NOTES

ON

AMAL MOTORCYCLE CARBURETTOR

DEVELOPMENTS

1924 -1976

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SECTION 1 - AMAL CARBURETTOR BASICS

A. Carburettors - a simple overview

Carburettors are devices for metering and mixing the air and fuel requirements of spark ignition internal combustion engines. In their crudest form, they can be viewed as venturi tubes placed in the inlet tract of an engine cylinder, with a fuel container (float chamber or float bowl) connected to the venturi section.

In operation, as the engine piston moves down the cylinder on its induction stroke, a volume of air is drawn through the venturi (or carburettor bore) to fill the cylinder space swept by the piston. The velocity of this moving column of air gives rise to a negative pressure in any drilling in the circumference of the venturi at right angles to the direction of air flow. This negative pressure is applied to the surface of the fuel within the attached fuel container, causing fuel to be drawn into the air stream. In an ideal venturi, the level of this negative pressure (or velocity head) is directly proportional to square of the speed of the air moving through the venturi. Since the venturi is therefore a "volume" measuring device, changes in air density (such as would result from an increase in the altitude at which the engine is being operated) will not be recognised, as air volume flow (and hence the velocity through the venturi) will remain constant at a given throttle opening and engine speed irrespective of air density.

To avoid fuel flowing into the venturi when no air is flowing through it, it is essential that the static fuel level in the fuel container is below the fuel outlet and, to achieve consistency of flow, this fuel level should be maintained at a constant level. Methods of achieving control of the fuel level in float chambers are briefly discussed later.

Practical applications of an engine demand power output variations from no load (engine idling) to maximum power, an increase of some 30 times in airflow requirements. To achieve these power output changes, it is necessary to limit (throttle) the amount of air and fuel mixture being drawn into the engine in accordance with required demand. This "throttling" is achieved either by employing a moveable slide or a rotatable valve plate at some point in the venturi tube downstream of the point of minimum cross-section (the venturi "throat").

In carburettors with a rotatable valve plate (normally termed the butterfly or throttle plate) controlling the air flow and with a fixed area venturi section (fixed choke carburettors), this 30 fold change in the air flow rate gives rise to, in the order of, a 900 fold change in the air velocity head (i.e. the depression available to act on the main fuel jet). Obviously, the selection of jet size to give the required air/fuel mixture ratio at one extreme of the air flow range will be massively incorrect at the other extreme, hence, a need for circuit splitting and appropriate corrective devices to be employed.

To overcome or reduce this major defect in "fixed choke" carburettors, it is possible to arrange for the "choke" or "throat" section of the venturi to be of variable area. In such arrangements, it is usual for a piston or slide to be positioned to move across the venturi tube so that the throat area increases with increased power (air) demand from the engine operator. This variable area throat enables a more uniform airflow velocity to be maintained across the engine power range and reduces dramatically the out of balance of the air and fuel flows.

Perfect matching of air and fuel is still difficult to achieve, due to variation in inlet manifold pressure downstream of the throttle slide and to the non uniform change in venturi area with throttle slide movement in most practical design solutions, and so, some correction of fuelling is therefore inevitable, although this will be to a lesser degree than in the fixed choke type carburettor.

In Amal "slide" type motorcycle carburettors, a further variation (and simplification) of this variable area throat theme, is the utilisation of the slide for both variation of throat area and for control of the airflow (throttle valve).

Efficient combustion of the air/fuel mixture drawn into the engine's cylinder(s) requires close control of the proportions of the air/fuel mixture within its limits of combustibility. In its simplest form, a carburettor's fuel circuit would comprise a float chamber, a fuel jet to control maximum fuel flow, a connecting channel to the venturi and a fuel discharge into the air stream through the venturi. Unfortunately, as briefly discussed above, such a simplistic system would fail to meet the needs of an engine. To achieve the required level of fuelling control, it is necessary to have more than one fuel circuit and to build into these circuits a range of restrictors (jets) and corrective devices (air bleeds).

Typically, the circuitry required will include a system to provide the main fuel demands up to maximum power; a system to provide the required fuelling when the air velocity through the venturi section is too low to provide sufficient negative pressure to lift the fuel from the float chamber to the discharge point; a system to provide the additional fuel for starting under cold engine conditions; and means of atomising the fuel entering the air stream to ensure even distribution and to aid combustion. The basic systems can be refined by the addition of extra control jets and air bleeds to achieve matching of fuel flow to demand.

B. Main Components of Amal Slide Carburettors

If we consider only slide type carburettors and the major elements, reproduced faithfully, with only minor changes, into the various designs manufactured under the Amal trademark since its inception on the amalgamation of the Amac, Binks and Brown & Barlow companies in the early 1920's, then the main design features are:-

(a) a housing (carburettor body), in which the throttle slide and the bore for air flow into the engine combine to form the air venturi, to mount onto the intake manifold of the engine

(b) a throttle slide/valve, spring loaded into the closed position, with a means of raising it to the fully opened, or any intermediate, position at the demand of the operator

(c) a fuel chamber (float chamber), which until the mid 1950's was a separate assembly, either remotely mounted or rigidly attached to the carburettor body

(d) a main fuel circuit from the float chamber to the venturi bore at the junction of the throttle slide and the air bore, incorporating a jet (main jet) to limit the maximum fuel flow into the engine

(e) air bleed circuit(s) allowing air into the fuel circuit(s) to assist in the control of fuel metering, to aid transport of the liquid fuel through the circuitry and to assist fuel atomisation of the fuel on discharge into the air stream

(f) a discharge port for the fuel into the air stream at the venturi (this is commonly described as the "spray tube" or "choke tube")

(g) a throttle needle, which is attached to the throttle slide, and its associated needle jet, which are arranged to form an additional variable area jet in the main circuitry between the main jet and the spray tube.

(h) a pilot fuel jet to supply the required fuel when engine power demands are so low that the air velocity through the venturi is insufficient to provide the negative pressure to lift the fuel from the float chamber to the discharge point.

(i) a means of achieving mixture enrichment when starting the engine from cold.

Considering each of these features:-

Bl. Carburettor Bodies

A carburettor body is essentially a housing to contain the venturi and a means of connection to the engine or its inlet manifold.

Choice in the design of venturi section is limited by practical manufacturing considerations,

A rectangular flow section with a slide across it can give a linear change of area with slide movement, and whilst this does not compensate the effects of inlet manifold vacuum changes on air velocity across the "throttle", it can reduce the degree and number of corrective devices needed to match fuel to air requirements. It is not the best choice when considering uniform mixing of air and fuel across the flow stream and it is difficult to maintain a consistent cross section in mass production.

A circular cross section flow area is likely to result in more uniform distribution of fuel across the flow stream and is easy to consistently reproduce in mass production. When used with a straight edge slide, (the simplest to produce), large changes in flow area arise from small movements of throttle slide position in the region of the bore diameter, whilst the opposite is true at almost fully closed or fully opened (engine idling and full power) positions. This means a greater degree of fuelling correction will be required to match engine needs, especially in the quarter to three quarter throttle open range.

Frictional problems arising from pressure differences across the slide, coupled with gravitational influences from the mass of the slide, effect both slide operation and positional repeatability. The gravitational friction effect can be virtually eliminated when operating with the slide in a vertical or near vertical plane, and this, together with the fuel circuitry complexities resulting from general "packaging" problems in arrangements other than with the air bore of the carburettor in the horizontal (or near horizontal) plane, led to virtually all Amal designs being of horizontal air bore (vertical slide movement) construction.

