JD Newman’s Website on brake Needed.

BRAKE KINETIC ENERGY REQUIREMENTS PER FAR PART 23.735

**YOU** are the builder and designer of your Dream Machine! **YOU** must decide on the correct minimum brake system you will need for BOTH a maximum effort abort, AND for a maximum effort stop during landing, for whatever reason!!

Bottom line — YOU must decide what brakes you should really have for YOUR aircraft, NOT what someone else says, no matter who they are!!!

Fortunately, this is really VERY simple to do! FAR Part 23.735 dictates what you should have. To calculate your required Brake Kinetic Energy needs as outlined in FAR Part 23.735, first, one needs to know the FAR equation to calculate their minimum Brake Kinetic Energy requirements. This FAR equation in Part 23.735 is:

KE = (.0443\*W\*V^2)/2 , where:

KE is Kinetic Energy in foot pounds (ft. lbs.)  
W is your aircraft’s Weight in pounds (lbs.)  
V is the aircraft’s speed in knots (KIAS) squared (to the 2nd power)

All this is divided by the number of brakes on our little planes. In our case, this is by 2 — we’re not flying a C-5 🙂

We’ll go over some example minimum foot pound (ft. lb.) braking requirement scenarios below, but first . . .

***Now, let’s look at the list of 5.00 x 5 size aircraft brakes that are available from various vendors:***

*NOTE — Cleveland Brakes are wonderful products. In fact, I use them for many of my Landing Gear Designs for much heavier aircraft. BUT, in the 5.00 x 5 regime, there are several versions that vary in braking ability:*

Cleveland’s *Standard* Duty 199-102 wheel and brake have a Kinetic Energy availability of 117,500 foot pounds per brake (recommended for the 1325 lb. Gross Weight Long-EZ)

Cleveland’s *Above Standard* Duty 199-156 wheel and brake have a Kinetic Energy availability of 155,000 foot pounds per brake

Cleveland’s *Heavy* Duty 199-152 wheel and brake have a Kinetic Energy availability of 192,000 foot pounds per brake [recommended for the Cozy MK-IV, and shown in ACS catalog (as of 06/15/03) for $690.00, and shown in the Wicks catalog for $693.75, both minus Axle Assemblies, Master Brake Cylinders, Remote Reservoirs and Parking Brake Valve]

Beringers — no one knows for sure what their true Kinetic Energy availability is. Logic dictates that it is impossible to have the Kinetic Energy numbers they claim with the thinner and lighter disc they have. If you truly want to know, send your Beringer brakes to Matco and they will test it. Also, check this link starting on page 13 – 18 of how to change a tire on their wheel. Special $150 tooling required. Personnaly, I would rather have a tube — MUCH easier to change on a trip. http://www.beringer.fr/images/NewsMot1/complet%20manual%2026-02-14%20SITE.pdf

Grove’s really nice look’n *Ultra High-Performance* 58-1 wheel and brake have a Kinetic Energy availability of 278,998 foot pounds per brake.

Cleveland’s *Super Heavy* Duty 199-197 wheel and brake have a Kinetic Energy availability of 289,000 foot pounds per brake [not shown in ACS catalog, but is shown in Wicks catalog (as of 06/15/03) for $767.50, both minus Axle Assemblies, Master Brake Cylinders, Remote Reservoirs and Parking Brake Valve]

*MATCO’s 3 Puck 5.00 x 5 Wheel and Brake Systems Brake Kinetic Energy is:*

MATCO’s W51LT 3 puck wheel and brake system has 327,932 ft. lbs. of Kinetic Energy available per brake (not shown in the Wicks catalog, but is shown in the ACS catalog (as of 12/03/2012) for $556.00, both minus Axle Assemblies, Master Brake Cylinders, Remote Reservoirs and Parking Brake Valve — but you can get the [MATCO’s](http://infinityaerospace.com/Brakes.PDF) and everything else from us for less money).

