"SU Carburettor"

by Tony Cripps

1. Introduction

The SU (Skinners Union) carburettor is a common sight to any Mini, 1100 and 1800 owner. At least nearly every owner of such a car would be familiar with putting oil in the piston damper at the top of the carburettor, and may even have had to resort to checking the float level, adjusting the mixture and attend to the mysterious process of centering the jet, but as usual, the average workshop manual does not offer much in the way of explanation of how the device works, and when they do, it is sometimes incorrect. For example, what exactly does the dashpot do? What does the main needle do? In this article we have look at what the carburettor does and why the SU carburettor is such a clever device.

2. Combustion

In an internal combustion engine, hydrocarbon fuel and oxygen are ignited by the spark plug to provide pressure in the combustion chamber. The ratio of the mass of air to the mass of fuel is very important and is called the air-fuel ratio or "mixture". Theoretically, we need a little over 14.5 times the amount of air (by mass) than fuel (the actual ratio depends on the blend of the fuel). At this mixture, all the hydrocarbons in the fuel combine with all the oxygen in the air during combustion and there is no free oxygen or hydrocarbons left over. The products of combustion under these conditions are carbon dioxide and water. In practice, this never happens and usually we get carbon dioxide (CO_2), water, carbon monoxide (CO), unburnt hydrocarbons (HC), and oxides of nitrogen (NOx). The combination of unburnt hydrocarbons and oxides of nitrogen, with sunlight, produce photochemical smog. If the mixture is too weak, or too rich, the fuel will not burn at all and we get flat spots and rough running.

At idle, (especially when the engine is cold), the mass of air and fuel (i.e. the "charge") coming into the combustion chamber is a minimum. Near the cylinder head walls, some of the liquid fuel doesn't completely get surrounded by oxygen. When the charge of the air-fuel mixture is greater (such as in wide open throttle) there is still some fuel near the walls of the combustion chamber, but this is a smaller proportion in comparison to the idle condition. Fuel at this location may not get completely burnt and instead of forming CO_2, will form CO instead, which can be measured in the tailpipe emissions by a CO meter. Some fuel may not burn at all in which case it passes out the exhaust system as free hydrocarbons (HC). The level of CO in the exhaust emissions is usually about 4% at idle for an old pre-emission control car, and this drops to about 1% at part throttle.

The *mass* of air entering the carburettor, and hence into the combustion chamber, is dictated by the throttle plate angle (i.e. our right foot). The mass of fuel being delivered by the carburettor depends on the diameter of a tube (the jet) through which the fuel passes from the float chamber into the air stream, and the pressure difference between one side of the jet and the other. We can say that the pressure on one side of the jet is atmospheric (the side that is connected to the float chamber) and the other side, is at the pressure at the venturi in the carburettor. The air rushing past this narrow passage increases in velocity and decreases in pressure. It is the decrease in pressure (compared to the float chamber side of the jet) that sucks liquid fuel up through the jet into the air stream – although it is more accurate to say that the increased pressure on the float chamber side pushes the fuel through the jet. It is important to know that the pressure, or depression, at the throat of a venturi depends on the flow rate (in litres per minute) and the size of the venturi. The greater the flow rate, the lower the pressure compared to that on the upstream and downstream sides of the venturi. The narrower the size of the venturi, the lower the pressure.

When we are at idle, we need a small amount of fuel flow. At part throttle, or full throttle, we need a greater fuel flow. We can therefore either increase the pressure difference, or increase the jet diameter to accomplish this. At acceleration, the throttle is opened quite rapidly. Air, having a lower density than liquid fuel, rushes through the carburettor and into the combustion chamber. The fuel, being a liquid, is at the same time being sucked through the jet in the carburettor but is slower to move than the air. The mixture in the combustion chamber is therefore weak (air-fuel ratio too high). To maintain a combustible mixture, we need to temporarily increase the amount of fuel entering the air stream.

