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A3_2 Through the fire and flames

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Abstract

In season seven of the popular television series Game of Thrones, a large structure called The Wall is felled by the blue fire of a dragon [1]. In this article we discuss the energy required to melt a hole straight through a wall of dimensions seen in this episode if it was made of pure ice, and how long this would take and whether this form of attack would be viable in a real-world scenario. We assume The Wall to be a similar temperature to a glacier, and the fire emitted by the dragon to be of a circular cross section. We found the energy to melt a hole through the centre of the wall to be $Q = 1.72 \times 10^{13}$ J, which would take a blue-flame-emitting dragon 14.4 days, meaning this form of attack would not be a good approach.

Introduction

In episode seven of the seventh series of Game of Thrones, the dragon Viserion is shown to hover in front of the approximate centre of The Wall - a large structure of ice that runs through the fictional continent of Westeros - and emit a continuous stream of blue flame [2]. We assume the edges of the wall are unaffected and that the dragon is at a constant distance from the surface of the wall aiming at the same area, thus imparting a constant value of heat to the wall. We take the dimensions of the wall to be $l = 482$ km long, $h = 213$ m tall and $w = 91$ m in width [3], and assume the jet of fire to have a circular cross section. We presume a uniform intensity of heat across the flame, meaning we do not need the dragon's distance from The Wall for calculations.

Method

In the clip of Viserion beginning to melt its way through the wall, the diameter of the jet of flame is clearly shown in comparison to the height of the wall [2], which enabled us to approximate a diameter of the jet of fire. The radius is measured to be $r = 13.3$ m. Using this value in the equation for volume of a cylinder

$$V = w\pi r^2. \tag{1}$$

The volume of ice melted is $V = 50500$ m^3. Using this value of volume to give the mass from the equation for density,

$$m = \rho V, \tag{2}$$

where the density of ice is $\rho = 917$ kgm^{-3}, the mass of ice melted by the dragon is found to be $m = 4.64 \times 10^7$ kg. The equation for energy is applied,

$$Q = mc\Delta T + mL, \tag{3}$$

where the temperature difference to raise the temperature of the ice to its melting point is $\Delta T = 9$ K [4], the latent heat of fusion is

$L = 334 \times 10^3$ Jkg^{-1} [5], and the specific heat of water is $c = 4190$ Jkg^{-1}K^{-1} [6]. The energy needed to melt the cylinder of ice is therefore calculated to be $Q = 1.72 \times 10^{13}$ J.

We assume the flame is a blackbody, with power given by the equation [7];

$$P = \epsilon \sigma A T^4, \tag{4}$$

where emissivity, $\epsilon = 1$ as per the laws of a black body, σ is the Stefan-boltzmann constant, A is the area of the flame impacting on the surface, and T is the temperature of a blue flame, 1800 K [8]. The power output of the flame is calculated to be $P = 3.31 \times 10^8$ Js^{-1}. This means that the total energy to melt the cylinder of ice considered above would take 5.20×10^4 s, or 14.4 days, to be emitted.

Conclusion

We can conclude that the scene where this event takes places ignores the physics of a flame melting ice, presumably for dramatic effect. The calculated time-scale would not be realistic as the dragon would more than likely expend its energy in order to remain airborne and emitting a continuous jet of flame. Even if it had managed to sustain itself for long enough, it is likely that some form of defence could have been rallied within 14.4 days to prevent the dragon from getting through. This means we believe this form of attack to be implausible. It may, however, be the case that the dragon's flame is hotter than we have assumed. In our calculations we did not consider the fact that as a hole is bored into a wall, its structural integrity may be affected so, The Wall may have fallen before the dragon had melted a path the whole way through. This could be a point for further study.

References

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