PEAK OF FLIGHT NEWSLETTER

ISSUE 486 | January 8th, 2018

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What do Model Rocket Engine Numbers Mean?

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What do Model Rocket Engine Numbers Mean?

By Tim Van Milligan

Figure 1: An engine code is printed on every model rocket motor. What does the code C6-5 tell us?

How model rocket engines are classified are printed on the outside of the motor casing. This combination of numbers and letters may look confusing, so we'll try to simplify them for you. I'll compare the code to something you are familiar with, which is your car. This will give your mind something tangible that makes a bit of sense. And once you understand the code, you'll have an easier time picking motors that will fit your particular model rocket.

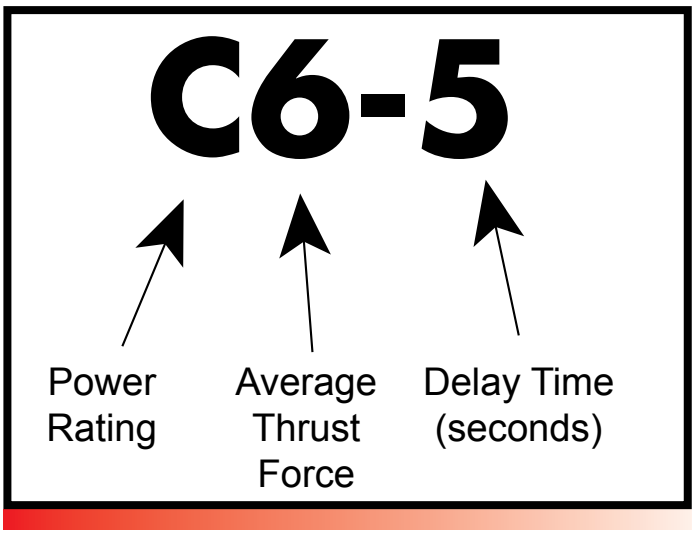

Figure 2: The letters and the numbers in the code give us an indication of the motor's performance.

In general, the motor classification code is broken down into just three simple parts. The parts are the power rating, the average thrust number, and the delay number.

The first "letter" in the code is the Power rating

Think about the power this way, and it may make a bit more sense: it is like the size of the gasoline tank in your car. The bigger the tank, the further your car can travel. In the case of a rocket, the bigger the fuel tank, the higher up in the air the rocket can fly.

In model rocketry, we use letters to designate the size of the tank. Here is the one simple trick you need to know: "when you go from one letter to the next in alphabetical order, the power doubles."

The smaller rocket motors are A, B, and C. So you would say that a "B" motor is twice as powerful as an "A" motor. What this means is that like the size of the gasoline tank in your car, if you double the size of the tank, the car can travel twice as far. In this case, the rocket can go approximately twice as high.

So if your rocket travels about 150 feet up in the air with an "A" motor, you can expect it to go approximately 300 feet up with a "B" motor.

That was simple right?

Now a "C" engine has twice as much power as a "B" engine, so it will take that same rocket to about twice as high as the B motor. In our example, you could expect the "C" size motor to travel to about 600 feet.

The critically important thing to remember here is that height is dependent on the size and weight of the rocket. Not every rocket is going to go 600 feet on a "C" engine. Some rockets will go higher, and some won't even get that high.

Now that you have a basic understanding of power, you can confirm this is true:

The "C" power rocket motor is about 4 times as powerful as an "A" motor. You would have to use four "A" size motors to get the same total power as a "C" motor.

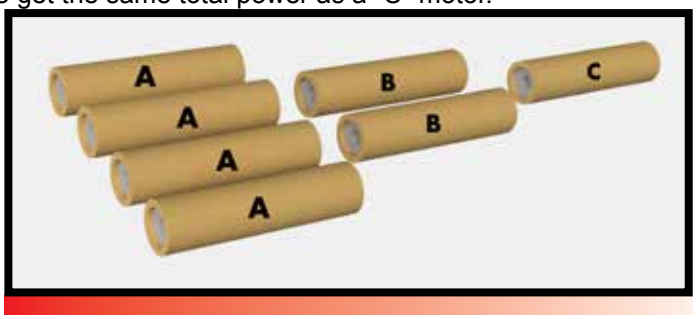

Figure 3: It takes four "A" rocket motors to equal the power to a single "C" motor.

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Similarly, if you got the next bigger motor, a “D” size, it again goes about twice as high in the same rocket as the “C” motor. The equivalent power of “A” size motors would be 16. That is a lot of “A” motors!

