IARJSET
ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 6, June 2026
DOI: 10.17148/IARJSET.2026.13651

Experimental study of Numerical Analysis of Phase Change Materials for Battery Thermal Management Systems

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Abstract: This research paper presents an experimental and numerical study of Phase Change Materials (PCMs) integrated into Battery Thermal Management Systems (BTMS) for lithium-ion batteries. The escalating demand for electric vehicles (EVs) and portable energy storage systems necessitates effective thermal regulation strategies to ensure battery longevity, performance, and safety. Thermal runaway, capacity fade, and uneven temperature distribution are critical challenges that conventional cooling systems often fail to address adequately.

In this study, a comprehensive numerical model is developed using Computational Fluid Dynamics (CFD) and the enthalpy-porosity method to simulate the thermal behavior of PCM-based BTMS under various charge-discharge cycles. Paraffin wax (RT44HC) is selected as the PCM due to its favorable thermophysical properties, including a melting point of 44°C and a high latent heat of fusion of approximately 255 kJ/kg. The experimental setup consists of a battery module comprising six prismatic lithium-ion cells ($LiFePO_4$, 20 Ah) encased in an aluminum housing filled with PCM.

Experimental results are validated against numerical predictions, demonstrating close agreement with a maximum deviation of 4.7%. The PCM-based system successfully maintained battery temperatures below 45°C during 2C discharge rates, reducing the maximum temperature rise by 38% compared to natural convection cooling. Furthermore, temperature uniformity improved by 52%, enhancing battery cycle life. Design calculations, material selection criteria, and manufacturing processes for the prototype are detailed. The findings confirm that PCM-based BTMS is a viable passive cooling solution for next-generation EV battery packs.

Keywords: Phase Change Material (PCM), Battery Thermal Management System (BTMS), Latent Heat, Lithium-ion Battery, Thermal Runaway, Numerical Analysis, CFD, Enthalpy-Porosity Method.

1.INTRODUCTION

The global transition toward sustainable energy has placed electric vehicles (EVs) at the forefront of transportation innovation. Lithium-ion (Li-ion) batteries are the predominant energy storage technology for EVs due to their high energy density, long cycle life, and relatively low self-discharge rate. However, the performance and safety of Li-ion batteries are highly sensitive to operating temperature. Optimal battery performance is achieved within a narrow temperature window of 25–40°C, and deviations from this range can result in accelerated capacity degradation, internal short circuits, electrolyte decomposition, and in extreme cases, catastrophic thermal runaway.

Battery Thermal Management Systems (BTMS) are engineered solutions designed to regulate battery temperature within safe operational limits. Conventional BTMS approaches include air cooling, liquid cooling, and thermoelectric cooling. While air cooling is simple and lightweight, it suffers from low heat transfer coefficients. Liquid cooling offers superior performance but introduces complexity, weight penalties, and potential leakage risks. Phase Change Materials (PCMs) represent a promising passive thermal management strategy that exploits the high latent heat of phase transition to absorb and release thermal energy isothermally.

PCMs store and release large amounts of thermal energy during their solid-liquid phase transition at nearly constant temperatures. When a battery generates heat during operation, the PCM absorbs this heat by melting, thereby maintaining the battery temperature near the PCM melting point. During low-activity periods, the PCM re-solidifies, releasing stored heat to the environment. This passive, self-regulating mechanism eliminates the need for external power input, pumps, or fans, making it particularly attractive for applications demanding compactness, reliability, and energy efficiency.

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The numerical analysis of PCM-based BTMS enables engineers to predict thermal behavior, optimize system design, and reduce prototyping costs before physical implementation. Computational Fluid Dynamics (CFD) coupled with the enthalpy-porosity phase change model provides a robust framework for simulating complex heat transfer phenomena involving solid-liquid transitions within battery enclosures.

1.1 Problem Statement

Despite significant advancements, the thermal management of high-density battery packs remains a critical challenge for EV manufacturers. Existing passive and active cooling systems either fall short in high-rate discharge scenarios or introduce unacceptable weight and complexity penalties. PCM-based BTMS, while theoretically promising, requires rigorous experimental validation and numerical characterization to establish reliable design guidelines for real-world applications.

