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Experimental Evaluation of Fan Speed Control and Physical Placement Effects on Thermal Performance of a Hybrid Liquid–Air Cooled Desktop System

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Abstract

The Design of Experiments (DOE) framework was used to study the effects of fan speed control and physical placement on a hybrid PC system. Three factors and three levels were considered in the experiment. The ideal conditions for effective cooling were determined, and the results were obtained by running the design in Minitab. Workload is found to be the primary driver of temperature increases in hardware, as expected. Fans exert secondary influence by helping cool the PC components. Despite its limited impact, physical placement also shows statistical significance in helping cool the PC. Good airflow around a PC placed on a trolley yielded the best cooling for the PC components. Residual analysis confirmed model adequacy. This result confirms that environmental factors, such as PC placement, have a meaningful impact on thermal behavior and should be incorporated into the hardware cooling strategy.

Keywords
Fan Speed Control, Personal Computer, Thermal Performance, DOE, Hybrid Cooling.

1. Introduction

Personal Computer (PC) enthusiasts spend time pushing PC components to their limits, overclocking, and running performance tests on newly released CPUs, GPUs, and memory. Over time, various PC parts have experienced shortages. From 2020 to 2023, the global semiconductor shortage affected PC components. The supply chain disruption and increase in demand during the COVID-19 pandemic, driven by cryptocurrency mining, led to pricing exceeding the MSRP. Despite the release of new generation GPUs, prices remain high. Although the demand for CPUs was high, their supply remained consistent compared to that of GPUs. Lately, the same instability has started to hit the memory market. This time, it's due to high demand for AI infrastructure and a short supply; prices have skyrocketed by over 2000% according to Han, S (2026) from DigiTimes, but they're finally starting to drop, though only by about 5%. While demand for PC functions continues to rise, upgrade options shrink. Every method to improve PCs' performance is important, and this is what this study aims to accomplish.

OCCT (Overclock Checking Tool) is a powerful diagnostic software designed to test and monitor the stability of overclocked computer systems. It is widely utilized by PC enthusiasts and professionals to push hardware to its limits and ensure reliable performance under heavy loads. According to its website, "OCCT offers a range of stress tests for CPUs, GPUs, RAM, and power supplies, providing real-time metrics and alerts on temperatures, voltages, and system load. By simulating intensive workloads, OCCT helps identify potential hardware issues, instability, or overheating that can arise from overclocking. With a user-friendly interface and detailed reporting, OCCT is an essential tool for fine-tuning system performance, troubleshooting, and preventing hardware damage." (2026)

iCUE (Corsair Utility Engine) is software developed by Corsair to enable users to manage and connect their devices and third-party hardware. It is a central hub for RGB lighting effects, fan speeds, cooling settings, and more. It is commonly used among streamers and gamers.
An important quality improvement tool used in this study is the Design of Experiments (DOE). DOE is described as a systematic statistical methodology for planning experiments in which input factors are deliberately varied so that their effects on a response variable can be efficiently and objectively estimated, while assuring valid inference using structured design principles such as replication, randomization, and blocking (Hinkelmann & Kempthorne, 2008). Replication is important because it helps separate real effects from random noise in the data. As explained by Klaus Hinkelmann and Oscar Kempthorne (2008), "Replication provides an estimate of experimental error and increases the precision of treatment comparisons." Similarly, Douglas C. Montgomery (2017) notes that replication is necessary because it allows researchers to estimate experimental error, which is essential when testing whether factor effects are truly significant.

1.1 Objectives

This study aims to conduct a full-factorial DOE experiment to determine the effects of fan speed and physical placement on the thermal performance of a hybrid PC system across varying workloads. Using a structured, full factorial DOE framework, the study specifically aims to:

1. Investigate the effect of fan speed levels on CPU and GPU temperatures.
2. Evaluate how physical placement influences system thermal behavior.
3. Assess the relative impact of workload intensity on component temperatures.
4. Identify statistically significant main effects and their interactions through ANOVA.

The unique aspect of this study is the integration of hardware-controllable fan-speed parameters with environmental placement factors within a unified experimental framework, enabling a more comprehensive analysis of hybrid PC cooling performance than prior studies have provided.

2. Literature Review

A PC (personal computer), also known as a desktop, is a system made up of various components that is a computing device capable of performing a variety of tasks. The components of a PC include the Central Processing Unit (CPU), Memory (RAM), Motherboard, Power Supply, and Operating System. With an integrated CPU, it's capable of running productivity and communication tasks like Word processing, spreadsheets, Email, and video conferencing. For more demanding tasks, such as entertainment and creative work (Gaming, Streaming, Graphics design, Programming, Photo and video editing, etc.), an additional Graphics processing unit (GPU) is recommended. These components generate heat when they go operational; the more intensive the task, the more heat they generate. The two parts that generate most heat are the CPU (the computer's brain) and the GPU (the computer's muscle). When these components get too hot, they slow down to prevent damage, which causes performance loss. This phenomenon is called throttling. To prevent throttling, it is important to provide effective cooling to these components.

