International Journal of Energy Production and Management
https://www.acadlore.com/journals/IJEPM

The Effect of Changing the Insulator Position in a Cylinder Consisting of Several Insulating

Zainab Qusay Shareef[1], Rafal Khalid Jasim Sulaiman[2], Waleed Mohammed Najm[1], Iyd Eqqab Maree[3], Yasir Hassan Ali[1], Emad Toma Karash[4*]

[1] Mechanical Engineering Techniques, Polytechnic College Mosul, Northern Technical University, 41001 Mosul, Iraq
[2] Autotronics Engineering Techniques, Polytechnic College Mosul, Northern Technical University, 41001 Mosul, Iraq
[3] College of Engineering, Sahel Nineveh University College, 41019 Mosul, Iraq
[4] Mechanical Technology Department, AL-Amarah University College, 62001 Amarah, Iraq

[*] Correspondence: Emad Toma Karash (emadbane2007@ntu.edu.iq)

Received: 09-01-2025 **Revised:** 11-12-2025 **Accepted:** 12-16-2025

Citation: Z. Q. Shareef, R. K. J. Sulaiman, W. M. Najm, I. E. Maree, Y. H. Ali, and E. T. Karash, "The effect of changing the insulator position in a cylinder consisting of several insulating," *Int. J. Energy Prod. Manag.*, vol. 10, no. 4, pp. 656–667, 2025. https://doi.org/10.56578/ijepm100407.

Abstract: Since heat loss in industrial systems results in energy waste and increased expenses, energy efficiency is essential for sustainability. The performance of the system is improved when pipes and cylindrical equipment are properly thermally insulated to reduce undesired heat transfer and maintain temperature. This research will study the effect of changing the insulator location for a cylinder containing high temperature water to know the effect of the distance of the insulator from the hot cylinder. The thermal insulator will be placed from the wool of gas at different distances in three models, the first model will be without thermal insulator in its walls. Four models will be designed in the Solid works program and then converted to the ANSYS program to apply thermal loads to them, to know the temperature distribution and the amount of heat lost through the wall of the four models, then analyze the results and compare them to find the best location for the thermal insulator from the hot cylinder. It appears that, when the same materials and conditions are used for thermal insulation, the insulator's effectiveness increases with its proximity to the body to be thermally insulated; the further away the insulator is from the source to be insulated, the more heat loss takes place. The reduction in the heat transfer rate in the transient state at the start of convection is largely dependent on the values of thermal conductivity, density, and specific heat. Although the materials in the practical application case are very close to the state of thermal stability, the effect of both specific heat and density in this case decreases, so we can conclude from the study's results that the true effect is limited to thermal conductivity alone in lowering the heat transfer rate. Furthermore, the graphs illustrating the correlation between time and the quantity of heat flux through the walls of the four models at various points in time demonstrate that the second model outperformed the others. In order to reduce heat loss from the hot cylinder, the study suggests that the insulator should be placed close to it.

Keywords: Temperature; Glass wool; ANSYS software; Thermal insulation; Energy; Finite element

1 Introduction

Thermal insulation is a crucial component utilized in the building of different types of walls. Various materials are employed based on the loads that must be met and the intended use. About 40% of the energy used is connected to the area of the wall. The density, heat capacity, and thermal conductivity of the composite wall layers are some of the factors that affect unstable heat transfer in different types of walls. An increased rate of heat transfer as a result of temperature variations will be caused by these factors [1–3]. Thermal insulation is typically required in both construction and industry when pipes and cylinders or equipment operate at temperatures that are significantly different from the surrounding air. The following factors may necessitate thermal insulation: Energy conservation; lowering the external temperature of pipes and equipment; maintaining process fluids at specific minimum temperatures in some situations to prevent unwanted reactions, solidification, precipitation, polymerization, etc.; and, lastly, preventing ambient moisture from condensing on the surface of pipes and equipment in low-temperature processes [4, 5]. Nowadays, energy efficiency is crucial for both environmental and economic sustainability. Significant energy waste and cost increases are caused by heat losses, particularly in process equipment, transmission lines, and power systems utilized in industrial facilities. In this regard, proper insulation applications with contemporary materials in pipes transporting hot fluids improve system performance and drastically cut down on undesired heat transfer [6, 7].

The properties of the materials being studied are typically taken to remain constant while tackling mathematical problems pertaining to heat transport. This is because there is frequently a lack of data and information about how they alter in response to temperature changes. For instance, as the temperature varies, so do the materials' density, specific heat, thermal conductivity, and other characteristics. Therefore, since these properties are not considered at lower or higher temperatures, it can be said that the conclusions produced while investigating materials with constant attributes are inaccurate. The outcomes obtained via conduction, radiation, convection, and other heat transfer methods are impacted by these changes in characteristics [8–12]. Calculating heat transfer through a water heater's cylinder wall requires consideration of conduction through the steel, glass wool, and air layers as well as potential convection at the inner and outer surfaces. The overall heat transmission can be determined by adding the individual thermal resistances of each layer [13, 14]. In engineering and practical applications, specific heat capacity is crucial. It aids in the design of heating and cooling systems as well as the computation of the energy needed to raise or lower the temperature of various materials. For instance, materials having a low specific heat capacity heat up or cool down rapidly, whereas materials with a high specific heat capacity require a significant amount of heat to change their temperature, making them appropriate for thermal storage applications [15, 16]. The type of conduction known as steady state conduction occurs when the temperature differential that drives the conduction remains constant, preventing additional changes in the spatial distribution of temperatures within the conducting object. Transient conduction, also known as unstable state conduction, is the broad name for the mode of thermal energy flow that occurs when temperatures change over time at any location within an item. Both free electrons (electronic thermal conduction) and the elastic vibrations of atoms and molecules (crystal lattice vibration) transfer heat through materials. Free electrons are particularly efficient in transferring heat. Electronic thermal conduction works similarly to electric conduction [17–21]. The following paragraphs will be discussed: 2. Literature Review; 3. The Purpose of the Research; 4. Design Models; 5. Results and Discussion; 6. Conclusions; 7. Future Studies; and 8. Recommendations.

