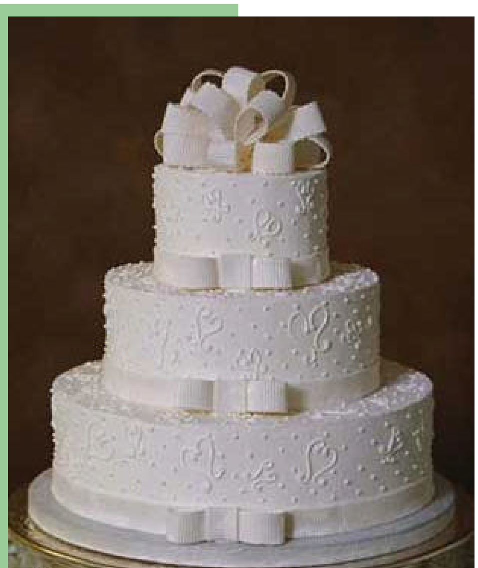
MegaMeet 2008

MegaSquirt

EFI Fundamentals

Bowling & Grippo

Lets make a cake!



Its C_8H_{18}!

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Fundamentals

Engine Controls is Like Making a Cake…

One Part Hydrocarbon

+

Lots of Air

+

Fire

=

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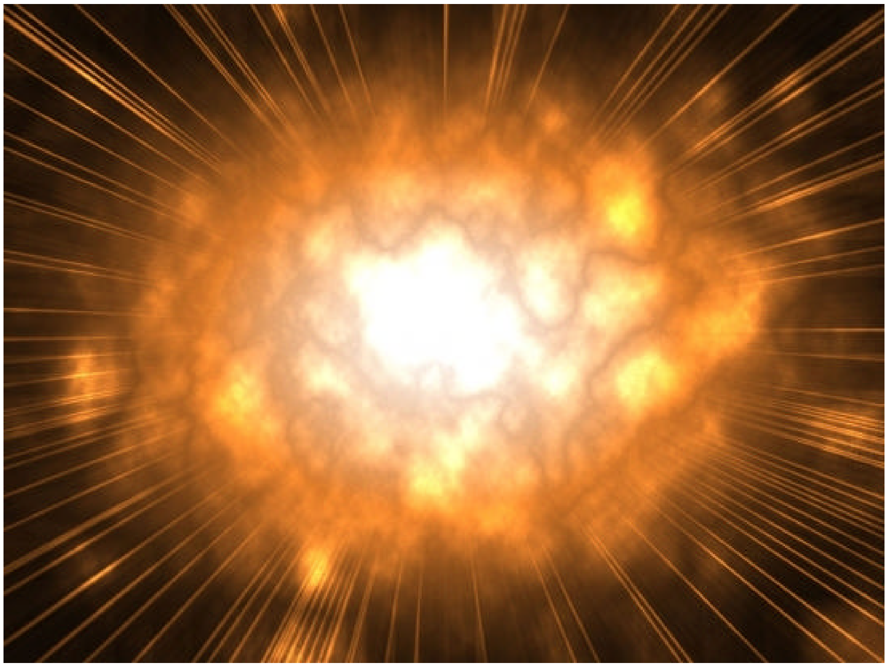
Fundamentals

Engine Controls is Like Making a Cake…



Fundamentals

Engine Controls is Like Making a Cake…

Results:

Water and Carbon Dioxide

But only if you got the mix right.…

Fundamentals

- To make the "perfect" explosion requires the correct mix of:
  - Hydrocarbon (form of C-H-O-N)
  - Air (Oxygen and Nitrogen)
- Then a good spark to get the energy out
- The "boom" part
- Then the remnants of the explosion:
  - H_2O
  - CO_2
  - NO_X
  - H_2
  - CO
  - H_xC_y
  - Other junk..

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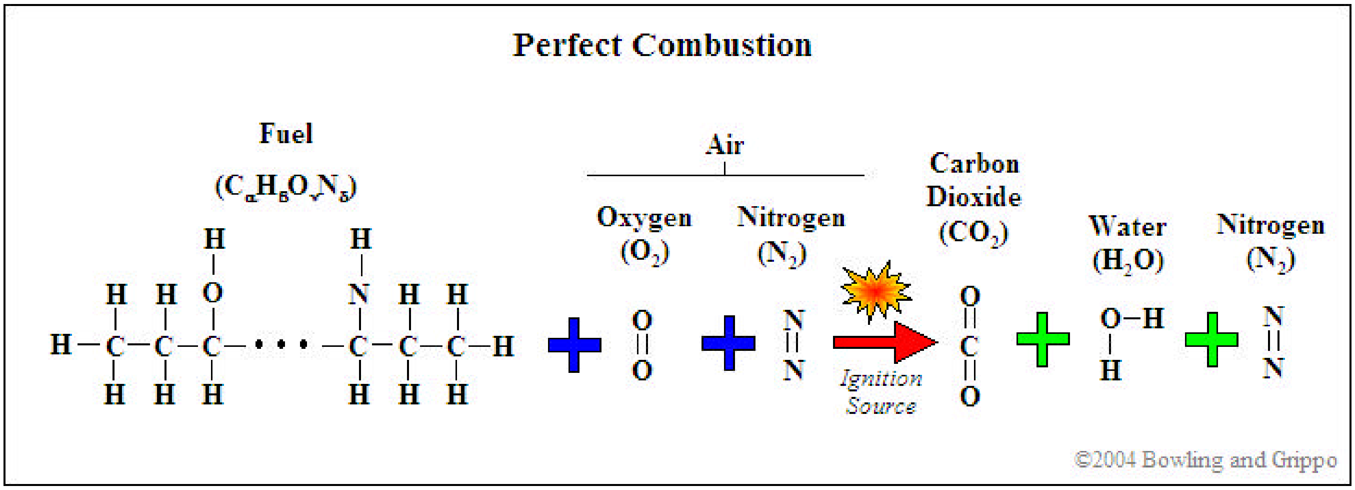
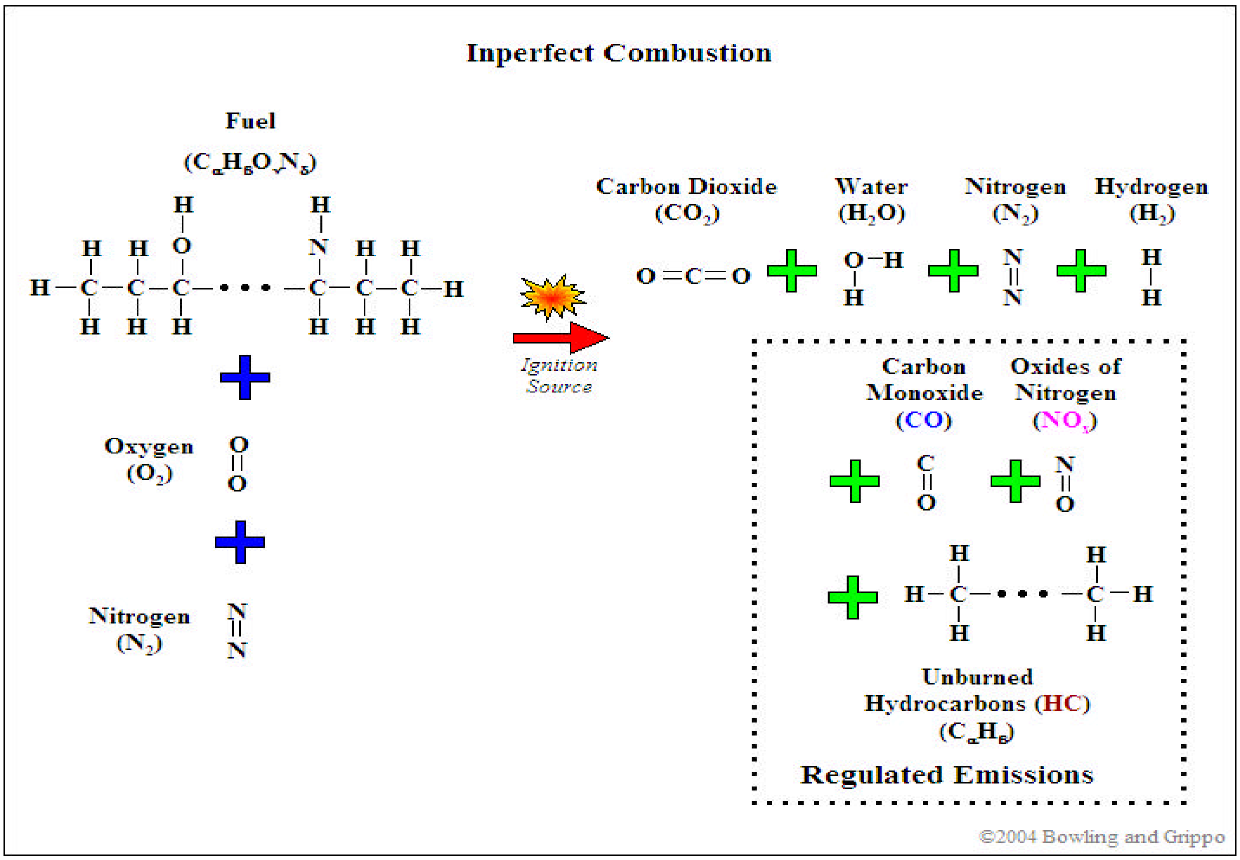
Fundamentals