*Now lets crunch some simple examples for required Brake Kinetic Energy Numbers for a few different planes. As you will logically see, one doesn’t need to fly a plane to know how well it will stop or not stop during an emergency abort or short field emergency landing — the FAR’s drive what brakes you should (logically) use:*

For example, the published Long-EZ (LE) canard stall speed is 55 KIAS at its 1325 lb. Gross Weight (GW). So, by using the FAR equation above, the required Brake Kinetic Energy for this weight of aircraft at a 60 KIAS (just above LE canard stall speed) maximum effort abort speed (or a maximum effort-to-stop upon landing touchdown speed), for example, is 105,655.5 ft. lbs. of Brake Kinetic Energy needed per brake — the original recommended brakes are more than enough. The maximum KIAS for this aircraft during a maximum effort-to-stop upon landing touchdown or a maximum effort abort using the original recommended brakes for that design at that aircraft’s 1325 lbs. GW is 63.27 KIAS (just back into the FAR equation). But a heavier canard aircraft (such as a 2050 lbs. GW Cozy MK-IV) would have a much higher canard stall speed — \*WELL\* above its touted 60 KIAS (I calculated 78.8+ KIAS for that GW). Then, even the recommended Cleveland *Heavy* Duty 199-152 brakes for the Cozy MK-IV would NOT be enough (i.e. — “not suitable” and NOT recommended by Cleveland themselves — again, use the FAR equation and specs above to verify the factual results for yourself).

To continue: sooo, a 2050 lb. Cozy MK-IV canard aircraft, for example, (or ANY aircraft for that matter at these weights AND speeds) that lands or rotates at 80 KIAS (per POH) needs 290,608 ft. lbs. of Brake Kinetic Energy PER SIDE / PER BRAKE per FAR for a maximum effort emergency abort, or a truly short field landing, to get’er stopped! Remember, the recommended brakes only have 192,000 ft. lbs. of Brake Kinetic Energy, and you need 290,608 ft. lbs.! In fact, 65.02 KIAS would be the maximum speed for this weight of aircraft at sea level on a standard day if you only have the recommended Cleveland *Heavy* Duty 199-152 wheels and brakes (note: you could never fly it this slow at 2050 lbs. GW — back into the FAR equation for this KIAS number). And remember, at a higher density altitude, you may be indicating 80 KIAS upon rotation, but your actual knots ground speed would be even higher. So, even the Cleveland *Super Heavy Duty* 199-197 wheels and brakes 289,000 ft. lbs. would be marginal — to not enough — at sea level on a standard day, and certainly not enough at higher density altitudes at the IAS of 80 knots used for rotation per POH, which could easily turn into a maximum effort abort, or landing.

The MATCO two puck brake that Mike Melvill recommends for Long-EZ’s in the Oct. ‘92 Canard Pusher newsletter has a stopping power / Brake Kinetic Energy of 283,613 ft. lbs. per brake. Since then (1992), MATCO has come out with the 3 puck wheel and brake system talked about above with a stopping ability / Brake Kinetic Energy of 337,932 ft. lbs. Per brake, and the weight is within a pound of the Cleveland *Super Heavy Duty* brake system! MORE EXAMPLES: if a Long-EZ is taking off at 1425 lbs. and aborts, or comes back for an immediate landing, at 60 KIAS, and using the FAR equation above, this aircraft needs 113,629.5 ft. lbs. minimum Brake Kinetic Energy per brake for a maximum effort stop. The recommended original Cleveland 117.5K brakes are fine. If a Long-EZ is flying at a heavier weight, say 1600 lbs., and aborts or lands at 72 KIAS, this aircraft needs 183,720.96 ft. lbs. Brake Kinetic Energy per brake for a maximum effort stop — the original brakes are NOT enough — the Cleveland *Heavy Duties* would be a minimum. Add 100 lbs. and the pilot will need 195,203.52 ft. lbs. of Brake Kinetic Energy for a maximum effort stop, then the Cleveland *Heavy Duties* would not be enough. Any brake action that exceeds the Brake Kinetic Energy available for that brake rotor will get hot, fade, eat up the brake shoes, may melt the fiberglass wheel pants and /or the fiberglass fixed or retractable main gear struts, & / or catch on fire, and the heat will warp the brake disc — now you are out of control AND in big trouble (that’s just one of the reasons our [*Infinity 1*](http://infinityaerospace.com/inf1kit.htm) has [Nose Wheel Steering](http://infinityaerospace.com/Nosestrt.gif)). This same problem may occur at higher speeds because of a higher density altitude — ALL these things above have already happened all too often. Let’s face it, many (most) EZ’s / canards are flying heavier, therefore landing and taking-off faster.

