

I S S U E 1 3 1 , S E P T 2 0 , 2 0 0 4

APOGEE

PEAK OF FLIGHT

N E W S L E T T E R

**SKY CAPTAIN and the
WORLD of TOMORROW**
www.SKYCAPTAIN.com

Feature Article

Rocket Engine Classification System Explained

Sky Captain and The World of Tomorrow
In Movie Theaters September 17, 2004

APOGEE
COMPONENTS

1130 Elkton Drive, Suite A
Colorado Springs, Colorado 80907 USA
www.ApogeeRockets.com email: orders@ApogeeRockets.com
phone: 719-535-9335 fax: 719-534-9050

Model Rocket Motor Classification System

By Tim Van Milligan

Editor's Note: This issue's article is an abbreviated version of the chapter in the book "Model Rocket Propulsion." You'll find a lot more information about rocket motors in that book, and I recommend it to all modelers.

Through your own experiences, you know that there are a variety of sizes and types of rocket motors. How can we tell them apart and compare them with each other?

A comparison can be made based on the coding system that is printed on each rocket engine. This simple classification system not only allows us to distinguish one motor from another, but it also tells us some basic information about the motor - which can be used to help us select the proper motor for our rockets.

The *power* of the motor makes a very convenient way to begin the classification of the rocket motor, so it will be described first. The power of the motor is called "*total impulse*." An *impulse* is the product of "force" and the "time" over which the force is applied. The total impulse is then the product of the force and the duration over which it was applied. In rocketry, the force is the "thrust" produced by the motor, and the time is the duration over which the rocket motor is producing thrust.

To explain this concept, a number of examples will be used. Suppose a rocket motor produces 10 Newtons of thrust force for one second. A graphical representation is shown in figure 1.

So the total impulse of the rocket motor is:

$$I_T = \text{Thrust} \times \text{time} = (10\text{N}) \times (1\text{s})$$

$$I_T = 10 \text{ N-s}$$

This is the impulse of the rocket motor for that one second. If we assume that all the propellant was consumed during that one second, we would say that the total impulse (I_T) that the motor could produce is 10 Newton-seconds. As can be seen from the graph, the total impulse is equal to the area enclosed by the box. It doesn't matter the shape of the graph, the total impulse is always equal to the area under the

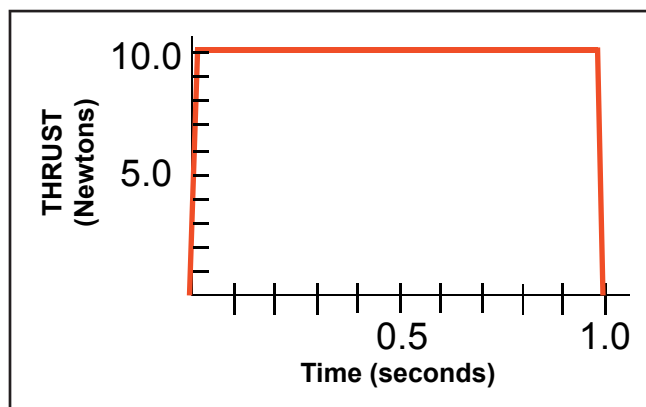


Figure 1: A simplified thrust curve.

"curve."

Because the total impulse is the area under the curve of the graph, the amount of thrust that the rocket creates during its burn doesn't really matter when designating the "power" of the rocket. So a rocket motor that has a thrust of 20 newtons for a duration of 0.5 seconds has the same amount of power as a motor that produces 10 newtons of thrust for 1.0 seconds (10 Newton-seconds).

Because the total impulse of the motor is not dependant on the way the propellant burns, the level of thrust produced, nor even the type of propellant burned, you can easily see that it is a useful indicator that can be used to compare different rocket motors. If one motor has a higher total impulse than another, it is said to have "more power."