Fundamentals



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Fundamentals

- If the mix is perfect, the results are a perfect match of hydrogen part of the hydrocarbon to the O2 to make H2O and the carbon part with O2 to make CO2
- If there was too much air, then there is left over O2 after the explosion – this is LEAN
- If there was not enough air then there was not enough O2 to combine with the hydrocarbon, the results are a hole bunch of leftover junk, including CO, H2, NOX,

Fundamentals

What is 'Stoichiometric'?

Octane, the most 'representative molecule' in gasoline, burns as:

$$C_8H_{18} + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$$

C_8H_{18} is the formula for octane. The oxygen (O_2) is consumed from the intake air. Nitrogen (N_2) is also present in the atmospheric air, but ideally does not participate in any reactions (it is quite inert at low temperatures). Note that the combustion products are carbon dioxide (CO_2) and water (H_2O), if the combustion is 'perfect'. Also, note that there are the same number of each kind of atom on each side of the chemical equation: 8 carbon, 18 hydrogen, 25 oxygen atoms on each side, so the equation is properly 'balanced'.

In practice, premium gasoline has a ratio of 8 carbon atoms to 15.4 hydrogen atoms in its composition on average (and historically very few other atoms). The higher carbon ratio is because of branches, double bonds, and rings that allow for fewer hydrogen atoms per carbon atoms. This means that gasoline will burn a bit richer than pure octane. A greatly simplified chemical analysis for perfect gasoline/air combustion (*the ratio of fuel to air required for perfect combustion is known as stoichiometric - pronounced 'stow-eék-kee-o-metric'*) is:

$$C_8H_{15.4} + 11.85\ O_2 \rightarrow 8\ CO_2 + 7.7\ H_2O$$

Note that there is no such thing as $C_8H_{15.4}$, but you can think of it as an average of various hydrocarbons, such as 65% C_8H_{14} + 35% C_8H_{18}, or a number of combinations that result in a carbon:hydrogen ratio of 8:15.4. Also, the coefficients above represent ratios of the number of molecules. If you want a 'correct' chemical equation in terms of molecules, multiply the coefficients by 20 (I.e. $11.85 \times 20 = 237$, $8 \times 20 = 160$, $7.7 \times 20 = 154$, etc.).

The 11.85:1 ratio of oxygen molecules to gasoline molecules is the ratio of their numbers, not their masses. To get the mass AFR, we need to calculate how much each molecule weighs. Carbon (C) has an atomic mass of 12.01 daltons (*the unit of atomic mass*), oxygen (O) is 16.00, and hydrogen (H) is 1.008.

Fundamentals

- Here are the terms used to describe the mass amount of air to fuel:
  - Air-Fuel Ratio = Mass of Air/Mass of Fuel
  - Fuel-Air Ratio = Mass of Fuel/Mass of Air
- Lambda is the Relative Air-Fuel Ratio to Stoich Air-Fuel Ratio:

??? ? = $(\text{Air-Fuel})_{actual}/(\text{Air-Fuel})_{stoich}$

- When lambda is less than one, the mix is rich…
- When lambda is greater than one, the mix is lean…
- $(\text{Air-Fuel})_{stoich}$ is roughly ~14.5 for unleaded, and ~9 for E85.

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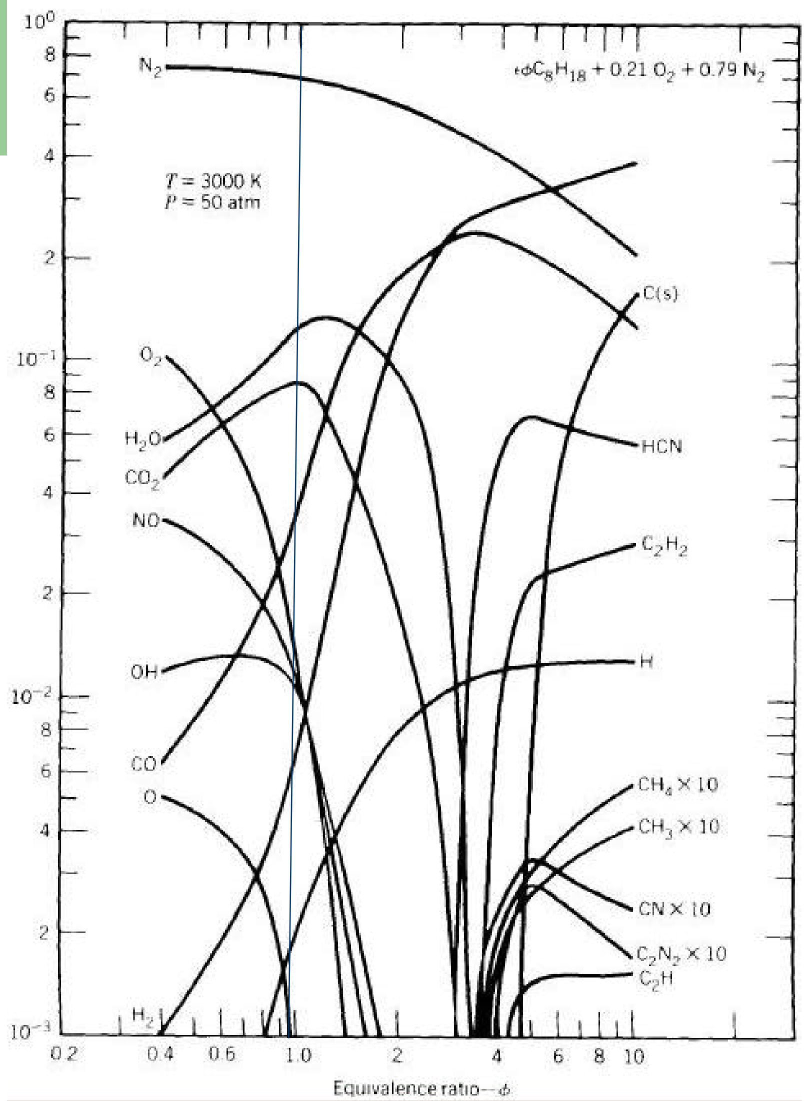
Fundamentals

- Engineers at times are *idiots* – someone being “cute” came up with the term “Equivalence Ratio”:

