CO2 Engineering Principles

I always tell my students that engineering is like a balancing act. When you do one thing to overcome a problem, often you create another totally different problem (hopefully, only one). Many times a solution is the midpoint between the two problems, never solving either entirely. It's a game of give and take. And in CO2 design, it is no different.

Engineering a CO2 car can be broken into four main principles. I've also added a story and a moral for your entertainment.

Engineering Principle No. 1: Mass
CO2 cars are a great deal lighter than barbells, but they still have weight; what scientifically we call Mass. This comes into play when students choose their body block from which to construct their cars. When doing so, they will be faced with blocks that weigh as little as 40 grams and ones that weigh upwards of 130 grams. Once again, it should be obvious that it takes less force to push 40 grams than it does to push 130. So why on earth would someone want to choose a 130 gram body block?

Because it's much stronger wood. That's why. If a car is designed to be hollow, or have a narrow body, a lighter piece of wood, such as a 40 gram block, may destroy itself in the normal course of racing. And if your car is in three pieces, it generally doesn't run very well. I've had classes where much slower cars have won their tournaments only because their faster counterparts disintegrated after half a dozen races.

The Balancing Act:
Advantages:
Cars with less mass go much faster.
Disadvantages:
Cars with less mass are less stable and less durable.

Engineering Principle No. 2: Drag
Take a piece of balsa wood, slap wheels on it, shoot it down a track at 80 MPH and the air rushing over the body and wheels will try to slow it down. Scientifically this is called drag: the resistance of wind moving over an object.

So how do you overcome drag? Start by making the body as aerodynamically "clean" as possible. Think of vehicles designed for high speed such as rockets and jet fighters and go from there. But don't forget the other parts of the car. Lola Cars, who make Indie style race car bodies, attribute as much as 50% of a car's drag to the wheels. So it's a good thing to try to get them out of the airstream as much as possible. But again, to do this will require more time and skill than just an ordinary car.

The Balancing Act:
Advantages:
Aerodynamically shaped cars are less "draggy," so they go faster.
Disadvantages:
Aerodynamically "clean" cars are more difficult to build.

Engineering Principle No. 3: Friction
Thanks to our friend gravity, everything has friction. On a CO2 car, friction occurs primarily in three places: between the wheels and the ground, between the axles and the car body, and between the eye-hook and the fish line track. So how do you eliminate friction? You can't. You can only reduce friction.

First, make sure the tires are free from any defects by carefully sanding or cutting them away. Make sure they are not rubbing on the car body! Next, add a dry lubricant such as powdered graphite between the axles and the straw used as a wheel bearing. Next, sand away any imperfections on the axles. Finally, be sure to install your eye-hooks properly. Poorly aligned eye-hooks are often the cause of a slow car.

The Balancing Act:
Advantages: A friction filled car is easy to build. A friction filled car is slow, so it tends to be more durable.
Disadvantages: Reducing friction takes a lot of extra effort, time and patience.

Engineering Principle No. 4: A Design Envelope
In the real world most everything has a limit. That limit could be technology available, labor available, materials, or cost. For example, oil tankers are designed to be just wide enough that they will fit through the Panama Canal. Our CO2 cars also have a set of minimum and maximum dimensions, called a Design Envelope.

Many students will automatically assume that if they make their car to the minimum specifications that it will be faster. Other students will keep their car at maximum length in hopes of having an advantage. Who's right? I've seen both approaches work. But one thing is sure: if your car doesn't meet the minimum or maximum dimensions, it won't be racing at all. Without a design envelope competition would be unfair and unsafe.

The Balancing Act:
Advantages:
Cars that follow a design envelope can compete equally and safely.
Disadvantages:
Cars may go faster if a design envelope is not followed, but will be disqualified.

A Tail of Two CO2 Cars.
Let's look at two cars as an example of how these principles interact: Speedy and Tank (based on a true story - the names have been changed to protect the innocent). Tank is made out of a heavy 100 gram block, and is shaped like, well, a tank. Speedy is sleek and aerodynamic, made from a 45 gram block, with the rear wheels partially set inside the body. Who do you think will win?