2 Literature Review

This study suggested a multi-layer composite insulation structure for high-temperature cylindrical thermal protection systems that consists of high-reflectivity foils, outside alternating alumina fiber materials, and inner carbon fiber materials. The findings indicate that when the gas pressure is less than 0.01 kPa, the density of the carbon and alumina fiber materials is 180 and 256 kg/m^3, respectively, and there are 39 layers of reflective foil, the composite structure performs the best in terms of thermal insulation. Additionally, a reduced emissivity of the reflective foils results in a much superior thermal insulation performance [22]. In this work, a finite-volume numerical model was used to simulate the combined radiation/conduction heat transport in high-temperature multilayer insulators. By contrasting the numerical model with observations of steady-state effective thermal conductivity, it was verified. According to the results, the best insulating design was achieved by positioning the laminates close to the hot boundary, with the top laminate 2 mm from the hot boundary, and utilizing an inter-lamellar spacing of 2 mm [23]. Using ANSYS software, a number of simulations on a heterogeneous multi-layer wall structure are the focus of this work. To demonstrate the numerical and graphical variations in a number of distinctive parameters, including temperatures, convection coefficients, and heat fluxes, the simulations were run. Additionally, ANSYS-derived parameter values were contrasted with those derived from traditional numerical computations [24]. The only way to keep control of the global energy problem is through energy management. Electrical component optimization is one of the most important management techniques. In order to optimize electric water heaters for domestic use, a comprehensive experimental and numerical investigation is described in this paper [25]. This optimization aims to simultaneously reduce water heating time and energy consumption. First, an experimentally validated thermal model specifically designed for the water heaters was constructed. A parametric analysis of the input power, volume, and exterior area of the entire heater was then conducted. It's encouraging that the results reveal significant energy savings. The results of this study indicated that the ideal thickness for insulation is between 2 and 17 cm, that energy savings range from 22.0 to 79.0%, and that payback periods range from 1.30 to 4.5 hours [26]. This article examined how insulation position affects building walls' heat transfer properties and how insulation thickness might be numerically optimized. The findings demonstrated that the attrition factor and average annual time lag are significantly impacted by the position of the insulation. Consequently, the middle of the wall has the ideal insulating thickness. When the insulation is positioned in the center of the wall, the temperature fluctuates the most, whereas the outermost insulated wall shows the least amount of variation [27]. For two composite slabs, numerical computations are conducted to determine whether the heat transfer coefficient on the heated surface is a trigonometric or an exponential function of time. The impact of temporal changes in the heat transfer coefficient on the transient temperature field of composite slabs are illustrated by the numerical findings [28]. The radius at which heat loss is greatest, known as the critical radius of insulation, was covered in this article. The greater the radius, the less heat is lost. Additionally, introduced the idea of choosing an affordable insulation material and the ideal insulation thickness to achieve the lowest overall cost [29]. The effect of the outer envelope's insulation layer position on the moisture content and heat transfer resistance of buildings' opaque outer envelopes was assessed numerically while accounting for the thermo physical characteristics of all building exterior wall materials [30]. The findings of the study enable us to precisely specify the outer envelope design solution throughout the project documentation phase. The best location for insulation was established for each individual design solution based on the requirement that there be no moisture buildup in the structure's thickness. There are many recent studies that used the finite element method and the ANSYS program to analyze the results. Among these studies are [31–33].

The following is a summary of the findings and conclusions of earlier research. A multi-layer composite insulation with low-emissivity foils produced the optimum thermal performance [22]. The best thermal insulation was achieved by spacing the layers 2 mm from one another close to the heated surface [23]. For multi-layer walls, ANSYS simulations and traditional calculations agreed well [24]. Water heater design optimization decreased heating time and energy usage [25]. Significant energy savings are achieved with an ideal insulating thickness of 2–17 cm [26]. For effective thermal balance, the center of the wall is the ideal place for insulation [27]. It is evident that the behavior of the thermal transition is influenced by the change in the heat transfer coefficient over time [28]. Lowering the overall cost and reducing heat loss are achieved by increasing the insulation radius [29]. The best place for insulation relies on the characteristics of the material and should keep moisture from building up [30].

3 The Purpose of the Research

The objective of this study is to investigate the temporal effect of heat dissipation rather than just the final steady-state effect by using precise geometric models created in Solid Works and thermally analyzed using ANSYS to comprehend the true impact of thermal insulation placement on decreasing heat flux over time.

Motivation: There is a glaring research gap that this study seeks to address. Prior research has frequently ignored the insulation site as an independent element influencing thermal insulation efficiency in favor of concentrating on the type or thickness of the insulation material. Additionally, by considering important physical characteristics like density, heat capacity, and conductivity, it aims to offer useful enhancements in the design of thermal insulation systems for heat sources like pipelines or cylinders.

According to the results, thermal conductivity is the main factor lowering heat transfer, and thermal insulation efficiency rises with insulator proximity to the heated body. The models also showed that when it came to minimizing heat loss, the second model did the best.

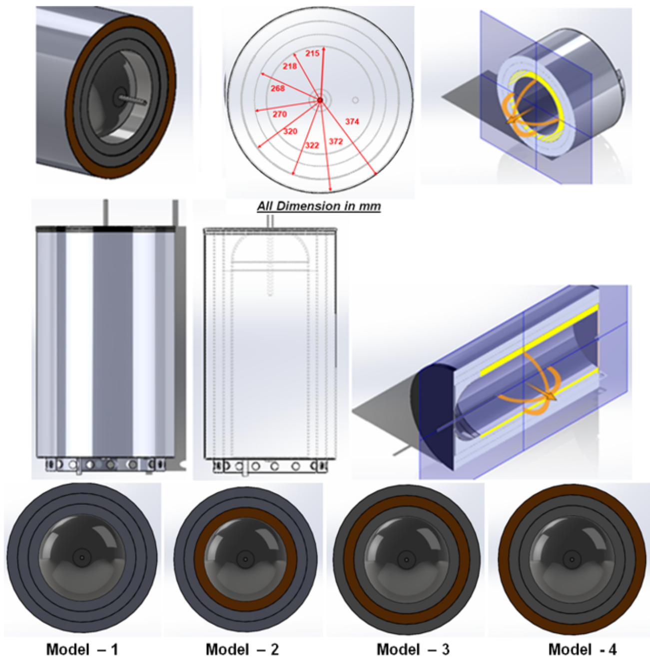

Figure 1. The four models utilized in this study, including their shapes, dimensions, and components of the cylindrical heater

4 Design Models

4.1 Model Shapes and Dimensions

The inner cylinder's dimensions were meant to be 430 mm in diameter, 3 mm in thickness, and 1215 mm in height. Its holes were 12.5 mm for the outflow and 25 mm for the intake. As seen in Figure 1, four models were created by rearranging the insulating glass wool. In order to illustrate the interior construction, the diagram additionally displays the heater's parts, components, and dimensions.

4.2 Materials Used

Table 1 shows the materials used in this study, in addition to their physical and thermal specifications that are included in the design calculations for the cylindrical heater.