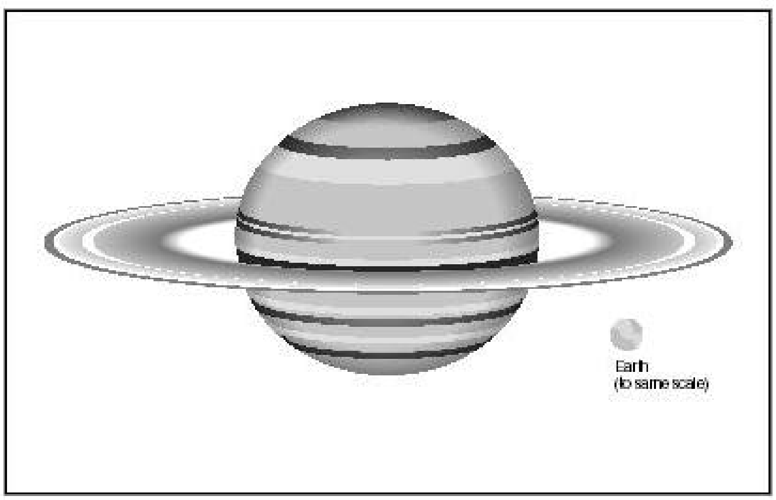
  ? ? ?????????? ?? ?? ?? = $(\text{Air-Fuel})_{stoich}/(\text{Air-Fuel})_{actual}$
- It’s the exact reciprocal to Lambda.
- It exists to simply confuse a simple term – however it is a bit more “intuitive” in its direction…
- When Equivalence Ratio is greater than one, the mix is rich…
- When Equivalence is less than one, the mix is lean…
- Actually, I like EQ ratio over Lambda (rich is a bigger number above 1), and all of the academic text uses EQ… But it still is silly to have reciprocal definitions just because…



Its all the gas results from different Equivalence Ratios

Fundamentals

- OK – Why do we need to use MASS air and MASS fuel, anyways?
  - Molecules have intrinsic mass, put a bunch of them together and their mass increases.
  - The volume of something depends on the density of the object:



ALTHOUGH SATURN IS MUCH LARGER THAN EARTH, IT IS MUCH LESS DENSE.

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Fundamentals

- Density: Is the Mass / Volume
- Things that have molecules have mass because molecules have mass
- Lots of molecules that congregate together in a volume have a specific mass that is the number of molecules times the mass of each one.
- If we **cram** in more molecules in a given volume the mass increases.
- A single atom of carbon, for example has a mass of 1.99×10^{-23} g.
- In other words, gram is about 50,000,000,000,000,000,000,000 larger than a carbon atom….

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Fundamentals

- Chemical engineers use a better *(cough)* unit called Atomic Mass Unit (amu) which is equal to 1.66×10^{-24} g.
- Here are some amu values:
  - Carbon = 12.011 amu
  - Hydrogen = 1.008 amu
  - Helium = 4.003 amu
  - Oxygen = 16.00 amu

- You do not have to worry about this, just note that the little molecules have mass and more of them means more mass. Think of a bunch of Ball Bearings…

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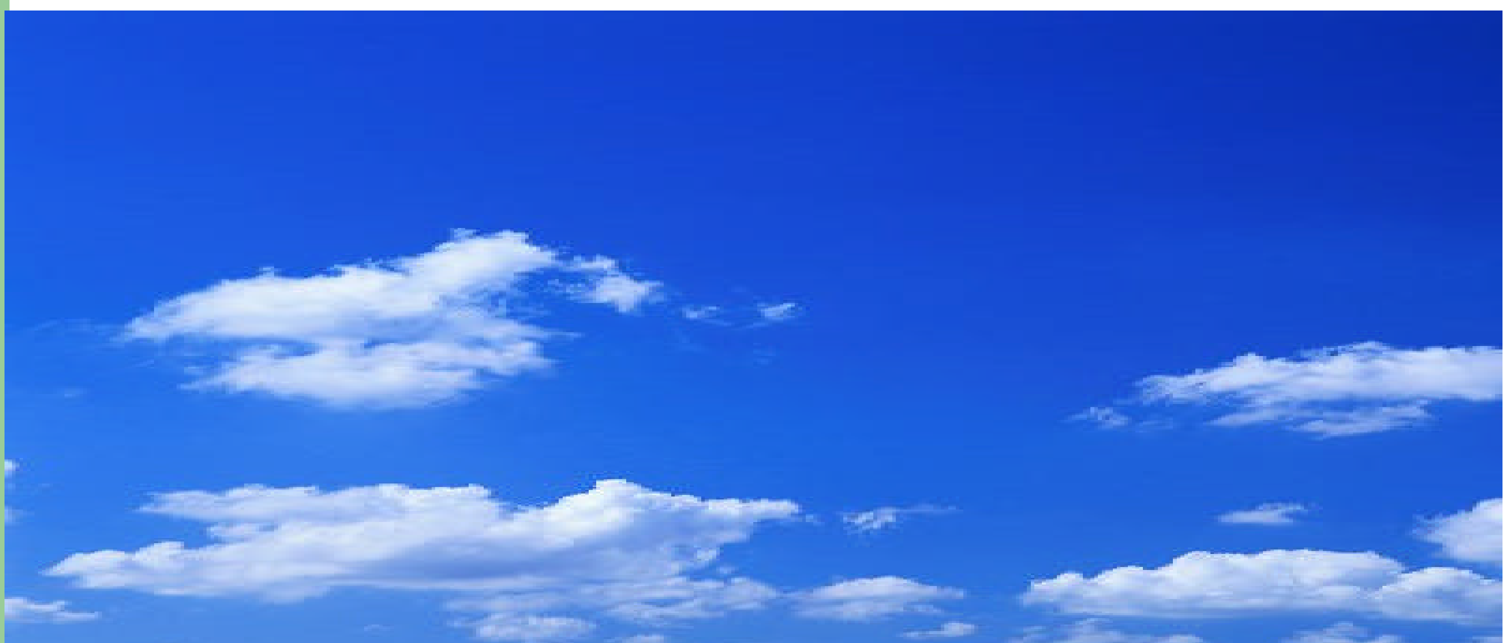
Fundamentals

What about AIR?



Does it weigh anything?

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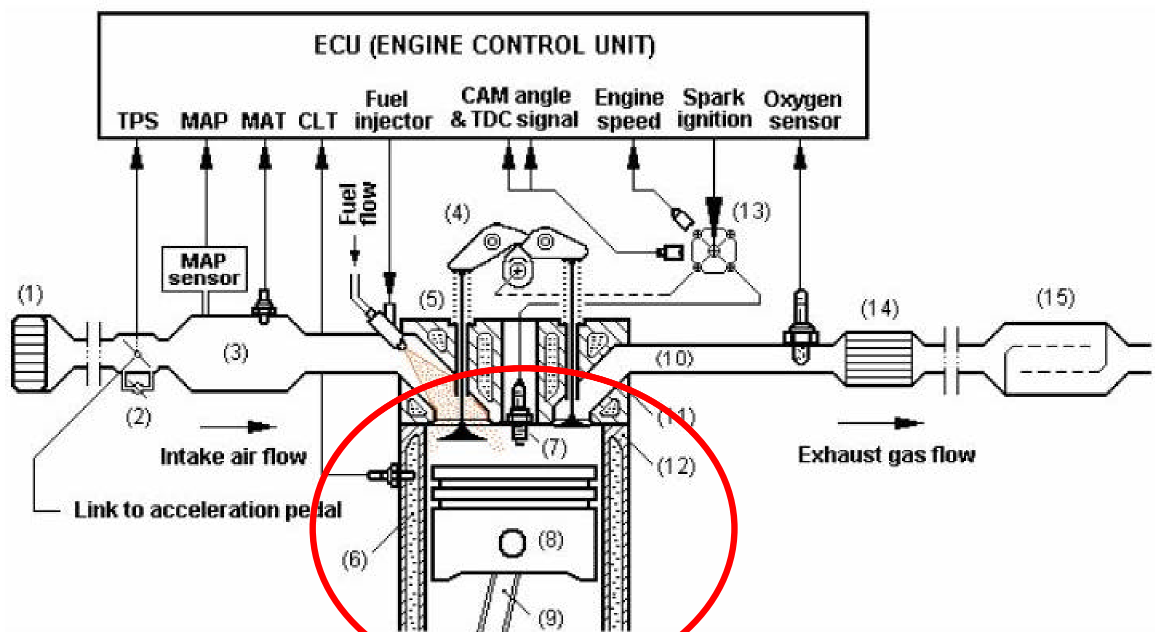
Fundamentals