In early Amal carburettor designs, i.e. the "standard" (6, 76, 276, etc.) and the "monobloc" (376, etc.) types produced prior to the "concentric" float bowl carburettor designs of the late 1960's, the desire to achieve a close approximation to the ideal circular cross-section venturi, led to the adoption of a "jet block" arrangement, where a separate cylindrical block formed the walls of the venturi throat and acted as a support for the hollow cylindrical throttle slide, which moved up and down in the annular gap between the external circumference of the "jet block" and the inner circumference of the slide bore machined in the body casting. In such an arrangement, with the slide in the fully open position, a smooth, circular cross-section venturi throat was formed, providing a high degree of airflow efficiency. The body casting required only two circular bores (one for air flow and the other for the slide) and as such, was simple and easy to manufacture.

To ensure that the cylindrical throttle slide did not rotate within the bore, guide(s) were positioned vertically on the jet block and these were fitted into accompanying slot(s) cut into the sides of the slide.

The general complexity of carburettors based on "jet block/smoothbore" principles, together with manufacturing difficulties encountered in the production of the associated slotted thin cylindrical slides remained as major deficiencies of the Amal range through to the late 1960's.

Repeatability of features and ease of manufacturing, dictated the use of machined die-castings for the body. In the years immediately following the "company amalgamation" in the 1920's, the main carburettor castings were "sand cast" using "naval gunmetal", i.e. cast bronze. In 1932, following improvements in manufacturing and material technology, "mazac" (a zinc alloy comprising 96% zinc and 4% aluminium with traces of copper and magnesium) replaced gunmetal as the casting material. These "mazac" castings were much cheaper to produce, were more suitable for mass-production and with thinner and more detailed casting sections being possible, an overall reduction in product weight resulted. To identify the change of material and die-casting methods, the carburettor type numbers were changed to 74, 75, 76 and 89.

Unfortunately, "mazac" has disadvantages in that it is a relatively soft alloy and can be subject to high levels of surface wear under sliding movements between two components. The material also has a tendency to permanent "creep" when subjected to temperature changes whilst under load, leading to distortion of bores, etc. However, its manufacturing cost advantages led to the continued use of this material for all bulk production until the current day. For certain designs, where weight or stability under changing temperatures, have been of more importance than pure manufacturing cost, aluminium has replaced mazac for the main castings.

The necessity for simple die construction meant that, until the introduction of the monobloc type of carburettor in the early 1950's, float chambers were not manufactured as part of the main carburettor body.

The method of attachment of the carburettor body to the engine inlet manifold or port, is, to a large degree, dependent upon the engine manufacturer's requirements and can be either flange mounting, using clamping screws (bolts) to clamp the body to the engine, or "spigot" mounting, where the carburettor body is fixed onto a spigot positioned in the engine inlet tract. Over the years, the Amal preference has been for the use of flange mounting by two securing screws or bolts, with spigot mounting being offered as an option.

To permit use of different types of carburettor on any single engine design, Amal adopted a "standard" flange mounting bolt arrangement with a 2-inch centre distance between the bolts. To satisfy some engine manufacturers requirements, some changes to this 2-inch standard were necessary. On some small bore carburettors in the 274 and 275 ranges, a smaller 1.574 inch centre distance was utilised, whilst on carburettors above $1^{1}/_{4}$" bore, bolt centres of 2.56 inch (65mm) were adopted.

When "spigot" mounting was employed, the standard manifold spigot sizes which the various carburettor bodies were designed to accommodate were:-

74 & 274 - spigots of $^{7}/_{8}$" and 1" outside diameter

75 & 275 -1" & $1^{1}/_{8}$"outside diameter

76, 276 & 376 – $1^{1}/_{8}$" & $1^{1}/_{4}$"outside diameter

89, 289 & 389 - $1^{1}/_{4}$" outside diameter

B2. Throttle Valves (commonly termed "Slides")

As discussed earlier, the throttle slide is positioned to provide a variable area restriction within the carburettor body, simulating the throat area of a venturi, into which fuel drawn from the float chamber discharges. Ideally, the flow section formed at the junction of the slide and the air bore should be smooth, in order to avoid excessive turbulence and to reduce frictional losses, and should be the point of minimum cross-sectional area in the air bore in order to maximise air velocity.

Some carburettor designs (notably the Gardner carburettor popular with some racing enthusiasts) have incorporated a flat plate as the throttle slide, but all Amal throttle slide arrangements have employed a cylindrical slide design with the centre axis of the slide positioned at right angles to the centre axis of the air bore.

With a cylindrical slide and "jet block" arrangement (see 6, 76, 276, 376 and 2000 series smoothbore carburettors as examples), at the fully open throttle slide position, none of the slide projects into the air bore and a smooth circular cross section exists from the air intake point in the body through to the exit into the inlet tract of the engine; simulating the ideal venturi arrangement. However, as the throttle is closed, more and more of the throttle slide edges protrude into the air bore, restricting the airflow. With a perfectly cylindrical slide moving across a round bore, it is obvious that as the slide approaches the fully closed position, there are two points of air restriction; at the forward (air intake) edge and at the rear (engine end) edge of the slide. In such an arrangement the major air pressure drop will occur at the forward edge, with a further minor pressure drop at the rear edge. The space between the two throttling points will be at a pressure very close to the pressure existing in the engine manifold downstream of the carburettor. Any change in slide geometry that increases the flow area at its forward edge, whilst leaving the rear edge untouched, will transfer the point of maximum pressure drop from the forward to the rear edge and the pressure in the space between these two edges will increase towards the atmospheric level. Since it is into this space that the fuel discharge point is positioned, changes to the forward edge geometry provide a convenient method of varying the negative pressure acting on the fuel circuitry at the smaller throttle openings.

In all Amal throttle slides, the variation in forward edge flow area is achieved by cutting the edge off at an angle; the greater the amount cutaway, the greater the forward edge flow area compared to that of rear edge flow area and the closer to atmospheric the pressure in the inner slide cavity becomes so "weakening" the resulting air/fuel mixture into the engine. As mentioned earlier, the slide cutaway is always presented to the incoming air by the action of the slide guide(s) in preventing slide rotation.

Prior to the introduction of the "Monobloc" range of carburettors, the amount of "cutaway" on the forward edge was specified in $^{1}/_{32}$" stages from the zero cutaway position, for example a slide for a 276 carburettor having a $^{1}/_{8}$" cutaway, was identified by the part number 6/4, with the first digit or digits identifying the carburettor basic type (i.e. 4 for types 4, 74 and 274; 5 for 5, 75 and 275; 6 for 6, 76 and 276; 29 for 29, 89 and 289; since each development within the various size series of these carburettors utilised slides of the same physical dimensions) and the last digit identifying the amount cutaway (i.e. 4 for 4 x $^{1}/_{32}$" stages).

For the "monobloc" and subsequent carburettor designs, the identification of amount of cutaway was changed from $^{1}/_{32}$" stages to $^{1}/_{16}$"stages.

The "jet block" throttle slide arrangement, whilst providing a smooth air bore with high air velocity across the fuel discharge port when operating with the throttle fully open, does not offer the same advantages when operating at partly open throttle. At part open throttle, the arrangement is more closely allied to a "fixed choke" type carburettor with low air velocities in the "throat" area, rather than the more advantageous "variable" area venturi needed to maintain air velocity (hence fuel metering depression). In order for the slide to fit over the "jet block", the walls of the slide are formed as an annular ring, with the hollow section inside this annular ring extending up the height of the jet block. At the "throat" section, where minimum flow area is required to maintain maximum air velocity, the cross-sectional area at engine idling airflow is the same as that on full power airflow and, as a consequence, air velocity will be almost non-existent and fuel metering depression will be dependent more upon inlet manifold pressure than on air throughput.

The throttle valve arrangement used on the "concentric" carburettor designs (see 200, 400, 600, 900, 1600, 1900, 2600 and 2900 carburettor series) attempted to compromise between the optimum requirements of both full and part throttle operations. By removing the jet block, it became possible to fill in the hollowed lower section of the slide and have a variable area throat section to maintain a more constant air velocity in this section.