Table 1. The thermal specifications of materials

No.	Material	Density (kg/m^3)	Specific Heat (J/kg·K)	Thermal Expansion (1/°C)	Thermal Conductivity (w/m^2 K)
1	Steel	7850	565.5	12×10^{-6}	46.1
2	Wood	400	1500	4×10^{-6}	0.14
3	Glass Wool	40	840	7×10^{-6}	0.032
4	Water	1000	4180	0.33×10^{-3}	0.65

4.3 Forces Applied

Air at -3 °C with a 10 w/m^2 K convection heat transfer coefficient below the surface of a steel cylinder heater with dimensions of 1215 mm in length and 430 mm in diameter. Maintained water at 75 °C. Figure 2 shows the load applied to the cylindrical heater and mesh have 59748 elements and 346925 nodes.

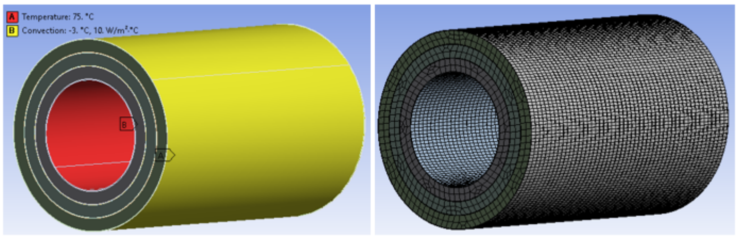

Figure 2. The load applied to the cylindrical heater

5 Results and Discussion

5.1 Path Results

The X-X path selected for each of the four models across the cylinder wall is displayed in Figure 3. The temperature distribution results for the four models along the X-X path are displayed.

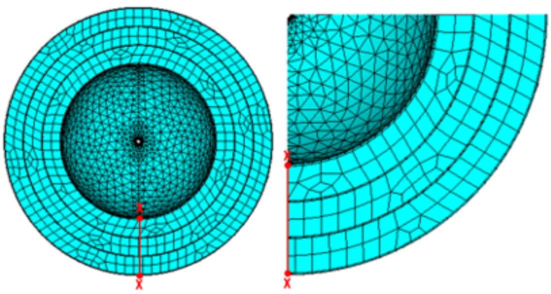

Figure 3. The path X-X chosen along the cylinders wall

The Figure 4 demonstrates that, in comparison to all other models, the temperature distribution over the path in Model 2 walls was lower. The temperature distribution of the four models changed significantly and somewhat up to 40 mm from the inner cylinder wall, according to the results obtained after three seconds. The temperature distribution changed and varied more after one minute, even up to 24 mm from the inner cylinder wall. The variations in the four models' temperature distributions grew after an hour. It is obvious from the graphic that the temperature distribution values of model two are lower than those of the other models. After 10 hours, a significant difference in the temperature distribution across the four models is evident from the figure. The lowest temperature distribution value was observed in the second model up to a distance of 102 mm, after which the temperature distribution values were similar in the third model up to the end of the last cylinder. In the case of the steady state thermal, the temperature distribution results obtained from the figure for the four models were almost identical to the temperature distribution results after 10 hours.

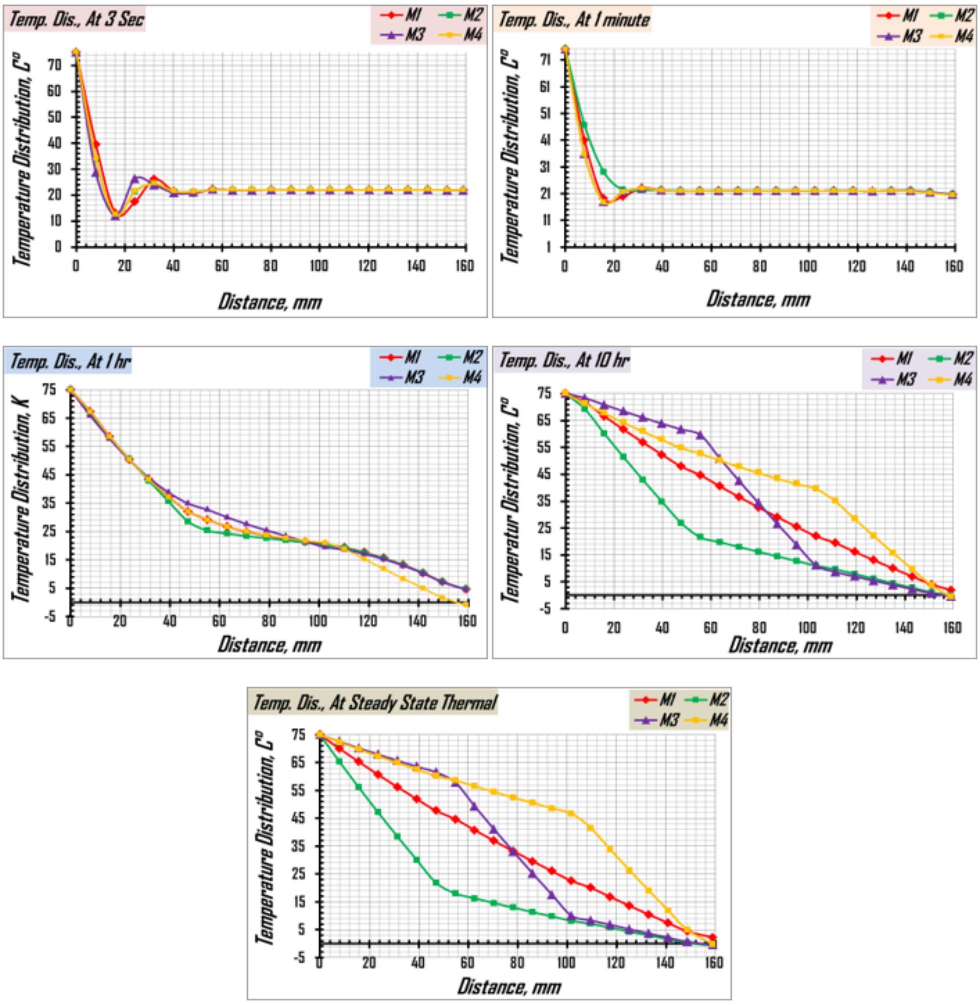

Figure 4. The path X-X result at ten minutes

5.2 Temperature with Time

Table 2. Results obtained transient thermal at three seconds

Parameters		Model I	Model II	Model III	Model IV
Temperature Over Time (K)	Min.	280.88	284.51	280.83	280.88
	Max.	294.46	294.37	294.45	294.46
Temperature Over Time (K)	Min.	348.15	348.15	348.15	348.15
	Max.	361.26	359.16	361.25	361.26
Heat Flux Over Time (W/m^2)	Min.	2.601×10^{-5}	6.965×10^{-6}	4.019×10^{-6}	9.051×10^{-6}
	Max.	1.404×10^{-4}	1.386×10^{-4}	1.573×10^{-4}	1.602×10^{-4}
Heat Flux Over Time (W/m^2)	Min.	11463	2417.1	11522	11463
	Max.	2501954	251374	2502634	2501925