The usefulness of the total impulse number has led to a simple way of classifying model rocket motors (professional rockets, like the space shuttle are not classified this way). Since the early 1960's rocket motors have been classified by a specific range of their total impulse. The arbitrary value of 2.50 Newton-seconds has been defined as an "A" motor. Progressing upwards in power level, a "B" motor has double the power of the "A" motor, so it has been set a 5.00 Newton-

Continued on Page 3

About this Newsletter

You can subscribe "FREE" to receive this e-zine at the Apogee Components web site (www.ApogeeRockets.com), or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

Motor Classification System

Continued From Page 2

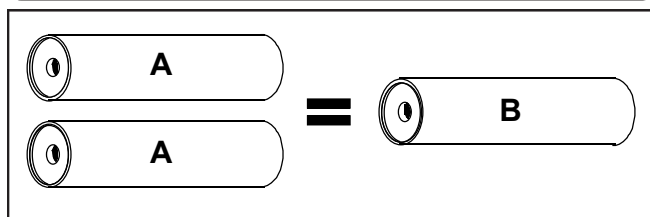


Figure 2: The “B” size motor has twice the power as an “A” size motor, even though the case size may be the same.

seconds. So to increase to the next power level, we simply double the total impulse of the previous motor classification.

The classification has been set at “maximum” values for total impulse. This means that a “B” motor may have a maximum total impulse of 5.00 Newton-seconds. If it was measured with a thrust stand as 5.01 Newton-seconds, it would be classified as a “C” motor.

Below, shown in Table 1, is a chart showing the rocket classification, and the total impulse the motor produces.

This chart can be extended as far as needed to classify

Code	Newton Seconds
1/4A	0 - .625
1/2A	.626-1.25
A	1.26-2.50
B	2.51-5.00
C	5.01-10.00
D	10.01-20.00
E	20.01-40.00
F	40.01-80.00
G	80.01-160.00
H	161.01-320.00
I	320.01-640.00

Table 1: Model Rocket Motor total impulse Classification System

even larger engines. The system of classification has been based on metric units. If values for a particular motor are in English units, you can convert to units (pounds of thrust) by remembering that one pound equals 4.4 Newtons.

All model rocket engines have a designation code printed on them that gives you some specific information about how the engine operates. For example, the designation code on the engine of “C6-5” tells it apart from one that is labeled

“B4-4.”

The first *letter* in the designation code tells you the power level in the engine. This was explained above. This letter will help you choose an engine for your rocket by giving you a relative altitude between two engines. For example, a “C” engine will lift a model approximately twice as high as a “B” engine, because it has twice the amount of power available. Similarly, the “C” motor will fly approximately four times higher than an “A” engine, because it has about 4 times the power of an “A” motor.

If there is a “fraction” in front of the letter, it indicates

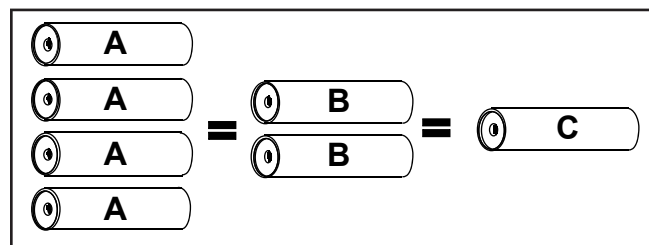


Figure 3: The “C” size motor has the same total power as four “A” size motors, or two “B” size motors. This means a rocket powered by a “C” motor will fly about four times as high as the same rocket with an “A” motor in it.

that the motor has that fraction of power of the “A” motor. For example, an “1/2A” motor has half the total power of an “A” motor. Thus a “1/4A” motor has a quarter of the power of an “A” motor.