A hybrid cooling system uses coolants to cool the CPU while using air cooling for the GPU and other components. Fan cooling uses ambient air outside the computer to move heat away from the components while drawing in cooler air. Water cooling uses radiative cooling, in which the coolant absorbs heat from the CPU and dissipates it to the outside through the radiator.

Fan arrangement and fan speed play a major role in cooling the PC. Based on the component arrangement, the fan arrangement on the PC case is crucial, depending on the cooling method and component positioning. Retureta et al.'s study in computational fluid dynamics on the Impact of Axial Fan Configuration on Thermal Management in Gaming Desktops reveals that XPG VALOR AIR with 14 fan layout configurations for forced crossflow inlet and outlet has the best thermal performance compared to CONF4VENT3 and CONF4VENT6, which are indicated not to be suitable for long demanding workloads. The study also confirms that increased airflow and fan speed reduce component temperature, but maximum fan speed is not always necessary if the components remain below the thermal throttling limit. (2025)

Indoor temperature also plays a major role in the PC's performance and cooling. At room temperature, where the PC is operating and climbing above 80 °F, the PC's performance may begin to slow. If the CPU's internal temperature exceeds 212 °F, performance will noticeably dip, and the CPU will throttle down to prevent overheating. Jihyun

Hwang and Taewon Lee (2021) examined the effects of various factors on the energy consumption of cooling equipment for an outdoor air-cooling system in a computer room. They also performed numerical analysis, considering various design and operating parameters, to identify the optimal operational strategy to minimize power consumption in computer rooms by integrating an outdoor air-cooling system into an existing HVAC system. The analysis results confirm that using the optimal airflow can reduce annual energy consumption compared to traditional air conditioning. While it is evident that performance is the primary indicator of temperature increase in components of a PC, an increase in fan speed helps with thermal increase, and outdoor air temperature plays an optimal role in the cooling of the components, this study takes a step further to study the temperature differences in the positioning of the PC.

3. Methods

3.1 Experimental Design

A three-factor, full-factorial design was implemented to evaluate the effects of fan speed, placement height, and workload condition on the thermal and energy performance of a hybrid-cooling desktop computing system. Each factor was tested at three levels, resulting in 27 unique treatment combinations.

Each treatment combination was replicated three times to enable unbiased error estimation and enhance statistical reliability, yielding a total of 81 experimental runs. The order of runs was randomized to minimize temporal bias and uncontrolled variability.

For each response variable (CPU temperature, GPU temperature, and estimated total power), a fixed-effects analysis of variance (ANOVA) model was specified as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + \varepsilon_{ijk}$$

μ = mean response or overall mean

α_i = fan speed

β_j = placement

γ_k = workload

ε_{ijk} = error term assumed to be identical, independent, and normally distributed.

The ANOVA decomposition is expressed as

$$SS_T = SS_A + SS_B + SS_C + SS_{AB} + SS_{AC} + SS_{BC} + SS_E$$

Results, such as the Sum of Squares, Mean Squares, and F-tests, were generated in Minitab at the 0.01 significance level.

3.2 Materials and Equipment

3.2.1 Experimental Platform

The PC used for testing was custom built made up of these components: NVIDIA GeForce RTX 4080 SUPER (GPU), AMD Ryzen 7 9800X3D (CPU), Patriot Viper Venom DDR5 64GB (RAM), CORSIAR iCUE h150I Elite LCD XT Liquid CPU Cooler, ASRock x870 Riptide Wife AM5 AMD Motherboard, 4TB SN850X NVME SSD, and Super Flower Leadex VI Platinum PRO 1000W Power supply, running on Windows 11 Home.

