The parachute deployment system on all high power rockets should be ground tested before the rocket is flown for the first time! This means estimating how much ejection charge is needed and then trying it out while the rocket is still safe and sound on the ground. This seems really obvious but I have seen many people skip this step and end up having serious damage done to their rocket when the recovery system failed. Of course I have also seen some folks use way too much black powder too! I guess those particular rockets were doomed to be blown apart anyway, be it on the ground or in the air!

I also feel that the ground test should be done with the rocket configured the same way as it will be for flight. I pack the parachute and recovery harness exactly the same as I would for launch. The amount of black powder can then be adjusted until the desired forcefulness of the separation is achieved. I tend to go for a "reasonably forceful ejection" but not so much that parts translate across the ground to the end of the recovery harness. I don't really have a good way to quantify it, but I would rather error on the side of slightly too strong rather than slightly too weak.

As a starting point for the ground test I use the chart below to estimate how many grams of black powder are likely to be needed. This is just an estimate! I'll get to the details later, but for now let me say this table assumes 15 psi for body tubes 5.38 inches or less in diameter. It assumes 350 pounds of separation force for body tubes larger than 5.38 inches. Remember this table is for generating an initial estimate. "Your mileage may vary." Many factors will influence the situation. Ground test it!

Body Tube Inside Diameter	Estimated Ejection Charge Size
1.53 inch	0.5 grams per 36 inches of length
2.15 inch	1 gram per 36 inches of length
2.56 inch	1 gram per 25 inches of length
3.00 inch	1 gram per 18 inches of length
3.90 inch	1 gram per 11 inches of length
5.38 inch	1 gram per 6 inches of length
6.00 inch	1 gram per 6 inches of length
7.51 inch	1 gram per 6 inches of length

Example: For a rocket with a body tube that is 5.38 inches across the inside diameter, my table tells me to use 1 gram per 6 inches of length. So if the compartment being pressurized is 24 inches long, I will need about 24/6 = 4 grams of black powder.

Actual Charge Sizes

Just for comparison, this next table shows the estimated values and the actual values I use for specific rockets.

Rocket Name	Tube ID	Tube Len	Estimated Charge Size	Actual Charge Size	Percent Difference
Wildfire	5.38"	25.9"	4.3 g	4.5 g	+4.7%
Vulcan	5.38"	24.0"	4.0 g	4.5 g	+12.5%

Scorpion Main	4.00"	20.3"	1.8 g	4.0 g	+122%
Scorpion Drogue	4.00"	17.5"	1.6 g	3.5 g	+118%
Nike Dart	2.56"	21.5"	1.2 g	1.5 g	+25%

From this table I can see that in every case the size of the ejection charge I selected based on ground testing was larger than the initial estimate. However, for most of these rockets the estimate is pretty close. On the other hand, the Scorpion required far more black powder than the estimate. This is due to several factors. One is the special nose cone retention system for the main chute and also the shear pins for the drogue chute. Scorpion also needed extra black powder because the parachute compartments have very limited space and both parachutes are packed into the airframe "very snuggly". The extra ejection charge is needed to ensure a good forceful ejection of these parachutes.

Derivation of Table for Estimated Ejection Charge Size

First we assume the entire mass of the ejection charge is burned and converted to a gas. Next from basic chemistry we use the ideal gas law equation:

$$PV = NRT$$

The constants for 4F black powder are:

R = 266 in-lbf/lbm
T = 3307 degrees R (combustion temp)
P = pressure in psi
V = volume in cubic inches = pi*(**D**/2)^2**L**
N = mass in pounds. (Note: 454 gm/lb)

A good rule-of-thumb is to generally design for 15 psi pressure. If this is used as the design goal, then the ideal gas equation reduces to:

$$N = 0.006 * D^2 L \quad \text{(grams)}$$

where **D** is the diameter in inches and **L** is the length in inches of the compartment in the rocket that is to be pressurized. **N** is the size of the ejection charge in grams.

However, on large diameter rockets, 15 psi will probably generate too much force! For example, a 7.5-inch diameter rocket has 44 square inches of area on the end of it so 15 psi would produce over 15*44 = 660 pounds of force!!

The amount of force needed for a large rocket is going to depend on a great many factors, but a reasonable limit is probably some where around 300-350 pounds. This is the same amount of force generated in a 5.5-inch rocket at 15 psi.

We can refine our equations for large rockets by adding a limit on the force that is to be generated. The force **F** (in pounds) is given by:

$$F = PA$$

where **P** is the pressure in psi and **A** is the area in square inches. Since **A** = pi*(**D**/2)^2 we can combine this equation with the ideal gas law equation to get:

$$N = 0.00052*FL \text{ (grams)}$$

This last equation tells us how many grams **N** of ejection charge to use to generate a specified force **F** in pounds for a given length **L** of pressurized compartment. What is interesting about this equation is that the diameter **D** is not present. It means that for large rockets the ejection charge size does not need to increase with body tube diameter.

Using these equations I created a handy reference table for various body tube diameters. That table is the one listed above.