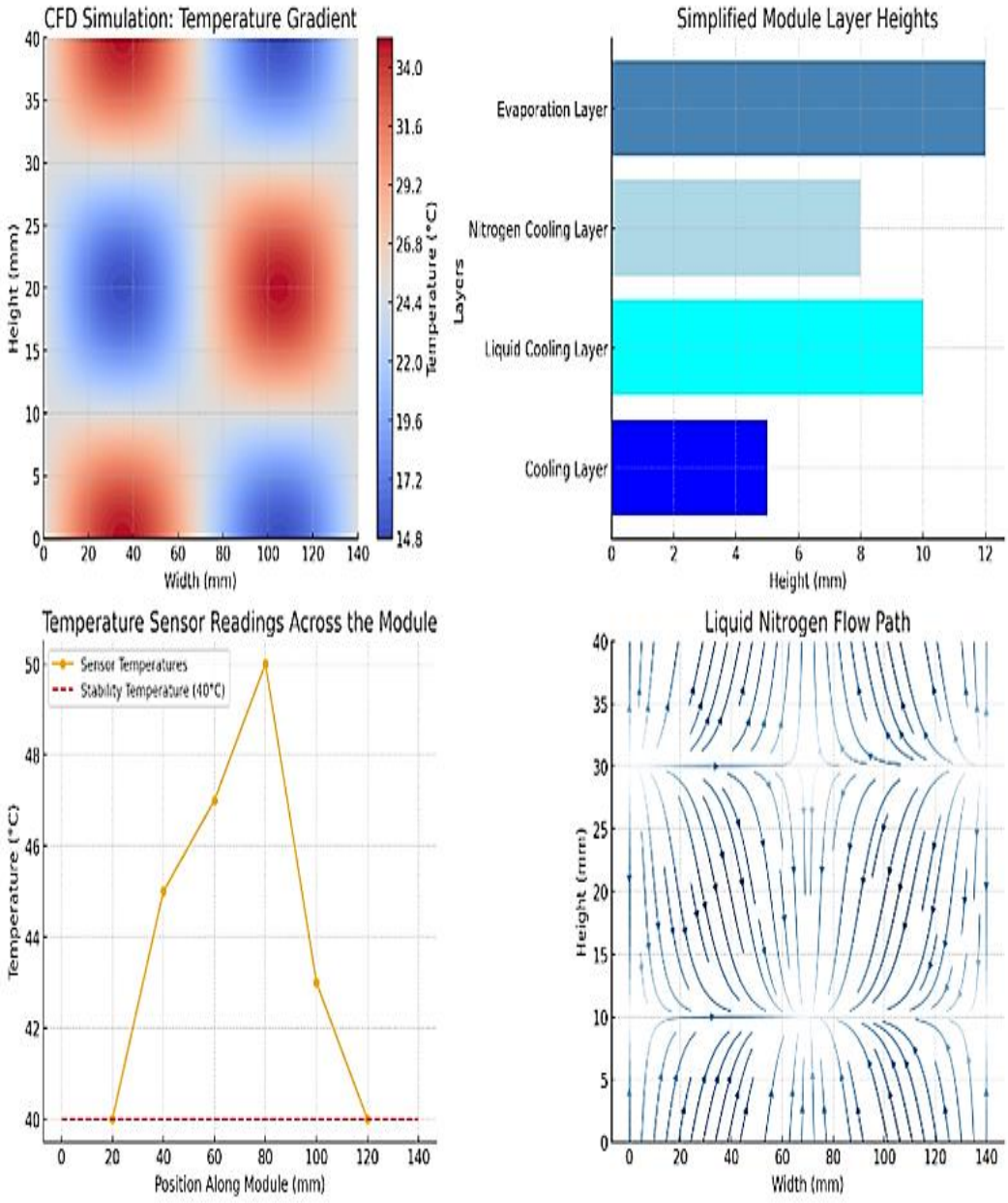
CFD Simulation: Temperature Gradient
Height (mm)
Width (mm)
Temperature (°C)
34.0
31.6
29.2
26.8
24.4
22.0
19.6
17.2
14.8
Simplified Module Layer Heights
Evaporation Layer
Nitrogen Cooling Layer
Liquid Cooling Layer
Cooling Layer
Layers
Height (mm)
Temperature Sensor Readings Across the Module
Sensor Temperatures
Stability Temperature (40°C)
Temperature (°C)
Position Along Module (mm)
Liquid Nitrogen Flow Path
Height (mm)
Width (mm)

Figure 5.