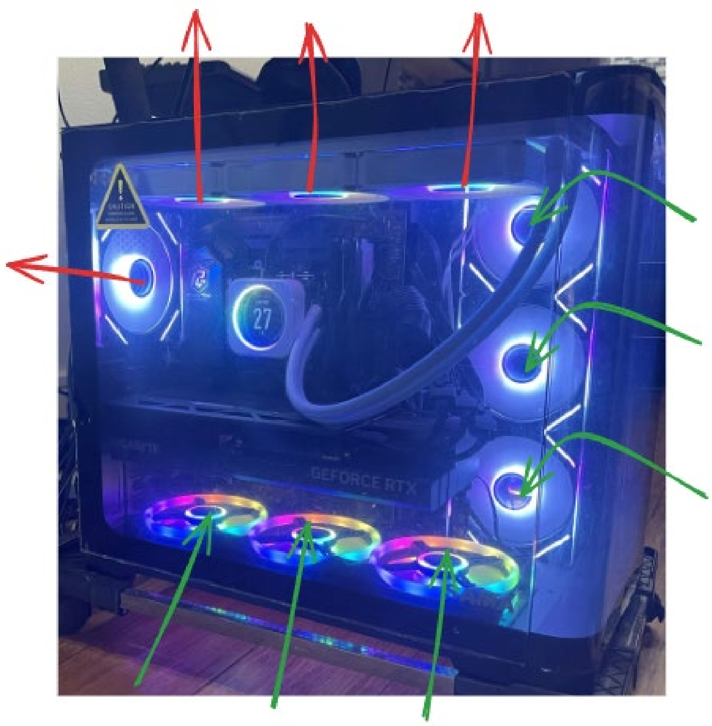

Figure 1. Fan Arrangement

The fan arrangement for this study, as shown in Figure 1 above, comprises three fans drawing air from the bottom and right back (6 fans in total). With 4 fans exhausting air, 3 at the top and 1 at the left. The 3 fans at the top are also connected to the radiator, which helps cool the CPU.

3.2.2 Instrumentation and Data Acquisition

Stress will be applied to the PC, and its temperature and power consumption will be monitored. Commonly stress-tested components include the CPU, GPU, RAM, storage, and the full system. In most real-life scenarios, all these components are used simultaneously, which is why the full system stress test was performed. The best software to achieve this goal is OCCT (Figure 2- Figure 3).

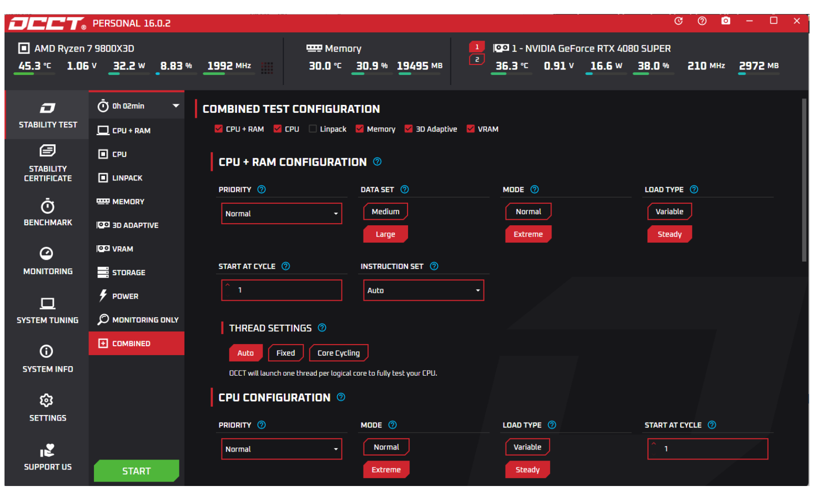

Figure 2. OCCT software

To control the fan speed, the iCUE software was used.

Figure 3. iCUE software

3.2.3 Choice of Factors and Levels

The first factor is physical placement (Table 1). This is where the whole PC will be positioned; the three positions are floor, on the trolley, and on the desk. Airflow obstruction access plays a major role here, and it is not necessarily about the elevation. Figure 4 below shows how it was positioned during the experiment.

Table 1. Factors and Levels

FACTORS	LEVELS		
	1	2	3
Placement	Floor	Trolley	Desk
Fan speed	654	956	1909
Workload	Idle	Medium	Heavy

Figure 4. Floor Placement (Left), Trolley Placement (Middle), and Desk Placement (Right)

The second factor is the fan speed. Rotations per minute (RPM) were fixed at 654 RPM (quiet), 956 RPM (balanced), and 1909 RPM (extreme), which is noticeably loud.

The third factor is the major driving factor, workload. Data were collected when the PC was idle, under medium load, and under heavy load. These load levels represent the real-life use of a PC, depending on the task it's being used for

3.4 Experimental Procedure

Step 1: PC is positioned at its placement
Step 2: Fan speed is adjusted on iCUE
Step 3: Workload is selected on OCCT
Step 4: Let the PC run for 10 minutes for stability and consistency
Step 5: Screenshot and record data into Excel
Step 6: Allow the PC to cool down for 15 minutes for the next round

3.5 Assumption Verification and Validity Controls

The diagnostic analysis checks for problems in the data, such as outliers and influential points that may skew the results. Minitab helped verify that the error term is homogeneous, constant, independent, and normally distributed.
To ensure data accuracy, the room temperature was kept consistent. Because each reptation was performed on different days, each reptation may have experienced different room temperatures, though the temperature range was 75°F to 77°F. Consistent data collection was maintained, and external variability was minimized. While going through the test, it was observed that the GPU integrated fan, which cannot be controlled, adjusts to the load. This may affect the dependent variable.

4. Data Collection

Minitab was used to create 81 experimental runs, resulting from 27 treatment combinations and 3 replications. The dependent variables are CPU temperature (°C), GPU temperature (°C), CPU power (W), and GPU power (W). Using OCCT for both workload generation and data collection ensures consistency and repeatability across all test conditions. The data acquired is shown below in Figure 5.