***I LOVE this one!***

Sometimes you’ll hear this argument of why “pilots” stay with brakes with less than the Brake Kinetic Energy that they need — “I’ve never had trouble stopping before.” But these “pilots” are just testing fate — an accident that has found a place to happen, simply waiting for the opportunity. These few “pilots” who say and believe this have never had to really get on their brakes at maximum weights and speeds in a worst case high density altitude and short runway length situation! Sure, they will work fine at lighter weights and/or slower speeds, building false confidence in their less than optimum brake system based on engine run-ups, taxiing, and normal slow speed braking. But again, that’s why this false sense of security abounds. And learning what Brake Fade is, at exactly the wrong time, is terrifying. I can’t make these points enough!

In July and August ‘95 (as some of you may recall), 2 canard aircraft and one life were lost partly because of the above — they both went off the end of the runway while trying to abort. There are documented numerous close calls and actual incidences throughout canard history. A canard at 2050 lbs. and 80 KIAS, aborting or landing, needs a minimum of 290,608 ft. lbs. of Brake Kinetic Energy PER BRAKE for a maximum effort stop! Even the 2 puck MATCO’s that Mike Melvill recommends (mentioned earlier above) are not enough. Set up different scenarios and crunch the numbers yourself.

As stated earlier, Cleveland’s are wonderful products, but as I mentioned, the tremendous stopping power of the MATCO’s in the 5.00 x 5 size wheel and brake world is NOT the only reason why we chose them for our [*Infinity 1*](http://infinityaerospace.com/inf1kit.htm) aircraft and our landing gear system needs:

1) we saved about 1.25+” in overall wheel width translating to thinner wheel wells and fitting better in the retrofit aircraft strakes (this also means thinner wheel pants if you still have the fiberglass fixed main gear, meaning a little less drag and DN pitching moment from the wheel pants);

2) the brake ‘lives’ within the diameter of the rims, so no brake parts hang below the rim to be ground off during a blown tire take-off or landing, and maybe ending up in a brake and / or hydraulic fire;

3) also, the MATCO three puck brake and rotor system can absorb more energy and dissipate heat better. So, the brakes will stop you expeditiously during maximum effort braking without getting hot, fading, eating up the brake shoes and warping the brake disc; and canard aircraft still with fixed fiberglass main gear — no more melting the fiberglass wheel pants and /or struts, and / or catching on fire, and no more hacking up the back side of your fiberglass fixed main gear strut for brake installation;

4) the brake shoes, also, last much, much longer saving $$$’s and requiring less maintenance, paying for themselves in a short time, and in many ways;

5) we can use DOT 5.0 brake fluid, which can be purchased anywhere, unlike MIL-5606 hydraulic fluid, which also requires it to be flushed yearly because it absorbs water causing internal brake system corrosion — DOT 5.0 does NOT absorb water, DOT 5.0 has a MUCH higher Flash Point, and DOT 5.0 is cheaper;

6) they are pretty, too 🙂 .

Like Phil Johnson has pointed out to the Cozy Group (assuming everyone has read the archives) — he intimates that a brake with a higher Kinetic Energy should be used and is available, and that if you don’t, you put yourself, your family, others, and melting your strut(s), at risk. In fact, 2 incidents come to mind tonight as I slowly type. Keith Spreuer destroyed his Cozy III a few years ago when he couldn’t stop on an aborted takeoff, and Capt. Harry Jenkins (7.5 year Hanoi Hilton guest) lost his life (decapitated) and his plane was destroyed about the same time as Keith’s incident when he couldn’t stop his Long-EZ from an aborted takeoff (his son was badly injured) going off the end of the runway through a chain-link fence. Both of these incidents occurred from using the \*recommended\* brakes, but flying their planes at the usual / typical heavier weights like most canards do, meaning faster abort, take-off and landing speeds. You, the designer and aircraft mfg., need to decide for yourself what brakes you will use for the type of flying (high density altitudes? ; short runways?) and flying weights you will be flying for if they are higher, the landing and abort speeds are higher. OBTW — Keith has the MATCO 3 puck brake system now on his Cozy MK-IV. Harry was ordering his when he got back from Oshkosh.