- The IDEAL GAS LAW:
  - P V = n R T
  - P is pressure
  - V is volume
  - N is the number of molecules
  - R is the *Universal Gas Constant*
  - T is the temperature

- All gas operates by this law, there is no getting around it. All gases must follow this law.
- It is the cornerstone of air-fuel control!
- Its not just good – its <u>IDEAL!</u>

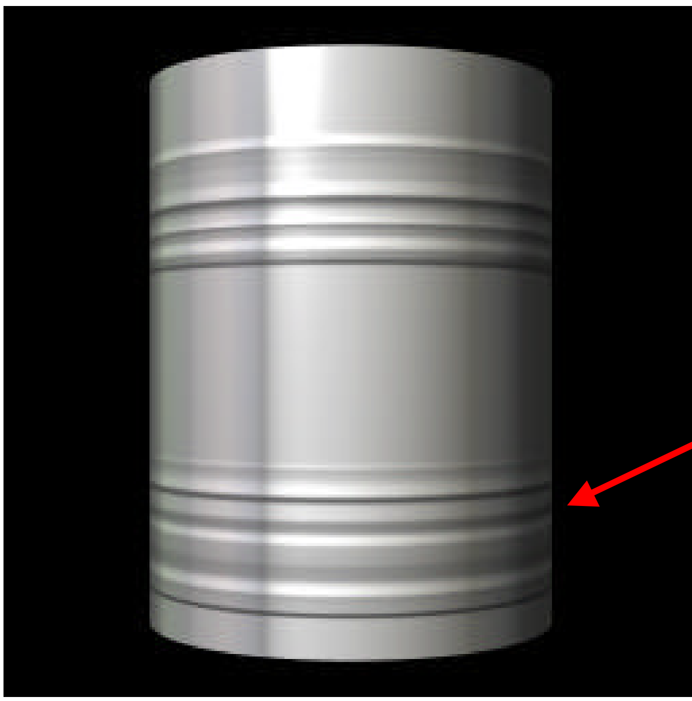
Fundamentals



(1) Air filter, (2) Throttle body and auxiliary-air device, (3) Intake manifold, (4) Cam and rocker-arm for valve system, (5) Intake/exhaust valve and valve spring system, (6) Coolant, (7) Spark plug, (8) Piston, (9) Connecting rod, (10) Exhaust manifold, (11) Cylinder head, (12) Cylinder block, (13) Ignition distributor, (14) 3-way catalyst, (15) Exhaust muffler.

This thing is the cylinder.

Fundamentals



How much air is in the cylinder?

Volume = 3.14159 * (diameter/2)^2 * height

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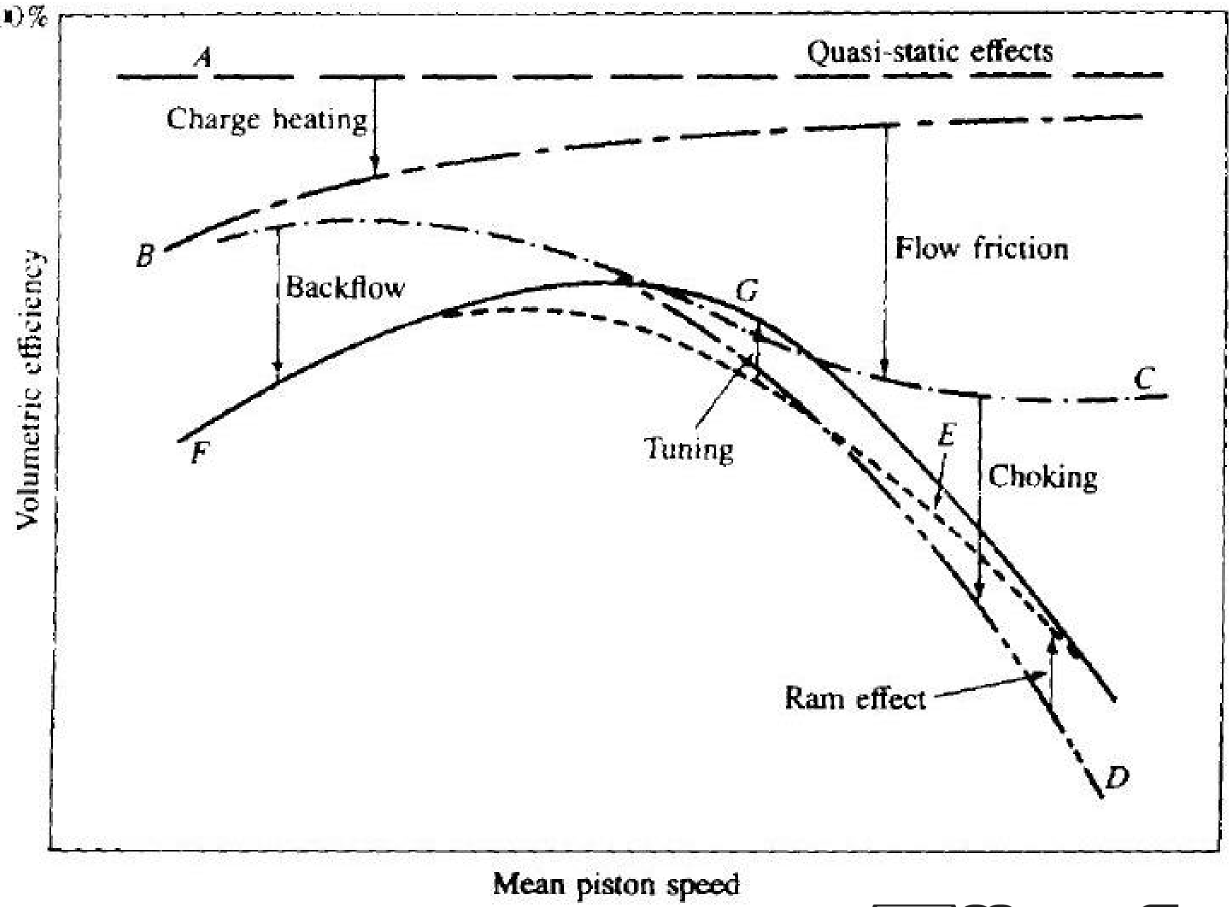
Fundamentals

How many jellybeans in the jar?

