Critical power and Anaerobic Power (W')

Most riders nowadays are familiar with their threshold heart rate or FTP power. However, your threshold isn't the only metric you should be worrying about. In this article we are going to look at anaerobic power – what is it? How do we use it and how we can train to increase it?

What is anaerobic power?

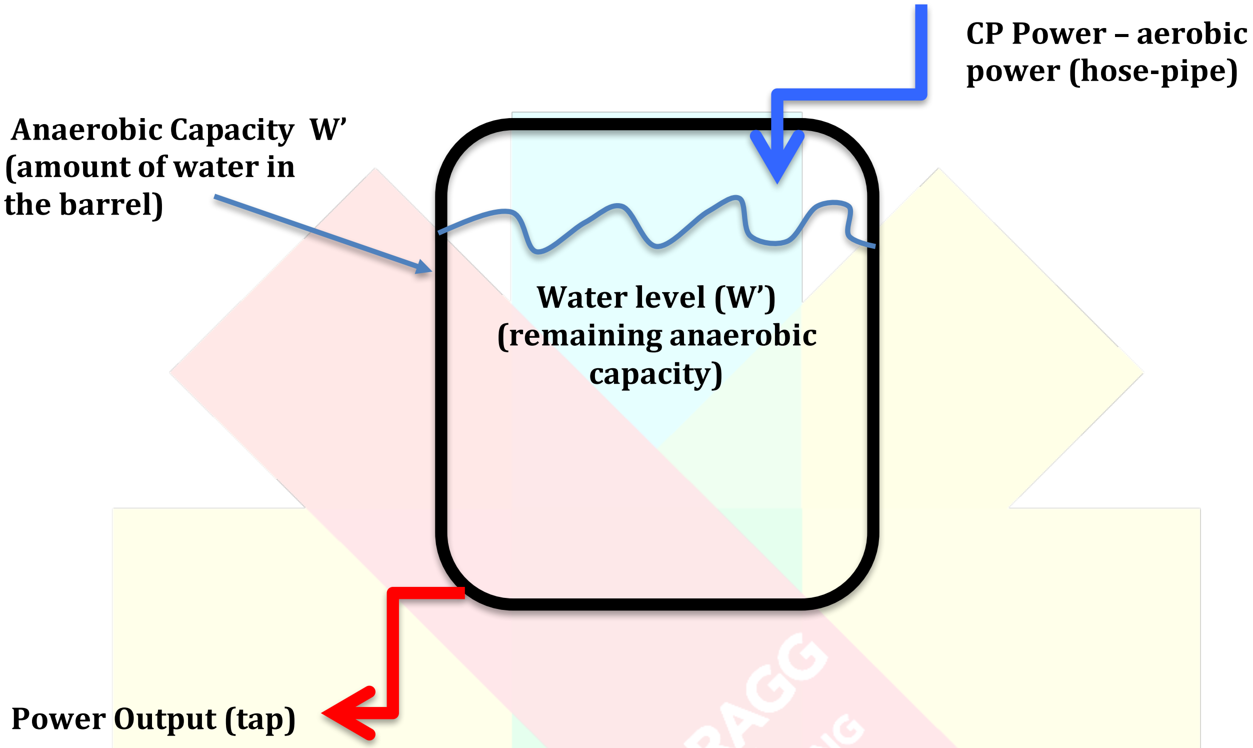
When people hear the term anaerobic their first thought is sprinting! This is because we have always been told that anaerobic means without oxygen and when we sprint we release energy so quickly that it has to come from anaerobic rather than aerobic sources. This happens as the aerobic pathways simply can't keep up.

This is of course 100% true, however what is often forgotten is that we can use both anaerobic and aerobic energy pathways together to produce power on the bike.

If you remember back to my piece on how to perform an FTP test (LINK) you will remember that we took 95% of the average power in your 20 minute test as your FTP power. This is because roughly 5% of the power in an FTP test comes from anaerobic energy pathways! In this example we can see that even in relatively long efforts we are still using some anaerobic energy! It therefore follows that the more anaerobic energy there is available the greater the amount of power we can put out on the bike.

Anaerobic + Aerobic = power output

To understand how both your aerobic and anaerobic systems work together to allow you to produce power we need to think of your anaerobic system as a big barrel of water.



Now consider that there is a hose-pipe going into the top of the barrel, this represents how much energy you can produce through aerobic pathways – this is your critical power.

