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Sky Rocket Performance Characteristics

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Over the years, we have occasionally had the opportunity to conduct brief studies of fireworks rockets, both sky rockets and smaller bottle rockets. Most recently, an investigation was performed using some Horse Brand sky rockets (Glitterous Lights, Clustering Bees, and Flying Butterflies). This short article is written in the belief that a summary of those results may be of general interest.

In our experience, much of what is reported here for the Horse Brand sky rockets, also applies to other brands of non-whistling sky rockets, and in a general way to smaller rockets. However, since not all brands and types of rockets were investigated, there can be no guarantee the results reported here are universally applicable. Further, there is no guarantee that these exact results even apply to different production lots of Horse Brand rockets.

The approximate characteristics of these rockets are as follows:

- Initial mass, 18 g (0.65 oz)
- Overall length, 400 mm (16 in.)
- Motor outside diameter, 15 mm (0.62 in.)
- Motor length, 70 mm (2.8 in.)
- Propellant mass, 4 g (0.15 oz)
- Motor burn time, approximately 3 s
- Heading mass, 3 g (0.11 oz)

In one series of measurements, thrust profiles were determined for these rocket motors. Figure 1 is a typical graph of propulsive force as a function of time (i.e., a thrust profile). These data were produced using a piezoelectric force transducer to sense the thrust of the rocket motor, and a digital oscilloscope to record the data.

It should be noted that the duration of significant thrust is much less than the total burn time of the motor. Thus, after the initial high thrust phase of the burning (approximately 0.2 s), the rocket is in a coasting mode for approximately 3 seconds.

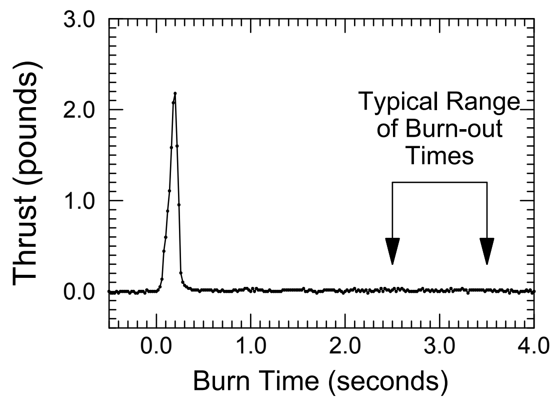

Figure 1. Typical thrust profile of a Horse Brand sky rocket.

Just how little thrust is produced during this coasting phase, can be seen in Figure 1, where the typical range of times until motor burnout is indicated. A relatively short, high thrust phase such as this is common for the non-whistling rockets that we have investigated to date.

Figure 2 is a typical graph of the speed of a sky rocket as a function of distance traveled. This data was collected by monitoring the flight of rockets flown horizontally on a distance calibrated flight range. To accomplish this, two video cameras were used. The first camera viewed the flight of the rockets from their approximate point of origin, to confirm that their flight path did not deviate significantly from their initial alignment down the flight range. The second camera viewed the rocket from a point 200 feet from, and perpendicular to, the flight range. This camera recorded the progress of the rocket along the flight range each 1/60th second, and allowed calculation of the rocket's speed along its path.

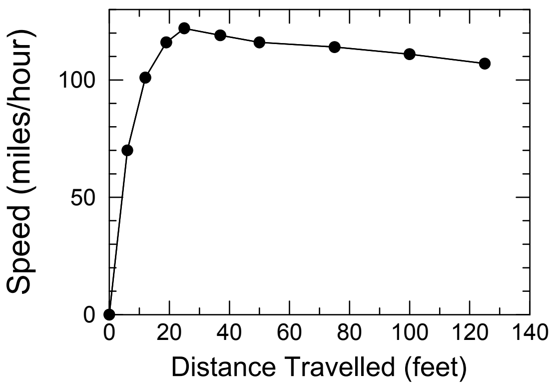

Figure 2. Typical graph of the speed of a Horse Brand sky rocket as a function of distance traveled.

In Figure 2, note the obvious ramification of the short thrust phase, specifically that the rocket's maximum speed is reached very early in its flight. In the data shown, the rocket's speed has peaked after only traveling approximately 25 feet down range. Thereafter, the rocket is mostly coasting, and its speed decreases.

As a result of data such as that illustrated in Figures 1 and 2, some safety related conclusions can be drawn. In the discussion to follow, unless otherwise stated, it will be assumed that the subject sky rocket is reasonably well designed, is fired according to instructions, and does not suffer a significant malfunction.