StdOrder	RunOrder	PtType	Blocks	Placement	Fan Speed	Workload	GPU Temp(°C)	GPU Power(W)	CPU Temp(°C)	CPU Power(W)
4	4	1	1	Floor	956	Idle	38.0	19.9	44.4	25.8
5	5	1	1	Floor	956	Medium	50.1	163.0	64.9	111.0
6	6	1	1	Floor	956	Heavy	58.9	204.0	67.2	116.0
7	7	1	1	Floor	1909	Idle	35.0	19.9	42.9	26.5
8	8	1	1	Floor	1909	Medium	51.3	148.0	62.6	111.0
9	9	1	1	Floor	1909	Heavy	59.6	210.0	64.6	116.0
10	10	1	1	Trolley	654	Idle	37.4	20.0	44.9	27.5
11	11	1	1	Trolley	654	Medium	55.0	181.0	66.3	113.0
12	12	1	1	Trolley	654	Heavy	59.9	211.0	69.2	117.0
13	13	1	1	Trolley	956	Idle	37.4	20.2	44.6	28.2
14	14	1	1	Trolley	956	Medium	54.2	173.0	65.4	112.0
15	15	1	1	Trolley	956	Heavy	55.5	202.0	68.0	115.0
16	16	1	1	Trolley	1909	Idle	34.6	20.1	42.8	26.7
17	17	1	1	Trolley	1909	Medium	51.4	168.0	61.9	112.0
18	18	1	1	Trolley	1909	Heavy	59.0	202.0	64.5	115.0
19	19	1	1	Desk	654	Idle	38.5	19.8	46.0	28.2
20	20	1	1	Desk	654	Medium	53.8	154.0	66.7	111.0
21	21	1	1	Desk	654	Heavy	57.7	208.0	68.8	115.0
22	22	1	1	Desk	956	Idle	37.7	22.8	44.8	29.0
23	23	1	1	Desk	956	Medium	56.3	166.0	65.5	111.0
24	24	1	1	Desk	956	Heavy	58.9	221.0	67.8	114.0
25	25	1	1	Desk	1909	Idle	34.6	20.1	43.4	27.0
26	26	1	1	Desk	1909	Medium	56.1	173.0	62.8	111.0
27	27	1	1	Desk	1909	Heavy	58.9	211.0	64.9	115.0
28	28	1	1	Floor	654	Idle	38.4	16.8	44.8	27.6
29	29	1	1	Floor	654	Medium	53.7	174.0	66.4	112.0
30	30	1	1	Floor	654	Heavy	56.4	203.0	69.1	116.0
31	31	1	1	Floor	956	Idle	36.9	18.0	44.4	27.2
32	32	1	1	Floor	956	Medium	50.3	148.0	66.4	113.0
33	33	1	1	Floor	956	Heavy	58.4	198.0	67.6	115.0
34	34	1	1	Floor	1909	Idle	35.0	16.7	43.1	26.1
35	35	1	1	Floor	1909	Medium	49.7	166.0	64.6	113.0
36	36	1	1	Floor	1909	Heavy	60.1	206.0	65.4	116.0
37	37	1	1	Trolley	654	Idle	36.7	17.5	45.0	27.2
38	38	1	1	Trolley	654	Medium	54.0	168.0	66.1	111.0
39	39	1	1	Trolley	654	Heavy	58.3	211.0	68.3	115.0
40	40	1	1	Trolley	956	Idle	35.2	17.9	44.2	28.1
41	41	1	1	Trolley	956	Medium	48.8	143.0	65.7	111.0