On the bottom of the barrel there is a tap, this represents how much power you are putting out – this is your power output

The water level in the barrel represents your anaerobic capacity (W').

Using this model we can explain a number of things relating to how much power you can put out.

1, Your maximal sustainable power (how much water you can allow out of the tap without emptying the barrel) has to equal your critical power (the hose-pipe or water coming into the barrel) – power is only sustainable if the amount of water in the barrel (anaerobic capacity) is not decreasing therefore the maximal sustainable power output equals your critical power (hose-pipe).

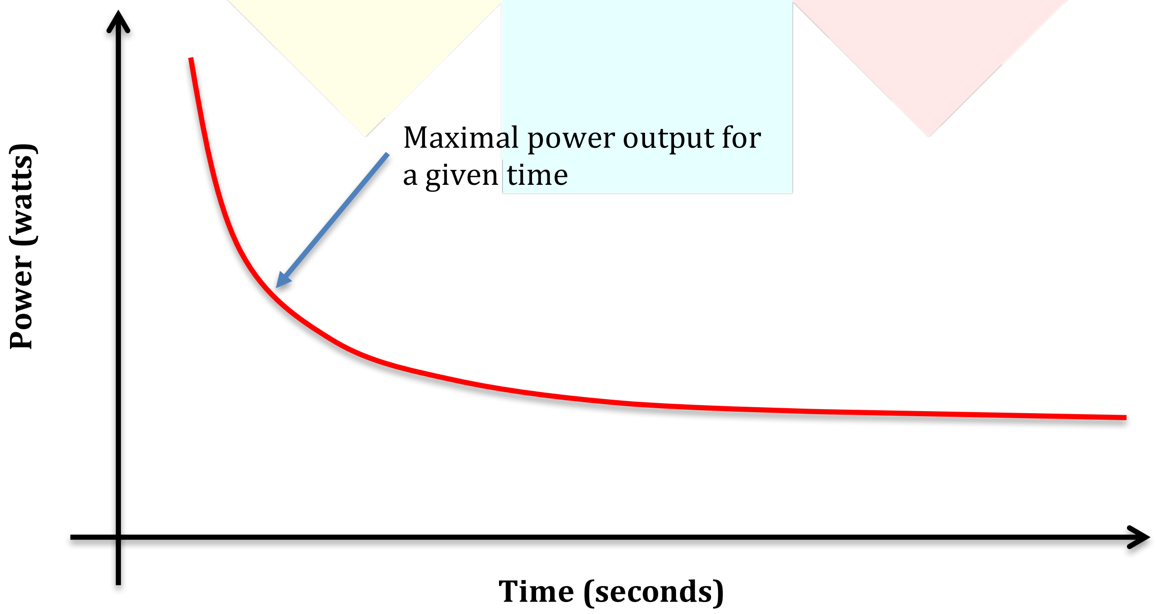
2, Power outputs above critical power are produced from a combination of critical power (hose-pipe) and your anaerobic capacity (water in the barrel). These power outputs are only sustainable whilst there is still water in the barrel (your anaerobic capacity isn't empty).

3, Once the barrel (anaerobic capacity) is empty, a bigger critical power (hose-pipe) will refill the barrel (anaerobic capacity) quicker than a smaller critical power (hose-pipe). We call this recharging your anaerobic capacity.

