Carburetion, Fuel & Survival

Here is what I know or "think I know" about carburetion. (I consider "Carburetion" from the float chamber to the combustion chamber)

I have read and talked to people about carburetors from when I was a kid. Most things I read and heard I found were correct but not all.

Early on, the saying "Cram more fuel and air into the combustion chamber at a time to make the most horse power". This is generally true but that is not all there is to it. Fuel (gasoline) as a liquid does not burn. I can see your eyebrows going up on that statement. Sit tight, I will explain.

Burning is combining a fuel (gasoline [hydrocarbons]) with Oxygen. Only about 1/5th of the air is Oxygen so it is necessary to get as much of each little molecule of fuel close to each little molecule of Oxygen to get it to burn. Much of the remaining contents of air is Nitrogen which will burn but it don't want to. (NOX)

So the fuel needs to be vaporized and providing you have enough molecules of each close enough to the others so that one can ignite the other. (propagation) If your mixture is too lean the flame will go out because the fuel molecules are too far apart in the soup it is in. When car manufactures first started to clean up the emissions (1968) they leaned out the fuel mixture. In doing so, they some times couldn't keep the fire lit because fuel molecules were so far apart. To help counter this, they widened the spark plug gap so more fuel molecules would be involved, but then had to increase the voltage from the coil so the spark could jump the gap and so it would be a hotter spark. This presented other problems. A lean mixture tends to burn hotter which tried to burn the Nitrogen in the air which produced NOX, a more poisonous gas than they were already producing. To counter this, they decided to dilute the combustion with already burned exhaust. (EGR) (Seems like you can't win for loosing) It took another 30+ years to get the power back and get the exhaust cleaned up.

Smart people have figured out that there is a "Ideal" mixture of gasoline and air for piston engines. They named this mixture "stoichiometric" For gasoline it is about 15 to 1 mixture. The trouble is that each different fuel has a different "Ideal" mixture. And when you put each in a different environment the "Ideal" mixture is different. The "Ideal" mixture in Jax, FL is very much different than in Denver. Even if the temp was the same. The "Ideal" mixture in Fairbanks in the winter is very much different than it is in Miami even if the pressure was the same. DUH! what do we do now? So that we don't have to get out and change the carb adjustments we add a barometric pressure adjustment device and a temperature compensator to the carbs. (All those little thingies on Japanese carburetors) Fuel injection systems have these automatic adjustment devices plus a few more.

Even though you need the fuel to vaporize to get it to burn, I found that it is better to attempt to atomize the fuel as much as possible without vaporizing it until it gets into the combustion chamber. Why? Because, you want the air to stay as cool as possible until it gets into the combustion chamber. Cool air don't vaporize fuel very well. The reason you want the air to stay cool as possible is because when air warms up it expands and you can't get as much into the combustion chamber at one time. A normally aspirated engine only has about 14+ PSI to push air in on the intake stroke. OK! I'll cram it in with a turbo charger or super charger. Guess what! you will make more power but the process of compressing the air to force it in, makes it heat up which fights you. Along comes Intercoolers to cool it back down so you can "Cram more in". The early Mitsubishi Starion came with a turbo charger and an optional Intercooler. The Intercooler version produced 30 more HP than the non intercooler turbo. What's that got to do with me and my carburetor ? A lot if you take your air from under the

hood where temperatures can reach over 130 deg. If it is 90 deg. outside, that would be a 40 deg difference and a good intercooler is hard pressed to drop 40 deg.

If you can start the vaporization just as the fuel/air mixture is entering the combustion chamber there is a cooling effect due to the fact that when a liquid turns to a vapor it must absorb heat. It absorbs the heat from the air, manifold and intake valve. Seems like a paradox, with a cooling effect but absorbing heat which makes it expand.