The fit of the throttle valve in its bore is of some importance in the carburettor's performance, especially at low air flows, and needs to be closely controlled in the manufacturing process. In an ideal carburettor design, all of the air and fuel entering the engine should be metered by the carburettor and controlled by the throttle valve. A loosely fitted throttle valve, whilst able to provide an adequate air seal from the carburettor into the engine manifold when the inlet vacuum is high and drawing the valve onto the engine side of the slide bore; is less than satisfactory under fluctuating manifold vacuum conditions as found in single cylinder engine applications. Lateral movements of a loose fitting slide under fluctuating manifold vacuum conditions lead to variations in air and fuel metering for given throttle valve openings as well as giving rise to noisy carburettor operation due to the valve rattling in the slide bore.

The throttle valve serves as an anchor point for the throttle needle, whose function is described in more detail later, so that any vertical movement of the throttle slide is transferred to the throttle needle. Different throttle valve designs used in the different carburettor arrangements lead to differences in the vertical distance of the needle anchoring point from the metering jet (needle jet) in which the throttle needle operates and when coupled together with variations in throttle bore diameter, result in a requirement for throttle needles of different lengths. On "jet block" carburettor slides, the needle anchor point is at the top of the slide, whilst in concentric designs, the anchor point is close to the slide base.

B3. Carburettor Fuel Chambers

The requirement is for a container, attached to the carburettor, within which the fuel level can be maintained at a given fixed level below the fuel discharge point into the air stream through the carburettor body,

Various methods of achieving a controlled fixed fuel level have been investigated at various times by carburettor manufacturers with the resulting preferred designs incorporating either, a "weir" over which the fuel will spill to maintain a constant fuel level on the carburettor side of the weir with the excess fuel spilling over being returned to the main fuel tank or, alternatively, a float which is positioned in the fuel chamber and arranged to operate a valve (commonly termed the needle valve) in the fuel supply pipe. With its simplicity of design and ease of manufacture, this latter arrangement has become the most popular method of fuel level control. The float, having a lower density than the fuel, rests in the fuel and is raised by its natural buoyancy to a certain predetermined position when it closes the valve in the fuel supply pipe. This prevents further fuel flow into the fuel (float) chamber until the fuel level falls and the downward movement of the float once more allows the valve to open. Accurate control of fuel level in a float and needle valve arrangement obviously relies on the balancing of the forces of float buoyancy and the pressure of the incoming fuel on the needle valve. Any factor influencing this balance, for example: change of fuel inlet pressure, change of float weight, change in fuel condition or density, change in the pressure acting on the surface of the fuel, etc., will have an effect on fuel level within the float bowl, which, in turn, will alter the net pressure acting on the fuel metering jet. High air velocity through the venturi throat and the resulting high depression acting on the fuel metering circuit will reduce the effects of any float bowl fuel level variations on fuel metering repeatability.

Virtually all Amal designs over the years have incorporated this float arrangement for fuel level control.

Prior to the design of the "Monobloc" type carburettor in 1953, all Amal carburettors used float chambers that were a separate and detachable entity from the carburettor itself. In such arrangements, the centre of mass of the fuel in the float chamber is to the side of, and remote from, the fuel metering jet and its point of discharge into the air stream. As the relationship between the relative heights of fuel level in the float bowl/the main jet/and the fuel discharge point is important for fuel metering consistency, remotely positioned float bowls result in variations in fuel metering under cornering, acceleration and/or braking conditions due to fuel surge in the bowl and connecting passage to the carburettor. In addition to the operating deficiencies, the multiplicity of castings required in a separate float chamber assembly, together with the added complexity of fixing the float chamber to the carburettor, result in an expensive carburetion system for what should be a relatively low cost engine assembly.

Prior to 1940, these early separate float chambers as used with Amal "standard" series carburettors, were designated by part number only; part nos. 22, 62 and 262 designating small capacity chambers; 64 and 264 designating "standard" capacity chambers; and 14 designating larger capacity chambers used principally for competition type applications. A combination of various prefixes and suffixes identified the float chamber assembly type; for example "H" designated a horizontal carburettor arrangement, "P" designated use with a fuel pump, "B" designated use of banjo fuel connections, "S" designated a short fixing arm and "L" designated a long fixing arm. With the introduction of the 274, 275, 276 and 289 types, float chambers were re-designated as series types identified by numbers, (i.e. 1, 2, 3, 4, etc.), with considerable variation in application detail being achieved by relatively few component changes. The vast majority of application specifications for the Amal "standard" carburettor range (series types 4, 5, 6, 29, 74, 75, 76, 89, 274, 275, 276 & 289) used the type 1 float chamber designation. This float chamber type number designated a medium capacity bowl, previously known under the 64/ part number series, that incorporated "bottom" feed of fuel into the bowl with attachment to and fuel feed to the carburettor being arranged again at the bowl base.

Within the detail part numbers of the components incorporated into the float chamber assembly, the method of attachment of the fuel feed pipe to the bowl is immediately identifiable by a suffix added to the detail part number for the float bowl sub-assembly, with bowl assemblies having a " banjo" type pipe attachment bearing a suffix "B" to the bowl part number. Bowl part numbers not having the "B" suffix, utilise a nut and nipple screwed connection of the fuel feed pipe.

Float chamber having the same fuel capacity as the type 1, but with their fuel feed inlet in the top cover, are designated as type 2 float chambers and again may have screwed or banjo type fuel pipe connection. The type 2 chambers have primarily been used on twin carburettor, twin float chamber type engine applications.

Both type 1 & 2 chambers are available with a choice of two different float chamber/carburettor mounting distances, with most applications utilising float chamber/carburettor connecting arms with 2.06 inch centres. The longer and less popular alternative is 2.68 inch centres. To cater for different carburettor installation angles and different size connections to the carburettor body, float chambers with various connection angles and connection points, were made available to engine manufacturers during the lifetimes of the product designs.

Type 3 and 4 float bowls are smaller capacity units (previously part numbers 22 and 62) and when used, are employed exclusively with smaller bore diameter carburettors. In practice, only a few type 3 and 4 float bowl applications exist.

For competition applications, a large capacity float chamber (302 series) was introduced into the range. These float chambers, were basically scaled up versions of the smaller series used with the standard carburettors and whilst being principally rigidly mounted to, but removable from, the carburettor body, were also available as remotely mounted units. The float chambers were only available with a top feed fuel inlet arrangement. In the very late 1950's, the 302 range was supplemented by an even larger capacity, remotely mounted bowl, marketed for competition use as the 504 series. To assist in the setting up of the installation of these remotely mounted bowls, an "as designed fuel level" mark was cast onto the exterior of the bowl casting.

All of the removable float chambers produced by Amal prior to and including the 504 series, utilised cylindrical floats that were "free floating" within the fuel chamber and operating directly on the float needle. As such, large displacement floats were required to exert sufficient sealing force on to the float needle. Larger floats meant greater float mass, which in turn resulted in greater sensitivity to inertia! forces (vibration, bounce, etc.) and less sensitivity to fuel level changes.

In 1962, a new remotely mounted float chamber was introduced for competition usage (allied primarily to the new GP2 series carburettors) that aimed to overcome the need to have large floats when high fuel flow rates were required. The new design utilised a pivoted float that was based upon a "lever" principle enabling the force generated by the float and acting on the float needle to be increased according to the ratio of the distance from the float centre of buoyancy to the pivot point over the distance from the float needle centre line to the pivot point. A smaller float and a smaller capacity float chamber could then handle the same fuel flows as the largest capacity 504 bowl. This new float chamber (the 510 series) was immediately identifiable by its rectangular cross-section and was commonly known as the "matchbox" float bowl. It was only available as "remote" mounted and incorporated a bottom feed type fuel inlet arrangement.