Table 3. Results obtained transient thermal at one minute

Parameters		Model I	Model II	Model III	Model IV
Temperature Over Time (K)	Min.	281.64	284.88	281.60	281.64
	Max.	292.33	293.17	292.33	292.33
Temperature Over Time (K)	Min.	348.15	348.15	348.15	348.15
	Max.	361.13	358.58	361.12	361.13
Heat Flux Over Time (W/m^2)	Min.	1.535×10^{-6}	7.664×10^{-7}	1.792×10^{-6}	9.646×10^{-7}
	Max.	1.421×10^{-4}	1.439×10^{-4}	1.825×10^{-4}	8.244×10^{-4}
Heat Flux Over Time (W/m^2)	Min.	1140.5	247.91	1140.5	1140.5
	Max.	824391	787291	824384	824394

Table 4. Results obtained transient thermal at one hour

Parameters		Model I	Model II	Model III	Model IV
Temperature Over Time (K)	Min.	277.44	77.46	277.41	272.19
	Max.	292.53	293.45	292.53	292.53
Temperature Over Time (K)	Min.	348.18	348.17	348.18	348.18
	Max.	354.08	350.11	354.08	354.08
Heat Flux Over Time (W/m^2)	Min.	3.107×10^{-8}	1.820×10^{-9}	1.186×10^{-8}	3.919×10^{-9}
	Max.	7.741×10^{-5}	3.503×10^{-5}	4.955×10^{-5}	6.837×10^{-5}
Heat Flux Over Time (W/m^2)	Min.	594.63	237.14	638.24	586.13
	Max.	24002	20250	24002	24002

Table 5. Results obtained transient thermal at 10 hours

Parameters		Model I	Model II	Model III	Model IV
Temperature Over Time (K)	Min.	273.54	272.38	272.13	271.45
	Max.	289.95	289.95	289.95	288.22
Temperature Over Time (K)	Min.	348.16	348.17	348.15	348.16
	Max.	349.16	348.33	349.16	349.16
Heat Flux Over Time (W/m^2)	Min.	1.813×10^{-9}	2.122×10^{-9}	3.423×10^{-10}	6.932×10^{-10}
	Max.	1.1507×10^{-4}	3.432×10^{-4}	1.931×10^{-4}	1.711×10^{-4}
Heat Flux Over Time (W/m^2)	Min.	609.27	227.38	608.8	601.28
	Max.	3176.9	2168.7	3580.3	3158.2

Table 6. Results obtained at steady state thermal

Parameters		Model I	Model II	Model III	Model IV
Temperature Over Time (K)	Min.	273.68	271.57	272.22	272.41
	Max.	273.68	271.57	272.22	272.41
Temperature Over Time (K)	Min.	348.16	341.18	348.15	348.16
	Max.	348.16	341.18	348.15	348.16
Heat Flux Over Time (W/m^2)	Min.	1.955×10^{-12}	1.914×10^{-12}	7.484×10^{-13}	5.593×10^{-13}
	Max.	1.955×10^{-12}	1.914×10^{-12}	7.484×10^{-13}	5.593×10^{-13}
Heat Flux Over Time (W/m^2)	Min.	3103.8	1299.1	2224.0	1897.1
	Max.	3103.8	1299.1	2224.0	1897.1

The distribution of Minimum Value Temperature over Time (K), Maximum Value Temperature over Time (K), Minimum Value Heat Flux over Time (W/m^2), and Maximum Value Heat Flux over Time (W/m^2) for the four models at various temperatures and steady state thermal are displayed in Table 2 to Table 6.

The following dynamic analysis of the evolution of heat transfer over time in the four models is revealed by a scientific comparison of the four tables:

First, the change in temperature over time: All models showed a progressive rise in interior temperatures from Table 1 to Table 4, suggesting a cumulative thermal response brought on by ongoing heat transport until a quasi-steady state was achieved. Model II maintained the maximum temperature across all phases despite this overall increase, indicating its increased ability to retain heat and minimize heat loss. As time passes, the disparities between the models progressively narrow, illustrating the system's tendency toward thermal stability.

Second, the Heat Flux Changes: As effective insulation increases, the rate of heat transfer through the wall decreases, as indicated by the tables' relative drop in heat flux values with time, particularly for Model II. By contrast, Model IV has the lowest thermal resistance, as seen by its consistent high heat flux values throughout all tables. According to science, the system is approaching thermal equilibrium as the temperature differential between the two sides gradually narrows over time, as seen by the overall decrease in flux.

Third, comparing how different models behave: The order of efficiency in all four tables was consistent: Model II did the best, followed by Model I, Model III, and Model IV. Although time alone dictates the rate at which steady state is reached, this consistency in ranking suggests that insulation placement, not time, drives thermal performance.

Scientific Finding: The following conclusions can be drawn from the time-course analysis of the four tables: As the system begins to stabilize, heat transmission gradually reduces. The most significant factor lowering heat flow efficiency is the insulator's position. Scientific research has demonstrated that Model II is superior in terms of retaining heat and lowering the rate of heat movement across all timescales.

Final Finding: Model II continues to be the most insulating and efficient at minimizing heat loss over time, as evidenced by the relationship between the four tables, which indicates a thermal evolution from unsteady to quasi-steady state.

Figure 5 shows a comparison between the values of heat flux in the four models at different times and steady state thermal. According to the results, the second model had the lowest heat flux values throughout all time periods and steady state thermal conditions when compared to the other models. For the second model, the lowest value (227.38 W/m) was noted after 10 hours. The Figure 5 also shows that the values of heat flux for the third model were better than the first and third models at all times and steady state thermal conditions.