A lot of other factors come into play too, including carburetor size and design, intake port design, valve size and position, compression ratio, combustion chamber design and cam design. Wooo! so much to worry about. It seems like every engine manufacture has their own idea as to what works best. Then add in each hot rod engine builder's own ideas. I don't know it all but here is what I have learned so far for normally aspirated engines.

- **High compression ratio not only squeezes the fuel/air mixture better but it makes a better suction on the intake stroke. (better volumetric efficiency)**
- **Fuel particles are much heavier than air so a tight turn in an intake will deposit fuel on the outer wall when trying to make a turn.**
- **Dynamic port design must be taken into consideration because the intake valve is CLOSED longer than it is open yet the air does not stop going into the carburetor at high RPM all that time the valve is CLOSED.**
- **Multi cylinder engines that have a single manifold have two or more cylinders at a time fighting for the same air in the intake.**
- **Sand blasted intake walls work better than polished ports. (who knew?)**
- **Exhaust tuning dramatically helps the intake, especially at high RPM. (All of us motorcycle racers knew that)**
- **Velocity stacks with good radiuses are a must on all carburetors**
- **Low resistance air filters are a must.**
- **Cool air available to the carburetor intake is a must.**
- **Carburetors and intake ports can be too large. (cam timing, lift, duration, valve size, compression ratio, exhaust design, intake port design size & design and carburetor size most be a <u>MATCHED</u> set for the kind of performance you are trying to achieve.)**
- **Fuel must match all of the above.**

Here is an example, if a manufacture has his engine design close to correct for what he wanted. It will have everything matched. Lets say you now have this engine and you want to hop it up a little. (This was me at the age of 17 and the engine was a 1938 Indian Chief.) I read a book on engine performance and it told me some basics of cam design. Cool!!! It said higher performance cams generally had a higher lift and longer duration and many cam re-grinders would just grind the base off of a stock cam to gain a higher lift and longer duration. Cool!!! So I took my cams out and went to my dads bench grinder and ground the base down on each cam. This meant I needed to adjust the lifters up to take up the excess clearance I now had. I had a straight road in front on my house and my younger brother

and I measured off a 1/4 mile drag strip and with my dad's stop watch I made a 1/4 mi. drag strip. I could lay about 15 foot of rubber on the start with the old cam. Cool!!! (we didn't say "Cool" back in those days but it was something like that) 18 seconds was the best time I could do.

With the new cams, I could only lay about 5 foot of rubber and it ran around 19 seconds. (not Cool) I played with the carburetor adjustment a little and found that it seemed to rev higher. I had been running the whole 1/4 in 3 gears. Now I noticed it would rev higher so I let it scream and found I now could run the whole 1/4 in just 2 gears. The time got down close to 17 seconds but I had lost low RPM torque.

The point is that what I did was somewhat wasted because I didn't know to do everything else to make the added cam lift and duration useful.

Years later a customer came into a shop I was working in and said he was disappointed in the performance he got when he bought a large carburetor and installed it. This is the same thing I did with my home made cams. You will only get a small portion of the performance available without correcting the whole engine.

About 10 years ago a friend who was a stock car driver and builder (he was tied in points with Darrell Waltrip just before Darrell went Grand National racing.) had a Isuzu pick up with an Olds 215 V-8 in it. It had a four barrel carb and stock exhaust headers but he had put a cam in and did some port work. It went strong but he got his doors blown off by a little Chevy with a big Chevy engine in it. he decided he needed a bigger engine and offered it to me cheep. I knew he did good work inside this little V-8 but from my motorcycle days I decided that with a 4 barrow carb and the exhaust headers, it was stopped up on both ends. At that same time my son told me about 4 two barrel down draft Weber carbs from a 308 Ferrari were available cheep. A light bulb went on in my normally empty head. So I purchased the carbs and the engine and sand cast my own intake manifolds and made my own headers. I hope to have this long time project running soon. I don't know if it would have redeemed his pride with the Little Chevy with the big Chevy engine but I am sure it will do better than what form he had it in.