The "monobloc" carburettor design was intended to reduce manufacturing cost by combining the float chamber and carburettor body into the one casting, whilst reducing the linear distance between the centre of mass of the fuel in the float chamber and the main jet. However, whilst the monobloc design gave significant manufacturing cost advantages over earlier separate float chamber carburettor systems, it reduced, but did not remove, the technical shortcomings of operating with a float bowl located to one side and remote from, the main jet circuitry.

In 1967, the "concentric" carburettor designs attempted to eliminate the surge effects in the float bowl under cornering and transient throttle conditions by arranging the centre of mass of the fuel to be on the vertical axis through the main jet and the fuel discharge point. In this design concept the float chamber itself, whilst still being a separate casting to the carburettor body is screwed directly to it and is arranged to hold the fuel concentrically around the main jet. Any change of force (such as from cornering, acceleration, braking, etc.) on the fuel surface will have minimal effect on the distance the fuel has to be lifted to effect discharge into the air stream. In an ideal arrangement, the main jet will be positioned so that it remains at the centre of gravity of the fuel irrespective of forces acting on the float chamber. This concept gave rise to the hemispherical design of the float bowl used in the Mark 1 concentric carburettor design.

Venting of the float chamber is an important aspect of design, as evaporation of fuel will take place from the exposed surface of the fuel and any build up of such vapours in the chamber will result in an increase in pressure on the fuel surface and uncontrolled change in the net negative pressure acting on the fuel jets. Similarly, if any restrictive device having a pressure drop across it, (such as an air cleaner), is placed in the carburettor air intake and an identical pressure drop is not applied to the surface of the fuel in the float chamber, then fuel metering variations can result. Prior to the "concentric" carburettor designs, venting of the float chamber to the surrounding atmosphere (external venting) was used in virtually all applications. Whilst this prevented the build up of fuel vapours and therefore, pressure in the float chamber, it did not provide compensation for the reduction of pressure acting on downstream side of the fuel circuitry when intake air filters were employed. This design deficiency was addressed with the introduction of the "concentric" carburettor designs and "internal" venting (where the float chamber is vented into the carburettor air intake area) was introduced as a standard feature.

The choice of material and method of manufacture are important factors in the consistency of the float mass and unit cost. Prior to the development of plastics, the preferred materials for the float were thin sheets of copper or brass. These materials could be readily spun or pressed into the required shapes and, although of greater density than the fuel in which they were required to float, they could be fabricated into hollow forms to reduce their overall density and so increase their effective buoyancy. In the early 1960's, the commercial exploitation of "plastic" materials having lower densities, improved manufacturing abilities and subsequently, lower costs and greater buoyancy, led to metal floats becoming obsolescent.

B4. Main Fuel Circuitry - Main Jet, Spray Tube, Emulsion Air, Needle and Needle Jet

(i) Main Jet

The main fuel jet limits the total amount of fuel drawn into the main fuel circuit from the float bowl. As discussed in detail in the "Amal Jet" manual, fuel metering jets are "volume" measuring devices, as is the air metering venturi, and the resulting flow through them is therefore sensitive not only to the orifice area and the depression applied to it, but also to the density and viscosity of the fluid being metered. Additionally, the specific heating value of the fuel will determine the heat (and therefore power) output of a given volume or mass of fuel discharged. It is obvious therefore, that a carburettor main jet selected to give the required maximum flow on an engine using a given fuel will not provide the same volume of flow and power output if the fuel's physical properties radically change. Further, as discussed in the initial "overview", a change in engine operating altitude will necessitate a change in fuel jet size to compensate for the change in air "mass-flow", since, if the fuel properties remain unaltered, the air velocity head acting on the fuel jet will remain the same and the fuel "mass-flow" will become out of balance with the air "mass-flow".

Examples are given below to illustrate these effects.

(a) Changing fuel type from premium grade petrol to methanol, as is usual on some racing applications:-

- premium gasoline properties: density 0.755 kg/litre, specific heating value 43.5Mj/kg, theoretically correct air/fuel ratio 14.7:1 by weight and so 1 litre of fuel requires 11.10 kgs of air.

- pure methanol fuel properties: density 0.79 kg/litre, specific heating value 19.7Mj/kg, theoretical air/fuel ratio 6.4:1, so 1 litre methanol requires 5.056 kg air.

Therefore, for the same air-flow as required for 1 litre of gasoline, 2.196 litres (11.10/5.056) of methanol will be required to maintain theoretically correct air/fuel ratios and, because of the differing specific heating values of the fuels, operation with methanol will result in an increase in the power output of some

4%. In practice, because of the additional heat taken out of the incoming air to vaporise the liquid methanol and the resulting increased volume of air and fuel mixture able to be drawn into the cylinder, the jet size for methanol usage is closer to 2.3 times that of premium gasoline and the power increase is closer to 10%.

(b) Increasing operating altitude by 1000 metres whilst continuing to use the same grade or type of fuel - air density decreases by approximately 10% per 1000 metre altitude increase and, since fuel properties remain constant, a corresponding reduction in fuel flow will be required to maintain the predetermined air/fuel mixture levels entering the engine.

When tuning a carburettor to an engine, the size of the selected main jet must be sufficient to provide the correct level of fuelling for the engine's full throttle maximum power operation. Obviously this main jet will continue to flow fuel at all other throttle openings, provided that the metering depression is sufficient to lift the fuel through the jet and into the air-stream. However, for reasons discussed earlier, the main jet selected for maximum power is unlikely to provide the required correct level of fuel flow at intermediate throttle openings or power outputs. Some correction of flow will be required and the following main fuel circuit refinements have been introduced, together with throttle valve cutaway, to adjust the main jet fuel flow to the part open throttle requirements.

Although Amal main jet orifice sizing has changed little since the 1920's, certain detail changes have been necessary to the jet's external geometry to suit particular carburettor designs. Prior to the introduction of the monobloc carburettor series, all "standard" series carburettors utilised main jets under the 4/042 part number series, whilst "racing" series carburettors (27, TT, RN and GP) utilised main jets that were radically different in appearance and were identified under the 3326, (later to become the 376/100), part number. With the introduction of the "monobloc" carburettor series, the 3326 jet range was re-designated as the 376/100 jet series and became the standardised jet design for almost all later major Amal motorcycle carburettor types, with the exception of the 363 monobloc and the 400, 500 and 200 carburettor series produced principally for the Spanish market.

(ii) Throttle Needle and Needle Jet

In order to limit fuelling under throttle openings other than fully open, it is necessary to restrict the amount of fuel being metered by the main jet. The degree of restriction required will need to be varied according to the throttle opening and can be provided by a variable section orifice acting as a restrictor situated in the main fuel circuit after the fuel has been metered by the main jet and before the fuel discharge point into the air venturi section. In practice, this variable area orifice is achieved by attaching a tapered needle (throttle needle) to the throttle valve and arranging the tapered end of this needle to move within a calibrated orifice (needle jet) in response to throttle valve movement. Since they are merely two component parts of the same metering orifice, the needle and its needle jet should be changed, when necessary, together as a pair. With the needle operating in and so contacting the needle jet at some point, wear can take place on both components and replacement of one in any repair operation will not necessarily result in a return to correct metering,

A secondary function of the throttle needle is to assist in the distribution of the metered fuel across the incoming air-stream. With the needle positioned across the air-stream, as the air moves passed the needle profile, an area of lower pressure is formed immediately behind and along the exposed length of the needle. Fuel passing through the needle jet is drawn into this area of lower pressure before breaking away from the needle and mixing with the air passing through the venturi section.

Positioning of the throttle needle and the spray tube on the centre cross section ensures maximum air velocity at this point when operating with a fully open throttle.

