How do I choose a VE table?

What you should understand about the choice you make.

Position 1 of this document:

An internal combustion engine is essentially an inefficient air pump since air is drawn into the combustion chamber, compressed and then pushed out the exhaust.

A measured characteristic of a pump is how efficient it is when compared to the sweep volume of the piston through the cylinder.

This efficiency is reported in Volumetric Efficiency (VE) values.

Fundamentals:

Let's work with a single cylinder pump with a 10 cubic inch displacement.

If we measure the air volume displaced by our pump for each rotation of the crankshaft it can be used to formulate basic VE.

Example:

- 10 CI cylinder
- 6 CI of air displaced per rotation of the crankshaft.
- 6/10 = 0.60 or 60%
- Under the condition above the pump has a VE of 60%.

As the crankshaft speed increases (RPM) the draw of air volume will increase and since air has a mass (weight) we may see the loading of the combustion chamber increase over the slower speed.

Presuming the higher speed of our pump now results in 6.4 CI of air being displaced by a single sweep of the cylinder.

Using the same equation as before:

- 10 CI cylinder
- 6.4 CI of air displaced per rotation of the crankshaft.
- 6.4/10 = 0.64 or 64%
- Under the new condition above the pump has a VE of 64%.

Why is this even important?

Let's move to our internal combustion engine.

There are many variations of engine parts that influence air flow therefore it's extremely difficult to accurately predict what the VE of your engine (air pump) is although we can speculate based on common conditions. More on this later.

Position 2 of this document:

For this discussion I am stating "the camshaft is the most common & greatest influence of the engines potential flow of air".

What about the CAM files?

A conceptual overview of the cam files (Cam1 – Cam4) supplied by the EFI manufacturer will help… not in specific detail but in general terms.

Let's work backwards on the cam profiles:

Presuming we build a very efficient motor and achieve a VE of 100% for a given high RPM with a specific radical camshaft. The power curve of that motor will track the characteristic of the air flow through the motor. *Let's not get wrapped up on the influence of timing, AFR, etc… just accept the relationship between air flow and power please.*

At idle that radical motor will be very inefficient and have a poor VE of 20-30%. As we dial up the RPM the air velocity increases and moves air volume per stroke of the piston. With the higher air velocity, we get a greater fill of the cylinder and we are increasing the air volume per stroke resulting in a greater VE value.

Let's call that VE Profile4 (Race Cam).

Now pull that radical camshaft and drop in a slightly milder camshaft (Still bumpy & fun). Changing nothing else in the motor we will see the power curve change because the air flow characteristics of the motor change. The motor may even have a point where it hits the same VE as the radical cam although it WILL happen at a different RPM.

Let's call this VE Profile3 (3/4 race)

Repeat this same thing for an RV cam and for a fuel economy cam to get VE Profile2 & VE Profile1.

Now we have 4 VE Profiles of Cam1, Cam2, Cam3 & Cam4.

Based on all these flow characteristics we can use math to calculate the air volume at a given RPM. Now that we can assess the volume of air we can add the appropriate quantity of fuel to the mix for the optimum Air to Fuel Ratio.

WHY?

Let use 900 RPM and 3000 RPM as the examples since all 4 cam profiles could possibly see that RPM (*Yes, I know a race motor will idle much higher than 900 but let's go with it for now anyhow*).

Profile1 (CAM1) will likely have a better idle profile so it is likely more efficient at 900RPM then say the larger cam profiles (CAM2-4).

CAM3 & CAM4 are likely so inefficient at low RPM it may be impossible to idle that low.

At 3000 RPM the Profile1 (CAM1) may have already peaked from an efficiency perspective although the larger profiles (CAM2-CAM4) likely have their best flow higher up the RPM range.

Therefore, you have the different CAM selections in the software/handheld as starting points.

SECRET SAUCE:

In the example above all 4 profiles would be an EXACT fit for the engine/cam combination because they were presumably a flow curve of the same motor with AFRs all dialed in, timing is correct, and the only difference was the camshaft.

The different camshaft is likely selected based on the use of the motor. Daily driver, Modest street/strip, Off-shore racing, Drag Race.
Each combination would result in its peak power being at different locations on the RPM range and the curve may be broad or sharp.

Why one CAM table does not fit all!

Because the camshaft is not the only part that impacts air flow.

Using the same motor with the first camshaft (Radical Race) as the base let's change a few things… Change the heads to lower flowing units. This will directly impact both the power curve and the air volume flow curve.

Add to this restrictive exhaust or change to open headers…. The power curve changes again and so do the air flows.

If the air flow is changing, we need to obviously change to fuel delivered to maintain the target Air to Fuel Ratio (AFR).
If the VE table is not exact then we need a correction table to apply/overlay against the selected VE table.

Modern EFI can manage this in two ways:

- Fuel Learn values
- Fuel Trim.

Fuel Learned values:

Essentially this is the correction factor of fuel delivery based on the O2 sensors readings (Lean or Rich). Of course, there are default limits to how much the system can "learn".
When you <u>start new</u> and select a CAM1 – CAM4 value the system starts with a 100% in the learned values. If the O2 sensor detects a RICH condition the learned value for that condition is reduced. To capture this the 100 value will need to be reduced to reflect a smaller fuel delivery offset. If it is reflecting a LEAN condition the learn value will be increased. This is to perform gross offsets of the actual VE against the CAM(1-4) profile you selected.

If the learned values reach the default limits, then the system cannot properly correct for the difference between the CAM(1-4) profile and the actual VE of the motor at that given

RPM/MAP condition.

(See correcting for VE discrepancies).

Fuel Trim values.
This also has default limits that can be reached. If you reach the limits you lose the ability to properly manage the actual AFR of the engine during transient conditions.

The Fuel Trim is really intended for transient conditions where the EFI can momentarily add or reduce fuel for the moment but not immediately alter the learns.

Correcting for VE discrepancies:

If you cannot find a CAM(1-4) profile that functions adequately for your engine combination then you have 2 choices and either may be fine for some cases and likely a matter of personal choice.

- Expand the default learn limits to allow your system to control the AFR.
- Modify the VE values in the selected table to match the actual VE for your combination.

How to adjust the default values or the VE table are not in scope of this document.