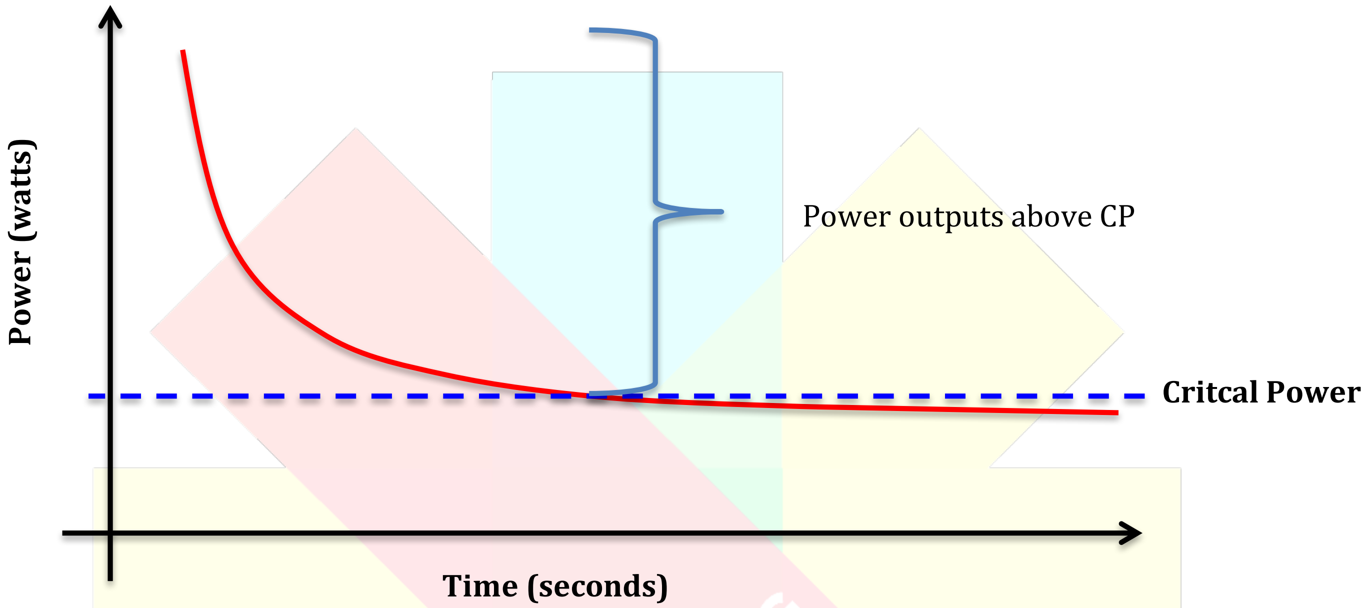
To understand how this process works in the real world we need to look at your power profile curve.

Power Profile Curve

You have probably come across a Power Profile graph on Strava or TrainingPeaks. This graph plots the maximal amount of power you can sustain for any given length of time! It looks something like this….



We can take this graph and add a line representing where critical power would fall on the graph. This is the point at which the graph flattens out – or the highest sustainable power output!

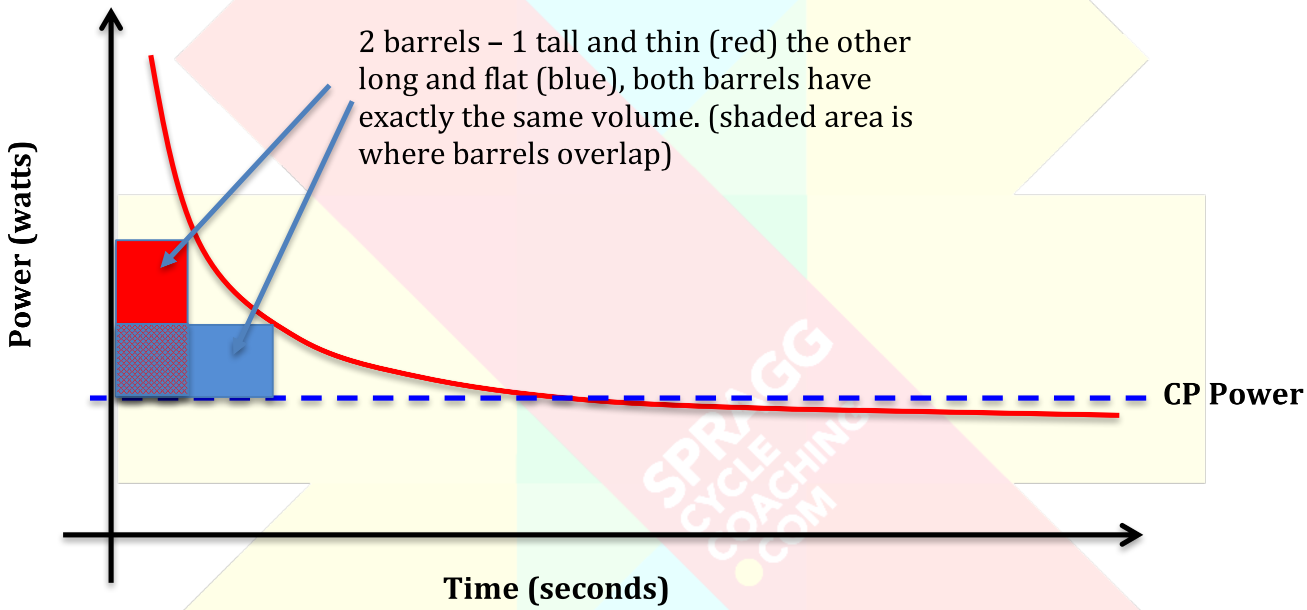


We know that for short periods of time it is possible to sustain a higher power output than critical power. These power outputs are represented by anything above the dotted line.