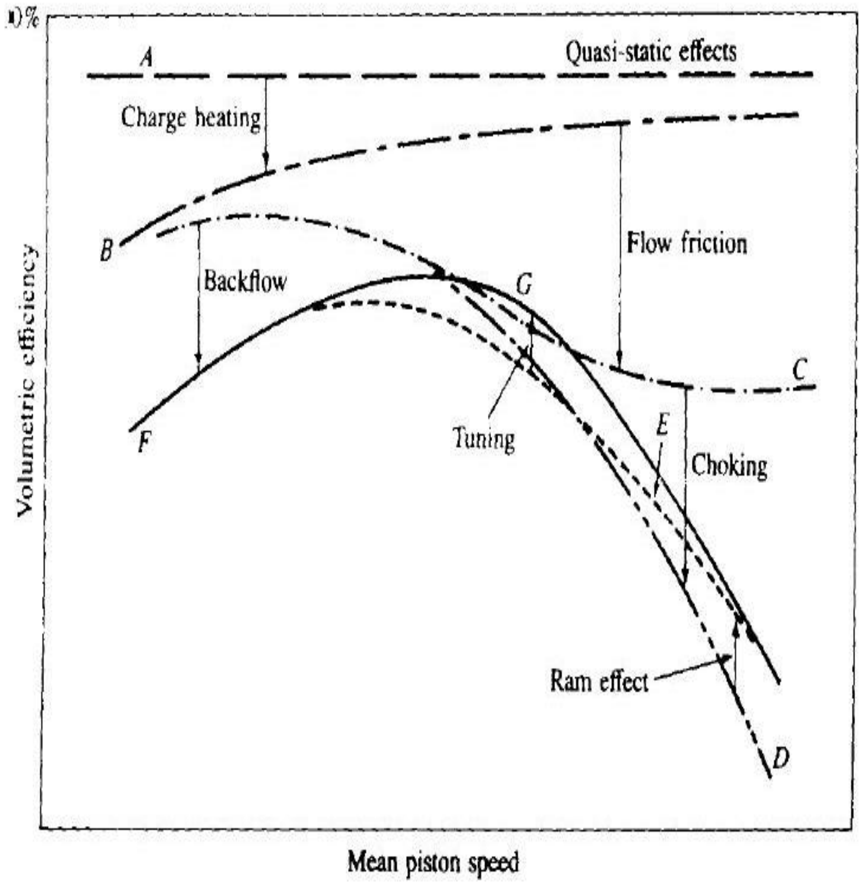
How much do they weigh?

Fundamentals



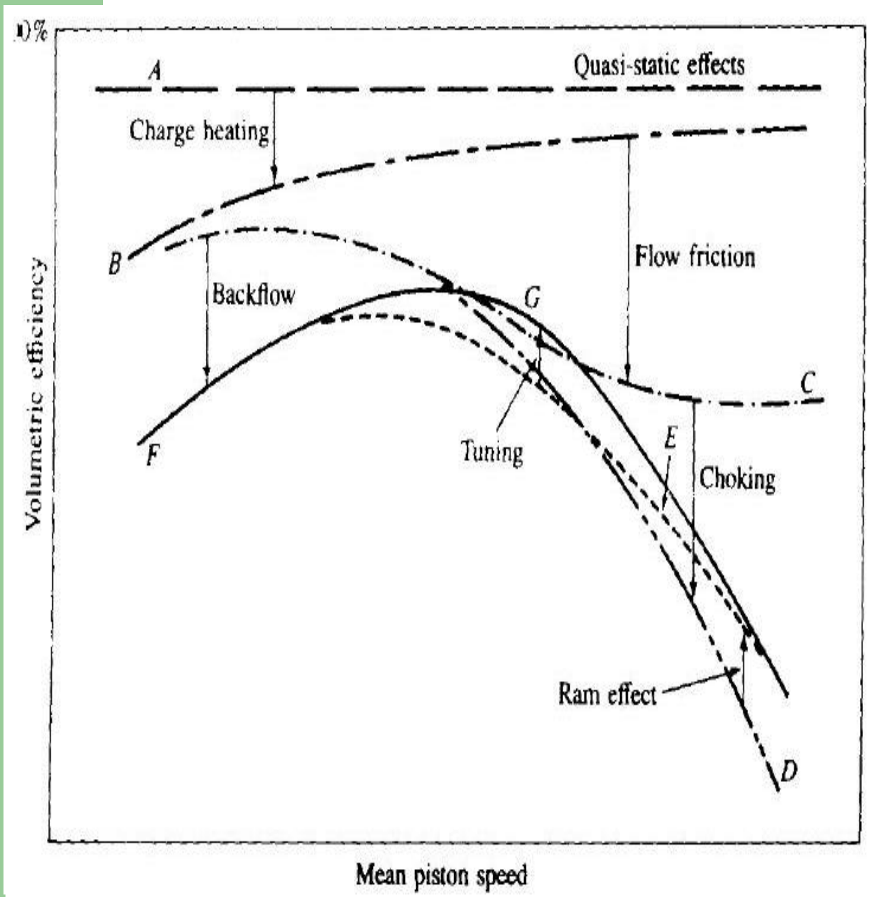
From Internal Combustion Fundamentals by Heywood

Fundamentals



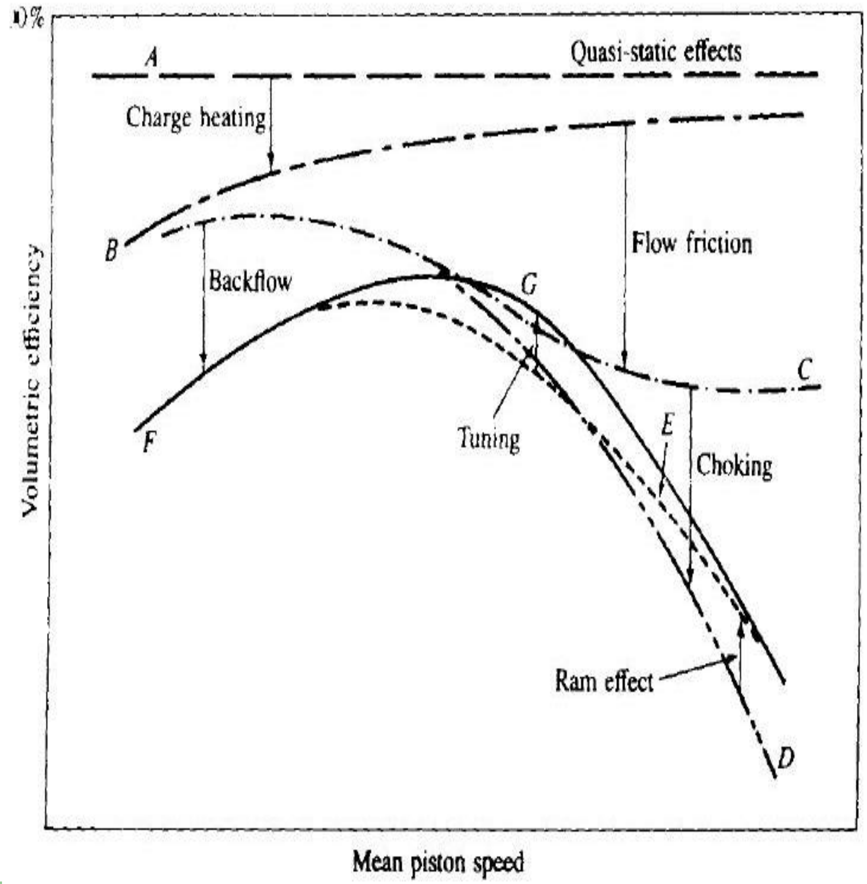
The A curve is the steady state (non speed dependent) effects which drop VE below 100%

