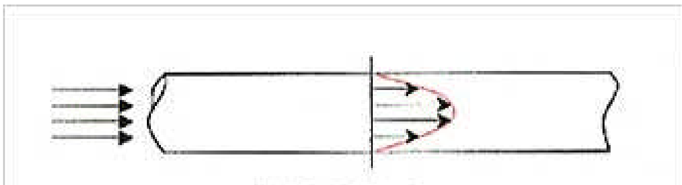
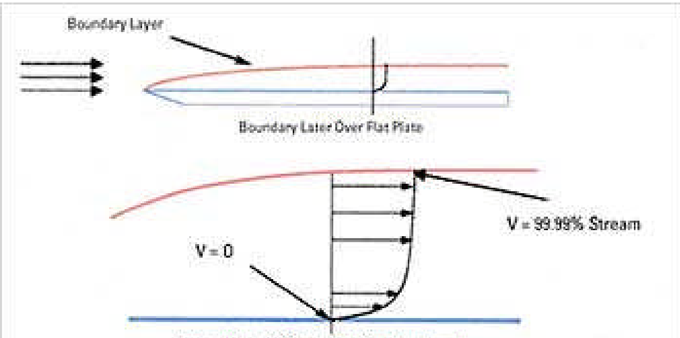
A boundary layer is defined as the region close to a body at which the speed of fluid changes rapidly from that of the body to that of the primary stream condition. If effect, the boundary layer is necessary to uphold what is called "the no slip condition," which states that the fluid contacting a surface is not moving in relation to surface. This can be easily demonstrated by looking at a pipe with water running through it.



Velocity Profile inside a Pipe

You can see that the velocity is Zero at the pipe wall, and the average fluid velocity is roughly 2/3 the maximum centerline velocity. The distribution is parabolic and mathematically, as well as intuitively leads to the conclusion that a bigger pipe can flow more water, with less momentum loss.

The same theory holds true in air, with the boundary layer of the pipe wall being directly analogous to any surface boundary subjected to airflow (neglecting the complexity difference between internal and external flow). This example also highlights some of the difficulties in wind tunnel work and testing where the tunnel diameter can drastically influence the data (size really does matter sometimes). For external flow, such as your disk, or helmet or whatever, let's look at the example of a flat plate.



Boundary Later Over Flat Plate

Enlarged Velocity Profile within Boundary Layer

The two diagrams above illustrate the behavior within the boundary layer, as the air moves from a relative velocity of zero at the surface, up to the free stream velocity represented by the red line. In a wind tunnel the free stream velocity is the air speed in the tunnel. Outdoors, the free stream is the local flow velocity due to a combination of wind speed and rider speed. The drag resulting from this boundary layer effect is called skin-friction drag.

Comparing the diagrams above, you can see that the pipe flow behaves as two boundary layers opposing each other (in two dimensions) and the velocity is never allowed to reach free stream (theoretical) velocity. This theory tells us that to have less skin friction drag, things should be moved apart from each other as to avoid boundary interference.

Boundary layer interference occurs when two or more boundaries lie in close proximity to each other. The pipe example above looks identical to two flat plates with flow between them. This phenomenon is of particular interest when looking at a wheel in a fork. The trend of late has been very narrow fork crowns with long, thin blades, generally airfoil derived cross-sections. These forks may behave better on their own than their predecessors, but with a wheel inserted, the results are generally less favorable. The worst offender by far is the composite spoked wheel, regardless of spoke profile. The spokes themselves, create large boundary regions, as do the fork blades, whereby inducing a very high-pressure wave front at the intersection of the boundary layers. To worsen the situation, the spoke behavior is not steady-state, as the spoke is still accelerating as it passes through the fork. The overall effect is a massive pressure wave creating a very high drag situation, and negating any drag reduction afforded by the wheel design.

Boundary layer intersection is much of the reason that a Zipp disk is flat. A lenticular disc may allow for improved strength using certain construction techniques, and even produce favorable tunnel data in some cross-wind situations, however, the bowed shape places the skin of the disc that much closer to the frame members of the bike. The worrisome members of the frame are primarily the seat stays, as both the disc and the seat stays at this point will have developed substantial boundary layers due to cross-flow. The chain stays are less bothersome as they are located Zero degrees to the direction of flow. Therefore, the boundary layer of the disc is small, while the chainstays themselves experience very little cross flow at all. The flat disc mitigates both of these problems. It maintains maximum distance from frame members, giving the absolute minimum boundary interference, and therefore, less total drag. As we have stated before, it is easy to make a disc or any given wheel look fast in the wind tunnel, but before believing any testing data, be sure to question the theory behind both the product, and the testing methods.