StdOrder	RunOrder	PtType	Blocks	Placement	Fan Speed	Workload	GPU Temp(°C)	GPU Power(W)	CPU Temp(°C)	CPU Power(W)
40	40	1	1	Trolley	956	Idle	35.2	17.9	44.2	28.1
41	41	1	1	Trolley	956	Medium	48.8	143.0	65.7	111.0
42	42	1	1	Trolley	956	Heavy	59.1	212.0	66.7	114.0
43	43	1	1	Trolley	1909	Idle	34.0	15.3	42.5	27.0
44	44	1	1	Trolley	1909	Medium	47.0	143.0	64.0	112.0
45	45	1	1	Trolley	1909	Heavy	57.3	212.0	64.7	115.0
46	46	1	1	Desk	654	Idle	36.4	17.1	45.5	28.0
47	47	1	1	Desk	654	Medium	46.0	113.0	67.8	91.2
48	48	1	1	Desk	654	Heavy	61.1	196.0	69.7	115.0
49	49	1	1	Desk	956	Idle	37.1	15.8	44.9	27.7
50	50	1	1	Desk	956	Medium	51.8	152.0	67.8	111.0
51	51	1	1	Desk	956	Heavy	56.3	210.0	68.2	114.0
52	52	1	1	Desk	1909	Idle	35.5	16.7	43.7	28.0
53	53	1	1	Desk	1909	Medium	51.9	180.0	64.1	113.0
54	54	1	1	Desk	1909	Heavy	57.8	204.0	66.0	116.0
55	55	1	1	Floor	654	Idle	37.6	17.3	46.0	28.2
56	56	1	1	Floor	654	Medium	51.5	118.0	67.4	110.0
57	57	1	1	Floor	654	Heavy	60.1	214.0	69.5	115.0
58	58	1	1	Floor	956	Idle	36.6	15.4	45.1	25.1
59	59	1	1	Floor	956	Medium	50.3	146.0	65.3	112.0
60	60	1	1	Floor	956	Heavy	59.3	206.0	67.9	114.0
61	61	1	1	Floor	1909	Idle	35.0	16.1	43.9	25.8
62	62	1	1	Floor	1909	Medium	45.8	139.0	64.9	112.0
63	63	1	1	Floor	1909	Heavy	57.0	183.0	67.4	114.0
64	64	1	1	Trolley	654	Idle	37.6	16.6	46.0	25.5
65	65	1	1	Trolley	654	Medium	48.0	141.0	66.3	110.0
66	66	1	1	Trolley	654	Heavy	56.9	207.0	69.3	114.0
67	67	1	1	Trolley	956	Idle	37.0	17.1	45.1	26.2
68	68	1	1	Trolley	956	Medium	47.7	132.0	66.4	111.0
69	69	1	1	Trolley	956	Heavy	56.2	182.0	67.7	114.0
70	70	1	1	Trolley	1909	Idle	34.8	15.7	43.2	25.5
71	71	1	1	Trolley	1909	Medium	46.5	127.0	63.0	110.0
72	72	1	1	Trolley	1909	Heavy	55.1	195.0	65.2	114.0
73	73	1	1	Desk	654	Idle	37.0	20.1	46.1	27.9
74	74	1	1	Desk	654	Medium	49.6	133.0	66.3	112.0
75	75	1	1	Desk	654	Heavy	61.3	215.0	68.9	115.0
76	76	1	1	Desk	956	Idle	37.3	19.6	45.5	27.2
77	77	1	1	Desk	956	Medium	52.7	138.0	65.7	111.0
78	78	1	1	Desk	956	Heavy	60.4	208.0	67.8	114.0
79	79	1	1	Desk	1909	Idle	35.5	19.8	44.5	27.1
80	80	1	1	Desk	1909	Medium	50.8	133.0	64.7	112.0
81	81	1	1	Desk	1909	Heavy	62.6	205.0	66.2	115.0

Figure 5. Full Factorial Design

5. Results and Discussion

5.1 Numerical Results

Each of the 4 responses was examined. The Minitab output on the effects of fan speed, physical placement, and workload is discussed.

5.1.1 CPU Temperature

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	26	8774.89	337.50	691.38	0.000
Linear	6	8766.35	1461.06	2993.06	0.000
Placement	2	5.43	2.71	5.56	0.006
Fan Speed	2	121.45	60.72	124.40	0.000
Workload	2	8639.47	4319.73	8849.23	0.000
2-Way Interactions	12	7.89	0.66	1.35	0.220
Placement*Fan Speed	4	2.01	0.50	1.03	0.400
Placement*Workload	4	0.42	0.11	0.22	0.928
Fan Speed*Workload	4	5.46	1.36	2.79	0.035
3-Way Interactions	8	0.65	0.08	0.17	0.994
Placement*Fan Speed*Workload	8	0.65	0.08	0.17	0.994
Error	54	26.36	0.49		
Total	80	8801.25			

Figure 6. ANOVA for CPU Temperature

The ANOVA findings displayed in Figure 6 above confirm that all three factors are statistically significant: fan speed and workload have p-values of 0.000, while placement has a p-value of 0.006, which is less than the significance level of 0.01.

However, none of the interaction effects are statistically significant, with their p-values greater than 0.01. This is further confirmed with the Pareto chart below in Figure 9.