Fundamentals



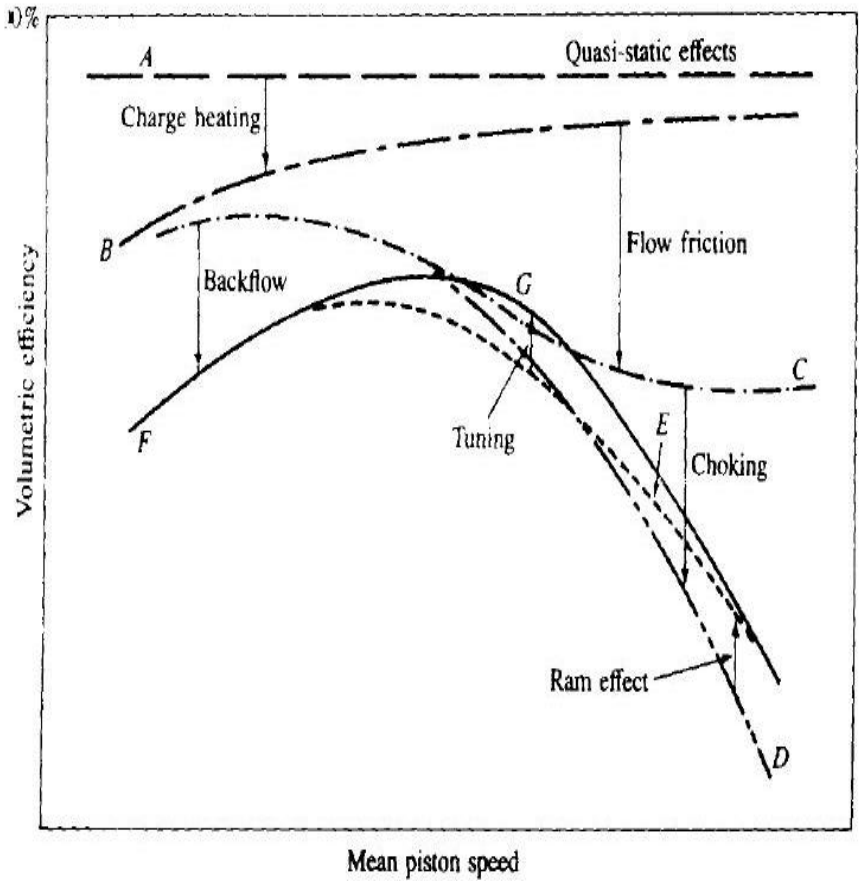
Charge-heating in the manifold drops the A curve to B – this has a greater effect a low speed because the (mass) air movement is slower and it has more time to heat up (I.e. longer gas residence time)

Fundamentals



Frictional losses drop the B curve to C, these are proportional to the square of the engine speed

Fundamentals



At higher engine speeds the air flow is "choked" and further increases in speed do not make more air flow, and volumetric efficiency drops dramatically, curve C to curve D (ouch!)

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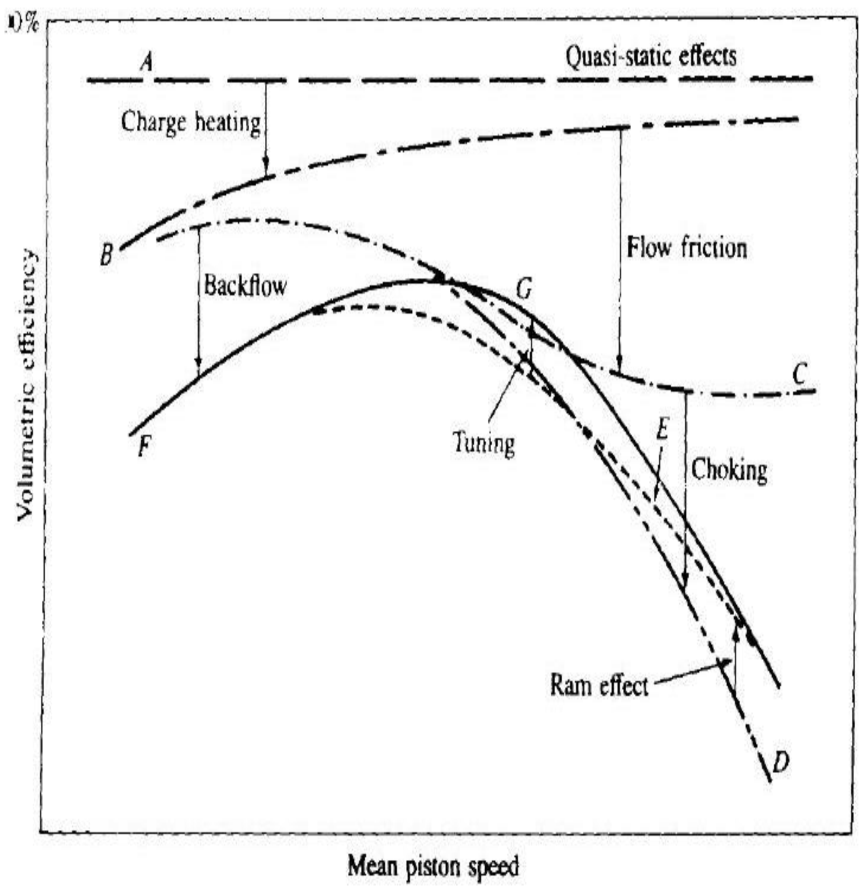
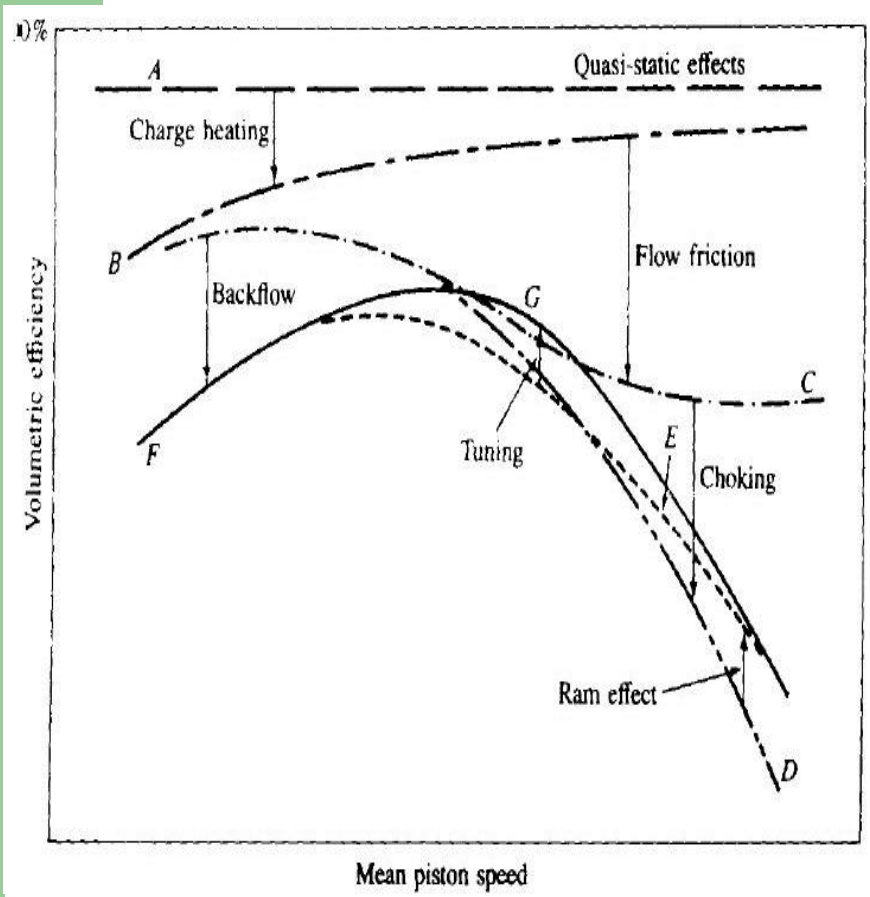
Fundamentals



Induction ram effects move the D curve up to E.