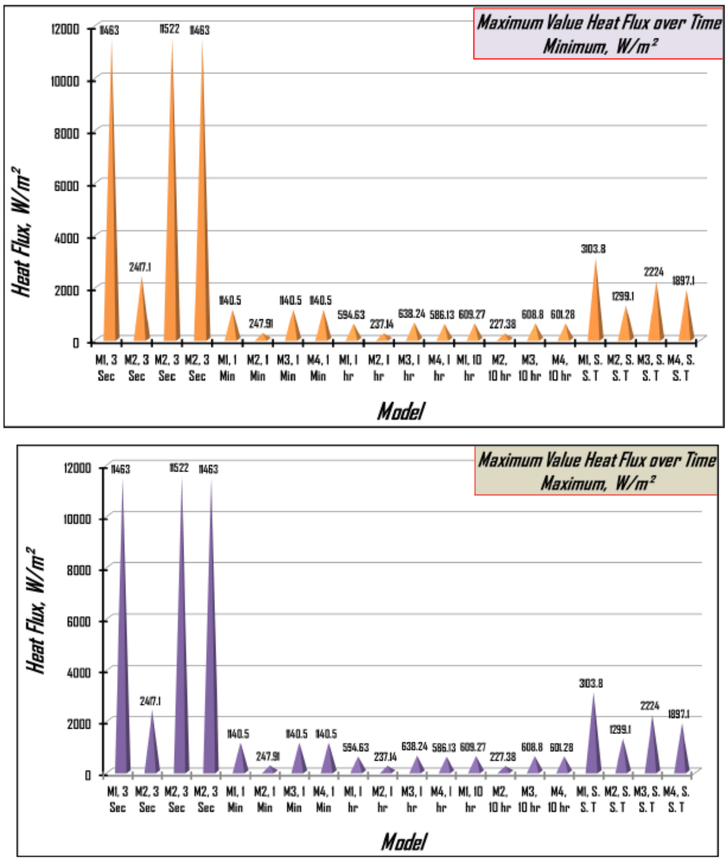

Figure 5. A comparison between the four models and the heat flux at different times, and the steady state thermal condition

5.3 Relationship Between Change Time and Temperature

Figure 6 shows a comparison of the relationship between time and temperature at different intervals. It illustrates that the maximum temperature distributions in the 3-second plot fluctuated slightly among the four models during the first 30 seconds, but then began to change significantly across all models. The temperature distributions for the 40–100 seconds period in Models 2 and 4 were higher than those for Models 1 and 3. Meanwhile, the values for Models 2 and 4 were significantly lower than those for Models 1 and 3 during the 100–180 seconds period.

The graph showing the temperature distribution's greatest values at one minute demonstrates that, in comparison to the other models, the first model's temperature distribution values were the lowest from beginning to end.

The values of the upper temperature distribution change within the first 200 seconds, as the 1-hour plot illustrates. Although the second model's values are obviously lower than those of the other models, they are otherwise nearly the same.

The maximum temperature distribution values are shown in the 10-hour plot, as the values are close to each other in the four models. Initially, the maximum temperature distribution values for the first model appear lower than those for the other models up to 1000 seconds, after which they appear higher than those for the other models until the end.

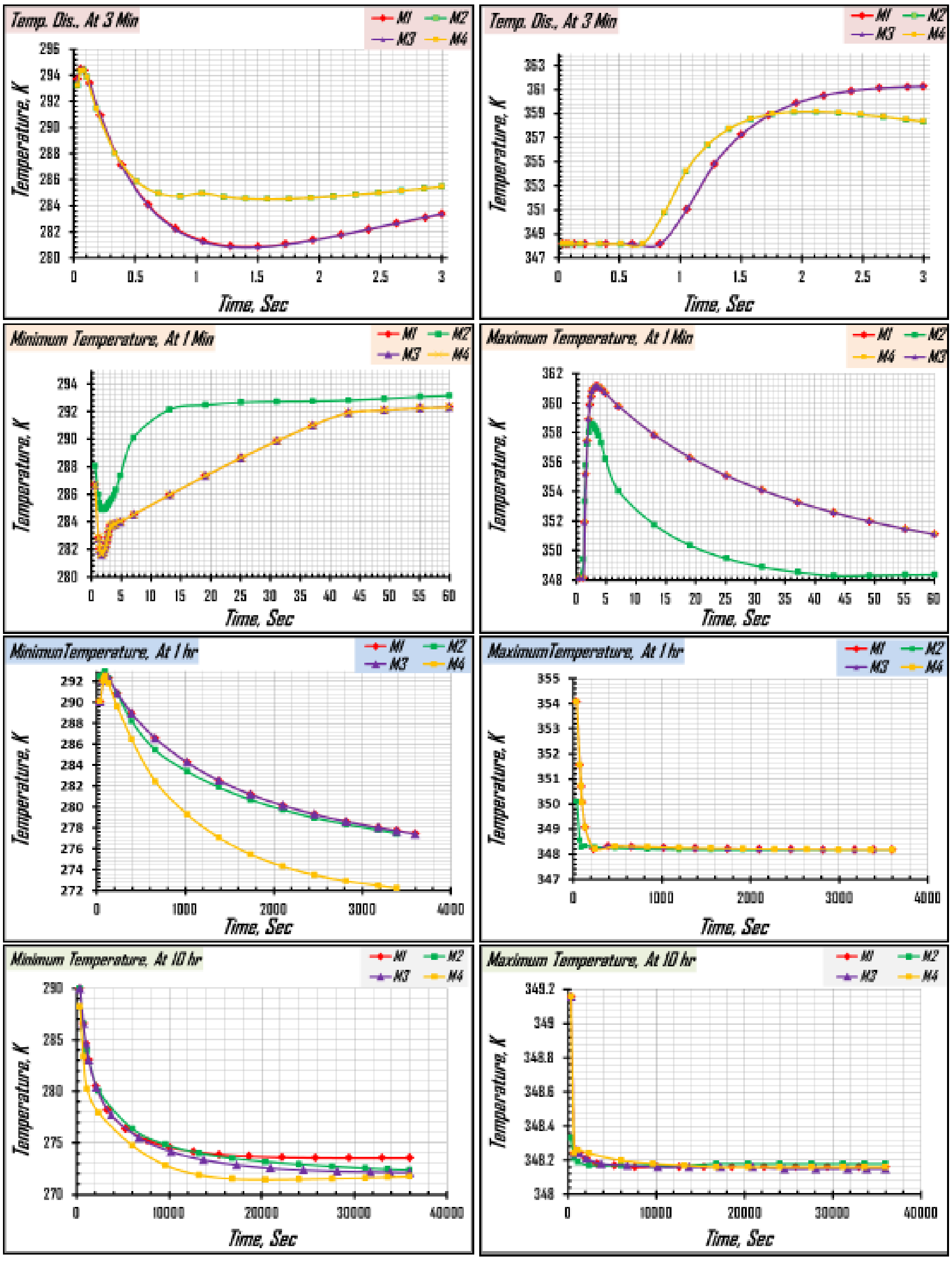

Figure 6. Results of the relationship between time and temperature at different times

5.4 Relationship Between Change Time with Heat Flux

The Figure 7 shows the relationship between time in seconds and heat flux in watts per square meter at different times. The plot at one second indicates that, in comparison to Models 1 and 3, less heat flux compares in Models 2 and 4 at intervals of 15 and 60 seconds, after which the heat flux levels in the four models are similar. Extensive Scientific Study and Mechanism Description:

1. Rapid decrease after sharp heat flow (0–3 seconds)

A peak heat flow results from the significant temperature differential between the heated body and the surrounding medium at the beginning of heating. Compared to M2 and M4, models M1 and M3 have a greater value. Mechanical Justification: Specific heat capacity (Cp) and density (ρ) are greatly impacted during this fast transition phase. While M1 and M3 are initially less effective because of the insulator's remote placement, M2 and M4 most likely have an insulating substance placed directly on the heated body, limiting the quick outward heat flow.

