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P1_8 Common Room Covid Costs

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Abstract

With Covid in the air, the University of Leicester have maintained a windows open policy to improve airflow. This will lead to an increased cost to heat the buildings. This paper finds the heating bill will rise by ∼4.9 times for the Physics Department common room, costing an extra ≈£5.61 per day to heat in winter.

Introduction

For 2021, The University of Leicester have enforced that the windows remain open across the university. Open wind flow leads to a loss of internal heat and an inflow of fresh air which requires heating. Therefore, the heating bill will increase. This paper estimates the excess energy cost to heat the Physics Department common room for a single day in November.

Method and Results

Windows Closed - To compare the scale of the heating bill to the normal cost, the power required to heat the room with the windows closed is firstly estimated. For this, the dimensions of the room are assumed as: 25m in length, 6m in width and 3m in height with windows which cover a 0.5m opening across a 5m length. These dimensions are illustrated in Figure 1.

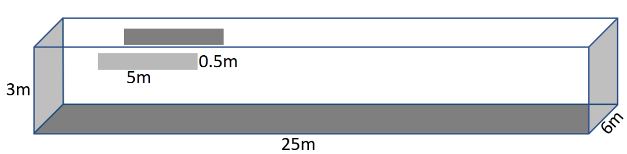

Figure 1: Diagram of the proposed common room dimensions, with internal walls and windows shaded.

For this calculation, the room is treated as being fully enclosed in brick walls, with a depth of 3 bricks. A non-zero heat flow exists through three external walls, where the other internal walls (shaded in Figure 1) are adjacent to rooms of the same temperature. The rate of heat flow is given by Equation 1.

$$\boldsymbol{I} = \frac{dQ}{dT} = -kA\frac{d\boldsymbol{T}}{d\boldsymbol{x}} \quad (1)$$

Where I is the thermal current, $\frac{dQ}{dT}$ is the rate of heat flow, k is thermal conductivity, A is the area over which the heat flows and $\frac{dT}{dx}$ is the thermal gradient over the boundary.

In this case, the thermal conductivity is taken as that of an insulating brick, 0.15 $\mathrm{Wm^{-1}K^{-1}}$ [1]. The temperature gradient (23.26 $\mathrm{K\ m^{-1}}$), is calculated from the internal temperature, assumed to be 25°C, the external temperature, 10°C, [2] and the thickness of 3 bricks, 0.645 m [3]. From the dimensions of the room, there is an exposed area of 300 $\mathrm{m^2}$. These values produce a heat flow rate of 1046.5 W. This must be matched by the energy input from the heating system. If the energy is charged at a cost of 17.2 p $\mathrm{kWh^{-1}}$ [4], the cost across an 8 hour working day will be £1.44.

Windows Open - Now, the scenario with the windows open is considered. The assumption made here is that a light breeze of 5 mph passes through the window 10% of the time; whilst light air flow at 2 mph, accounts for the remaining time [5]. The rate of volume flow of air through the windows can then be found by:

$$\dot{V} = A_{windows}\bar{v} \tag{2}$$

Where $\dot{V}$ is the volume flow rate, $A_{windows}$ is the total area of the windows perpendicular to the wind and $\bar{v}$ is the average wind speed.

The average wind speed is a weight average of the values above, in units of m s^{-1}, this gives 1.296 m s^{-1}. The adjacent area of both sets of windows is found as follows. Figure 2 shows the projection of an open window onto its plane, here the projected length, is given by $L = 0.5\cos(15°)$ where the window opening angle has been estimated at 15°. The exposed height, W, is $0.5 - L$. Hence, the total exposed area, $A_{windows} = W \times$ (5 m) $\times 2$ (two sets of windows). A total exposed area of 0.1704 m^2 was found, giving a volume flow rate of 0.2209 m^3 s^{-1}. This can be converted to a mass flow rate through Eq. (3).

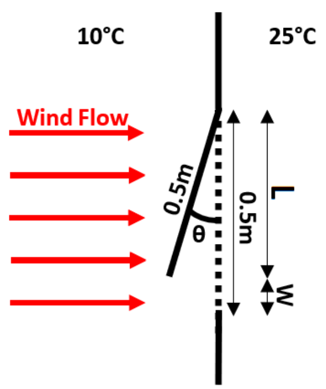

Figure 2: Diagram of the projection of open windows

$$\dot{m} = \rho\dot{V} \tag{3}$$

Where $\dot{m}$ is the mass flow rate and ρ is the density of air. The density of air is assumed to be the typical value of 1.225 kg m^{-3}, giving a mass flow rate of 0.2706 kg s^{-1}.

Finally, the power required to heat an inflow of air at this rate is found by Eq. (4):

$$P = \dot{m}c_P\Delta T \tag{4}$$

Where P is the power, c_P is the specific heat capacity of air at constant pressure and ΔT is the temperature change required.

Here ΔT is 15 K (external to internal temperature) and c_P is assumed to be 1005 J kg^{-1} K^{-1} [6]. This gives a required heating power of 4079 W, translating to a cost per working day of £5.61, again using a price of 17.2 p kWh^{-1} [4].

Conclusion

The additional electricity cost, per 8 hour working day, to heat the common room of the Physics Department with the windows opened, has been estimated at ≈£5.61. This represents an increase of ∼4.9 times. Hence, it can be inferred there will be a notable increase to the University's electricity bill across the 2021/22 academic year as a result of this policy.

References

[1] `http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/thrcn.html` [Accessed 30/11/2021]

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[3] `https://www.designingbuildings.co.uk/wiki/Brick_wall` [Accessed 30/11/2021]

[4] `https://www.gocompare.com/gas-and-electricity/guide/energy-per-kwh/#:~:text=According\%20to\%20the\%20Department\%20for,p\%2FkWh\%20for\%20their\%20electricity.`[Accessed 30/11/2021]

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