At closed and near closed throttle valve openings, when metering forces are too low to allow consistent control and atomisation of the liquid fuel stream, it is usual for the throttle needle to prevent flow through the needle jet and for the fuel required for engine operation to be provided by through a "pilot jet circuit". For convenience of manufacture, Amal throttle needles have a constant diameter section from their anchoring point on the throttle valve down for a sufficient length to enter the needle jet orifice at engine idling throttle valve openings. The diameter of this parallel section severely restricts any metering signal being applied to the main jet when the throttle valve is in the engine idling position by being a close fit within the metering section of its needle jet. As briefly discussed in the section on throttle valves, different carburettor bore sizes and different throttle valve designs, result in needles with differing lengths of constant diameter section.

Virtually all throttle needles manufactured by Amal are manufactured from nominal 0.100 inch diameter bar-stock ground down to 0.0985/0.0987 inch diameter and this latter dimension is used for the constant diameter section from the fixing point down to the start of the tapered section at the "off-idle" throttle position. This diameter, together with the need to have some clearance between the needle and the metering orifice of the needle jet to prevent seizure, determines the "standard" metering jet diameter (0.106 inches). For carburettor tuning purposes needle jets are available in $^{1}/_{1000}$ of an inch increments up to 0.115 inch and then in $^{5}/_{1000}{}^{th}$ inch stages up to 0.125 inch. In pre-monobloc designs, some half size increments were available (i.e. 0.1065 and 0.1075), but these were later discontinued as being of little benefit to the tuning process. Below size 0.106, the needle in jet clearance presented problems in assembly that led to the adoption of a minimum recommended size of 0.105" for general use.

Ideally, the tapered section of the throttle needle can be shaped to provide the required restriction in the main fuel circuit for any given throttle opening/load condition. In the interests of ease of tuning and manufacture, Amal use only constant gradient tapers rather than the infinitely variable tapers used on automotive constant depression carburettors of the Zenith or SU types.

Minor changes to the position of the needle in the needle jet orifice for carburettor setting adjustment purposes, are possible by altering the needle anchoring point on a given needle. On Amal needles, this adjustment is achieved by the use of anchor clip locating grooves formed at the upper end of the needle. These locating grooves are usually 0.0625 inches apart and are numbered downwards from the uppermost groove. It is usual (but not exclusively) for all factory settings to be derived with the locating clip positioned in the middle groove.

A listing of the throttle needles used on the popular Amal motorcycle carburettors over the years is appended below. The list illustrates the increasing popularity of two-stroke cycle and alcohol (methanol) fuelled engines, which has led, in turn, to the growth in the numbers of throttle needle profiles being required to achieve satisfactory carburettor tuning.

Prior to the "Mark 1 Concentric" carburettor designs introduced in 1967, no distinction was made between needle jets used for 4 stroke or 2 stroke engine types, although some design differences were necessary to accommodate usage in the different carburettor designs (i.e. Part numbers 4/061 for "standard" carburettors up to 276, 29/076 for carburettors up to 289, 316/065 for racing carburettors and 376/072 for monobloc designs). With the introduction of the "concentric" carburettor designs, the tuning benefits of having different needle jet arrangements for differently cycled or fuelled engines was recognised and the range of needle jet designs rapidly increased to include jets for 4 stroke engine cycle (part number identified by "carburettor series number"/122), 2 stroke engine cycle ("carburettor series number"/079) and alcohol fuelled engine operation ("carburettor series number"/100),

A typical design of needle jet, used for Mark 1 carburettor applications on four-stroke engines, is shown below. The key features of the jet are the diameter of the metering section, the relative position of the metering section within the jet, and the inclusion of emulsion air bleed holes. Prior to the introduction of the "Mark 1 concentric" carburettor designs in 1967, all Amal needle jet arrangements were broadly similar with the metering orifice in the upper portion and no emulsion air holes (as per the Mark 1 series two stroke needle jet assembly). The inclusion of air emulsion holes was an improvement introduced with the Mark 1 series.

On Mark 1 four-stroke needle jets, the chamber formed in the needle jet above the metering section of the needle jet provides an area for emulsification of the fuel and a capacity of emulsified fuel to assist in eliminating any excessive fuel/air mixture weakening on sudden opening of the throttle valve, i.e. on sudden acceleration of the inflowing air stream.

As described later, air bleeding of the main jet circuitry is primarily to provide a means of controlling the depression (or "signal") acting on the main jet, with the bleed air being fed around the outside of the needle jet in such a way as to degrade the depression existing at the spray tube. In later developments, further control of the fuel feed "signal" was found to be possible by feeding air into the needle jet itself, above the metering section, through a number of small, controlled size "emulsion" holes. Air passing through these holes into the annular ring between the needle and its needle jet reduces the area of the passage available to flow fuel and by breaking up the liquid fuel stream, assists in the atomisation of the fuel issuing from the orifice. An emulsified fuel/air column has less mass than that of a solid fuel stream and offers a distinct advantage on sudden throttle openings in that a more rapid change in fuel flow can be achieved.

Due to the resulting pulsating air stream, average air velocities (if flow direction is ignored) through carburettors used on four-stroke cycle engines under full open throttle conditions tend to be higher than is the case for the same carburettor under steady airflow conditions and the need for fuel enrichment under transient throttle conditions is greater. The fuel metering characteristics of carburettor on a four-stroke engine, (pulsating airflow), are therefore necessarily different from those of the same carburettor on a similar output two-stroke engine, (steady airflow), with the two-stroke application resulting in a leaner air/fuel mixtures unless corrective measures are applied.

To reduce the fuel capacity, "well" of fuel, above the needle jet, the metering section is at the top (air bore end) of the jet on 2 stroke needle jets after 1968, leading to a shorter constant diameter section on the throttle needle. Whilst to assist in greater fuel flow as the throttle is progressively opened, throttle needles utilised with two stroke engines have a sharper taper (shorter metering section) than those used with four stroke units.