2. 15–60 seconds later

Slowly, the heat flux starts to level out. Compared to M1 and M3, M2 and M4 continue to have lower flux values, suggesting superior insulating effectiveness.

For mechanical reasons: As heat starts to permeate the material, the thermal conductivity coefficients (k) start to become more significant. The insulator's closeness to the source lowers the outward conduction rate.

3. One hour later

Find that the heat flux has increased, particularly in M1 and M3. M2 continues to have the lowest flux, with M4 coming in second, suggesting steady insulating effectiveness.

Mechanical Justification: The flux increases gradually due to the slow rate of conductive heat transfer. For a longer time, the model with the insulator nearer the heated cylinder (M2) lowers the quantity of heat that is transported outward.

4. Ten hours later

Although the flux amounts in the four models vary, they all reach steady state: M2: Best performance lowest value. M1: The worst performance the highest value. M4 and M3: In the middle.

For mechanical reasons: The most crucial element in steady state is the thermal conductivity coefficient, k. Here, the distinction in the location of the insulator and its long-term impact on heat transmission or blocking are emphasized.

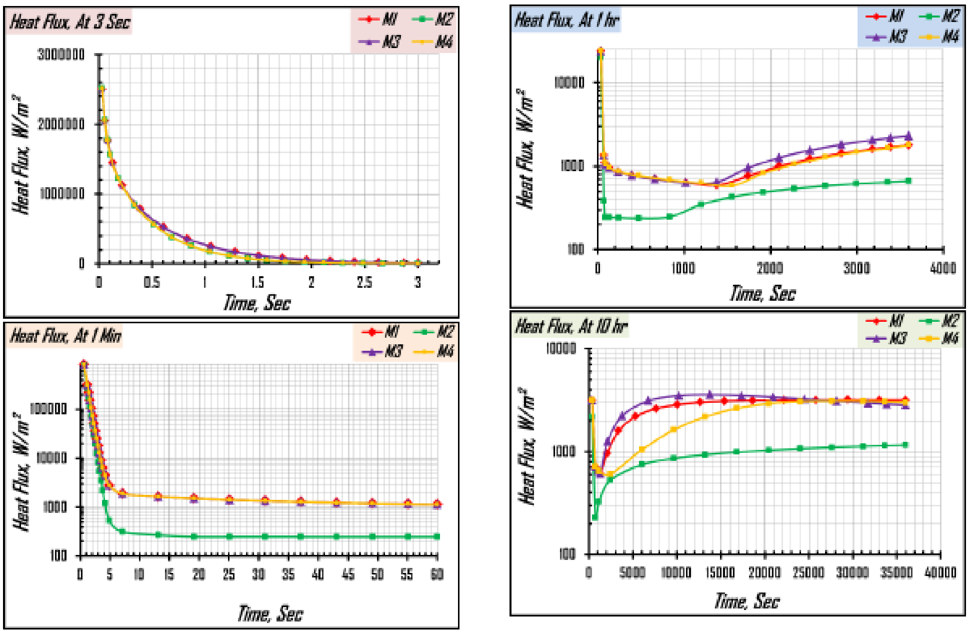

Figure 7. Comparison of time and heat flux for the four models at different time intervals

A comparison with very recent findings in the realm of thermal insulation and heat transfer utilizing modeling and simulation techniques like ANSYS and Solid Works was conducted based on the examination of our study's results. Below, a thorough scientific comparison is given, citing current scholarly sources:

1. How heat loss is affected by insulator location:

This research found that "The closer the insulator is to the object to be insulated, the lower the heat loss; the further it is from the source, the greater the loss". The studies [34, 35] demonstrated that, in comparison to placing the insulation after an air gap or at a distance, placing it directly on the surface of the object to be insulated reduced heat loss by 15% to 30%. Thermal modeling and 3D models in ANSYS-like software were used to verify this. Comparing: The outcome directly supports the findings of our investigation. Heat loss decreases when the insulator gets closer to the heated object.

2. The influence of thermal characteristics (conductivity, density, and heat capacity) with time:

The findings from this research are: At the onset of thermal loading, density and specific heat capacity have a significant effect; as the steady state is approached, the effect of the thermal conductivity coefficient becomes more pronounced. Results from a recent studies [36, 37]: High density and high heat capacity materials reduce the rate at which temperatures rise at the start of loading, which is advantageous for insulation applications. The thermal conductivity coefficient (λ) becomes the main determinant of heat loss when thermal loading persists for an extended length of time. Comparison: Since the influencing qualities vary based on the time phase of the thermal loading (transient versus steady-state), the finding is entirely in line with what was mentioned in your study.

3. Models with insulation next to the hot cylinder are the best.

The study's findings were: Reducing heat flow was most effectively achieved by the second model, which positioned the insulation next to the hot cylinder. Recent researched [38, 39] has demonstrated that the best thermal performance is achieved when insulation is designed with the first layer next to the hot tube having a low thermal conductivity. Simulations also revealed that the layers' placement has a significant impact on the insulation's long-term efficacy, particularly when internal heat preservation is necessary.

What is already understood:

•Several studies have demonstrated that heat loss decreases with insulating quality.

•The significance of insulating interior or exterior walls has been covered in some literature (such as studies on tanks and pipes).

New findings from this study:

•Utilizing precise modeling in Solid Works and ANSYS to present a quantitative and comparative study of four geometric models that differ only in the insulation position.

•Using precise time-based data and not just the "total amount of heat lost", it is shown that the insulation's close proximity to the heat source dramatically lowers heat flow.

•Not depending only on final or steady-state values, as is uncommon in earlier studies, but rather on a time-dependent heat flow simulation.