As mentioned above, fuel is a mixture of hydrocarbons – chemicals containing carbon and hydrogen in various combinations. During combustion in the cylinder, the hydrogen in the fuel combines with oxygen in the air to give water. The carbon in the fuel combines with oxygen in the air to produce carbon dioxide. That is, water is a product of combustion, there is no getting rid of it. When you see water dripping from your exhaust pipe, it is water from combustion condensing out of the exhaust gases. It is important therefore to always drive your car some distance after starting it from cold so that all this condensed water can be heated up and driven off lest it remain in your muffler and rust it out.

3. SU operation

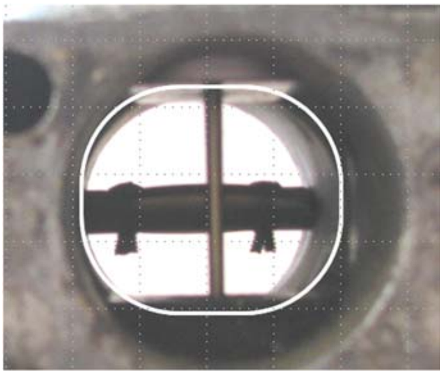

Fig. 1 *Full size venturi at wide open throttle*.

In an SU carburettor, the diameter of the jet and the size of the venturi are altered to let more or less fuel through it in response to air flow. How to alter the diameter of the jet? By putting a tapered needle down through the middle of it. The more the needle is inserted, the narrower the effective diameter of the jet. The needle position is determined by the height of a piston to which the needle is connected. The operation of this piston is important. As many readers will know, but perhaps not appreciate the significance, is that this piston can be held at nearly any position from fully down, or closed, to the fully up position with much the same amount of force. The force has to overcome the mass of the piston, and the spring, which readers will know is quite a soft spring. If you raise or lower this piston with your finger (with the engine not running), you will find that it has much the same resistance (except when you are actually moving it and have to overcome resistance of the damper) to your finger's effort wherever you position it. The piston itself acts as a restriction to the air flow. That is, it is itself acting as a variable venturi, or narrowing, of the passage of air through the carburettor. This venturi is in fact a rectangle of constant width and variable height. The upper side of the piston is ported to the pressure at the venturi narrowing.

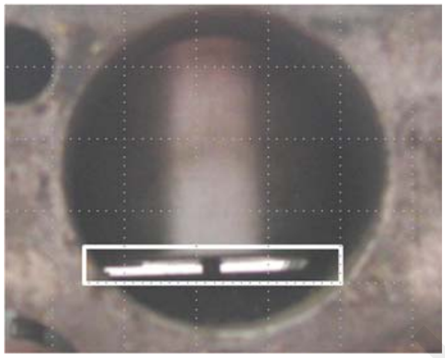

Fig. 2 *Narrow venturi at idle*.

So, what happens is that at a particular throttle opening, a certain amount of air in litres per minute is drawn through the carburettor. Let's imagine the piston is initially down (at idle). If we open the throttle slightly, engine manifold vacuum tends to pull more air through the rectangular venturi formed by the piston and the throttle body. The greater flow rate of air through this venturi results in a *decrease* in pressure, which lifts the piston up – thus opening the venturi and tending to bring the pressure back to its former level. The piston will not drop, *because it takes the same amount of pressure to hold the piston at any position* so it just stays in the new position (remember the finger test). Since the piston has now been raised, more air, in litres per minute, can flow through the larger venturi as required by the engine. Since the piston has been raised, the needle, which is tapered, allows more fuel to be drawn from the float chamber, thus ensuring that the correct air-fuel mixture is maintained. The actual pressure at the venturi, and at the jet, is the same as before. When we close the throttle, the air flow through the carburettor decreases. This *increases* the pressure at the venturi and the piston is forced back downwards. In doing so, the height of the venturi decreases and tends to restore the pressure back to its former level. The piston then settles at a height appropriate to the air flow – the pressure at the venturi is back to its old level. Since the pressure at the venturi and hence the jet, is constant, no matter what position the throttle is in, manufacturers can have some confidence in shaping the needle in the knowledge that they will also know what effective diameter of jet will provide a known quantity of fuel. SU carburettors fall into a class of what are called Constant Depression types, of which the CD Stromberg is a similar example, employing a diaphragm instead of a piston.