Now the “A” size motor is not the smallest, even though “A” is the first letter in the alphabet. How do you designate in the motor classification code a motor smaller than an “A?” For example, let's say the power of this smaller motor is half of the “A” size motor. What would that look like in the code?

What you’ll find is that on the motor, the smaller motor would have a fraction number in front of the “A.” Any guess on what that fraction number would be? You guessed right! It is a 1/2. So the motor code for that motor would be: 1/2A.

And the motors go smaller than that too. The motor smaller than the 1/2A is the 1/4A. Notice that this is again half the size of the the 1/2A.

The smallest currently available rocket motor is the 1/8A. It takes 8 of them to make the equivalent power of a full “A” size motor.

Why not anything smaller? Because the power they produce is so weak that it couldn’t lift the weight of the rocket off the launch pad. It is like trying to drive your car with no gas tank whatsoever. It only has the amount of gas that is in the gas line. You can probably start the car with the amount of gasoline in the lines, but you will barely get out of your driveway.

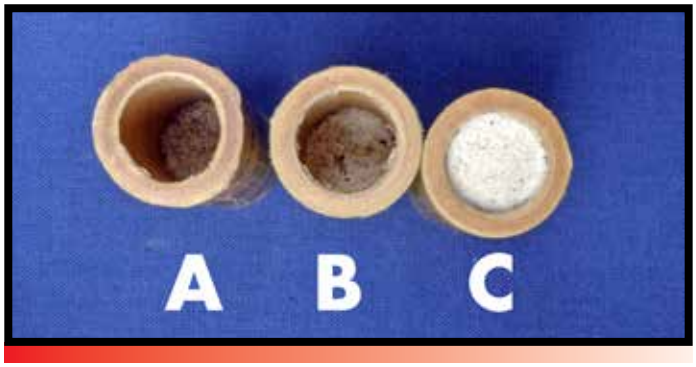

Figure 4: If you look down the top, the “A” motor hardly has any propellant inside, where the “C” motor is filled to the top. That’s how they make the “C” four times as powerful.

On the other end, there is no limit to how big of a rocket motor you can get. It really depends on the size of your wallet and how much you can afford to pay. As I write this, the largest motor we have at Apogeerockets.com web site is a “L” size motor. As of today, the cost of that size motor is over $230. But if you have the money, you can go bigger than that. The largest commercially available motor as of right now is a “P”. That is the equivalent of over 32,000 “A” motors!

The Average Thrust Rating

The number immediately following the letter is the Average Thrust of the rocket motor. Remember, there could be a fraction in front of the “letter.” What we’re talking about here is the number after the letter.

This is where the motor classification can start to get confusing. The reason is you don’t have something tangible to compare one number on one motor to the number on the next one.

For example, Estes sells both an B4 and a B6 rocket motor. How are they different?

Since they both start with the letter “B,” that tells you that they have similar power. They would both lift the identical rocket to approximately the same altitude.

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The Average Thrust Rating is how fast the propellant inside is burned up. Again, let's go back to the example of driving your car. The number after the letter tells us how hard you stomp down on the accelerator pedal. The higher the number, the faster you accelerate from a standstill

Figure 5: If you stomp hard on the accelerator, you'll jump forward quickly. But in the process, you'll burn your gas quickly so you don't go as far.

Gently press the gas pedal down, and you slowly move forward. Stomp on it hard, and the engine guns, and you may squeal the tires as you lurch forward quickly. It is the same with rocket motors. The number may be relative, but the higher that the number is, the faster your rocket will accelerate. The higher the number… the faster your rocket will travel!

If the average thrust number was exactly double, you'd accelerate twice as fast. For example, say an average thrust level of 4 got you to a speed of 100 mph in 6 feet. If you double the average thrust, the rocket would reach a speed of 100 mph in just 3 feet.

But what happens to your gas mileage when you accelerate quickly all the time? Right. You don't get good mileage, and you can't travel as far.

The same thing happens in a rocket motor. The higher the number, the quicker you take off, but you don't go as high.

So when we said previously that a B4 and a B6 went approximately the same height, what you'll actually find out is that the B4 will go a little bit higher. Not by a huge amount, but a "little bit" higher…

Why does the B4 go higher than the B6? Because of the force of Aerodynamic Drag. This drag force is proportional to the square of the speed of the rocket. When you square any number, that is hugely significant. What this means is that if you double the speed, the drag force doesn't just double, it goes up four times.

$$D = \frac{1}{2} \rho V^2 S C_d$$

Drag Force

Velocity

Figure 6: The drag force is proportional to the square of the rocket's velocity. If you double the velocity, the drag force increases by a factor of 4.