The first number in the code (after the letter) tells you the average thrust produced by the engine. This level is expressed in Newtons. This number gives us a very general indication of the shape of the thrust curve of the motor. For example, a

Continued on Page 4

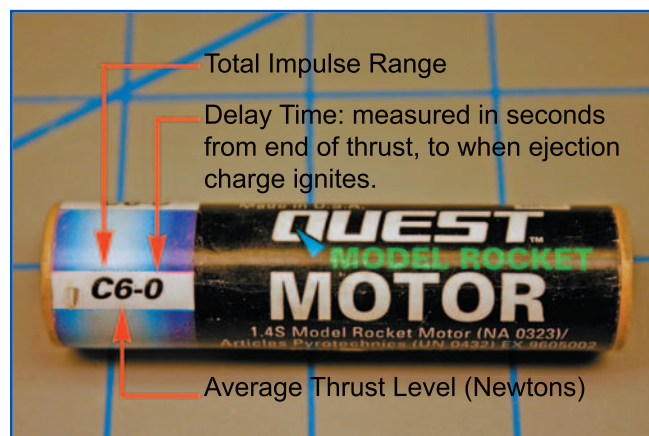


Figure 4: Every rocket motor is labeled with the “motor classification system,” like this one.

Motor Classification System

Continued From Page 3

"E15" engine produces an average of 15 Newtons of thrust over its burn time.

Compare this graph with a "E6" rocket motor. Even though both motors have the same power and should fly roughly to the same height, the "E15" motor produces more thrust, but has a very short burn time compared to the "E6" motor.

Why have a motor that produces less thrust? There are a

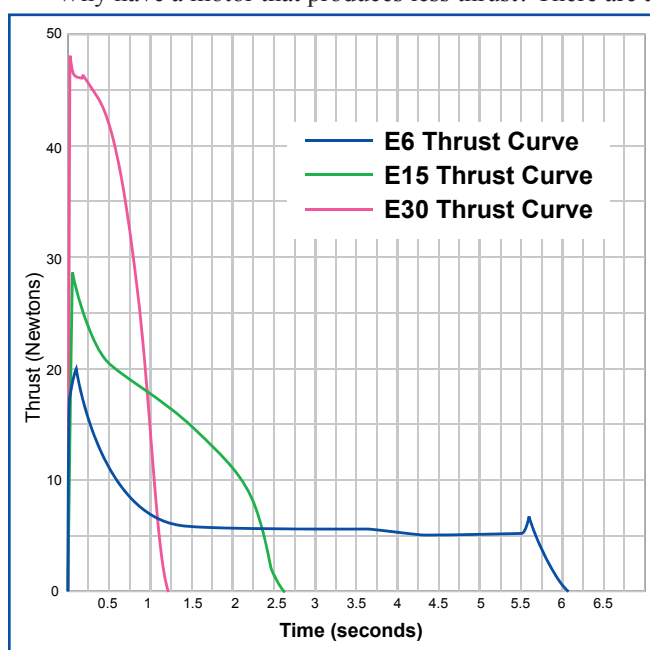


Figure 5: Thrust curves for Low [E6], Medium [E15], and High [E30] thrust rocket motors. While all these motors have the same power, they each have unique applications.

couple of reasons. First if your model is not built to withstand an average of 15 Newtons of thrust, then it may be ripped apart when launched. For models that are fragile, like rocket boosted gliders, it is better to use a rocket motor that has a lower thrust level. But, on the other hand, heavy rockets may not fly fast enough with a low thrust motor to be stable when launched. For these models, you want a high average thrust to help lift the model quickly to sufficient speed where the fins become effective in controlling the flight path of the rocket.

Another reason to have a low thrust model is to give slow flight speeds, which makes it easier to follow the rocket — especially if you are trying to track how high the rocket flew.

Finally, a lower thrust rocket will actually fly higher through the atmosphere than a high thrust rocket motor (of equal total impulse). Why is this true? Because the drag force increase four times for a doubling of the speed of the model. So a model that flies twice as fast will have four times the drag, and thus will not be able to coast as high as a model that flies slow and steady.

Finding Average Thrust

The average thrust is found by taking the total impulse that the motor produces divided by the time which the motor produces thrust. Thus a motor that has a total impulse of 10 Newton-seconds and burns for 2 seconds would have an average thrust of five newtons ($10 \div 2 = 5$). If the same motor burned in 1.67 seconds, it would have an average thrust of 6 newtons.