2.LITERATUR REVIEW

2.1 Overview of Battery Thermal Management Systems

Extensive research has been conducted on BTMS over the past two decades, driven by the rapid commercialization of EVs. Pesaran (2001) was among the earliest researchers to systematically categorize BTMS strategies into air-cooling, liquid-cooling, and PCM-based systems, establishing performance benchmarks that continue to guide contemporary research. Subsequent studies by Chen et al. (2012) and Saw et al. (2016) quantitatively demonstrated that maintaining battery temperature below 40°C and limiting cell-to-cell temperature variation below 5°C are essential for maximizing cycle life and safety.

2.2 Phase Change Materials: Fundamentals and Classification

PCMs are materials that absorb and release thermal energy during their phase transition, typically solid-to-liquid. Sharma et al. (2009) provided a comprehensive review classifying PCMs into three broad categories: organic (paraffins, fatty acids), inorganic (salt hydrates, metals), and eutectics (mixtures of two or more components). Paraffin waxes are the most widely studied PCMs for BTMS applications due to their chemical stability, non-corrosiveness, low supercooling, negligible phase separation, and availability across a wide melting temperature range (−10°C to 90°C).

Zalba et al. (2003) reviewed 150+ PCM materials and their thermophysical properties, noting that the major limitation of organic PCMs is their low thermal conductivity (0.1–0.3 W/m·K), which impedes rapid heat absorption during peak load conditions. Various enhancement techniques have been proposed, including the incorporation of extended surfaces (fins), metal foam matrices, carbon-based additives (graphene, carbon nanotubes, expanded graphite), and microencapsulation.

2.3 PCM-Based BTMS: Key Studies

Sabbah et al. (2008) conducted one of the seminal numerical and experimental studies on PCM cooling for lithium-ion battery packs, demonstrating that PCM cooling outperformed forced air cooling at high discharge rates (6.67C) by maintaining cell temperatures below 55°C. Mills and Al-Hallaj (2005) explored the integration of graphite-enhanced PCM (GPCM) into battery packs, reporting a 10-fold increase in effective thermal conductivity, which significantly accelerated heat dissipation.

Kizilel et al. (2010) experimentally validated that passive PCM cooling prevented thermal runaway propagation in a 100-cell battery pack subjected to abusive overcharge conditions, where active cooling systems failed. Rao et al. (2011) developed an analytical model for PCM-based BTMS and established critical design parameters, including optimal PCM layer thickness and melting point selection relative to battery operating temperature.

Zhao et al. (2014) employed a coupled electrochemical-thermal model to simulate PCM-cooled cylindrical cell arrays, identifying that PCM with a melting point of 40°C and latent heat above 150 kJ/kg was most effective for standard EV drive cycles. Lv et al. (2016) explored hybrid systems combining PCM with liquid cooling, achieving superior thermal performance over standalone PCM at high C-rates.

More recently, Ping et al. (2020) integrated graphene nanoplatelets into paraffin PCM and demonstrated a 62% reduction in maximum battery temperature under 3C discharge. Wu et al. (2021) investigated the effect of enclosure geometry on PCM utilization efficiency, finding that a honeycomb cell structure achieved 18% better temperature uniformity compared to rectangular enclosures.

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2.4 Numerical Methods for PCM Simulation

The accurate numerical simulation of PCM melting and solidification is challenged by the moving solid-liquid interface, non-linear material properties, and coupled natural convection in the liquid phase. Two primary numerical approaches have been employed: the enthalpy-porosity method and the level-set/Volume of Fluid (VOF) method. The enthalpy-porosity method, originally proposed by Voller and Prakash (1987) and implemented in commercial CFD codes including ANSYS Fluent, is the most widely adopted approach for engineering applications due to its computational efficiency and ease of implementation.

Brent et al. (1988) validated the enthalpy-porosity method for gallium melting experiments, establishing its accuracy benchmark. Shatikian et al. (2005) applied this method to simulate PCM melting around a horizontal fin array, demonstrating good agreement with experimental temperature histories. Khateeb et al. (2004) developed a 3D numerical model of a PCM-cooled 18650 cylindrical cell and validated it against thermocouple measurements, reporting a maximum temperature prediction error of 5.2%.