*Something that is not required by the FAR’s, but should be:***Brake Torque capability**

There is a lot of confusion between Force and Energy . . . two very different and important parameters. Stopping Force is a Torque related parameter. Energy is a capacity parameter. The Energy rating is indirectly linked to Torque (and therefore Force) because of the effect on the friction coefficient when the disc gets too hot.

KE is Energy not Force. Seems subtle, but is an important distinction. A higher Energy brake means nothing without the Torque rating of the brake. You could design a brake to have twice the Energy rating of the original design, and yet provide less brake Torque (and therefore less deceleration which translates to stopping distance). Basically, the Energy rating can be used to tell you how hot it will get for a given weight and velocity aircraft, and the Torque rating can be used to determine the deceleration rate, and therefore distance. If too low a Energy rated brake is used, the Torque output drops (because the pads overheat . . . brake fade) and deceleration is lost. Both ratings must be used to select the correct brake for your aircraft. For some reason, General Aviation (GA) and the FAR’s pay attention only to the Energy Rating . . . bad idea!

Sooo, to calculate Brake Torque requirements for YOUR plane, the equation is:

T = (.31 x W x Rtire)/N

Where:

T = Torque required per wheel and brake in inch pounds for a 10 ft/sec^2 deceleration rate. Torque ratings are approximate values at 450 PSI of brake pedal pressure, and varies with brake conditioning;

W = Design landing weight in pounds

Rtire = Tire radius in inches

N = Number of wheel with brakes

So, a 2050 lb. aircraft needs a brake capable of 2224.25 in. lbs. of Torque Stopping Force per brake. The MATCO 3 puck W51LT brake system is capable of 4266 in. lbs. of Torque Stopping Force per brake @ 450 PSI of brake pedal pressure, so you’re “good to go” 🙂 .

*Here’s the bottom line: YOU are the aircraft mfg.*

\* If you still sincerely believe you will NEVER see over a 65.02 take-off, abort or landing KIAS in your 2050 lb. canard aircraft (again, I calculate 78.8+ KIAS canard stall speed for 2050 lbs. GW), by all means, use the recommended Cleveland *Heavy Duty* 199-152 wheels and brakes — they’re just fine for this GW and speed during landing or aborting (NOT!);

\* If you don’t believe this for an instant like 99+% of all canard builders, there are other more powerful brakes available;

\* Also, if you have a hard-on against MATCO for \*whatever\* reason (i.e. — they’re not paying you a commission; someone says ‘that’s what the “designer” says to use’; ‘others haven’t had a problem before’, etc.), even though MATCO has a superior stopping brake in the 5.00 x 5 size available and over 65% of Sport Aircraft use MATCO’s (and for all the other reasons to use them listed above), for Pete’s sake at least use the Cleveland *Super Heavy Duty* brakes, model 199-197 capable of 289,000 ft. lbs. of stopping force (but remember, you’ll need 290,608 ft. lbs. at sea level minimum, and MORE at a higher density altitude — and you’ll pay a lot more over the MATCO’s), so that you \*might\* have a fighting chance to get’er stopped if ya really gotta.

**Now \*YOU\* crunch the numbers for YOUR plane!**

Gang, I hope this helps (HTH). Call me ANY afternoon if you have ANY questions about brakes, or about ANYTHING else !

OBTW — Glasair III’s are switching over to the MATCO 3 puck W51LT wheel and brake system, too, for the above reasons. Also, they can get rid of that brake blister in their gear doors on the bottom of their plane.