The *last number* in the designation code (after the "dash") is the time (in seconds) between propellant burns out and when the ejection charge fires. A "C6-5" rocket motor

Continued on Page 5

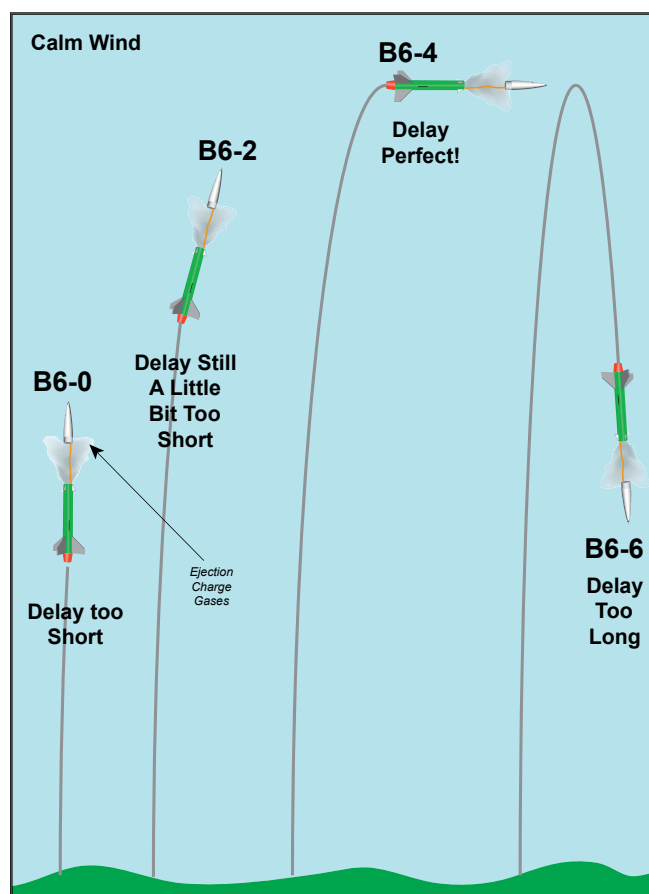


Figure 6: Picking the delay is important too!

Motor Classification System

Continued From Page 4

has a five second delay after the thrust portion of the flight ends, and then the ejection charge fires to push the parachute out of the rocket.

It is optimum to select a delay time that will eject the parachute when the rocket is traveling at its slowest speed. This occurs when the rocket is at the highest point in its flight (the highest point is called the “apogee”). Why at this point? Because if the model is traveling fast when the parachute opens, the forces on the parachute could rip it apart. This would result in the model coming down to earth at a very high speed.

The chart in Figure 6 shows where in the flight path the parachute would be ejected if different delay times are used.

As you can imagine, the delay time must be chosen very carefully. Too soon, or too late, and the recovery system may be stripped from the model. The delay you pick depends on the mass of the model, how much drag it will produce, the angle at which the model is launched, and how stable the model is. It is very difficult to accurately determine the delay needed without performing at least a computer simulation for the model's flight. I always recommend running a RockSim computer simulation. It tells you incredible amounts of information about the rocket's flight.

Finally, the classification code for each motor can also tell us approximately how long the motor burns. The burn time for each motor is equal to the total impulse of the motor divided by its average thrust level:

$$t_b = I_t / T_{avg}$$

So to determine the burn time of a B2 motor, we simply divide the total impulse of the motor (B motors have 5 N-s of total impulse) by the average thrust of 2 newtons. The result is a burn time of $5 \div 2 = 2.5$ seconds. If there is a slight difference between this number and the actual burn time, it is a result of the manufacturer “rounding” the average thrust of the motor. In this case, the actual average thrust for a B2 is 1.7 Newtons, which has been rounded up to 2 Newtons. Using the actual time would result in the burn time of 3 seconds (the correct value). Likewise, if the actual total impulse of the motor is less than the given value (i.e., a C motor having 9 Newton-seconds of total impulse instead of 10), then the calculated burn time can also be slightly off the actual measured value.