Fundamentals



Late intake valve close timing allows advantages to be taken (increased air charging) at higher RPMs screws up the volumetric efficiency at lower RPMs due to backflow of exhaust gas (curve C and D to F)

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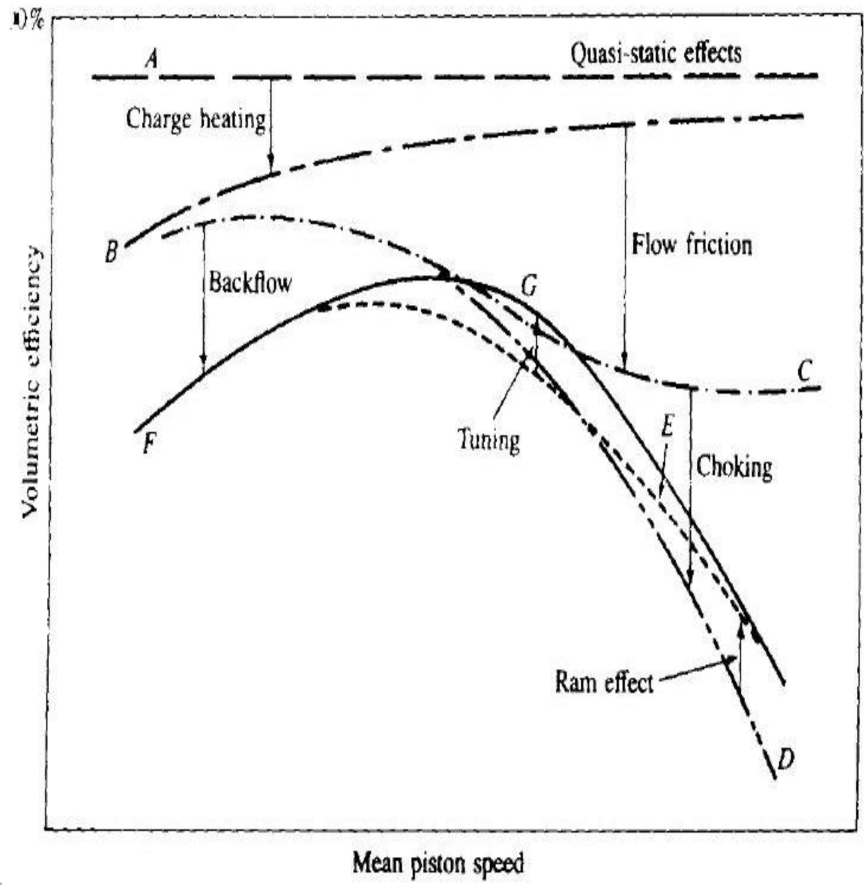
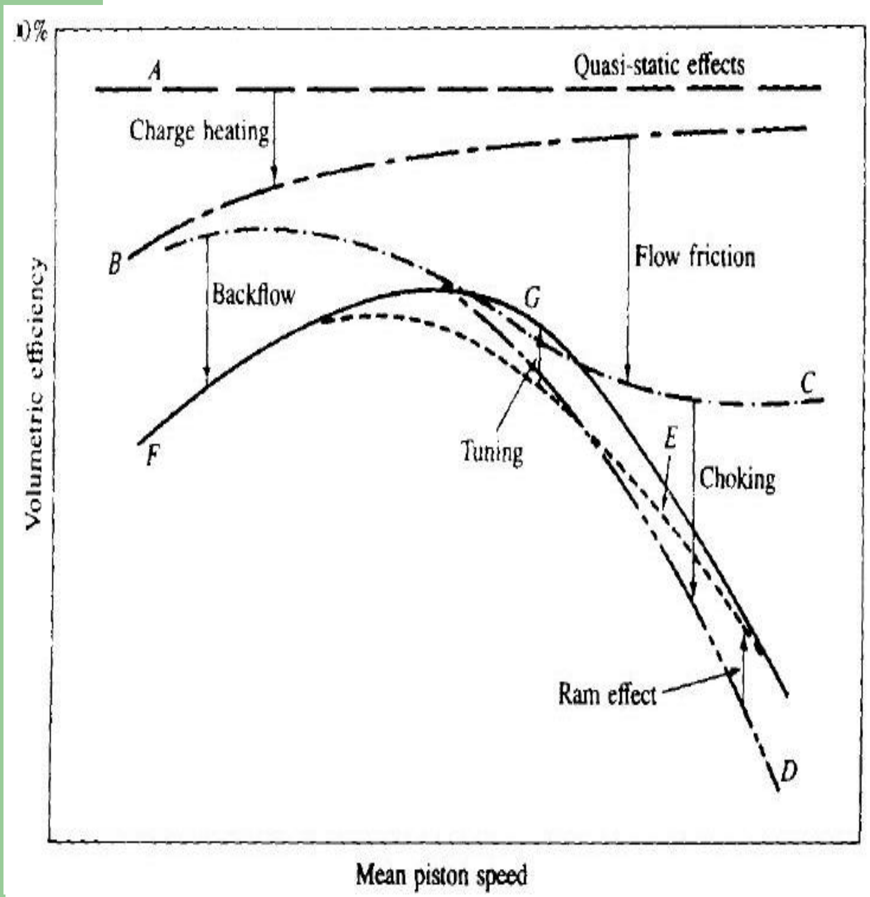
Fundamentals



Finally curve G is after a bit of intake and exhaust tuning which gives an increase at mid range RPMs….

Fundamentals

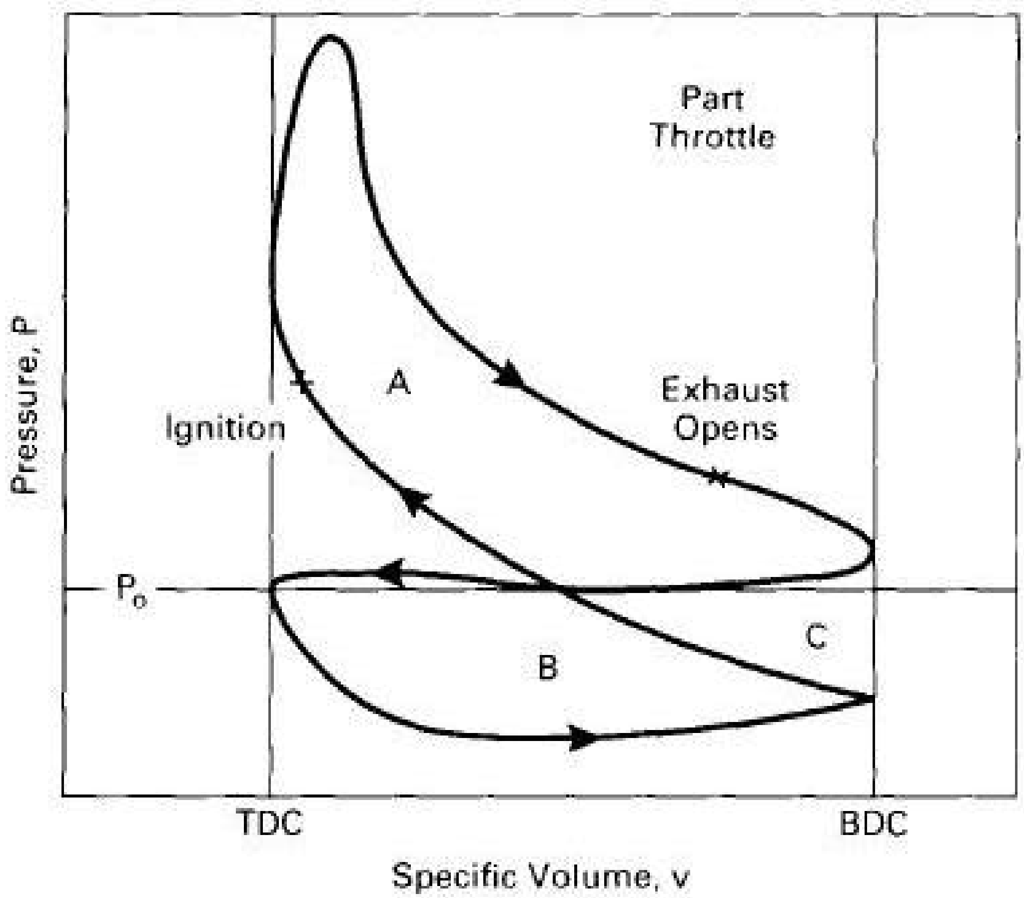


Now, ask yourself the following question….