Returning to the barrel model we know that to put out more than crtical power you need to use some of the water contained in the barrel – your anaerobic capacity.
To achieve your best power output at the end of an effort the barrel needs to be empty. If the barrel isn't empty you had some more water in reserve that you could have used.
So it follows that if we are looking at maximal 10 min power we would need to let out the water in the barrel slower than for a maximal 3 min effort.

Now, if we consider the shape of the barrel. We know that to hold the same amount of water the barrel can take various different shapes as long as the volume of the barrel remains the same. So the barrel could be tall and thin or long and flat as long just as it holds the same amount of water.

We can see this process in action on the power profile graph. Below I have drawn onto the chart two barrels. One is tall and thin the other long and flat. What you will notice is that both barrels, when placed along the critical power line and the y axis, touch the power profile line.



Because we can see that both barrels perfectly fill the gap between the power profile line and critical power we can see that anaerobic capacity it always constant. The rate at which we use it when cycling is what dictates how much power we can sustain for a given time!

Predicting Power Outputs

So far we have seen that anaerobic capacity can be used in conjunction with aerobic energy (critical power) to produce short-term power outputs. We have also seen that the amount of anaerobic energy (water in the barrel) is constant but limited. Finally in the last graph we saw that the amount of anaerobic energy available is the same across all power outputs above critical power.

Therefore, if we know a rider's critical power and we know how large their anaerobic capacity is, in theory we can predict how long they can sustain a certain power output or what power output they can sustain for a certain period of time!

We measure anaerobic capacity in joules – this is important as 1 watt of power = 1 joule per second.

Our example rider has an aerobic capacity of 20Kj (20000j) and a critical power of 300w.

We can now calculate how long they can sustain 400w.

400w (flow rate out of tap) – critical power (300w) (flow rate into barrel) = 100w (this needs to come from the water in the barrel)

100w = 100 joules / second (the extra amount of water that needs to come from the water in the barrel)

20000j (water in barrel) / 100 joule per second (flow rate needed from barrel) = 200s (how long before the barrel is empty)

200s = 3 minutes 20s – This is how long this rider would be able to produce 400w!!

Likewise lets say their coach had set a maximal 10-minute effort for them – we can easily calculate the power output they can sustain for 10-minutes!

10 minutes = 600s

20000 j / 600s = 33.3w

300w (CP) + 33.3w = 333.3w – this is what this rider could sustain for 10 minutes!

The many names of Anaerobic Capacity

Anaerobic capacity is called various things dependent upon which training platform you choose to use. Golden Cheetah for example will refer to it as W' (pronounced w prime) whereas TrainingPeaks WKO will refer to it as FRC (functional reserve capacity). Other articles may, as we have here, refer to it as anaerobic capacity or even anaerobic work capacity however you can use all these models in the same way to predict both time to exhaustion and the maximal sustainable power output for a given period of time.

Testing your CP and Anaerobic Capacity

There are a number of tests to determine the size of a rider's CP and anaerobic capacity. The quickest of which (read most painful) is what is known as the CP3 test – A 3 minute max effort where by start off by sprinting as hard as possible and then try to continue and make it to the three minute mark! The idea with this test is to empty the barrel as quick as possible and then continue. If the barrel is empty, then the maximum power you can sustain is equal to your CP power. Once you have an accurate score for CP you can calculate the size of the anaerobic capacity based on the average power for the 3 minutes. This is not a test I would recommend doing on your own only do this under laboratory supervision as it is incredibly intense!

Another way to predict your CP and anaerobic capacity is over a number of individual time trials ranging from 3 minutes to 15 minutes. Doing this allows software such as TrainingPeaks WKO or Golden Cheetah to draw your power profile curve. Once you have the curve it is possible to predict CP power (based on where the curve flattens) and then calculate the size of your anaerobic capacity. Otherwise with a bit of clever math and an excel spread sheet a clever coach can calculate CP and W' and then track changes in them over time. This allows them to track how an individual athlete responds to a certain training stimulus.

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