SU & Stromberg

Carburetors like the SU and the Stromberg are "Constant Velocity" carburetors. They are called Constant velocity carbs because the air going across the jet is held roughly at the same speed no matter what the throttle position or the RPM is. Even though when you open the throttle a higher volume of air goes in, it's speed across the jet is maintained close to what it was at idle. The different amounts of fuel is controlled by a tapered needle in the main jet. The method used is a vacuum controlled piston which supports the metering needle. In the SU the piston is in a close tolerance fit in a cylinder on top of the carb commonly called the pot. The piston has no rings or seals on it. It does have several grooves called air dams. These air dams slow down any air leakage past the piston. The piston and pot are a matched set and should not be mixed up with any other. In the Stromberg the piston rides in a small cylinder attached to the top (pot) but uses a rubber diaphragm to hold a vacuum over the piston. The vacuum over the piston in either the SU or the Stromberg is transmitted by holes at the base of the piston on the engine side. At low RPM the piston of either carb would jump up and down with each pulse of vacuum produced by the engine so a method was needed to dampen this jumping. A shock absorber was installed in the top of each piston. This dampened the pulses at low RPM but it was there for another reason too. If the driver were to open the throttle too quickly the piston would jump up too fast and this would lower air speed initially across the jet which would lean out the mixture even though the metering needle was pulled further out of the jet. But with the shock, the piston was held down when the throttle was opened quickly. The opened throttle plate would allow more air in and

since the piston did not raise right away, the air speed across the jet increased which in turn drew more fuel in to the air stream. This takes the place of the accelerator pump on a standard carb. This design was the step between a standard carburetor and fuel injection. Several other car manufactures made a version of the SU with some success. With a constant air speed over the jet at all throttle settings and a tapered needle controlling mixture, it was more possible to have the mixture correct at all engine speeds. This was an advantage over a fixed jet carb that had the air speed vary and the fuel mixture by transition from one jet to another jet through the RPM range. As conventional carburetors tried to cope they added a air flow controlled butterfly attached to a metering needle to smooth out this transition of fuel mixture. The SU was ahead of it's time for many years. However, electronic fuel injection can more precisely meter fuel under countless changes in demands and environments.

Fuel mixture at "stoichiometric" is a compromise, not the most economic mixture and not the most horse power mixture. Horse power goes down as you change the mixture from stoichiometric toward lean but economy goes up. Horse power goes up as you move from stoichiometric toward a richer mixture but economy goes down. I read two reports on this from two large corporations. One contended that horse power continued to climb as they went richer than "Ideal" to a point of 15% richer, then it started to drop off. The other said they went 40% richer before the power started to drop off. The difference between these two figures was due to the different engine designs.

Alcohol Fuel

When you get into different kinds of fuel, like alcohol the above is still true but the figures change dramatically. For example, on a gasoline engine that is leaned out, the economy raises and HP goes down to a point where economy drops off also. This same engine if richened up will gain HP to a point where HP drops off. This range or band of useable power on gasoline is considered narrow as compared to an alcohol engine. An alcohol engine can operate in a very wide band or range of mixtures as compared to gasoline. Even without any test equipment a good mechanic can easily tell if a gas engine is too lean or too rich but it is more difficult to tell if an alcohol engine is too lean or too rich as the band of mixture that it performs well in is a very wide range. However, it does show in exhaust gas temperature so tuning an alcohol engine can be done with just a little equipment. You might say, "Why are you telling me all this stuff about alcohol fuel, I don't care about that" Well! you better, as many new cars sold today are E-85 compliant and E-85 is 85% alcohol. Many major cities have E-85 fuel stations now. Right now just about everything in the US as in many other countries on earth is heated, cooled and transported by oil and a large portion of that oil comes from outside of the US and comes from very unstable countries. Many of these countries that produce this oil have been at war with everyone around them since recorded history. Alcohol is a good alternative fuel, but even if we turned all of the farm land into producing alcohol, we can not supply the volume of fuel we consume. So it is necessary that we utilize all of the alternative fuels to reduce our dependence on foreign oil.