With all of these differing effects, how can a tuning map be generic for all engines????

Its all in the airflow…

Fundamentals



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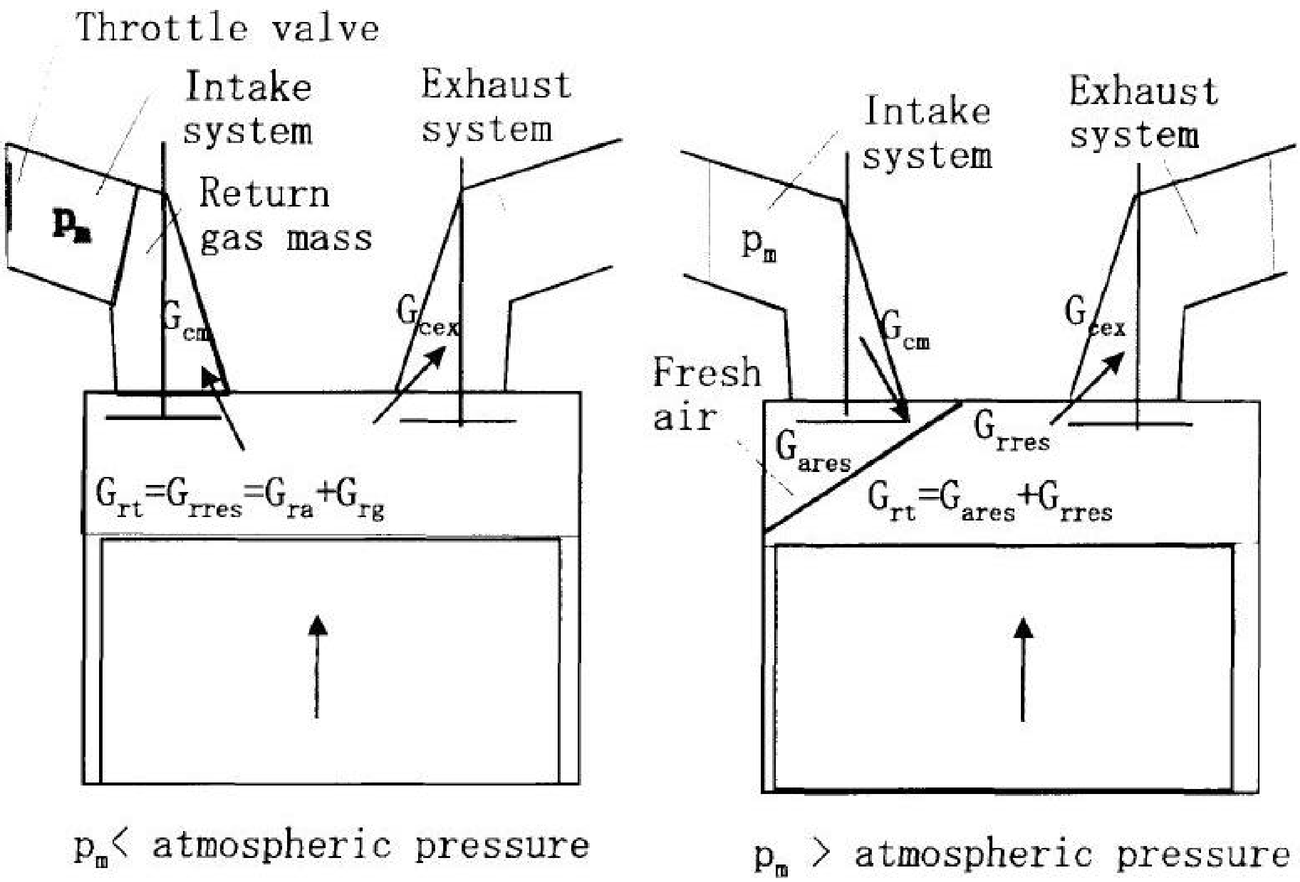

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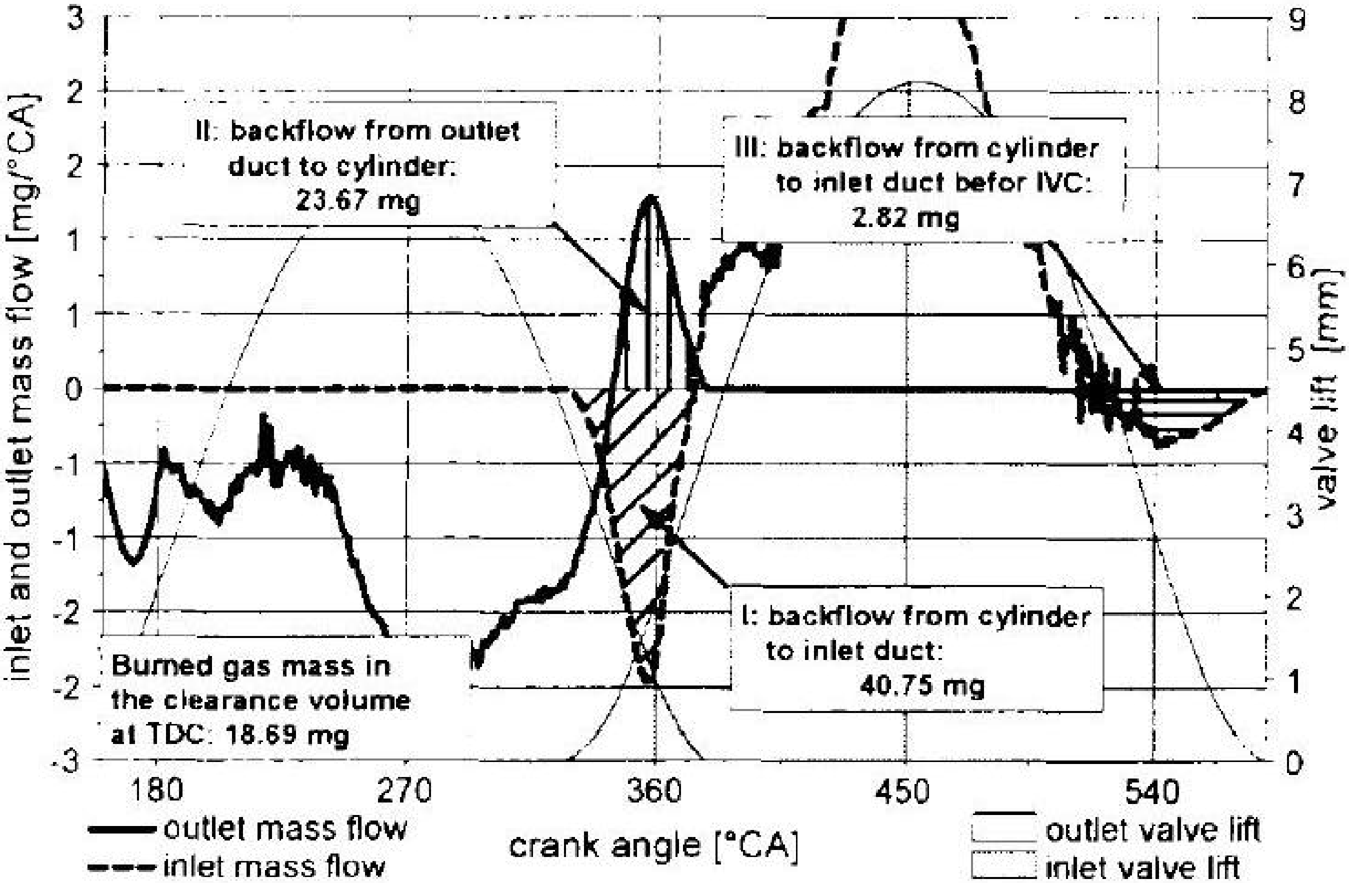

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