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A2_7 Claiming water from the Moon

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Abstract

This paper looks at how the recently discovered water-ice on the Moon could be employed for use in a long term mission or a more permanent Lunar Base. We find that to create liquid water at least 7.7 x 10^5 J kg^{-1} is needed. The ways of producing this energy requirement through solar panel technology or using the Sun's radiation directly is discussed. We find that the most realistic approach is via solar panels, and that these need only be of modest size (3.4m^2) to supply enough water to support a five-person crew on the Moon.

Introduction

On 13th November 2009 NASA announced that their LCROSS mission had been successful in discovering "significant" quantities of water thrown up by the man-made impacts [1]. It has been found that the energy needed to transport enough water to the Moon from Earth is a factor 10^8 J $person^{-1}$ day^{-1} greater than the energy needed to raise the same quantity of water-ice from the surface of the Moon [2]. The implication, therefore, of the NASA findings is that a mission to the Moon or the creation of a Lunar Base would now be more feasible. This paper aims to look at how the water-ice can be melted and what energies would be needed in order to claim the water-ice from the regolith.

Constants

The specific heat capacity, *c*, of ice is 2.05 kJ kg^{-1} K^{-1} and of water is 4.18 kJ kg^{-1} K^{-1} [3] (these values are assumed to stay constant over the whole change in temperature for the ice/water). The latent heat of fusion, L_f, of the ice to liquid water transition is 333.5 kJ kg^{-1} [3]. 1 AU is taken to be 1.50 x 10^{11} m [3].

Discussion

Assuming that the crater is a simple model of pure water-ice underneath a regolith layer, once the water-ice has been mined we look at ways of converting the ice into useable water.

The ice in the crater is at a temperature of approximately -213 °C [4]. The energy needed to melt the water-ice into liquid water or even into water vapour can be calculated using the equations of specific heat capacity (1) and latent heat (2),

$$Q = mc\Delta T, \tag{1}$$

$$Q = mL_f, \tag{2}$$

where *Q* is the energy produced, *m* is the mass of the water, and *ΔT* is the change in temperature. The total energy needed to melt the ice from its lowest temperature into liquid water is 7.7 x 10^5 J kg^{-1}.

In the future it is possible that a Lunar base will be constructed; the base will need electric power to be successful, which could be created through the use of solar panels. The electricity created by the panels could also be used to melt the ice. There are many types and sizes of solar panels available but here we take the example of the solar panel array used on the Hubble Space Telescope which converts the Sun's energy in to 2,800 W of power [5]. The total power supplied by one such array divided by the energy required to melt the ice gives a melting rate of 3.6 x 10^{-3} kg s^{-1} or 13.1 kg $hour^{-1}$. However, these rates have been calculated on the assumption that the power generated incurs no losses during transfer from the panel to a heat generating device and that all the power created would be allocated to just melting the ice, which of course would not be true in reality.

Another way that the melting could be achieved is by placing block of ice directly in the Sun's radiation and allowing the energy to melt it. The power output, P_{out}, of the Sun is accepted to be 3.839 x 10^{26} W [6]. At a radius, *r*, of 1 AU (the mean Earth-Sun distance, here is also taken to be the mean Moon-Sun distance for simplicity) the mean power, P_s, that falls on the surface is calculated using

$$P_s = P_{out}/4\pi r^2, \tag{3}$$

is 1.4 x 10^3 J s^{-1} m^{-2}. Using the Sun's natural power output it is possible to acquire enough energy to melt the ice at a rate of 1.8 x 10^{-3} kg s^{-1} m^{-2}. However, as the Moon holds no atmosphere, we suggest that a dome formed of a material such as acrylic could hold an atmosphere-like environment, which would encourage thermal retention allowing the ice to melt. Liquid water could then drain away into storage tanks below and the inner surface of the dome would catch any water molecules that had acquired enough energy to be converted to water vapour.

Now we consider the total power output needed to mine the ice and melt it over the course of an example six month mission, or 1.58 x 10^7 s, with a five-person crew. It has been found that 21.7 x 10^3 J is needed to mine 5110 kg of ice, which is sufficient for this example mission [2]. To melt 5110 kg of ice, using the earlier result from (1) and (2) we find that 1.27 x 10^{10} J are needed. Therefore, the total energy needed to mine and melt the ice is approximately 1.27 x 10^{10} J. Dividing this by the power output of a single Hubble-type solar panel, we find the time that it would take to extract and melt this ice is 4.54 x 10^6 s.

Dividing the total energy needed by the length of the mission gives a necessary continuous power output of 249 W in order to melt 5110 kg of ice over the mission duration. Assuming that the power output of the solar panel is directly proportional to its area, where the area of a Hubble-type solar panel is 19 m^2 [7], using the ratio of the power output and the necessary continuous power, the area of a Hubble-type solar panel needed to melt the ice over the course of the mission is 1.69 m^2. Similarly, using the result from (3) we find the area needed using the power output of the Sun falling on the surface (assuming the Sun's output incurs no losses) is 0.18 m^2. This is 89% more efficient than using a Hubble-type solar panel (for an idealised situation). However, one further consideration is required. The solar panel will only be in the Sun's light for approximately half the Moon's orbit, so in order to acquire the necessary power output we simply double the areas we have calculated. Thus we would require a solar panel of 3.4m^2.

Conclusion

We have discussed two methods of melting the ice. We appreciate that using the Sun's power output to directly melt the ice has been treated in an idealised and simplistic manner and may not reflect a realistic measure of its true capabilities. This is especially true since ice has a high albedo (the ratio of reflected to incident light), thus a large proportion of the Sun's energy would be reflected rather than absorbed. However, we have also demonstrated that a relatively modest sized solar panel is sufficient to provide the energy required to melt the ice at a rate that could support a five person crew on a Lunar base. An advantage of solar panels over direct solar absorption is the ability to channel the energy and maximise its use; for example, using metal heating rods implanted into an ice block. We also appreciate that we have used a simplified model of the Lunar surface, whereas in reality water-ice will be combined with the rest of the material that composes the Lunar surface, which could cause difficulties in the aforementioned methods of claiming water. Once the true ratio of the composition of the surface is known further research could be conducted into refining a method to claim the needed water.

References

[1]*http://www.nasa.gov/mission_pages/LCROSS/main/prelim_water_results.html*

[2] Rolfe *et al*. (2009). Water on the Moon: an energy comparison. *Journal of Special Topics*

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[4]*http://www.nasa.gov/mission_pages/LCROSS/FAQs/index.html*

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[6] Carroll, Bradley W.; Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, Pearson Addison-Wesley, pp. Appendix A

[7] *http://hubblesite.org/the_telescope/hand-held_hubble/the_real_thing.php*