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Was WALL-E's Fire Extinguisher Adequate For His Space Scene?

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Abstract

This paper investigates Disney's movie *WALL-E* and whether the fire extinguisher he uses had enough carbon dioxide, CO_2, in it, to last for his entire space flight and if not, how many extinguishers he would require and the actual mass of CO_2. The extinguisher used by WALL-E was estimated to contain 2 kg of CO_2. The findings of the paper were that WALL-E's extinguisher was not of adequate size and would have lasted only 16 s of the scene which lasted 105 s. For the completion he would have required 6 further extinguishers, totalling 7. With impurities of an extinguisher considered the actual mass of CO_2 required was calculated to be 13.77 kg and not 14 kg.

Introduction

In Disney's animated movie, *WALL-E*, set in 2105, the Earth has been left uninhabitable, due to the human race neglecting the environment [1]. This results in a spaceship, the Axiom being built which leaves the Earth with the remaining population onboard whilst robots have been left to clean up the planet. Some 700 years later in 2805, the Axiom is still in space having sent the robot, EVE, to Earth to see if it is habitable once again. EVE meets a cleaning robot called WALL-E. They become friends and end up on the axiom with proof that Earth is habitable. Along the way they have some fun and mischief [2].

In one particular scene WALL-E is in an escape pod and accidently initiates self-destruct sequence. Just before the pod explodes WALL-E grabs a fire extinguisher and evacuates from the pod. Now floating in space he uses the fire extinguisher to navigate towards EVE, who has her own propulsion system. The two of them fly together around the Axiom in a romantic scene [3].

This paper will look at whether the fire extinguisher would last the whole length of the flight scene and if not, how many fire extinguishers would be required with the actual mass of CO_2 required also being ascertained.

Previous analysis on this scene has been carried out looking into the motion and forces of WALL-E during the scene and not what this paper will be discussing [4, 5].

Assumptions

- That future advancements of technology for fire extinguishers has not occurred resulting in improved and more efficient extinguishers.
- The extinguisher used is filled with carbon dioxide, CO_2, and it is assumed that the gas is behaving as an ideal gas whose molecules occupy negligible space in comparison to the volume of the extinguisher [6].
- The extinguishers presently made are 99% pure, as a result the quoted mass of CO_2 in an extinguisher is not completely accurate with the mass containing some impurities [7].
- The lack of external pressure in space which would see a pressurized container potentially perforate due to a lack of resistance opposing the internal pressure pushing outwards will be disregarded [8].
- The extinguisher is operating at a temperature of 293.15 Kelvin (K), this is the operating temperature stated on the technical extinguisher sheets. This is due to an extinguisher not operating in space due to the extreme temperature [9, 10].
- The extinguisher will be modelled as a cylinder. Due to the inverse domed bottom and domed top negating one another, forming a cylinder.

- WALL-E used the extinguisher when off screen once he started flying with Eve.
- WALL-E used the extinguisher from the moment the escape pod exploded.
- Each time the extinguisher is used the lever is fully pressed expelling CO_2 at a maximum rate.

Initial Calculations

WALL-E's height is 3'4", 1.016 metres (m) [11]. In the scene it can be seen that the extinguisher is approximately half his height giving the extinguisher a height of approximately 0.508 m.

Presently, a 2 kilogram (kg) CO_2 extinguisher manufactured has a height of 0.531 m, a diameter of 0.111 m, which is the closest sized fire extinguisher to the one used in the scene. This CO_2 fire extinguisher has a discharge time of 16 s, this is the time it would take for all the gas to escape the cylinder if the lever was held down constantly. The extinguisher has an internal pressure of 212 Bar, 2.12×10^7 Pascals (Pa) [10].

From watching the scene from it was estimated that the discharge time of the fire extinguisher was 105 seconds (s) with a breakdown of:

Use Time (s)	Description
2	Inside escape pod
15	From escape pod to EVE
6	Continued use
7	7 bursts approximated to 1 s per burst
4	Aimed at EVE & 3 small bursts
17	Start of flight sequence
56	Main flight sequence
Total discharge time = 105 s	

Table 1 – A table showing the total discharge time of WALL-E's fire extinguisher during his flight scene [3].

Discussion and Further Calculations

The total discharge time WALL-E required from his fire extinguisher was 105 s, as shown in table 1. From the assumption that a 2 kg CO_2 extinguisher was used by WALL-E, with a discharge time of just 16 s it can clearly be seen that the extinguisher would not have lasted. For WALL-E to have completed the flight he would have required 6 and a half extinguishers, as he can't have half an extinguisher it will be proposed he requires 7 of them.

It would be expected that WALL-E would therefore require 14 kg of CO_2 however due to the extinguisher containing impurities, it does not contain a full 2 kg of CO_2. The actual mass of CO_2 required for the scene can be calculated. Firstly, the volume of one extinguisher will be found using [12]:

$$V_{cyclinder} = \pi r^2 h, \qquad (1)$$

where π is a constant with a value of 3.142, r is the radius and h is the height of the cylinder. Using equation 1 and previously stated values the volume of the cylinder is found to be 5.138×10^{-3} m^3. The number of moles of CO_2 inside 1 extinguisher can be calculated using the ideal gas law [13]:

$$PV = nRT. \qquad (2)$$

Equation 2 applies to a perfect gas where P is the pressure in Pascals (Pa), V is the volume in m^3, n is the number of moles, R is the gas constant with of value of 8.31441 J K^{-1} mol^{-1} for CO_2 and T is the temperature in K [14]. Using previous stated values, the number of moles of CO_2 in the extinguisher is found to be 44.69 moles.

The actual mass of CO_2 in an extinguisher can now be calculated using:

$$m = nM, \qquad (3)$$

where m is the mass of CO_2 in g, n is the number of moles of CO_2, 44.69, and M is the molar mass of CO_2, 44.01 g mol^{-1}. Using these values, a mass of 1970 g, or 1.97 kg, is calculated. By multiplying this value by the 7 cylinders required for WALL-E to complete the seen the total mass of CO_2 required is found to be 13.77 kg and not 14 kg as would be expected if impurities are not considered [15, 16].

This mass is found to be 98.4% of the 14 kg, a typical extinguisher is 99% pure and so with number of significant figures being considered this is a reasonable value [7].

Conclusion

If WALL-E would have used the fire extinguisher stated earlier than he would only have been able to complete 15.2% of the space scene. For WALL-E to have completed the space scene he would have required 7 extinguishers and an actual mass of 13.77 kg of CO_2

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