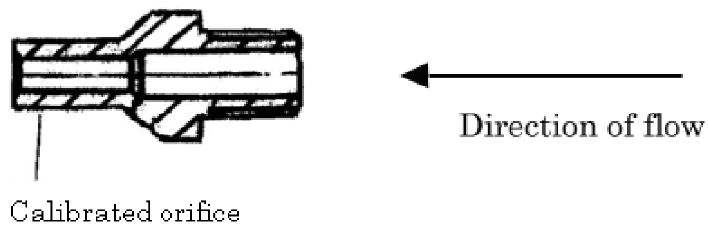
AMAL THROTTLE NEEDLES

Part Numbers, Markings & Where Used

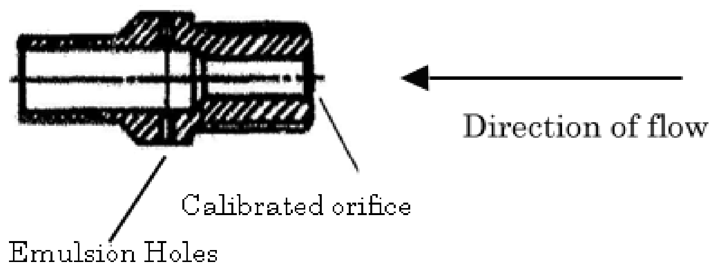
PART NOS.	MARKINGS	WHERE USED
4/065	4	Series 4, series 74 & series 274
5/065	5	Series 5, series 75 & series 275
6/065	6	Series 6, series 76 &, series 276
29/075	29	Series 39, series 89 & series 289
185/119	RN	Remote Needle Carburettors
316/007	GP	GP carburettors
316/029	5GP6	GP carburettors
316/030	GP6	GP carburettors
316/146	5GP	GP carburettors
316/403	3GP6	GP carburettors
316/465	3GP	GP carburettors
316/502	TT2	TT series carburettors
3971	10	TT series carburettors
Spain GP	Dl	GP carburettors
363/013	A	Monobloc (BSA)
370/013	E	Monobloc
375/063	B	Monobloc
375/105	B2	Monobloc
376/063	C	Monobloc
376/096	Cl	Monobloc (BSA Special)
376/116	C2	Monobloc
389/063	D	Monobloc
389/088	D2	Monobloc
416/067	R	400 series
622/063	U	Spanish -.Mark 1 2 stroke
622/063	1 V groove	UK Mark 1 2 stroke (profile same as
622/099	Y	Spanish - Mark 1- alcohol
622/124	Ul or 2 V groove	Mark 1 - 4 stroke
622/176	XA	Mark 1½
622/278	5 V groove	Mark 1 - 4 stroke emission setting
928/063	X or 3 V groove	Mark 1 - 2 stroke
928/075	XI	
928/099	Z	Mark 1 - alcohol
928/104	4 V grooves	Mark 1 - Norton special
928/108	XB	
928/113		
1034/063	O	Mark 1-2 stroke
1034/077	PI	Alcohol (rich setting}
1034/098	OA	
1034/099	P	Mark 1- alcohol
2036/063	2F1	2000 series - 2 stroke
2036/077	2E3	2000 series -Alcohol
2036/124	2E1	2000 series -4 stroke
2036/125	2E2	2000 series - Alcohol
2622/063	2B1	2600 series- 2 stroke
2622/124	2A1	Mark 2 -4 stroke
2622/125	2A2	Alcohol settings
2928/030	2C3	4 stroke emission setting (Triumph)
2928/063	2D1	2 stroke
2928/124	2D2	4 stroke
2928/125	2C2	Alcohol settings

Examples of Amal Needle Jets

Traditional - No Emulsion Holes



Mark 1-4 stroke with Emulsion Holes



(iii) Spray Tube (or Choke Tube)

A "spray" (or "choke") tube in an Amal carburettor is an essential component in the fuel metering circuitry and serves two major purposes in the overall circuitry. Its primary function is to locate the point of sensing the air velocity head in the main air stream away from the walls of the venturi where surface friction and localised turbulence may result in a "signal" that is not truly representative of the main air stream velocity, whilst its secondary (and almost as important) function is to discharge the metered fuel into the fastest moving and, if possible, the central section of the air passing through the venturi. By discharging the fuel info the high velocity air stream away from the venturi walls, better atomisation of the liquid fuel, better mixing with the air and a more stable velocity head signal, are achieved.

As was the case with needle jets, the spray tube was not considered as a carburettor tuning feature until the introduction of the Mark 1 Concentric carburettor designs. Prior to this, one spray tube design suited each carburettor type, i.e. 4/069 for "standard" carburettors, 316/144 for GP carburettors, 376/072 for "monobloc", etc.

With the "concentric" carburettor design, the potential for using the spray tube as a setting tuning feature was recognised and various shapes and lengths of tube began to evolve. The earliest designs were merely hollow cylindrical tubes, within which the discharge end of the needle jet was located, the ends of which were positioned a given distance into the air-stream away from the venturi walls. By removing or chamfering the downstream side of the projecting tube, the cross-sectional area subject to the air velocity head can be increased and the level of "depression" acting on the main fuel circuit can be changed.

(iv) Main Fuel Circuit Air Bleeding and the use of Emulsion Air

As briefly mentioned earlier in this document, air bleeding of the main fuel circuit serves in the matching of fuel metering to the engine's requirements and in assisting in the emulsification of the liquid fuel stream.

By allowing air to be drawn into the main fuel circuit after the fuel has been metered by the main jet, the depression (main air velocity head) that acts upon the main jet is debased, the fuel flow from the main jet lessens and a weaker air/fuel mixture results. As the depression acting on the air bleed circuit is that generated by the main air velocity head, the amount of bleed air drawn through the circuit increases with increasing main airflow. By controlling the maximum amount of bleed air feeding into the system, the slope of the main fuel discharge versus metering depression curve can be varied to match differing engine requirements.

Until the early 1970's and the need for closer matching of engine fuelling requirements, the main air bleed was routed around the outside of the discharge end of the needle jet and acted principally to debased the metering depression acting on the main fuel circuit. With the introduction of the "concentric" carburettor designs and their greater range of tuning features, a means of providing greater control of fuelling for four stroke engines was developed, offering additional advantages in fuel atomisation and acceleration response. By lowering the metering orifice to the inlet end of the needle jet and drilling small holes (emulsion holes) through the upper end of the jet into the annular space between the walls and the needle above the metering orifice, additional control of the fuel metering signal transmitted down onto the main fuel jet could be achieved. The small streams of air bubbles admitted through these emulsion holes into the fuel stream passing through the needle jet, reduced the space available to fuel flow and assisted the eventual atomisation of the fuel mixing with the main air stream. Control of the number and of the emulsion holes provided an additional means of altering the main jet fuel flow. The lighter mass of the emulsified fuel stream (compared with that of neat fuel) also helped provide a more rapid response to sudden throttle position changes.

As discussed in the section on venting of the float chamber, the location of the source of any bleed air is of significance in fuel metering consistency and, ideally, should be such that the pressure acting on the intake to the emulsion air circuitry should be the same as that of the air entering the carburettor intake.

To achieve satisfactory emulsification of the liquid fuel, it is necessary to have multiple small air droplets in the fuel to maximise the surface in contact with the fuel for vaporisation purposes. At the same time, it is necessary to regulate the amount of air bleeding to avoid over-weakening of the fuel flow. In the Mark 1 concentric carburettor design, Amal found it convenient to deal with both air bubble size and air-bleed amount together by placing controlled size holes in the upper end of the needle jet orifice of 4-stroke type needle jets and to ignore further tuning possibilities other than the removal of the bleed holes on 2-stroke applications to achieve a "richening" effect. In the Mark 2 concentric design, an additional air restrictor was placed in the entrance to the air emulsion circuit and further tuning of the fuel circuitry became possible by alterations to this emulsion air restrictor size.

(v) Pilot Jet Circuitry (idling system)

When the airflow through the carburettor is low, the metering signal (air velocity head) acting on the main jet is almost non-existent and any resulting fuel flow and atomisation will be spasmodic on 4-stroke applications and unacceptably low on 2-stroke applications.

To overcome this deficiency, it is usual in carburettor design to supply additional fuel under almost closed throttle operation, to a discharge port located downstream of the throttle edge. Here, manifold pressure is low and the pressure drop across the port high, so ensuring an adequate and stable metering signal and a high degree of fuel atomisation. Unfortunately, with such a high metering signal available, the size of the required fuel jet is too small and the sensitivity to usual manufacturing tolerances too great, for any practical application. To control this metering signal and to bring it to a more acceptable level, it is necessary to employ air dilution (air bleeding) of the pilot circuit, In order to match the pilot flow to the requirements of numbers of engines of the same (or different) types, which will have their own degree of manufacturing variations and therefore, fuelling requirements, some adjustment of the pilot circuit flow is essential. This can be achieved either by adjusting the size (or area) of the outlet port, or by adjusting the amount of bleed air permitted into the circuit, or by adjusting the amount of fuel metered by varying the fuel jet size or flow passage. The first of these possibilities with the outlet port area varied by a tapered adjustment screw (idle volume screw) has been favoured by some of the major manufacturers of automotive carburettors, notably Zenith, Solex and Bendix. Both of the latter two solutions have been used in Amal carburettor designs, with the adjustment of fuel flow passage being utilised in some early designs, but with bleed air adjustment being more popularly utilised for road machine usage.

The use of manifold pressure as the metering signal source for the pilot fuel circuit brings with it a major shortcoming - manifold pressure is at near its minimum level at the closed throttle conditions that exist at engine idling operation and increases rapidly as the throttle valve is opened. To cover the lack of fuelling from the main jet circuitry at low airflows, the pilot circuit needs to provide an increasing level of fuel flow with increasing airflow until the main jet fuel flow is sufficient to supply the needs of the engine. This transition point will vary depending upon the particular setting and characteristics of the carburettor and engine.