Adjust Your Mixture With NO High Tech Tools

Working in a Jaguar dealership in FL for many years, I was confident in my abilities to tune most any carburetor and or injection system on most any imported car and I was confident in my skills when using CO equipment and a scope. I could tune SUs or Strombergs with or without CO equipment.

One day I was tuning an MG with the scope and an exhaust analyzer when I noticed an old man watching me. In this shop customers were allowed in the shop area and he was waiting for his car to have some service work done on it. He asked about the equipment and I didn't mind so I explained a little about the analyzer and the scope and how we could adjust mixture on the carbs with the analyzer and even see a difference in scope patterns when rich or lean.

He said he was a mechanic when he was young and that he had to adjust mixture without any equipment on cars in the 30s and 40s. He explained how he did it by adjusting the throttle idle speed down as low as he possible make it still idle. Then he would turn the mixture screw which ever made the engine either smooth out or speed up. Then he would turn the throttle stop screw down again to get the engine to run as slow as possible, and repeat the mixture adjustment to get it to speed up. He soon arrived at a point where if he turned the mixture screw in either direction the engine would die. He would then reset the idle stop up to normal idle speed and it was finished. He was going on the idea that his ideal mixture for idle would make the most horse power at idle. (slightly richer than stoichiometric)

I was working on an MG with two SUs so I tried it instead of the standard method using the piston lift pin. I used his method and when finished I checked it with the CO equipment and it was well within range. I got curious so I got a fuel injected car and used his method on it and when finished I checked it and it was also well within proper range. Within the next few weeks I checked several different kinds of cars and it worked on everything I tried it on. And I thought I knew it all. Here was a man who had not worked on cars since the 40s. Who showed me a method to just about match what high tech equipment could do even on an electronic fuel injection systems which had not even been invented when he had quit working on cars.

He was using the internal drag of the engine itself as the drag of a dynamometer. He forced the engine to labor to just keep running and turning the mixture screw which ever way made it speed up. The reason it speeded up was because it was producing more power. He would force it back slow again to put it under labor again and he would arrive quickly at a point that if he made it leaner or richer it would loose power and die. This was for idle mixture adjustment only as that was all he had an adjustment for. I wonder how many other low tech solutions there are to high tech equipment.

When you modify an engine you change a lot of things. You change the necessary advance curve of the ignition system, change the fuel mixture needed through out the RPM range. You can even change what kind of fuel is needed for that engine.

Most everyone has heard about a 200 MPG carburetor that was bought up by the oil companies and hidden form the public. I seen one working one time. It was on a Moped. Ha!

A piston engine (including diesels) only run on expanding gases. The gases are expanding because they are burning. (getting hot) The measurement of this heat is usually quoted in BTU or it's Caloric value. Gasoline has more BTUs than Alcohol and Diesel has more BTUs than gasoline. You might then say "Then why do the fastest engines (most powerful) engines run on alcohol?" Because there are other factors involved. As you raise the compression ratio of a piston engine, you gain more volumetric efficiency. (more bang for the bucks) As you continue to raise the compression ratio burning gasoline, you reach a point where the gasoline does not just burn but it explodes. (detonation) (abnormal combustion). The burning of the fuel was producing a "Push" on the piston which was pushing on the crankshaft which was producing power to move a car, truck, motorcycle or whatever. When the fuel explodes it produces a sharp spike of expansion not like a "Push" but more like a sharp hammer blow on the piston which don't turn the crankshaft but just strikes it. This produces no power and does cause massive damage in a very short time. Alcohol can be compressed much more than gasoline without exploding thus it does not have the low limits that gasoline has. These limits for gasoline are expressed in an Octane number. The method (two) used to rate a gasoline does not really apply to alcohol so they have assigned a number to alcohol. Octane is not a measurement of power but just a measurement of a point of detonation of a gasoline in a specific engine. Nothing more, nothing less. With today's engines and the different kinds of fuels that soon will be available we need a better method to rate a fuel.