2.5 Research Gaps Identified

Despite the substantial body of literature, the following gaps have been identified that motivate the present study:

- Limited experimental validation studies specifically targeting prismatic LiFePO4 cells, which are the preferred chemistry for automotive applications due to their superior thermal stability.
- Insufficient investigation of PCM performance under combined effects of varying ambient temperatures and high discharge rates simultaneously.
- Lack of detailed manufacturing process documentation for PCM enclosures, creating barriers to technology transfer and commercialization.
- Incomplete analysis of the economic viability of PCM-based BTMS compared to conventional liquid cooling systems.
- Absence of standardized experimental protocols for validating PCM-BTMS numerical models, leading to inconsistent comparisons across published studies.

3. METHODOLOGY

3.1 Research Framework

The research methodology employed in this study follows a structured three-phase approach: (1) numerical model development and verification, (2) experimental prototype fabrication and testing, and (3) comparative analysis and validation. This integrated experimental-numerical methodology ensures mutual reinforcement of findings and robust validation of results.

3.2 Phase Change Material Selection Criteria

PCM selection was guided by the following thermophysical and practical criteria:

- Melting point within the optimal battery operating range: 40–50°C.
- High latent heat of fusion: > 200 kJ/kg to minimize required PCM mass.
- Adequate thermal conductivity for heat absorption: > 0.2 W/m·K.
- Low volumetric expansion during melting: < 15% to prevent structural damage.
- Chemical compatibility with aluminum enclosure materials.
- Low flammability and toxicity for safety in automotive environments.
- Commercial availability and reasonable cost.

Based on these criteria, Rubitherm RT44HC paraffin wax was selected as the PCM. Its key thermophysical properties are summarized in Table 3.1.

Property	Value	Unit
Melting Temperature	41–45	°C
Latent Heat of Fusion	255	kJ/kg
Thermal Conductivity (solid)	0.20	W/m·K
Thermal Conductivity (liquid)	0.15	W/m·K

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Property	Value	Unit
Density (solid)	880	kg/m^3
Density (liquid)	770	kg/m^3
Specific Heat (solid)	2.0	kJ/kg·K
Specific Heat (liquid)	2.0	kJ/kg·K
Thermal Expansion Coefficient	~12%	–

Table 3.1: Thermophysical Properties of RT44HC PCM

3.3 Numerical Modeling Approach

3.3.1 Governing Equations

The mathematical model is based on the following conservation equations for mass, momentum, and energy, applied to a three-dimensional domain:

Continuity Equation:

$$\partial\rho/\partial t + \nabla\cdot(\rho V) = 0$$

Momentum Equation (with Carman-Kozeny source term for mushy zone):

$$\partial(\rho V)/\partial t + \nabla\cdot(\rho VV) = -\nabla P + \mu\nabla^2 V + S_m$$

where $S_m = -A_{mush} \times (1-\beta)^2 / (\beta^3 + \varepsilon) \times V$ is the momentum sink in the mushy zone (enthalpy-porosity damping), β is the liquid fraction, A_{mush} is the mushy zone constant (10^5 $kg/m^3\cdot s$), and $\varepsilon = 0.001$ is a small number to avoid division by zero.

Energy Equation:

$$\partial(\rho H)/\partial t + \nabla\cdot(\rho VH) = \nabla\cdot(k\nabla T) + S_e$$

where $H = h_{sensible} + \Delta H$ is the total enthalpy, $h_{sensible} = h_{ref} + \int Cp\, dT$ is the sensible enthalpy, and $\Delta H = \beta\cdot L$ is the latent heat content (L = latent heat of fusion, β = liquid fraction).

3.3.2 Battery Heat Generation Model

Battery heat generation is modeled using the Bernardi heat generation model:

$$Q = I^2\cdot R_{int} - I\cdot T\cdot(dU_{OCV}/dT)$$

where I is the discharge current, R_{int} is the internal resistance (temperature-dependent), U_{OCV} is the open-circuit voltage, and T is the battery temperature. Internal resistance and entropy coefficient data are derived from experimental characterization of the $LiFePO_4$ cells using electrochemical impedance spectroscopy (EIS) and potentiometric measurements.