That high velocities are reached very early in its flight has positive ramifications regarding stable and safely-oriented flight. This is because it is during the initial, low speed portion of a rocket's flight that it is least stable and most susceptible to becoming reoriented from its intended direction. For that reason, external guidance such as a "wooden trough or iron pipe at a 75° angle" is required. Thus, if the rocket quickly reaches at least a modest speed, the distance through which such guidance is necessary, is reduced, and safety is enhanced.

That essentially all of the rocket's propulsive energy is expended during the first 0.2 second has another positive safety ramification. For example, were the rocket to become seriously reoriented any time after the first 0.2 seconds (≈30 feet) of its flight, there is insufficient means for the rocket to propel itself away from its current path. That is to say, the rocket will tend to continue with the velocity (speed and direction) it assumes during the reorienting event. In other words, after the reorienting event, the rocket will not be capable of dangerously accelerating in an unsafe direction.

One type of event with the potential for reorientation could be a collision with a massive object. For example, consider a hypothetical case of a rocket colliding with a wall or tree trunk, causing it to be completely stopped but now aimed in the direction of the person that fired it. If this collision occurs after the rocket has traveled approximately 30 feet, the rocket must fall essentially vertically to the ground because no propulsive energy remains. It definitely does not have the ability to return and injure the person that ignited it.

On the other hand, that the rocket quickly reaches a particularly high speed, and thereafter merely coasts to reach its peak altitude, can have negative safety ramifications as well. One such example would be in the case of misuse, where a rocket is launched in the direction of people. In that case, were it to impact a person, the rocket could potentially be traveling with dangerously high energy. In Figure 2, the speed peaked at over 120 miles per hour. (In another test, a speed in excess of 150 miles per hour was recorded) Given the likely mass of the rocket at that point in its flight [15 g (10.54 oz)], this amount of energy upon impact is roughly equivalent to that of a two-pound weight falling from a distance of 11 feet. This is approximately the energy of a hammer falling off the top of a tall step ladder onto one's toe. [Most unfortunately, there was a recent fatality of a child resulting from such a rocket impact to the temple of her head.] If the rocket motors were redesigned slightly, such that the initial velocity was a little less, and the duration of thrust was longer, such accidents could be made less severe.

One way in which peak rocket speed could be reduced, without significantly altering the height it reaches, is shown in Figure 3. This can be accomplished simply by using a motor core that is less deep. Figure 3 illustrates how this would be accomplished and is apparently the method used in the older "Sky Bloom" rockets from West Lake Brand. Figure 4 is the thrust profile of a typical Sky Bloom rocket. (Note that the peak thrust is about 30% less, and its duration is longer.)

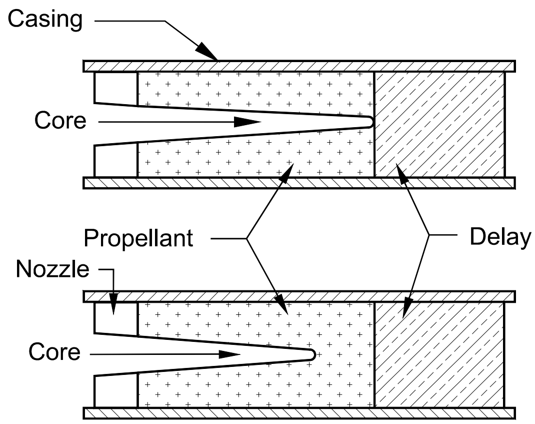

Figure 3. Rocket motors with varying core length.

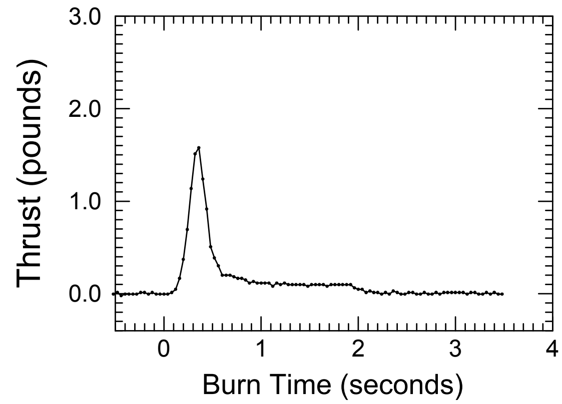

Figure 4. Typical thrust profile of a Sky Bloom rocket.

Obviously, this brief article has not exhausted the subject of sky rocket performance and safety. However, hopefully, it has presented useful information.

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