VULCAN II

Recovery Dynamics Calculations

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Parachute Sizing Calculations

The parachute equation was used to determine the terminal velocity of the entire rocket at the position when each parachute is deployed. The equation uses weight W of the entire rocket and parachutes, air density ρ which varies with altitude, coefficient of drag of the parachute C_{Do}, and surface area of the chute S_c.

$$v = \sqrt{\frac{2W}{\rho C_{Do} S_c}}$$

The objective here is to find chute sizes to decrease the velocity of the entire rocket under 20 ft/s.

Drogue

The drogue parachute is 42 inch in diameter where its surface area was determined from the simple equation $\pi D^2/4$. This will give the rocket terminal velocity of 26.82 m/s at 2000 m above sea level before the main chute is deployed.

Main Parachute

The main parachute is 192 inches in diameter. This will give the rocket terminal velocity of 5.61 m/s at 1000 m above sea level when the main chute is fully deployed.

Opening Shock Load

The structural integrity of the load bearing part of the rocket is crucial to a safe descent. The greatest force on the structure is when the primary parachute deploys and undergoes its transition from packaged to fully deployed. The force on the system in this entire phase is known as the parachute opening shock force.

The following equations used to calculate opening shock load are the impulse equation

$$F\Delta t = p$$

And the equation for momentum

$$p = m\Delta v$$

Given the dry mass of the rocket was estimated 65kg, the terminal velocity with the drogue deployed is 20 m/s, and terminal velocity with the primary deployed is 5 m/s, we have the following derivation:

$$p = m\Delta v$$

$$p = m\Delta v \Rightarrow p = 65\ kg * (20 - 5)\ m/s = 975\ N$$

The rough estimation time for unfurling is 0.2 sec. So inputting the number gives:

$$F\Delta t = p \Rightarrow F * 0.2 = 975;$$

$$F = \frac{975}{.2} = 4875\ N \approx 1100\ lbf$$

The entire system of lines of the parachute itself is rated to 6000 lbf. So in the scenario where the bolts and threading are arbitrarily strong, then the lowest Δt the lines are able to withstand is 0.037 sec.

Black Powder

In order to the first of stage of the recovery system, the recovery bay should be pressurized to 15 psi. At this pressure, the shear pins should break and the drogue parachute should deploy.

To calculate the amount of black powder to achieve the required pressure, the ideal gas law equation was used.

$$N = PV/RT$$

The effective volume of the recovery bay with the parachutes inside was calculated as 351.66 in^3. The universal gas constant for the black powder was given as 266 in lbf / lbm. The combustion temperature for the black powder is 3307.

Given these values the amount of black powder needed 2.722 g which will provide a force of 684.95 lbf on the nose-cone.

Shear pins

Each 4-40 nylon 1 inch shear pin can hold 35 lbf in shear. There are three shear pins holding the nose-cone totaling 105 lbf. Thus the blast from the black powder, which is 684.95 lbf, should very easily break these pins.