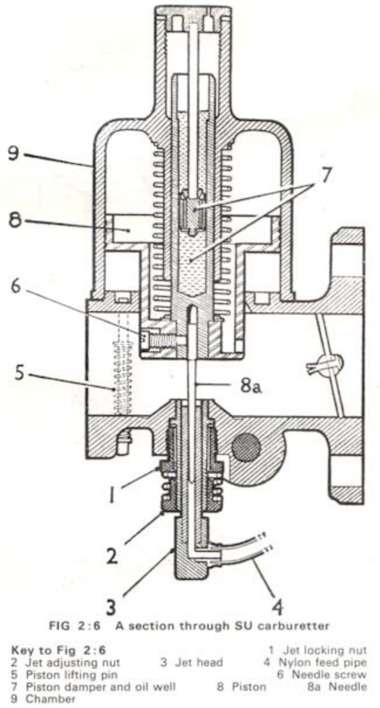

Fig. 3 *Carburetter cross section.*

When the engine is cold, we are accustomed to pull out the choke. We need more fuel at this point because when the engine is cold, a lot of the fuel does not get vapourised and without extra fuel going in, the mixture that is in the vapour phase would not ignite (it would be too lean). We therefore suck in more liquid fuel to compensate. In the SU carburettor there is no choke as such although it is still labelled that way on the cable. Instead, the choke cable pulls the jet down from its normal position a few mm which, due to the taper of the needle, makes the effective jet diameter larger.

During acceleration, the mixture is made richer by damping the piston so that more suction is temporarily applied to the jet which increases the fuel flow through it. When the "acceleration" is finished, the piston settles down again to a new position which depends on the throttle plate position as described previously. If you tip out the oil from the carburettor damper, you will most likely get a huge flat spot under acceleration. If you put heavy oil in there, you may get faster acceleration but at the cost of increased fuel consumption and black smoke from the exhaust.

4. Dashpot

There's an interesting issue in relation to the oil level in these dashpots that requires your attention. BMC workshop manuals usually state "*pour in sufficient quantity of engine oil to bring the level to about ½ in. (13 mm) above the top of the hollow piston rod*." For and Austin 1800, Intereurope repeats this advice verbatim. Scientific Publications No 66a offers "*pour in about a teaspoonful of light engine oil*", while Haynes just says to "*top up the damper*". Autoexpress provides a helpful "*top-up with engine oil to a level ½ inch (13 mm) above the top of the hollow piston rod*" but then adds "o*n dust-proofed carburettors, with a transverse hole across the neck of the chamber and no vent hole in the damper cap, the level must be ½ inch (13 mm) below*". Interestingly, all those manuals that show a cutaway view of the device clearly show the oil level as being *below* the top of the piston rod, and I believe this is the correct level despite what the text says. In an early Mini owners handbook, from 1962, the instructions are "*pour oil into the hollow piston rod until the level is ½ in (13 mm) from the top of the rod*" and the accompanying picture clearly shows the level being below the top of the rod. If oil is poured ½ above the top of the rod, it will most assuredly spill out the breather hole when the piston damper rises, and any excess will soon be sucked down into the piston chamber where it will eventually be consumed by the engine. The only possible advantage of over filling the piston rod is to provide some lubrication of the piston rod from time to time during normal routine service.

But, what oil to put in there? We have "light engine oil", "engine oil" and "thin engine oil" all mentioned in various BMC instructions. Some people even support the use of automatic transmission fluid for this purpose. To my mind, these cars were designed when oils were not the multi-grade products they are today. When the engine is cold, it would be helpful to have the oil a little thicker (higher viscosity) to provide a little more rich a mixture for acceleration compared to when the engine is at operating temperature – where the damper oil can be thinner. So, my personal recommendation is a single viscosity oil, such like Singer sewing machine oil. Various BMC documentation indicates SAE 20 oil for the carburettor dashpot, somewhat lighter than what is used in the engine. Note, it is possible to purchase the correct "SU Damper Oil" from an online store.