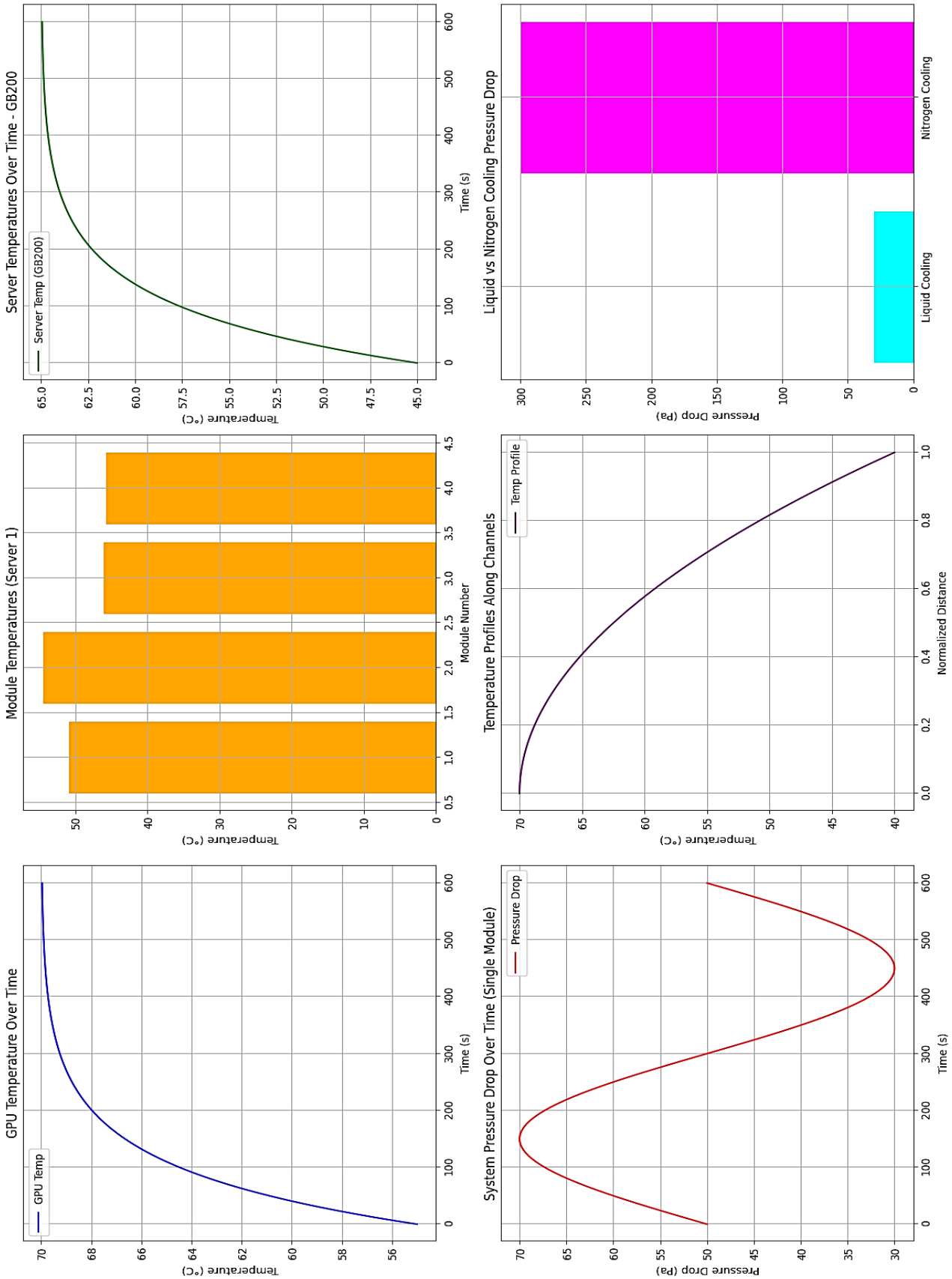
Server Temperatures Over Time - GB200
Server Temp (GB200)
Temperature (°C)
Time (s)
Liquid vs Nitrogen Cooling Pressure Drop
Liquid Cooling
Nitrogen Cooling
Pressure Drop (Pa)
Module Temperatures (Server 1)
Temperature (°C)
Module Number
Temperature Profiles Along Channels
Temp Profile
Temperature (°C)
Normalized Distance
GPU Temperature Over Time
GPU Temp
Temperature (°C)
Time (s)
System Pressure Drop Over Time (Single Module)
Pressure Drop
Pressure Drop (Pa)
Time (s)

Figure 6.