To satisfy the fuelling requirements of the engine at "idling" operation through the pilot circuit, the manifold pressure signal is heavily degraded and the fuel flow is adjusted to provide the correct flow just for this operating point. As the throttle valve is opened, manifold pressure rises (i.e. manifold vacuum falls) and the heavily degraded fuel metering signal decreases rapidly and the fuelling provided by the pilot fuel jet falls rather than rising as required to satisfy the engine.

Problems that result from using a pilot circuit to satisfy the light load fuelling requirements have, over a number of years, led to circuitry refinements that in principle have been used by all carburettor manufacturers. By placing a second (and perhaps more) pilot outlet hole (progression or bypass hole) close to and upstream of the throttle edge and main pilot outlet hole, a source of air for "bleeding down" the pilot fuel jet metering signal is obtained that will result in a progressive reduction of bleed air as the throttle is opened. Although this "progression hole" will initially act as a pilot air bleed, due to the pressure difference that will exist across the throttle valve (or plate) edge, as the throttle is opened and the pressure difference between the pilot and progression holes reduces, the progression hole (or holes) will gradually change from air bleeds to additional fuel feed holes. This supplements the idle fuel flow in a manner necessary to compensate for the initial deficiencies of the main circuit and yet, as the throttle is opened and the fuel flow from the main jet increases the negative pressure on the idle and progression holes diminishes and the pilot circuit fuel flow decreases, whilst not completely ceasing until fairly high throttle openings.

Through use of the pilot jet size, the adjuster screw setting, the idle outlet diameter and the progression hole diameter, considerable scope for carburettor tuning exists from closed throttle to above ¼ opened throttle positions. With given pilot jet and progression hole sizes, increasing pilot outlet hole diameter will result in greater pilot fuel flow and increasingly more sensitive pilot screw adjustment. With fixed pilot outlet hole and pilot fuel jet sizes, increasing the diameter of the progression hole will result in fuel flow weakening and less sensitivity of the pilot adjuster screw at close throttle operation with increased fuel flow as the throttle is opened and the bypass hole flows fuel rather than bleed air. For the amateur enthusiast, neither of these outlet hole size changes is recommended for tuning purposes.

(vi) Cold Start Enrichment

Virtually all Amal motorcycle carburettor designs, other than the designs specifically for racing engine use and the modern Mark $1^1/_2$ and Mark 2 concentric arrangements, have employed intake air restriction as a means of achieving cold start enrichment.

The most popular arrangement is for a manually controlled slide to be fitted into the upstream half of the throttle valve. Under normal running conditions, this auxiliary slide is held in the raised position so that it offers no resistance to airflow through the carburettor bore. When starting the engine from cold, or when high levels of mixture enrichment are required, the auxiliary slide is lowered to restrict airflow and to increase the level of depression in the venturi area (increasing depression on the main jet). By adjusting the position of the auxiliary slide, a very coarse adjustment of fuel flow can be achieved.

For the racing carburettor designs (27, TT, RN, GP and GP2), a different method of achieving cold start enrichment was utilised. In this, a manually controlled air bleed was placed in the main fuel circuit on the discharge side of the main jet. In the normal engine operating mode, this air bleed is open and acts as the main circuit air bleed. When enrichment is required for cold engine operation, the air bleed circuit is closed (or partially closed) and a richer main jet flow results. In practice, some riders have used this circuit to provide acceleration enrichment, whilst others (by tuning the device for normal sea-level operation with the air bleed fully or partially closed) have used the air bleed circuit for weakening off the mixture under increasing altitude operation.

To provide enrichment just for initially firing up of the engine, all Amal motorcycle carburettor applications (excluding the Mark 2 concentrics) have incorporated a float "tickler" device, which enables the rider to manually depress the float in the float chamber causing the fuel level to rise and a rich mixture to result. Obviously, this fuel enrichment is only of short duration, as decreases it rapidly as the fuel level in the bowl returns to its normal operating level.

The Mark $1^1/_2$ and Mark 2 concentric carburettor designs both utilise an additional air bled fuel circuit to provide the enrichment for cold engine starting. A manually controlled air circuit, bypassing the throttle valve, is built into the carburettor. The velocity head of the air flowing through this circuit when the manually operated control valve is opened draws fuel from a separate cold start enrichment fuel jet and this mixture is then fed into the engine's inlet manifold tract downstream of the carburettor throttle valve.

SECTION 2 - CARBURETTOR TYPES AND DEVELOPMENT REASONS

The main carburettor types manufactured by Amal for motorcycle engine use are listed below, together with an analysis of the probable reasons that may have led to the various design changes over the years.

This section is not intended to describe in detail the various carburettor assemblies and their component parts, as these are more than adequately covered by the various product leaflets released by Amal over the years. The purpose of this section is to discuss product development progression. It must be recognised that the reasons given for the various development changes that were made, are the author's own interpretation of the probable thinking of the Amal engineers at the time of the carburettor designs and, because of the elapsed time between the actual point of the developments and today, are difficult to corroborate.

2.1 Amal Carburettors for Standard Road Machines

2.1.1 Initial "Standard" Carburettor Series - 4, 5, 6 & 29

These were the first products of the Amac, Binks and Brown & Barlow amalgamated companies and remained as Amal's principal production range throughout the 1920's and early 1930's, with some applications continuing in production until the start of the Second World War.

All of the "standard" series were based on the same design principles and differed only in their respective air bore sizes and those components specifically allied to the carburettor size. The principal castings (carburettor body, mixing chamber cover, float chamber and float chamber cover) were all of bronze and most other main components (jet block, throttle valve, jets, etc.) were manufactured in brass. Floats were formed from copper sheet.

The various carburettor identification numbers formed a reference for the different carburettor body sizes –

type 4 covering air bore sizes of $^{21}/_{32}$", $^{23}/_{32}$" & $^{25}/_{32}$"

type 5 covering air bore sizes $^{13}/_{16}$" & $^{7}/_{8}$"

type 6 covering air bore sizes $^{15}/_{16}$", 1" & $1^{1}/_{16}$"

type 29 covering air bore sizes $^{13}/_{32}$", $1^{1}/_{8}$" & $1^{5}/_{32}$"

Main jet emulsion air was provided by "external" air bleeds sited around the jet holder boss of the carburettor body.

The pilot fuel jet was a calibrated drilling in the jet block itself.

Manufacturing problems, high production costs and limited production throughput, all resulting from the use of crude sand castings, provide the impetus for design change.

2.1.2 Types 74, 75, 76 and 89

When introduced in 1932, these designs were almost identical to the earlier 4, 5, 6 and 29 series, except in that new technology was employed for the main castings with the use of a zinc based alloy suitable for high volume production pressure die-casting. This gave rise to manufacturing cost reductions, due partially to basic material costs and partially to the improved casting techniques allied to the new material usage. This latter meant greater definition of casting profiles and reduced wall thicknesses, which in turn led to manufacturing cost reductions.

Carburettor bore sizes and many of the components were the same as those used in the earlier series, as were the basic fuel and air circuits (other than the introduction of the pilot "bypass" circuitry into the pilot system) and even after the introduction of these newer series, the older 4, 5, 6 & 29 ranges continued to be manufactured, although in lower numbers.

With improvements in engine technology and the increasing use of Amal equipped engines in countries other than Britain, problems with the ingestion of dust and dirt particles into the engine, resulting in accelerated engine and carburettor slide/body wear, began to arise due to the use of unfiltered intake air. The fitment of intake air filtering devices to the carburettors to remove the dust particles from the air entering the engine cylinder(s), lessened the wear problems, but without circuitry changes, did not address the problems of fuel metering variability in the sensitive idle and off-idle operating regions due to blocking of the jets and air bleed circuits by dust/dirt originating from the continued use unfiltered ("external") emulsion and bleed air.