Conclusion

Knowing how model rocket motors are classified, we

can now compare the performance capabilities of various propellants used in different rocket motors. This is an exercise that will be performed in chapter 8 of the book *Model Rocket Propulsion*. Keep one thing in mind as you go through these calculations: for NAR contest certified rocket motors, the manufacturer must keep their total impulse below the maximum allowable for that motor class. This makes a contest more fair to all competitors. For an illustration of this, the NAR classification code sets the total impulse of a “E” motor between 20.01 N-s and 40.00 N-s. Obviously 40 N-s is what you want to have, but where in the range the motor actually falls is many times unclear. If the actual total impulse is 32 N-s, your calculations for determining specific impulse may be wrong, if you made the assumption that the motor had a total impulse of 40 N-s.

Further Information

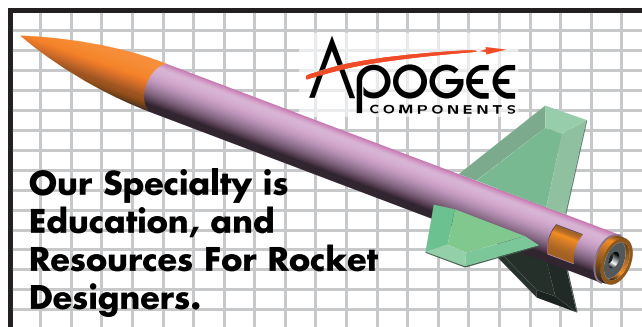
Selecting Rocket Motors: A three part article. See the *Peak of Flight Newsletter* archives for issues 38, 39, and 40. <http://www.ApogeeRockets.com/education/newsletter/archive.asp>

Model Rocket Propulsion: Learn how rocket motors work! A textbook suitable for grades 8 and above. http://www.ApogeeRockets.com/mod_rocket_propulsion_bk.asp

RockSim computer software: Use it to select the proper rocket motor for your models. Download a FREE demo version at: <http://www.ApogeeRockets.com/rocksim.asp>.

About the Author:

Tim Van Milligan is the owner of Apogee Components (<http://www.apogeerockets.com>) and the curator of the rocketry education web site: <http://www.apogeerockets.com/education>. He is also the author of the books: “*Model Rocket Design and Construction*,” “*69 Simple Science Fair Projects with Model Rockets: Aeronautics*” and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with “SUBSCRIBE” as the subject line of the message.





STAGING HIGH POWER ROCKETS

By Ray Dunnakan

"Staging High Power Rockets" is 20 pages long, with four chapters: Introduction, Inline Staging, Parallel Staging, and Parasite Staging. The introductory chapter explains the differences between traditional modroc staging and staging with composite motors; it also discusses sustainer ignition methods, G-switches, pull-pins, breakwires, igniters, and recovery. Each additional chapter discusses booster recovery, stability, ignition, timing and motor selection as they apply to the three types of staging; as well as specific issues such as interstage couplers, mounting hardware, etc.

This book is not just for high power flyers! The information and techniques in this book can also be applied to mid-power rockets flying on E, F or G motors. Whether you're new to the hobby or an "old hand" looking for new challenges, there's something for everyone in "Staging High Power Rockets".

**Be sure to say you saw it in the
Peak-of-Flight newsletter!**



<https://secure.mcneely.net/extreme/extremestore.html>

**FREE Demo Version
Download It NOW!**



Compare Features!
Bargain Price of Just: **\$95**

RockSim Makes Designing Rockets Easy, Accurate, and Affordable

- Easiest Software to Learn, and Fastest To Use.
- Create Templates and Patterns to Build Your Rockets.
- Generates The Most Accurate Simulation Results.
- Saves You Money By Preventing Design Errors and Launch Mistakes.
- Used By More Rocketeers - Because It Is So Reliable.
- "The Best Value For Your Money!"

APOGEE
COMPONENTS

Visit the Apogee web site for more information:

www.ApogeeRockets.com/rocksim.asp

