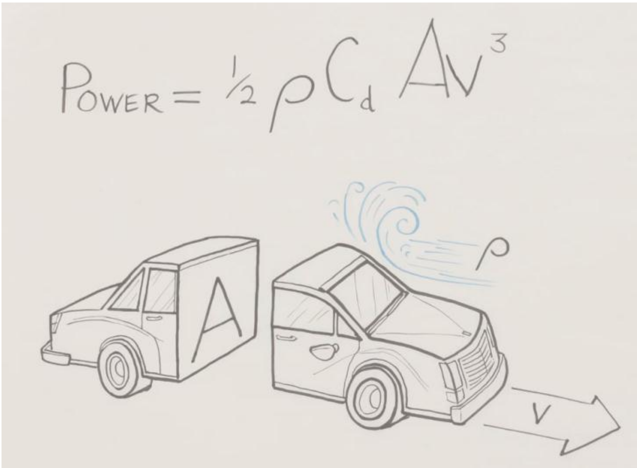
Fluid Flow: Reducing Energy Losses in Design

Companion to the video: Script and Illustrations

We know friction causes mechanical energy loss, but moving objects can lose energy another way – through fluid drag.

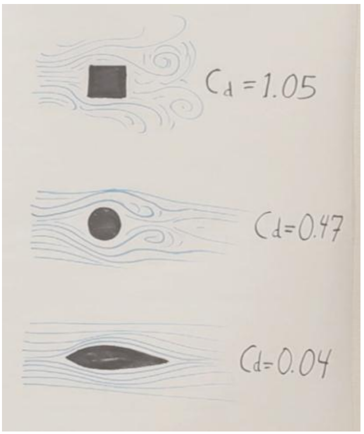
Imagine a car speeding down the highway. It's not just losing energy to the rolling resistance of the wheels on the road. The air is resisting it too.

The power required to move the air molecules out of the way depends on the density of the air, the car's cross sectional area, and the CUBE of its velocity.



It also depends on the drag coefficient, which is a way of quantifying aerodynamics.

If the car has a more streamlined shape or less surface friction, it'll disturb less air.



You can determine the drag coefficient of your design using the Navier-Stokes equation, but that can be impossible to solve with pen and paper.

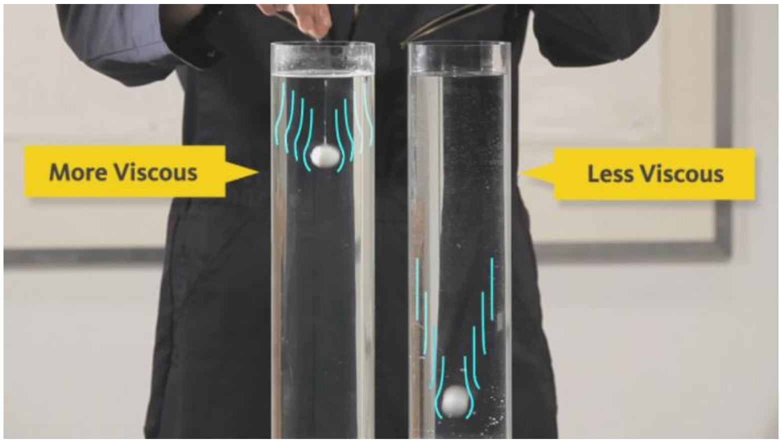
So you'll have to calculate it experimentally in a wind tunnel, or use an estimated value, or use computational tools to do the math for you.

Most cars have a drag coefficient of about .3, while a streamlined car might have half that.

You can improve the shape, but the equation tells us the most effective way to reduce losses from drag is to reduce SPEED.

Since velocity is cubed, doubling the velocity means eight times more power lost to drag.

Now what happens in a more viscous fluid, like liquids? Here we find drag caused by the friction of layers of fluid sliding against each other.



We can reduce that too. For instance, new swimsuits engineered for low viscous drag have helped Olympic swimmers break world records.

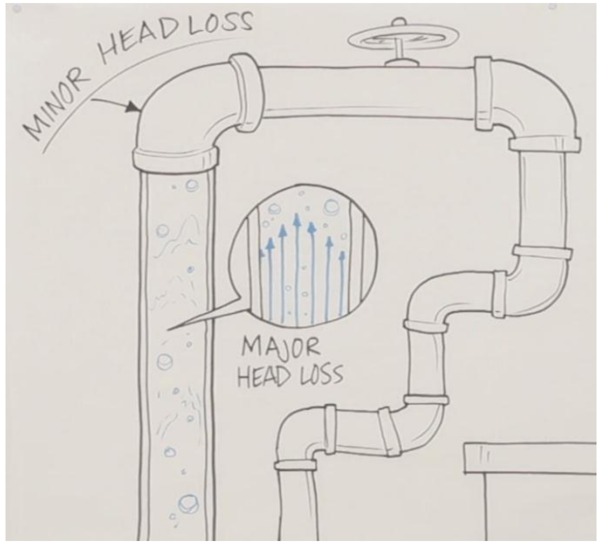
Now, what happens when you move fluid through an object instead of an object through a fluid?

Like water in a pipe.

The same laws of motion apply, but in a different way. Instead of measuring the energy loss directly, people measure pressure loss, also known as "head loss".

Here energy gets lost in two ways: by fluid drag against the walls of the pipe itself, which is called major head loss,

And losses caused by going around corners or through valves and joints, which is called minor head loss.



Here's a simplified version of the equation for major head loss.

Major Head Loss

$$H \sim \frac{f L v^2}{D^5}$$

Let's say you're pushing air through the ducts in a building.

To reduce major head loss, you can make the ducts smoother to reduce surface friction…

you can reduce the length…

and for a big improvement, you can reduce the velocity...

But since head loss drops with the FIFTH POWER of diameter, a bigger duct gives you ENORMOUS improvements.

Doubling the diameter cuts losses by 32 times!

Minor head loss, despite its name, can really add up, too.

An air duct this size going around a sharp bend like this is equivalent to going through a much longer straight pipe like this.

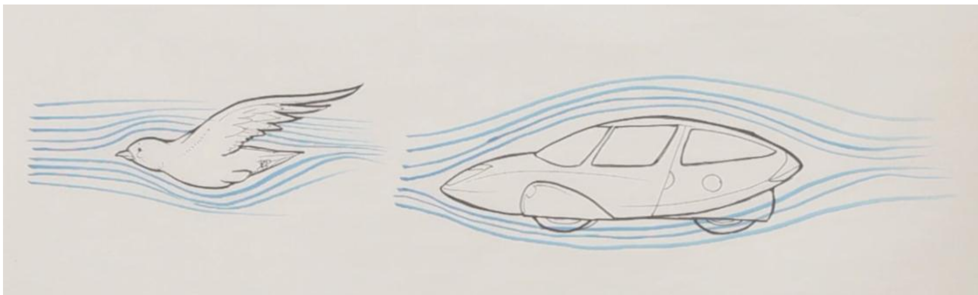
If there are too many sharp bends in your duct system, you might double the energy loss accidentally.

On the other hand, a smoother and gentler bend like this is equivalent to a straight pipe like this.

As you select shapes and materials, look for places where movement is happening.

Moving an object through a fluid causes energy loss. And moving fluid through an object does the same. With the right design thinking, you can cut these losses drastically.

And since designs that optimize fluid flow often looks like forms we see in nature, your users will love it.



It won’t just save them energy and money; it'll look beautiful, too.