To wrap your mind around this, say you were running in a track meet. Around your ankles, you were wearing those wrap-around weights. On each ankle, you have 3-pounds of weight. The guy next to you is also running with the same weights on his ankles. But you're a faster runner… twice as fast as he is. And as you run, the weights expand and get heavier. And like aerodynamic drag, they grow in proportion to the square of the speed at which you run. Since you are twice as fast as the guy next to you, your weights expand to 9-pounds per ankle (which is from 32). Yeah… you're fast.

But you're burning through calories at a much higher rate. Eventually, you are exhausted and you just can't run any further. Meanwhile the guy in the lane next to you catches up and surpasses your distance. You're still faster, but the guy next to you goes farther because he's not fighting as heavy of weights around his ankles.

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In rocketry, if you want speed, you want to chose the rocket motor with the higher average thrust level. A higher number after the letter.

But there is a downside to that… you don't go as high.

There are always trade-offs in rocketry. This is engineering and "rocket-science" after all. When you want one feature, it is always traded for by losing something else. Example: you want speed? OK, but you have to give up altitude to achieve it. That is the price you always have to pay.

There is also a trade-off by picking a motor from the lower end of the range when it comes to Average Thrust Level. The lower the number, the slower you go. Unfortunately, it also means the rocket is less stable as it takes off. Slow rockets have a tendency to weathercock into the wind (**Figure 7**). Weathercock means they turn into the wind as they fly. Instead of going vertically, they end up flying more horizontally. So again, they don't go as high - even though they may travel a long way. You're probably going to have a long walk retrieving them.

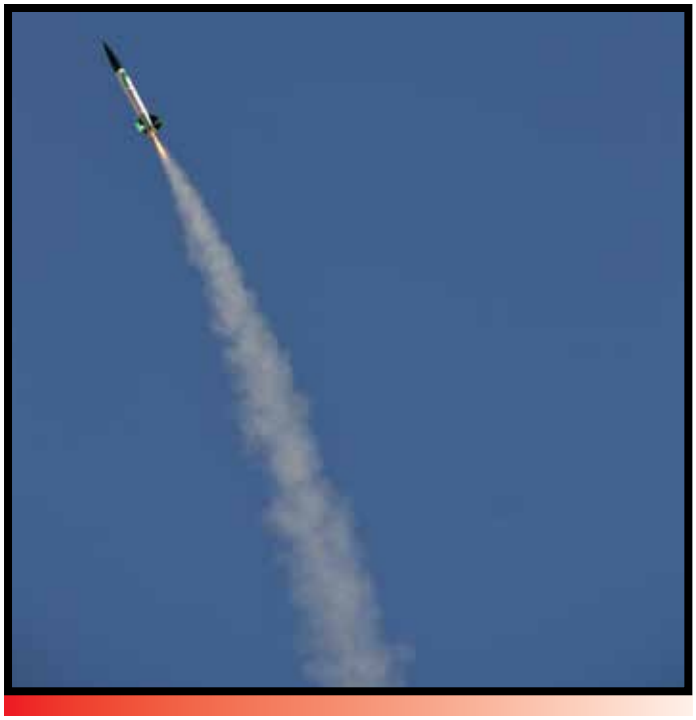

Figure 7: Apogee Zephyr rocket with slight weathercock from launch.

What this means is that there is no "best" rocket motor for any rocket. You don't get speed and distance and stability. You only get one or two, not the third at the same time.

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So when a customer asks me "what is the best motor for my rocket?" I don't know how to answer them. I don't know what they want. Do they want speed, or do they want altitude?

In small rocket motors, you don't often have a lot of choices. But in the bigger ones, there is a lot more variation. For example, in G-size rocket motors, you have a choice of 19 different ones from Aerotech, ranging from a G25 to a G339.

If you don't know which one to pick, my suggestion is to pick one in the middle of the pack. For example, most of the G motors from Aerotech seem to cluster in the range of having an average thrust of 70. The units on this number are in Newtons - but don't let that confuse you.

Since the "70" number seems to be in the middle of the cluster, the motor will give you a little bit of all the qualities you may be after. It may not be optimized for what you really want, but it will probably give you a decent flight.

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The Delay Number

After the Average Thrust number in the rocket motor classification code, you will see a dash, followed by another number. The number immediately after the dash is the Delay Time of the rocket motor. This delay time is measured in seconds.

For example, a -5 means the delay time is five seconds.

