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P2_8 Ciaphas Cain makes a splash

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Abstract

In the novel Ciaphas Cain: The Last Ditch by Sandy Mitchell [1], Ciaphas Cain crashes onto an ice world aboard a transport freighter. We calculate that the heat of the hull, as described in the book, would melt 4.5×10^{11} kg of ice. This large quantity of ice would be sufficient to engulf such a ship, making disembarking afterwards impossible.

Introduction

In the novel Ciaphas Cain: The Last Ditch by Sandy Mitchell [1], the titular hero Commissar Ciaphas Cain crashes onto the ice world of Nusquam Fundumentibus aboard a transport freighter following a failed attempt at atmospheric braking. Following impact, the freighter, called the Fires of Faith, comes to rest on a frozen lake where the heat of the hull following re-entry begins to melt the ice and causes the ship to sink. In this paper we aim to calculate the quantity of ice which would melt as the hull cools, to explore how the events of the book would occur in reality, and whether the ship would sink completely into the ice.

Theory

To calculate the quantity of ice which would melt, we must first find the thermal energy in the hull of the Fires of Faith at impact. To do this we will make some assumptions, based on the test of the novel. First, we are told that the hull is glowing on re-entry[1]. Assuming that the hull is made of steel, this gives it a temperature of around 1000°C[2]. We are not told the size or shape of the Fires of Faith, but we can make some grounded assumptions on this. As this novel is set in the Warhammer 40,000 universe, we can assume the ship is of a similar size to a smaller Imperial Navy warship, as the vessel is large enough to transport Cain and his regiment, but is not a full-sized warship[1]. We will assume therefore that the ship is the same size as a Falchion class escort, which is 2.2 km long and 0.3 km abeam[3]. Given the general design of Imperial ships in Warhammer 40,000 it is not unreasonable to approximate the shape of the ship as a cuboid. The book also tells us that the inner layers of the ship are survivable [1]. Therefore we will assume only the outermost 10% in each dimension are heated to 1000°C. This means the heat energy is contained in a shell of the hull, as shown in figure 1. This means the total heated volume is given by

$$V_{total} - V_{innerhull} = V_{heated}, \quad (1)$$

where V_{total} is the total volume of the ship, $V_{innerhull}$ is the volume which is not heated where the crew hide to survive, and V_{heated} is the heated volume. The final assumption we will make is that the hull will cool to the temperature of the surroundings. We will assume that this is the

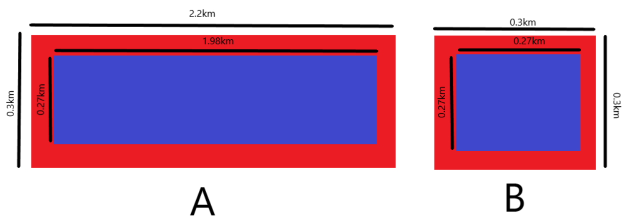

Figure 1: The heated section of the hull of the Fires of Faith. A shows the plan view, and B shows the end-on view

same as the temperature as in the Antarctic, which at coldest is -89.2 °C[4], by assuming the ice is in thermal equilibrium with the air.

Methodology and Results

We can find the energy lost from the hull as it cools using

$$Q = m_{hull} \times C_{steel} \times \Delta T_{steel}, \tag{2}$$

where Q is the emitted energy, m_{hull} is the mass of the outer hull, C_{steel} is the specific heat capacity of Steel, and ΔT_{steel} is the temperature change of the steel as it cools. The mass of the hull, m_{hull} is given by the volume multiplied by the density of steel, ρ_{steel}, which is 8050 kg m^{-3}:

$$(V_{total} - V_{innerhull}) \times \rho_{steel} = m_{hull}, \tag{3}$$

and specific heat capacity of high-carbon steel is 490 Jkg^{-1} K^{-1}[5]. The energy required to melt a mass of ice is given by

$$Q = m_{ice} C_{ice} \Delta T_{ice} + m_{ice} L. \tag{4}$$

The specific heat capacity of ice C_{ice} is 2040 Jkg^{-1} K^{-1}[5], the specific latent heat of fusion L is 3.4×10^5 Jkg^{-1} and the ice will be raised to 0°C before it begins to melt. By equating equations 2 and 3, and substituting in equation 3 for the hull's mass, we can find an equation for the mass of ice:

$$m_{ice} = \frac{(V_{total} - V_{innerhull})\, \rho_{steel} C_{steel} \Delta T_{hull}}{C_{water} \Delta T_{ice} + L}. \tag{5}$$

We can then insert the assumed values, and we find that the heat melts 4.5×10^{11} kg to 2 significant figures.

Conclusion

The calculated quantity of ice which would melt is 4.5×10^{11} kg, which corresponds to a volume of 4.9×10^8 m^3. This is a very large amount of ice, and is several times the volume of the ship in question. Therefore the ship would sink into the lake, and it would be impossible to exit.The crew would simply drown as the meltwater floods the ship. A better estimate could be obtained by considering a temperature gradient across the outer hull, rather than a uniform temperature. It is also worth noting that this study assumes all the heat is used in melting and none is used in evaporation or sublimation. A much improved value could be obtained by including these considerations.

References

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