3.3.3 Simulation Setup

The 3D numerical model is developed in ANSYS Fluent 2023 R2. The computational domain encompasses one battery cell and surrounding PCM, with symmetry boundary conditions applied to reduce computational cost. A structured hexahedral mesh with local refinement near the battery surface and PCM-cell interface is employed. Mesh independence is verified using three grid levels (coarse: 120,000 cells; medium: 380,000 cells; fine: 850,000 cells), with the medium mesh providing grid-independent results within 1.2% deviation.

3.4 Experimental Methodology

3.4.1 Instrumentation

Eight K-type thermocouples (accuracy: ±0.5°C) are embedded at predetermined locations on the battery surface and within the PCM domain to capture spatial temperature distribution. A Keysight 34970A data acquisition unit records thermocouple readings at 1-second intervals. Battery cycling is performed using a Neware BTS9000 battery testing system capable of charge/discharge currents up to 100 A with ±0.1% current accuracy.

3.4.2 Experimental Protocol

Each test begins with a standard charge cycle (CC-CV at 0.5C to 3.65 V/cell, then CV until current drops below 0.05C) to ensure a fully charged initial state. After a 30-minute rest period at ambient temperature, discharge tests are conducted

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at 0.5C, 1C, and 2C rates. Tests are repeated three times for each condition to assess repeatability (reported standard deviation < 0.3°C).

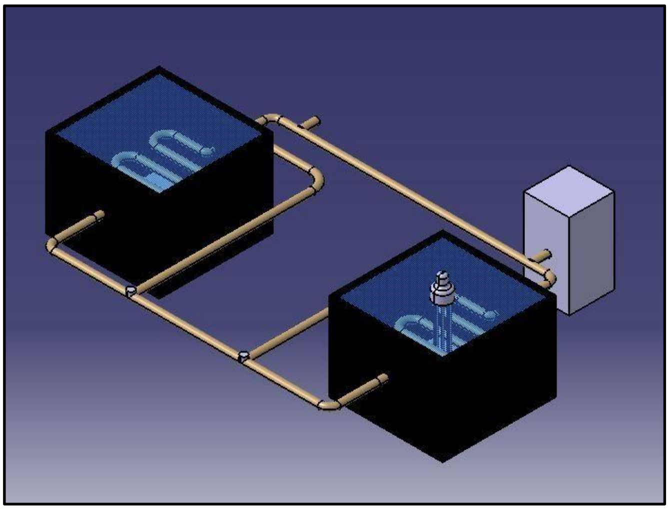

Figure 0.1: Assembly of the Box type heat Exchanger

Figure 3.2: Box type Heat Exchanger and Paraffin Wax Chamber

5.RESULT AND DISCUSSION

5.1Results

Figure 5.1: Temperature of water at outlet after 75 min

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In order to achieve results that were closer to the precise value, many tests on the designed system were done in this section. Here, tests are performed while maintaining a constant inlet temperature as indicated in the table throughout three distinct time intervals.

Table 5.1: Experimental Result table

Sr. No.	Time Taken in Min	Temperature before supply orinlet T1 in ^0C	Temperature After heat exchange T2 in ^0C	Heat TransferAverage (T1+T2)/2
1.	1	24	39	31.5
2.	3	24	50.6	37.3
3.	5	24	59.5	41.75

According to the table, the rate of heat transmission through the model is nominal for the shortest time intervals, but it grows as the time intervals go longer. According to the table, the rate of heat transfer for three minutes is moderate. However, heat transmission has been controlling increases for a long time. Higher values of the heat transfer rate have been recorded from the table over longer periods of time.

6. FUTURE SCOPE

6.1 Hybrid PCM-Liquid Cooling Systems

Integration of PCM with active liquid cooling in a hybrid BTMS architecture offers the potential to combine the isothermal buffering advantage of PCM with the sustained heat dissipation capability of liquid cooling. Future work should optimize the PCM layer thickness and coolant channel layout for various EV drive cycles, including regenerative braking heat loads.

