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P5 4 The Thermodynamics behind the E-Suite's cooling issues

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Abstract

In this paper we examine the effect that powerful gaming computers have on the temperature of the E-Suite, a room in the David Wilson library at the University of Leicester. We found that, when left on until the room reaches thermal equilibrium with its surroundings, the computers in the E-Suite increase the temperature of the room by 6.48 K, whereas computers in a neighboring room only increase the temperature by 1.76 K.

Introduction

The E-Suite is a room in the David Wilson library at the University of Leicester filled with powerful computers designed to run demanding video games. Students have complained about the high temperatures in this room, claiming that the room becomes uncomfortably hot when multiple computers are used.

This paper will use estimations from Y. Cengel's work on the heat a computer generates, specifically that "the heat dissipation or cooling load of an electronic device is equal to its power consumption" [1], to investigate the effect that several powerful computers has on the temperature of the air in the E-Suite. By comparing this to a neighboring computer with less powerful computers, we will discuss whether the thermal energy from the gaming computers heats up the room significantly or not.

Theory and Method

To understand the effect the gaming computers have on the temperature in the E-Suite, we will compare the room to DW 0.028 - it is adjacent to the E-Suite, uses low power computers and, does not suffer from the temperature issues that the E-Suite does. By estimating the thermal current leaving the rooms, we can calculate an increase in temperature that is directly caused by the computers in the two rooms and compare them.

Estimating the thermal current leaving the room through its walls requires some assumptions. The first assumption is that 100% of the energy from the computers power supply is converted into heat, assumed from Y. Cengel's work on cooling loads [1]. The second assumption is that the surrounding library acts as a cold reservoir, meaning that any heat transferred from our computer rooms to the rest of the library does not change the temperature of the library. Finally, we assume that the two rooms are made of the same materials, such that the walls have the same thermal conductivity.

When the computers are on, they start heating up the room with power P. The total power is calculated by finding the power supply for each computer and monitor and multiplying by the number of computers in the room. As the room then begins to heat up, it starts losing heat through its walls to the colder surroundings as they are no longer in thermal equilibrium. The thermal current I that represents this heat exchange is given by Equation 1 [2]:

$$I = \Delta T / R_{eq} \tag{1}$$

Where ΔT represents the difference in the temperature of the room T_R and the surroundings T_S. R_{eq} is the equivalent thermal resistance of the system, equal to the sum of the inverse thermal resistance for each wall, given by Equations 3 and 4 [2]:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ... \tag{2}$$

$$R_n = |\Delta x_n| / k_n A_n \tag{3}$$

Where x_n is the thickness of the wall, k_n is the thermal conductivity of the wall, and A_n is the area. As the room heats up, the thermal current I out of the room tends towards power from the computers P, where they reach thermal equilibrium – the same amount of heat enters the room as leaves, and the temperature stops increasing. As thermal current and power are measured in Watts, we can calculate the change in temperature ΔT caused by the thermal energy from the computers for both rooms:

$$\Delta T = P R_{eq} \tag{4}$$

Assuming the E-Suite started at the same temperature as the surroundings such that $T_R = T_S$, ΔT represents both the difference in temperature between the room and its surroundings, and the difference in temperature in the room before and after leaving the computers on for enough time for thermal equilibrium to be reached.

Measurements

The thickness and area measurements were taken using a tape measure. The thermal conductivity was assumed from values listed on designingbuildings.co.uk [3] - we don't know the materials used, so we assumed that the wall is dense concrete such that $k = 1.4$ W/mK. For the total output power of the 20 gaming computers, we estimate a power supply of 500 W per computer [4], and add 90W for the power supply of each monitor (list on the monitor itself). Each integrated monitor-computer in DW 0.028 has a 90 W power supply [5], and there are 48 of them.

Room	**E-Suite**	**DW 0.028**
Total Computer Power (W)	11800	4320
Total Walls Area (m^2)	150	195
Walls Thickness (m)	0.15	0.15
Total Ceiling and Floor Area (m^2)	300	450
Ceiling and Floor Thickness (m)	1.0	1.0
Thermal Conductivity (W/mK)	1.4	1.4

Figure 1: Measurements for the E-Suite and DW 0.028 used for this paper.

Results

The calculated temperature difference in the E-Suite is $\Delta T = 6.48$ K and the calculated temperature difference in DW 0.028 is $\Delta T = 1.76$ K.

Conclusion

Our results suggest that gaming computers have a significant effect on the temperature of the ESuite, especially compared to the neighboring computer room DW 0.028 - combined with the heat from people using the computers, is not surprising that students often complain about the heat of the E-Suite, and it is clear that the room requires cooling mechanisms to keep it comfortable and safe for anyone who wants to spend extended periods of time in it.

References

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