The delay time is measured from when the propellant is burned up (completely consumed) and stops producing thrust, to when the ejection charge fires to push out the parachute (**Figure 8**).

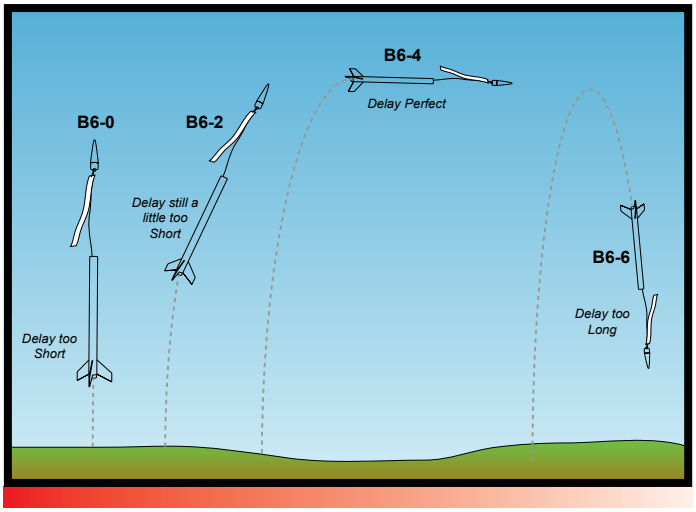

Figure 8: The delay time controls when during the flight the ejection of the recovery device is pushed out of the rocket.

The delay time is important, because your rocket needs to be traveling pretty slow when the parachute is ejected. If the rocket is traveling too fast when the parachute is thrown out into the air, it will get ripped to shreds.

Think of traveling down the interstate highway in the back seat of your car at a speed of 75 mph. You stick your hand out the window and release a little plastic parachute. The chute opens instantly, and tears the strings right out of the canopy. Now the chute isn't much good at slowing you down, is it?

For the sake of the parachute, you always want to release it out of the rocket when it is traveling at a slow speed. Otherwise, you stand a good chance of ripping strings out (**Figure 9**).

Figure 9: Ripped shroud lines from premature parachute deployment.

Did you know even small rockets go really really fast? Reaching speeds in excess of 200 mph is fairly typical. That is what makes rocketry so exciting - you go really fast. But you can't release the parachute when the rocket is moving at that speed. You have to wait for it to slow down.

That is the purpose of that delay number in the motor classification code. It tells you how long the motor will wait before it fires the ejection charge to push out the parachute or streamer.

For a rocket that travels really fast (remember those high average thrust motors?), you'll want a longer delay time because it is going to take longer for the rocket to slow down. For rockets that use lower average thrust motors, you're probably going to want to choose a lower delay number.

Again, this is a relative number when you don't have any experience picking rocket motors.

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I always recommend using a rocket simulation software to help select rocket motors. The reason is that you can run the simulations and see what is a good delay to choose for a particular rocket design and weather conditions at the launch site. I've been flying rockets consistently since the mid 1970's and I could say I have a lot of experience. But when I guess, I often get it wrong. It is only when I use the simulation software that I feel confident to launch the rocket.

How to Pick Motors

In this article, I didn't want to use a lot of technical mumbo-jumbo. I just wanted to give you some examples that will get your mind thinking of the right concepts. If you understand the basic concepts of the rocket motor classification code, you will have a much easier time picking the correct rocket motors for your kits.

The next step is to go a little deeper and start looking at what the actual numbers mean. For that I suggest reading a previous article that I wrote on this same subject. You'll find it in Peak-of-Flight Newsletter 131 (https://www.apogeerockets.com/education/downloads/Newsletter131.pdf).

After that, I still recommend running computer simulations, like using the RockSim software. I know running simulation software can seem to be a little daunting. It seems like your progress in rocketry drags because physical rockets aren't being flown. It certainly isn't as exciting as launching a real rocket and seeing what it does. But I hope to suggest to you that you'll actually progress faster when you do run simulations. For evidence of this, I can point to the students in TARC that are knee-deep in simulations right now, and are really progressing at an incredible rate. While under a very tight budget, they are going from complete novice fliers to being almost ready to do their L1 certification flights. I'm not here to sell you software, I truly believe that running simulations will help you get to your goals quicker and at a lower price than you could learn through trial and error.

My process of picking motors using a step-by-step approach is found in Apogee Technical Publication #28 which can be downloaded for free at: https://www.apogeerockets.com/downloads/PDFs/Tech_Pub_28.pdf

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE ezine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.