Something new in this article: The "spatial location of the insulation" was examined in the study as an independent and significant element, backed by precise numerical models, whereas the majority of earlier research concentrated on insulation thickness or materials.

6 Conclusions

The following conclusions can be made from this study based on the outcomes of creating four models with the Solid Works program, applying thermal loads to them with the ANSYS program, and evaluating the outcomes:

1. Under the same conditions and using the same materials for thermal insulation, it is concluded that the closer the insulator is to the body to be thermally insulated, the better it is; the farther it is from the source to be insulated, the more heat loss occurs.

2. The results show that at the onset of thermal loading on the material, density and specific heat capacity have a direct and substantial influence. As the material gets closer to steady state, the conductive heat transfer coefficient starts to have an impact, which causes this effect to lessen.

3. Additionally, the second model was the best model, as shown by the plots showing the relationship between time and the amount of heat flux passing through the wall of the four models at various times. Accordingly, it is preferable for the insulator to be near the hot cylinder that needs to be insulated and the heat that needs to be retained in it rather than situated far away.

4. The study's conclusions emphasize how crucial the thermal insulator's position is as a basic and independent factor in lowering heat flux. The closeness of the insulator to the heat source considerably lowers heat loss, according to accurate modeling over time. This is an aspect that has not been emphasized in earlier studies, which frequently concentrated only on material type or thickness.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] R. H. Mageed, H. J. Kurji, and A. A. Abdulrasool, "A numerical study to determine the effect of an insulator location on the transient heat transfer," *J. Ecol. Eng.*, vol. 24, no. 10, pp. 105–114, 2023. https://doi.org/10.12911/22998993/170035

[2] N. J. Wange, M. N. Gaikwad, and S. P. Pawar, "Analytical solution for three-dimensional unsteady heat conduction in a multilayer cylinder with volumetric heat source," *Int. J. Adv. Eng. Manag. Sci.*, vol. 2, pp. 285–291, 2017. https://doi.org/10.24001/ijaems.icsesd2017.71

[3] T. Pekdoğan and T. Başaran, "Thermal performance of different exterior wall structures based on wall orientation," *Appl. Therm. Eng.*, vol. 112, pp. 15–24, 2017. https://doi.org/10.1016/j.applthermaleng.2016.10.068

[4] C. Arkar, S. Domjan, and S. Medved, "Lightweight composite timber façade wall with improved thermal response," *Sustain. Cities Soc.*, vol. 38, pp. 325–332, 2018. https://doi.org/10.1016/j.scs.2018.01.011

[5] S. S. Hussein, "Optimum single and layered pipe insulation for a given heat load under natural convection heat transfer," Master's thesis, Al-Nahrain University, Iraq, 2011.

[6] F. Li, P. Jie, Z. Fang, and Z. Wen, "Determining the optimum economic insulation thickness of double pipes buried in the soil for district heating systems," *Front. Energy*, vol. 15, no. 1, pp. 170–185, 2020. https://doi.org/10.1007/s11708-020-0680-5

[7] M. Tükel, E. Tunçbilek, A. Komerska, G. A. Keskin, and M. Arıcı, "Reclassification of climatic zones for building thermal regulations based on thermoeconomic analysis: A case study of Turkey," *Energy Build.*, vol. 246, p. 111121, 2021. https://doi.org/10.1016/j.enbuild.2021.111121

[8] A. Ucar and F. Balo, "Determination of the energy savings and the optimum insulation thickness in the four different insulated exterior walls," *Renew. Energy*, vol. 35, no. 1, pp. 88–94, 2010. https://doi.org/10.1016/j.renene.2009.07.009

[9] J. L. Jordan, D. T. Casem, J. M. Bradley, A. K. Dwivedi, E. N. Brown, and C. W. Jordan, "Mechanical properties of low density polyethylene," *J. Dyn. Behav. Mater.*, vol. 2, no. 4, pp. 411–420, 2016. https://doi.org/10.1007/s40870-016-0076-0

[10] M. Fernández-García, J. F. Sánchez-Pérez, F. del Cerro, and M. Conesa, "Mathematical model to calculate heat transfer in cylindrical vessels with temperature-dependent materials," *Axioms*, vol. 12, no. 4, p. 335, 2023. https://doi.org/10.3390/axioms12040335

[11] H. P. Song, K. K. Xie, and C. F. Gao, "Temperature, thermal flux and thermal stress distribution around an elliptic cavity with temperature-dependent material properties," *Int. J. Solids Struct.*, vol. 216, pp. 136–144, 2021. https://doi.org/10.1016/j.ijsolstr.2021.01.010

[12] S. Ding and C.-P. Wu, "Optimization of material composition to minimize the thermal stresses induced in FGM plates with temperature-dependent material properties," *Int. J. Mech. Mater. Des.*, vol. 14, no. 4, pp. 527–549, 2018. https://doi.org/10.1007/s10999-017-9388-z

[13] F. Liu, G. Zhang, Y. Zhang, and Z. Zhang, "Heat transfer characteristics of triple-tube latent heat storage system placed horizontally and vertically," *J. Energy Storage*, vol. 71, p. 108163, 2023. https://doi.org/10.1016/j.est.2023.108163

[14] M. Sanchouli, S. Payan, A. Payan, and S. A. Nada, "Investigation of the enhancing thermal performance of phase change material in a double-tube heat exchanger using grid annular fins," *Case Stud. Therm. Eng.*, vol. 34, p. 101986, 2022. https://doi.org/10.1016/j.csite.2022.101986

[15] H. M. Ali, T. Rehman, M. Arıcı, Z. Said, B. Duraković, H. I. Mohammed, R. Kumar, M. K. Rathod, O. Büyükdağlı, and M. Teggar, "Advances in thermal energy storage: Fundamentals and applications," *Prog. Energy Combust. Sci.*, vol. 100, p. 101109, 2024. https://doi.org/10.1016/j.pecs.2023.101109

[16] M. Sajawal, T. Rehman, H. M. Ali, U. Sajjad, A. Raza, and M. S. Bhatti, "Experimental thermal performance analysis of finned tube-phase change material based double pass solar air heater," *Case Stud. Therm. Eng.*, vol. 15, p. 100543, 2019. https://doi.org/10.1016/j.csite.2019.100543

[17] O. M. E. S. Khayal, S. E. E. Ali, A. Awadalla, and A. A. M. Mohammed, "Steady state heat conduction in rectangular and cylindrical geometries: A review," *Excell. J. Eng. Sci.*, vol. 1, no. 2, pp. 70–81, 2024.