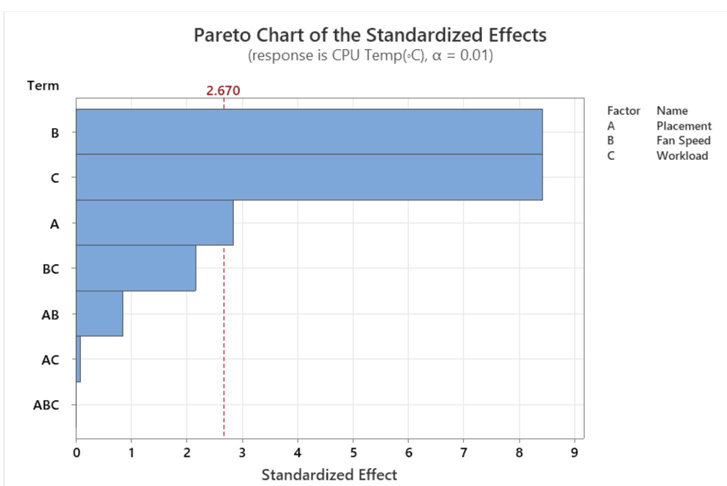

Figure 7. Pareto Chart for CPU Temperature

5.1.2 GPU Temperature

The GPU response differs slightly from that of the CPU. The ANOVA findings confirm that only the workload factor is statistically significant: fan speed has a p-value of 0.021, placement has a p-value of 0.035, and workload has a p-value of 0.000, which is less than the significance level of 0.01.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	26	6960.49	267.71	67.52	0.000
Linear	6	6866.87	1144.48	288.65	0.000
Placement	2	28.22	14.11	3.56	0.035
Fan Speed	2	32.85	16.42	4.14	0.021
Workload	2	6805.80	3402.90	858.25	0.000
2-Way Interactions	12	51.29	4.27	1.08	0.397
Placement*Fan Speed	4	24.16	6.04	1.52	0.208
Placement*Workload	4	8.21	2.05	0.52	0.723
Fan Speed*Workload	4	18.92	4.73	1.19	0.324
3-Way Interactions	8	42.34	5.29	1.33	0.247
Placement*Fan Speed*Workload	8	42.34	5.29	1.33	0.247
Error	54	214.11	3.96		
Total	80	7174.60			

Figure 8. ANOVA for GPU Temperature

However, none of the interaction effects are statistically significant, with their p-values greater than 0.01. This is further confirmed with the Pareto chart below in Figure 9.

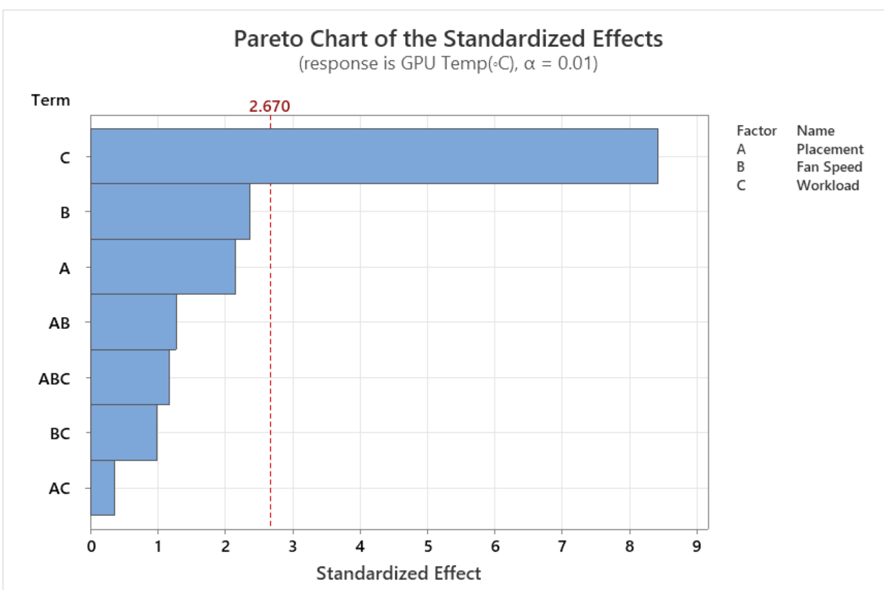

Figure 9. Pareto Chart for GPU Temperature

5.1.3 Power Consumption Analysis

When it comes to power consumption from both GPU and CPU, fan speed and placement have no statistical significance, nor do any interaction effects. The workload with a p-value of 0.000 alone determines the decision, as shown in Figure 10.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	26	502096	19311	111.98	0.000
Linear	6	499719	83287	482.97	0.000
Placement	2	22	11	0.06	0.939
Fan Speed	2	7	3	0.02	0.980
Workload	2	499691	249845	1448.83	0.000
2-Way Interactions	12	1313	109	0.63	0.803
Placement*Fan Speed	4	957	239	1.39	0.251
Placement*Workload	4	260	65	0.38	0.824
Fan Speed*Workload	4	97	24	0.14	0.966
3-Way Interactions	8	1063	133	0.77	0.630
Placement*Fan Speed*Workload	8	1063	133	0.77	0.630
Error	54	9312	172		
Total	80	511408			

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	26	132896	5111.4	867.32	0.000
Linear	6	132758	22126.3	3754.46	0.000
Placement	2	5	2.6	0.44	0.644
Fan Speed	2	4	2.2	0.37	0.695
Workload	2	132748	66374.2	11262.58	0.000
2-Way Interactions	12	98	8.1	1.38	0.204
Placement*Fan Speed	4	23	5.8	0.99	0.420
Placement*Workload	4	38	9.6	1.63	0.180
Fan Speed*Workload	4	36	9.0	1.52	0.209
3-Way Interactions	8	41	5.1	0.87	0.547
Placement*Fan Speed*Workload	8	41	5.1	0.87	0.547
Error	54	318	5.9		
Total	80	133215			

Figure 10. ANOVA for GPU Power (left) and CPU Power (Right)

5.1.4 Model Adequacy

The figures below show the Residual plots for both CPU and GPU temperatures. The normal probability plot shows that the points approximately follow a straight line, indicating a normal distribution of the residuals. The plot of residuals vs the observation order in Figure 11 does not show any obvious pattern. Therefore, the independence of the error term with the observation order or time is not violated in this case. There is no obvious pattern, indicating the residuals/errors are homogeneous, constant, or identically distributed.