Tank went together rather easily, with the student designer drilling some rough holes in the bottom to reduce Tank's mass. On race day, Tank was big, green, and ready to go. Speedy took lots of out of class hours to get those rear wheels inset into the body. On race day, last minute preparations where undertaken to correct some friction problems where rear wheels rubbed on the body. But speedy was sleek, thin, and ready on time.

In their first races, Tank was soundly defeated as his car exhibited the aerodynamic qualities of a brick, and his high mass contributed to a slow race. But his run was straight and stable, and he was in one piece ready for his next run.

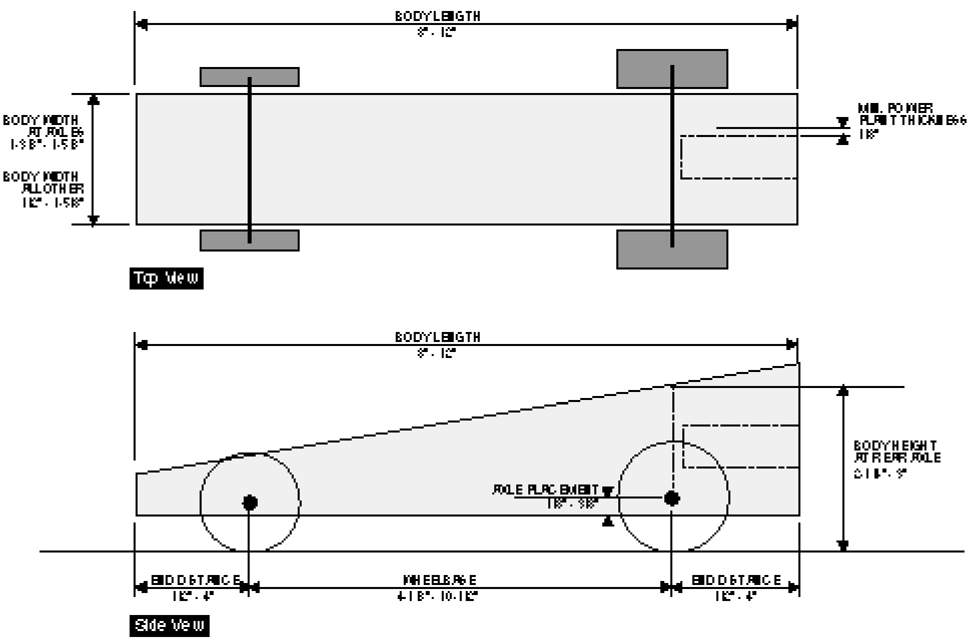
Speedy won his first race handily, crushing his opponent by over 2/10ths of a second. But Speedy's rear axle bearing was damaged from the stress of such high speed on his less durable lightweight balsa wood body. Speedy lost his next race as a friction problem with the rear wheel was not resolved in time.

Finally Speedy met Tank in a race for third place. After his first loss, Tank had managed to beat other cars that were faster than his, but either developed friction problems or breakage. In their race together, Speedy jumped out to a commanding lead, his aerodynamic shape and low mass working in his favor. But Tank, who's shape was less aerodynamic and mass was greater, remained straight and very stable as it ran down the track friction free. As Speedy reached the halfway point, the back axle again began to come loose and developed a great deal of friction. Tank rolled ahead for a narrow victory.

Tank was soundly defeated in the next race, and came in second in his class. Speedy went home third.

Moral of the story:
All engineering principles affect each other to some degree. Cars made to one extreme or another may win, but risk ignoring the balance needed between principles.

CO2 Design Envelope Diagram



Design Envelope Chart

Body:
Length: 12” max, 8”min
Height: 3” max, 2-1/4”min
Width at axles: 1-5/8”max, 1-3/8”min
Width all other: 1/2" minimum

Axles:
Diameter: 1/8"
Wheelbase: 10-1/2” max, 4-1/8”min
Distance from bottom: 3/8”max, 1/8”min
Distance from end of body: 4” max, 3/8”min

Safety:
Power plant housing thickness:1/8” minimum
Screw eye separation 10-1/2” max, 6”min

Mass
45g min to 170 max

Notes:
-Body Height is measured at rear axle, including wheels.
-Mass includes all parts, but not CO2 cartridge.