5. Air Cleaner

A major disadvantage of liquid hydrocarbon fuel is the need to get the fuel from the liquid into the vapour phase before it enters the combustion chamber. If we get liquid in there, not only will the fuel inside the drops not be next to an oxygen molecule, ready for combustion at the command of the spark plug, but as we will have all experienced, the spark plug will become wet and cease to function. It takes heat to convert a liquid into a vapour, as one can readily experience by the cooling effect of perspiration. Thus, carburettors tend to run cold as heat is used to vapourise the fuel entering the inlet manifold. It is said that the original Mini engine was turned around because when the carburettor was at the front, it got so cold that it iced up. Often, car manufacturers connect the inlet and exhaust manifolds together so as to form a hot spot directly under the carburettor to help with vapourising the fuel. The unfortunate side effect of this is that the density of charge of air/fuel entering the combustion chamber is reduced, thus reducing the available maximum power output. This raises the interesting question of where the air horn of the air cleaner should point in an Austin 1800? BMC often allow some variation in positioning of the air cleaner so that in cold weather, air can be drawn in past the exhaust manifold and prevent the carburettor from icing up. An examination of the previously mentioned workshop manuals reveals that the majority of photos and line drawings show the air horn pointing vertically down the back of the engine. I suspect this is for English cars where the weather is usually colder than in Australia and the common practice of pointing it out to the side is probably better in this country. If the air is too hot before it enters the carburettor, it becomes less dense and the air-fuel ratio (by mass) will be affected.

How many readers have, at some time in their lives, fitted a pancake or ram flow air cleaner in the belief that this offers unrestricted flow and greater power? Recommendation: remove it and go back to standard. You will find that the standard manufacturer's air cleaner has an air horn at the carburettor (not the large tube on the air cleaner body, but an elbow or casting where the air cleaner mounts to the carburettor). For our front wheel drive cars, it is a small air horn, but carefully shaped to bring in the air to the carburettor with as little turbulence as possible. Taking this air horn off, and having the air just come over the sharp corner of the carburettor casting is a sure way to restrict air flow. The restriction offered by the air horn and air cleaner assembly has been flow tested during design and the needle and jet will have been calibrated to suit. Unless you have a dynamometer to test needle profiles it is best to leave it all as it should be. Running an engine unintentionally lean will lead to valve and piston failure.

6. Needle

It is interesting to know that the flow of liquid through a tube depends on the radius of the tube raised to the fourth power, everything else being equal (i.e. for the same pressure difference). This means that the slightest wear on either the jet or the needle is magnified greatly in terms of the effect it has on mixture. This is why it is necessary to have the needle centered in the jet – to prevent wear. It is also important that the correct needle, jet and piston spring be fitted. The taper of the needle is critical to performance and the practice of running sandpaper over the needle in an attempt to extract more performance should be avoided.

7. Pinging

Of course ignition timing and carburetion work together to provide that smooth ride we are all accustomed to in our Austin's. A common cause of damage and problems is pre-ignition, detonation, "pinking" and "pinging". All these terms almost mean the same thing and refer to sources of ignition other than the spark plug in the combustion chamber. A very high compression ratio (such as if you have taken off too much from your head during a machining operation) will result in the mixture becoming so hot during the compression stroke that it ignites on its own (like a diesel). Hot spots in the combustion chamber can glow red hot and become a source of ignition. When there is a secondary source of ignition, there are two flame fronts and when they meet, the resulting turbulence creates shockwaves of high magnitude which overload the mechanical parts of the engine and cause damage. Running-on after you turn off the ignition on a hot day is a sure sign something needs attention in the cylinder head or cooling system. If you look carefully, the engine often runs backwards when running on which may cause problems in the valve train. In some cases running on can just be a result of the idle speed setting being too high. Some later model emission control cars have a throttle stop solenoid to close of the throttle completely when the ignition is turned off to avoid this undesirable event.

In contrast to the complexity of a modern fuel injection system, the simplicity and reliability of an SU carburettor represents a significant part of that pleasurable BMC ownership experience that is denied to owners of more modern vehicles.

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