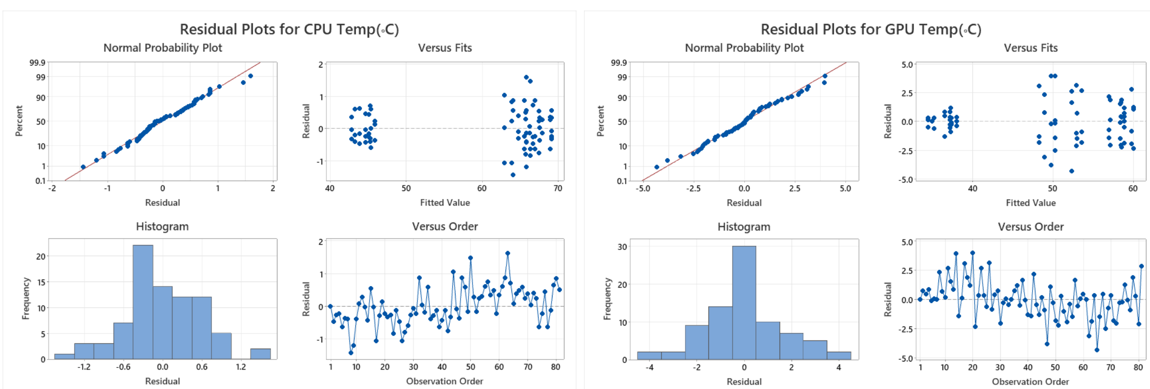

Figure 11. Residual Plots for CPU Temperature (Left) and GPU Temperature (Right)

5.2 Graphical Results

Minitab helps create a visual representation of the factor to see how its effects behave across each level.

5.2.1 Main Effect Plot

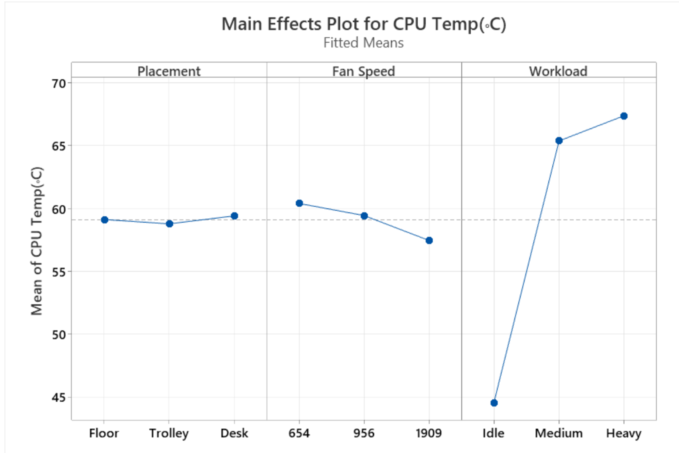

Figure 12. Main Effects Plot for CPU Temperature

From Figure 12, the main effect plot for CPU shows that Workload has the greatest impact, with a significant increase in temperature from idle to heavy conditions. Fan speed decreases as RPM increases. The different placements also show little effect, with the trolley helping most with temperature and the desk being the worst. The change in temperature for placement might be a little, but it is statistically significant.

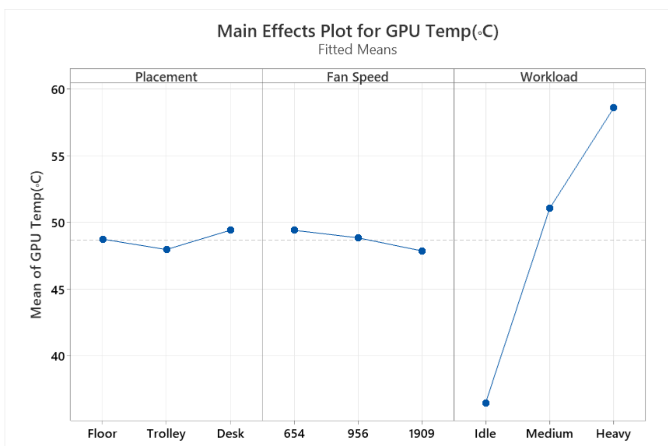

Figure 13. Main Effects Plot for GPU Temperature

From Figure 13, the main effect plot for CPU shows that Workload has the greatest impact, with a significant increase in temperature from idle to heavy conditions. Fan speed decreases as RPM increases. The different placements also show little effect, with the trolley helping most with temperature and the desk being the worst. The change in temperature due to placement and fan speed is too little to be statistically significant.