As far as carburetion vs. injection, for several years I had the job of trying to convince mechanics who only worked on carburetors to start working on fuel injection systems. I tried several different approaches but the one that I had the most success with was to show that an injection system was just a carburetor that was taken apart and spread all over the intake manifold. For each part of a carburetor I would show which part of an injection system was there and took it's place. It is much easier for an electronic fuel injection system to deliver a atomized fuel into the engine in a more exact mixture that is needed than it is for a carburetor to do. This means that the carburetor as we know it today will go the way of the 8 track tape player.

If you have made modifications to your engine, intake and / or exhaust system and you now need to re-jet or re-adjust your carb. Here is a procedure I used with success. I am taking for granted that you don't have CO or any other test equipment.

For a fixed jet carburetor

First you need to get the main jet correct then work your way down the line to idle mixture. The main jet in most carburetors is the restricting force from about half throttle on up to full throttle. (Do NOT do this test if you have a CAT in your exhaust system)

To test your carb to confirm the range your main jet is in effect, just run the engine until operating temp then remove the main jet and put it in your pocket. Start the engine and run it at lower RPM and slowly rev the engine up and watch your tach. At the RPM that it starts running rough and blowing black smoke is the approximate point that your main jet takes over or would have taken over if it were not in your pocket. Most fixed jet carburetors will run as usual at lower RPM with the main jet out. There are many variations to the mid range jetting. Some just use a port in the side of the carb near the idle jet port and others have an emulsion tube that acts as a mid range jet. An emulsion tube allows a small amount of air to enter and mix with fuel before entering the main air stream in the intake. Some emulsion tubes are numbered and you can re-jet that by getting a different tube and yet others have a fixed "air correction" jet to feed the air to the emulsion tube and thus you can change that to a different number to correct a mixture in this range. Below that is your accelerator pump and idle jet. From the idle jet to a accelerator pump and a transition port just above the idle port and the emulsion tube and air correction jet, fuel metering is a little hap-hazard as compared to electronic fuel injection. However, most carburetors perform quit well considering. The trouble starts when you modify your engine and you upset all that the carburetor manufacture has done.

To get your main jet in the ball park, you should purchase several jet sizes and start with the richest (largest) first. When we had leaded fuel it was easier even though reading plugs was an art. With unleaded gas it is not as easy but you can still take plug readings. It is best to start with a new set of plugs (not installed yet). Run the engine until you bring the oil temp up to operating temp. It takes more driving than to just get coolant up to operating temp.

Find a straight stretch of road where you can safely pull off the road and take a plug wrench with you. Install the richest jet you have and rev the engine to see if it will rev up OK then install the new plugs. Make a fast cruise run and while at cruise turn off the ignition at the same time depress the clutch to get the engine to stop rotating as quick as possible. (If you have a locking steering, be careful not to turn the key back to the lock position) As soon as you can get stopped pull a couple of plugs and look closely at the edge of the plug and the center insulator. If you are too rich, both the edge and the insulator will be flat black. If they are both black change one step leaner on the main jet and repeat the test. Each time you make a run and put in a leaner main jet the center insulator will lighten up. Don't keep leaning the jets until the insulator is very white and clean as that is too lean. The edge of the plug should stay flat black and the insulator should be clean but not white clean. Always go too rich and

work your way back toward leaner never the other way.

You can't very well do plug readings for the lower range jets due to the fact that not enough heat is produced to get a good reading. For low and mid range jetting, you can have someone rev the engine at low RPM and and mid range and watch the exhaust for puffs of black smoke (rich) then adjust leaner until only a very light puff can be seen on a quick throttle opening.

For the idle mixture adjustment try the test listed above that the old man showed me.

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