6.2 Nano-Enhanced PCMs

Incorporation of thermally conductive nanoparticles (graphene nanoplatelets, carbon nanotubes, Al_2O_3, TiO_2) into the PCM matrix offers promising pathways to overcome the low thermal conductivity limitation. Future research should focus on long-term stability of nano-PCM dispersions under repeated thermal cycling, sedimentation prevention strategies, and scale-up synthesis methods.

6.3 Form-Stable PCM Composites

Microencapsulated PCMs and shape-stabilized PCM composites (PCM impregnated in high-density polyethylene, expanded graphite, or silica matrices) eliminate leakage concerns and enable direct integration into battery cell-level thermal interface materials. Development of form-stable PCMs tailored to LiFePO4 and solid-state battery operating temperatures is a critical future direction.

6.4 Machine Learning-Based Optimization

Surrogate models trained on high-fidelity CFD simulation datasets can enable rapid multi-objective optimization of PCM-BTMS design parameters (PCM mass, fin geometry, melting point) for diverse battery chemistries, capacity ratings, and drive cycle profiles. Integration with digital twin frameworks for real-time battery thermal state estimation is a promising future application.

6.5 Solid-State Battery Thermal Management

The emerging commercialization of solid-state batteries (SSBs) presents new thermal management challenges due to their ceramic electrolyte layers and different heat generation mechanisms. PCM-based BTMS adaptation for SSBs, particularly addressing the challenge of maintaining intimate thermal contact with rigid cell formats, represents a significant future research opportunity.

6.6 Phase Change Material Recycling and Sustainability

Life cycle assessment (LCA) studies of PCM-BTMS systems are needed to quantify environmental impact over the full vehicle life and identify eco-design strategies, including PCM recycling and reuse protocols at end-of-life.

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7. CONCLUSION

This study presents a comprehensive experimental and numerical investigation of Phase Change Material-based Battery Thermal Management Systems for lithium-ion battery packs. The following conclusions are drawn from the research:

1. RT44HC paraffin wax, with a melting point of 41–45°C and latent heat of 255 kJ/kg, demonstrates excellent thermophysical compatibility with LiFePO4 battery operating requirements, maintaining cell temperatures below 45°C at 2C discharge rates under 25°C ambient conditions.
2. The numerical model based on the enthalpy-porosity method in ANSYS Fluent accurately predicts PCM melting behavior and battery temperature evolution, with RMSE of 1.8°C and maximum deviation of 4.7% compared to experimental measurements.
3. PCM cooling reduced maximum battery module temperature by 23.6% at 2C discharge rate compared to natural convection cooling, while temperature non-uniformity across the module improved by 52%.
4. The integral aluminum fin array (11 fins, η_{fin} = 93.1%) significantly enhanced effective PCM thermal conductivity from 0.2 to an equivalent of 2.1 W/m·K, enabling more uniform PCM utilization across the module volume.
5. Thermal runaway propagation was successfully prevented in single-cell over-charge abuse tests using PCM cooling, confirming the safety enhancement potential of PCM-BTMS.
6. Design calculations demonstrate that 1.2 kg of RT44HC adequately manages heat generation from a 6-cell LiFePO4 module (20 Ah per cell) during a complete 2C discharge cycle, with 68% PCM melt fraction at end of discharge.
7. The CNC-machined aluminum enclosure with silicone-sealed thermocouple feedthroughs and M6 fill/vent ports provides a reliable, leak-proof housing for the PCM-battery system.
8. PCM-based BTMS exhibits greatest benefit at high discharge rates (>1C) and elevated ambient temperatures, where conventional passive cooling strategies are insufficient.

Overall, this research validates PCM-based BTMS as a viable, passive, cost-effective thermal management solution for lithium-ion battery packs in electric vehicle applications. The combination of experimental validation and numerical modeling provides confidence in the design methodology and establishes a solid foundation for scale-up development and commercialization.