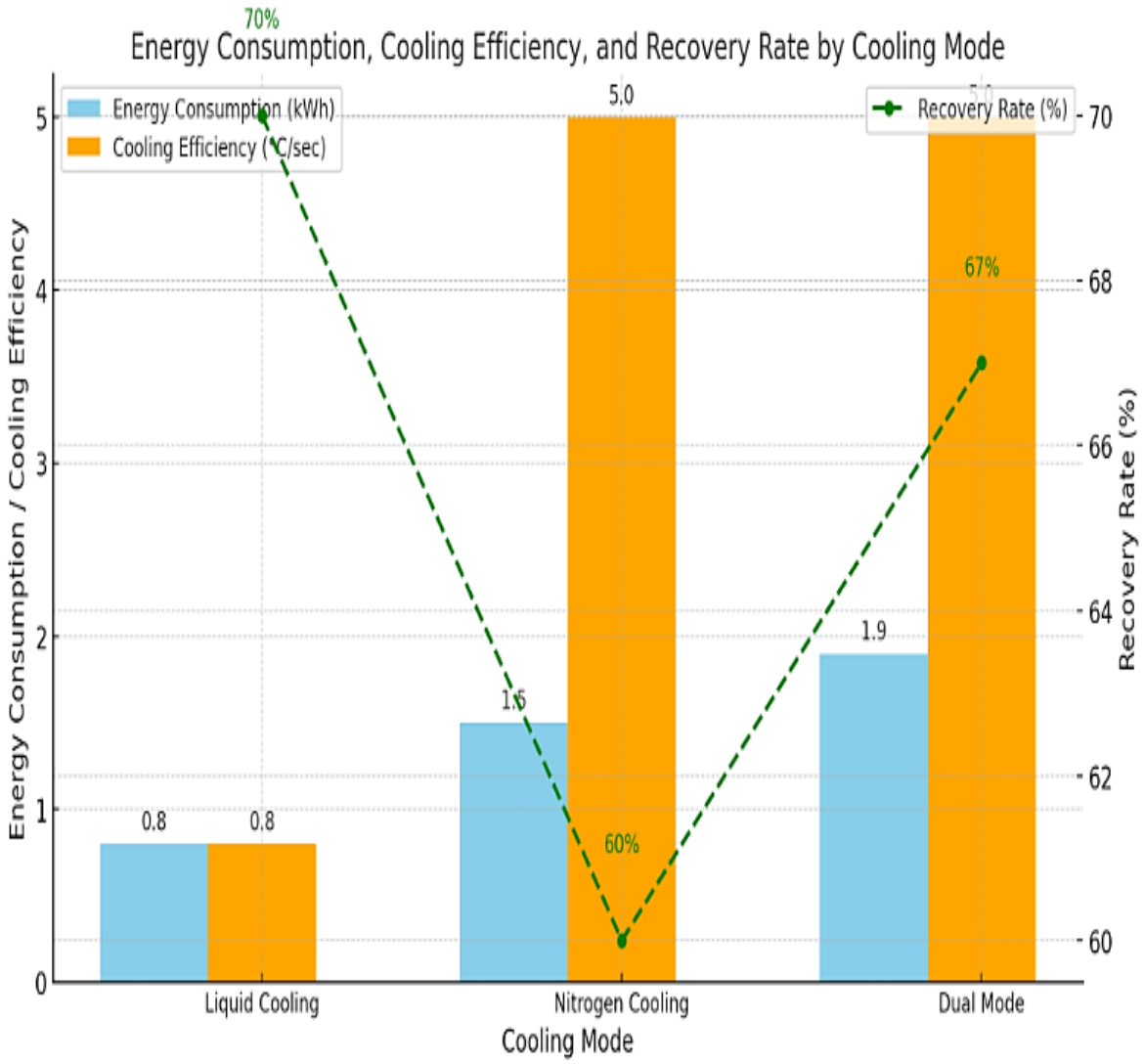
Energy Consumption, Cooling Efficiency, and Recovery Rate by Cooling Mode
Energy Consumption (kWh)
Cooling Efficiency (°C/sec)
Recovery Rate (%)
Energy Consumption / Cooling Efficiency
Recovery Rate (%)
Cooling Mode
Liquid Cooling
Nitrogen Cooling
Dual Mode
0.8
0.8
1.5
5.0
1.9
70%
60%
67%

Figure 7.