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GAS GUN FOR LAUNCHING RAW MATERIALS FROM THE LUNAR SURFACE; Allan M. Russell, Hobart and William Smith Colleges, Geneva, New York 14456.

A number of space manufacturing programs that have been suggested require transportation of large amounts of raw materials from the lunar surface to a processing or fabrication site in free space. While rockets could, of course, be used for this purpose they require the consumption of large amounts of fuel which must be supplied from earth, a requirement that is prohibitively expensive.

Various transportation systems have been suggested that minimize the amount of mass that must be used for propulsion, by converting available energy directly into motive power. An electrical catapult or transport linear accelerator (TLA) was proposed by Clarke (1) and later by O'Neill (2). This would accelerate small payloads to lunar escape velocity by means of electrical energy. Another electrical launching device called an Electropult was developed by Westinghouse Corporation during the second world war for the purpose of launching planes from ships (3). The main difficulty with such devices is their inherent low efficiency and low power to mass ratio. O'Neill has considerably improved recent designs through the use of super-conducting technology. However, electrical catapults continue to have large mass requirements and suffer from losses due to a need to decelerate sophis-ticated conveyer buckets. This paper describes an alternative system that uses gas propulsion.

The lunar escape velocity of 2370 ms^{-1} can be attained by a single stage light gas gun that operates with hydrogen gas. Light gas guns have been used on ballistic ranges for a number of years and have launched pro-jectiles at speeds of up to 11,000 ms^{-1}, almost five times the lunar escape velocity (4).

Application of the equations governing the behavior of hypersonic pro-jectiles in uniform cylindrical barrels leads to one equation relating the mass of the barrel to the barrel material and the speed and mass of the projectile, and another equation relating the length of the barrel to the bore radius, the gas pressure, and the mass of the projectile.

$$M = 5.22 \frac{\rho}{\sigma} V^2 m \qquad \text{and} \qquad L = 4.67 \times 10^6 \frac{m}{R^2 P}$$

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where M is the mass of the barrel in tonnes
V is the muzzle velocity in ms^{-1}
ρ is the density of the barrel material $kg\ m^{-3}$
σ is the tensile strength of the barrel material in $N\ m^{-2}$
L is the length of the barrel in m
R is the bore radius in m
P is the gas pressure in the reservoir in $N\ m^{-2}$
m is the projectile mass in kg.
The constants are for hydrogen gas at 200°C

For a high strength composite material, i.e. a boron or graphite epoxy such as PRD-49 with $\rho = 1.38 \times 10^3$ and $\sigma = 1.65 \times 10^9$

$$M = 24.5\ m.\ \text{(at lunar escape velocity)}$$

One could imagine, therefore, a 245 tonne gas gun of barrel diameter 2 meters and length 234 meters, launching a 10 tonne projectile using hydrogen gas in a reservoir at $2 \times 10^8\ N\ m^{-2}$ (2 k bar). The gas would not be allowed to escape, but would be recompressed and stored at high pressure. If a nuclear reactor were the energy source, it could be used to drive the compressor directly without the need to generate electrical energy, a considerable saving in mass.

A nuclear power source (without shielding) and compressor that would be required to operate such a gun every half hour are estimated to have a mass of about 600 tonnes. With 10% of the mass of the system budgeted for auxiliary equipment, and if it is assumed that the gas is stored at high pressure below the lunar surface, the total mass approaches 1000 tonnes. Estimates of the mass of an electrical launching system of the same capacity run as high as three times this.

References

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