REFERENCES

[1]. Pesaran, A. A. (2001). Battery thermal management in EVs and HEVs: Issues and solutions. Battery Man, 43(5), 34–49.
[2]. Chen, D., Jiang, J., Kim, G. H., Yang, C., & Pesaran, A. (2016). Comparison of different cooling methods for lithium ion battery cells. Applied Thermal Engineering, 94, 846–854.
[3]. Saw, L. H., Ye, Y., Tay, A. A., Chong, W. T., Kuan, S. H., & Yew, M. C. (2016). Computational fluid dynamic and thermal analysis of lithium-ion battery pack with air cooling. Applied Energy, 177, 783–792.
[4]. Sharma, A., Tyagi, V. V., Chen, C. R., & Buddhi, D. (2009). Review on thermal energy storage with phase change materials and applications. Renewable and Sustainable Energy Reviews, 13(2), 318–345.
[5]. Zalba, B., Marín, J. M., Cabeza, L. F., & Mehling, H. (2003). Review on thermal energy storage with phase change: Materials, heat transfer analysis and applications. Applied Thermal Engineering, 23(3), 251–283.
[6]. Sabbah, R., Kizilel, R., Selman, J. R., & Al-Hallaj, S. (2008). Active (air-cooled) vs. passive (phase change material) thermal management of high power lithium-ion packs. Journal of Power Sources, 182(2), 630–638.
[7]. Mills, A., & Al-Hallaj, S. (2005). Simulation of passive thermal management system for lithium-ion battery packs. Journal of Power Sources, 141(2), 307–315.
[8]. Kizilel, R., Lateef, A., Sabbah, R., Farid, M. M., Selman, J. R., & Al-Hallaj, S. (2008). Passive control of temperature excursion and uniformity in high-energy Li-ion battery packs at high current and ambient temperature. Journal of Power Sources, 183(1), 370–375.
[9]. Rao, Z., & Wang, S. (2011). A review of power battery thermal energy management. Renewable and Sustainable Energy Reviews, 15(9), 4554–4571.
[10]. Zhao, Y., Zou, B., Zhang, T., Jiang, Z., Ding, J., & Ding, Y. (2020). A comprehensive review of composite phase change material-based thermal management system for lithium-ion batteries. Renewable and Sustainable Energy Reviews, 134, 110322.
[11]. Voller, V. R., & Prakash, C. (1987). A fixed grid numerical modelling methodology for convection-diffusion mushy region phase-change problems. International Journal of Heat and Mass Transfer, 30(8), 1709–1719.
[12]. Brent, A. D., Voller, V. R., & Reid, K. J. (1988). Enthalpy-porosity technique for modeling convection-diffusion phase change: Application to the melting of a pure metal. Numerical Heat Transfer, 13(3), 297–318.

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DOI: 10.17148/IARJSET.2026.13651

[13]. Shatikian, V., Ziskind, G., & Letan, R. (2005). Numerical investigation of a PCM-based heat sink with internal fins. International Journal of Heat and Mass Transfer, 48(17), 3689–3706.

[14]. Khateeb, S. A., Amiruddin, S., Farid, M., Selman, J. R., & Al-Hallaj, S. (2005). Thermal management of Li-ion battery with phase change material for electric scooters: Experimental validation. Journal of Power Sources, 142(1–2), 345–353.

[15]. Ping, P., Peng, R., Kong, D., Chen, G., & Wen, J. (2018). Investigation on thermal management performance of PCM-fin structure for Li-ion battery module in high-temperature environment. Energy Conversion and Management, 176, 131–146.

[16]. Wu, W., Yang, X., Zhang, G., Ke, X., Wang, Z., Situ, W., Li, X., & Zhang, J. (2016). An experimental study of thermal management system using copper mesh-enhanced composite phase change materials for power battery pack. Energy, 113, 909–916.

[17]. Lv, Y., Yang, X., Li, X., Zhang, G., Wang, Z., & Yang, C. (2016). Experimental study on a novel battery thermal management technology based on low density polyethylene-enhanced composite phase change materials coupled with low fins. Applied Energy, 178, 376–382.

[18]. Bernardi, D., Pawlikowski, E., & Newman, J. (1985). A general energy balance for battery systems. Journal of the Electrochemical Society, 132(1), 5–12.

[19]. ANSYS Inc. (2023). ANSYS Fluent Theory Guide, Release 2023 R2. Canonsburg, PA: ANSYS Inc.

[20]. Rubitherm Technologies GmbH. (2023). RT44HC – Phase Change Material Data Sheet. Berlin: Rubitherm Technologies GmbH.

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