5.2.2 Interaction Effects Plot

The nature of lines in the interaction effect plot (Figure 14) provides information about their interaction effects. If the lines are parallel, there are no interaction effects between the factors. However, if the lines are nonparallel, an interaction occurs. The more nonparallel the lines are, the greater the interaction strength in Minitab. Fan speed and workload are the only plots that show a slight nonparallel line, solidifying the interaction effect.

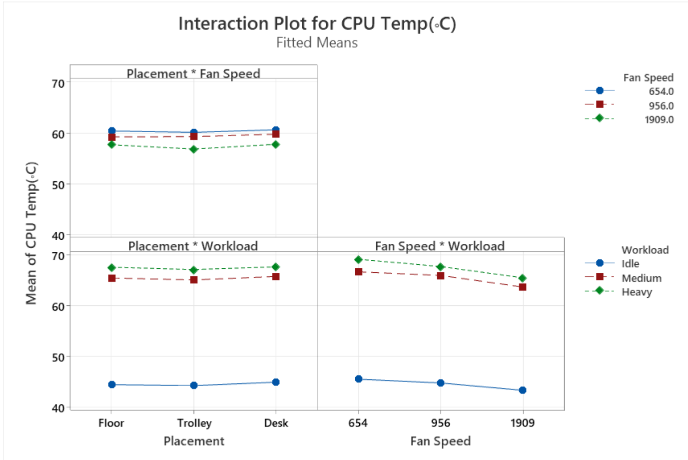

Figure 14. Interaction Plot for CPU Temperature

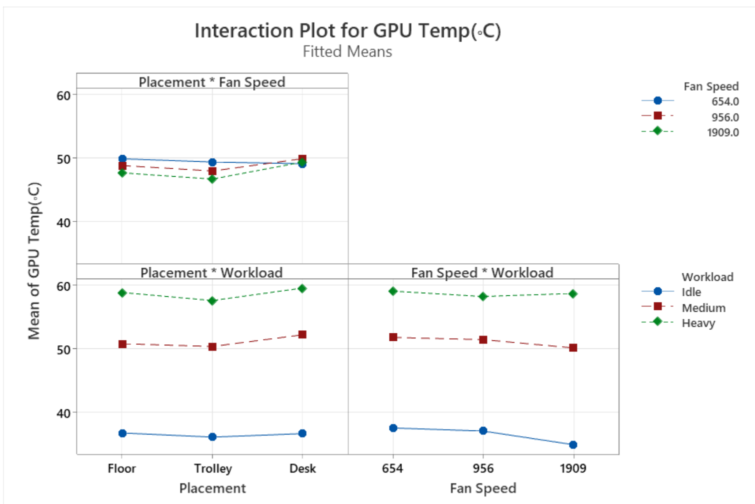

Figure 15. Interaction Plot for GPU Temperature

This plot in Figure 15 shows no intersecting lines among the factors, indicating no major interaction effects on GPU temperature.

5.3 Proposed Improvements and Validation

Based on the statistical analysis, the best operating settings are identified to minimize the temperature while keeping energy consumption constant. The goal was to improve performance without upgrading the part by finding cost-free means to cool the component.

It is recommended to run the fan at max speed under heavy load work as the CPU temperature is reduced by approximately 4–6°C. GPU reduction is about 2–3°C, due to the GPU's internal fan control, which was beyond manual control. If the noise from running the fans at high speed is disturbing, it is fine to set them to mid-level, as the temperature improvement is not significant. Another recommendation is not to run the fan at low speed, even when the PC is idle, as the energy savings are negligible. The trolley will always be recommended at all levels, regardless of fan speed or workload.

New hardware is not necessarily needed to run a cooler, more stable system. Two simple changes, such as turning up the fan and lifting the PC off the floor to improve airflow, can produce real, measurable temperature improvements. This is a practical, low-cost win for enthusiasts looking to extend the lifespan of components and keep their desktop running reliably under pressure.

6. Conclusion

To sum up the experiment, the findings show that fan speed and physical placement affect temperature increases in Hybrid-cooling PC components, specifically the GPU and CPU, while the rest of the components were also operating. The result affirms the expectation that workload is the primary driver of temperature increase and confirms that fan speed provides effective cooling, especially under heavy load.

Physical placement of a PC was also found to have a statistically significant effect on CPU performance. Placing a PC on a trolley with good airflow access can make it run more efficiently. However, the magnitude of its effect is small; it can be the fine line that separates a winner from a loser in a competitive setting like gaming.

Fan speed and workload interaction is the only interaction effect with impact. Proper diagnostics were also performed on the collected data to confirm the PC system's proper behavior.

Overall, both the operating conditions (workload and fan speed) and the environmental conditions (placement) play a role in how smoothly and quickly a PC runs. Simple adjustments, like moving the PC to a better airflow position, can yield improvements without upgrading any parts.

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