[18] R. L. McMasters, F. de Monte, and J. V. Beck, "Generalized solution for rectangular three-dimensional transient heat conduction problems with partial heating," *J. Thermophys. Heat Transf.*, vol. 34, no. 3, pp. 516–521, 2020. https://doi.org/10.2514/1.t5888

[19] P. E. Crittenden and K. D. Cole, "Fast-converging steady-state heat conduction in a rectangular parallelepiped," *Int. J. Heat Mass Transf.*, vol. 45, no. 17, pp. 3585–3596, 2002. https://doi.org/10.1016/s0017-9310(02)00066-2

[20] E. A. Al-Bayati, T. A. Tahseen, and S. R. Aslan, "Numerical simulation of the effect of rounded edge cylinders on drag coefficient," *NTU J. Eng. Technol.*, vol. 4, no. 2, pp. 24–30, 2025. https://doi.org/10.56286/ntujet.v4i2

[21] S. R. N. Aldeen and Q. A. Yousif, "Enhancement of convective flow and heat transfer using nanofluids: A critical review," *NTU J. Eng. Technol.*, vol. 4, no. 2, pp. 54–72, 2025. https://doi.org/10.56286/8qvp4a25

[22] M. Chen, P. Zhang, and Q. Li, "Design and heat transfer analysis of a compound multi-layer insulations for use in high temperature cylinder thermal protection systems," *Sci. China Technol. Sci.*, vol. 61, no. 7, pp. 994–1002, 2018. https://doi.org/10.1007/s11431-017-9250-x

[23] J. Yue, J. Liu, X. Song, and C. Yan, "Research on the design and thermal performance of vacuum insulation panel composite insulation materials," *Case Stud. Therm. Eng.*, vol. 64, p. 105437, 2024. https://doi.org/10.1016/j.csite.2024.105437

[24] S. I. Felicia-Elena, D. Radu-Cristian, and D. Adelaida-Mihaela, "Numerical simulation of heat transfer through uniform multilayer walls using ANSYS," *WSEAS Trans. Heat Mass Transf.*, vol. 18, pp. 325–331, 2023. https://doi.org/10.37394/232012.2023.18.28

[25] M. F. Amran, S. M. Sultan, and C. P. Tso, "A comprehensive review of mixed convective heat transfer in tubes and ducts: Effects of prandtl number, geometry, and orientation," *Processes*, vol. 12, no. 12, p. 2749, 2024. https://doi.org/10.3390/pr12122749

[26] A. Bolattürk, "Determination of optimum insulation thickness for building walls with respect to various fuels and climate zones in turkey," *Appl. Therm. Eng.*, vol. 26, no. 11–12, pp. 1301–1309, 2006. https://doi.org/10.1016/j.applthermaleng.2005.10.019

[27] M. Ozel, "Effect of insulation location on dynamic heat-transfer characteristics of building external walls and optimization of insulation thickness," *Energy Build.*, vol. 72, pp. 288–295, 2014. https://doi.org/10.1016/j.enbuild.2013.11.015

[28] R. Chiba, "An analytical solution for transient heat conduction in a composite slab with time-dependent heat transfer coefficient," *Math. Probl. Eng.*, vol. 2018, pp. 1–11, 2018. https://doi.org/10.1155/2018/4707860

[29] D. K. Sahu, P. K. Sen, G. Sahu, R. Sharma, and S. Bohidar, "A review on thermal insulation and its optimum thickness to reduce heat loss," *Int. J. Innov. Res. Sci. Technol.*, vol. 2, no. 6, pp. 1–6, 2015.

[30] I. Antypov, V. Kaplun, A. Mischenko, O. Shelimanova, S. Tarasenko, V. Tkachenko, and O. Borychenko, "Assessment of the impact of the location of the insulation layer on the humidity regime and heat transfer resistance of the external building envelope," in *Studies in Systems, Decision and Control*. Springer Nature Switzerland, 2024, pp. 279–318. https://doi.org/10.1007/978-3-031-67091-6_13

[31] E. T. Karash, T. A. A. Sediqer, and M. T. E. Kassim, "A comparison between a solid block made of concrete and others made of different composite materials," *Rev. Compos. Mater. Av.*, vol. 31, no. 6, pp. 341–347, 2021. https://doi.org/10.18280/rcma.310605

[32] M. K. Najem, E. T. Karash, and J. N. Sultan, "The amount of excess weight from the design of an armored vehicle body by using composite materials instead of steel," *Rev. Compos. Mater. Av.*, vol. 32, no. 1, pp. 1–10, 2022. https://doi.org/10.18280/rcma.320101

[33] E. T. Karash, "Modelling of unilateral contact of metal and fiberglass shells," *Appl. Mech. Mater.*, vol. 87, pp. 206–208, 2011. https://doi.org/10.4028/www.scientific.net/AMM.87.206

[34] A. E. Akdağ, M. Koru, and M. Davraz, "Numerical and experimental determination of thermal insulation performance of a composite block with different insulation materials," *J. Therm. Anal. Calorim.*, vol. 150, no. 12, pp. 8977–8990, 2025. https://doi.org/10.1007/s10973-025-14241-5

[35] K. Sun, Y. Wei, Y. Zhou, J. Jia, Y. Hong, J. Qin, and J. Li, "Insulation performance of a new annular heated air curtain in cold-region tunnels: Numerical modeling, effects analysis, and prediction," *J. Therm. Anal. Calorim.*, vol. 149, no. 14, pp. 7485–7501, 2024. https://doi.org/10.1007/s10973-024-13327-w

[36] A. Nandy, Y. Houl, W. Zhao, and N. A. D'Souza, "Thermal heat transfer and energy modeling through incorporation of phase change materials (PCMs) into polyurethane foam," *Renew. Sustain. Energy Rev.*, vol. 182, p. 113410, 2023. https://doi.org/10.1016/j.rser.2023.113410

[37] W. Wang, Y. Li, D. Huan, H. Liu, Y. Li, and Z. Hu, "Application and thermal field analysis of multilayer thermal insulation in in-situ forming process of thermoplastic composites," *J. Thermoplast. Compos. Mater.*, vol. 37, no. 8, pp. 2608–2634, 2024. https://doi.org/10.1177/08927057231218703

[38] X. Luo, D. Xu, Y. Bing, Y. He, and Q. Chen, "Thermal performance and building energy simulation of precast insulation walls in two climate zones," *Buildings*, vol. 14, no. 9, p. 2612, 2024. https://doi.org/10.3390/buildings14092612

[39] M. R. A. Alrasheed, "Optimizing the thickness of multilayer thermal insulation on different pipelines for minimizing overall cost-associated heat loss," *Processes*, vol. 12, no. 2, p. 318, 2024. https://doi.org/10.3390/pr12020318