The introduction of intake air filtering, whilst still using "external" venting of the fuel chamber, necessitated retuning of the carburettor settings to overcome the enrichment resulting from the pressure differences acting on the fuel circuitry. As discussed earlier, the metering signal acting on the fuel jets is the difference between the pressure acting on the surface of the fuel in the float chamber and the depression acting on the upstream side of the jet as a result of air velocity. The pressure drop in the air passing through the restriction of the air filter, is added to the velocity head of the air flowing through the venturi, so giving rise to a higher depression acting on the upstream ride of the fuel jet than would have been the case with an open (or unfiltered) air intake. If the pressure acting on the surface of the fuel in the float chamber is not always matched to that of the pressure of the air after filtration, fuel K metering signal variations will occur. With atmospheric pressure giving rise to a relatively stable pressure on the fuel in the float chamber ("external" venting) and a pressure drop in the intake air being drawn through the filter that increases rapidly with increased air flow, significant fuel metering differences arise between an external float chamber vent/unfiltered intake air combination and a external float chamber air/filtered intake air combination.

2.1.3 Types 274, 275, 276 & 289

These types were introduced into production in 1939 in an attempt to achieve filtering of all air entering the carburettor and engine and to simplify carburettor circuitry, without change to the method of venting of the removable float chamber. The redesigned carburettors were, to a large degree, visually and technically identical to the earlier 74, 75, 76 and 89 types, with bore sizes, body dimensions, materials and component designs being generally interchangeable between the two series.

The earlier series numbers were modified to identify the change from "external" to "internal" venting of the carburettor air circuitry and the component changes necessary to accommodate this.

The "internally" vented carburettors were easily recognised by the body casting differences from the earlier series. To accommodate the need to draw emulsion bleed air from the air stream after any filtering had taken place, the body casting was modified to include an angled web under the air intake connecting to the lower section of the body casting at throttle slide/jet block bore. Included in the angled web was a cored emulsion air passage connecting the air intake to throttle slide bore at the jet block base position. A single drilled hole in the jet block base then carried the emulsion air through from the cored passage through to the main jet circuitry, so eliminating the multiple emulsion air holes, which had carried unfiltered air, that were drilled around the circumference of the body in the lower throttle slide/jet block area and through into the jet block base itself.

All of the "standard" carburettor types through to and including the 274, 275, 276 & 289 series, utilised detachable float chambers that were, of necessity, mounted to the left or right of the carburettor body and attached to it by complex and expensive arrangement of connecting arms, banjos and bolts, resulting in numerous different float b6wl casting options. Overall, the complete carburettor assembly was expensive in the areas of initial die manufacture and the subsequent maintenance/running costs as well as in cost of the final saleable product. Additionally, as road speeds of the motorcycles fitted with these carburettor assemblies rose, so major defects were encountered with weakness or richness of the fuel/air mixtures being drawn into the engine on cornering due to the position of the float chamber in relation to the main jet assembly.

The period of austerity immediately after the Second World War led to a rapid increase in the number of small motorcycles, scooters and powered bicycles (auto-cycles) and a decrease in the size of the engines powering them. An increased use of two stroke engine types also became apparent, probably to boost the power/weight ratio of the engine, whilst retaining the advantages of the less complex engine assembly.

The increasing need to reduce cost and complexity of the carburettor assembly for these small engine applications led to the combined float chamber (223 carburettor) design in 1945. In this design the previous detachable cylindrical float chamber was integrated into the carburettor body casting, eliminating the need for separate float chamber/carburettor sub-assemblies with their multiple castings and complexity. Solid throttle valves, sliding directly in, (and relying for support on), the main carburettor body, were utilised, again as a cost saving measure.

With an air bore diameter of $^{11}/_{16}$" the 223 carburettor was suitable for engine capacity applications similar to those of the 274 series carburettor, but with the integrated casting design and circuitry simplifications derived from the Binks based small engine carburettors of the 1920's and 30's, (types 52, 53, 93, 103, 104, etc), a carburettor with considerable cost reductions resulted. As with the 274 designs, both spigot (1" o.d.) and flange type (two stud 1.574" centres) fixing were available with the float chamber cast on either the right or left hand side of the body according to the required application. A rash of other small bore carburettors of similar design principles, but of different air bore diameters, too numerous to mention in detail, (1940's - types 223, 261, 308, 359, etc; 1950's - 352, 353, 361, 379, etc.; and late 1950's - 523, 561) followed over the next 8 years, leading to the first of the "monobloc" designs in 1954, (1955 model year production).

2.1.4 "Monobloc" Carburettors - Types 375, 376, 389 and 689

The "monobloc" designs attempted to utilise the small carburettor series combined float chamber cost advantages whilst locating the float chamber centreline closer to the centreline of the main fuel jet. The float chamber continued to be positioned on the side of the main carburettor body, but through the use of a pivoted, (as the 510 series), rather than free floating, float, a redesign of the fuel cut-off seating assembly (needle valve) led to a more efficient, consistent and repairable assembly at a lower overall cost.

A "jet block" assembly was still employed, but instead of the throttle slide bore passing right through the body as had been the case in the earlier "standard" carburettor series, the slide bore was reduced in diameter at its lower end and the now simplified jet block, clamped to the body by the main jet holder. This particular redesign led to a major cost reduction as the simplified jet block was now able to be manufactured from a die-casting rather than the previously employed fabricated brass assembly.

A further major change from the "standard" carburettor range was the redesign of the pilot circuitry to include a removable pilot jet rather than the calibrated hole previously drilled in the jet block. This provided the dual benefit of enabling a common jet block to be used for all applications of a given size carburettor and an easily removable pilot jet for tuning and cleaning purposes. In service adjustment of the idle mixture was provided by adjustment of the idle circuit bleed air volume.

Although the "monobloc" carburettors were made available with the same mounting options (spigot or flange) as the "standard" carburettor range, the float chamber was always on the left hand side (as viewed into the air intake) of the carburettor body with the pilot and throttle adjusters necessarily positioned on the right. This led to complications on twin carburettor engine applications due to the required spacing between carburettor centres and to the difficulties of adjusting the left hand carburettor of the pair. Various "stop gap" solutions to the twin carburettor problem were introduced, including using only one of the two float chambers to supply fuel to both (this led to a body casting version that incorporated a "chopped off' float chamber), but problems persisted until the introduction of the 689 type late in the life of the monobloc series, which was a mirror image (i.e. left handed adjustment, right hand float chamber) version of the 389 type and could be used in conjunction with the 389 in larger engine twin carburettor applications.

As a cost saving on the 375 carburettor of the series (363), the body of the air filter was cast integral with the carburettor body, as had been the case with some of the earlier small carburettor types, specifically for the BSA Company.

The different identification numbers in the "monobloc" series identified the carburettor bore sizes available in the same manner as had previously been employed for the "standard" carburettor series, i.e.

- 375 covering the $^{21}/_{32}$", $^{23}/_{32}$", $^{25}/_{32}$" sizes of the earlier 4, 74 & 274 series and also the $^{13}/_{16}$" and $^{7}/_{8}$" sizes of the 5, 75 & 275 series. The 363 version was made in $^{25}/_{32}$" and $^{13}/_{16}$" bore diameters.
- 376 covering $^{15}/_{16}$", 1" and $1^{1}/_{16}$" sizes as the previous 6, 76 and 276 series.
- 389 covering $1^{1}/_{8}$", $1^{5}/_{32}$" and $1^{3}/_{16}$" sizes of the earlier 29, 89 and 289 series.

One of the major manufacturing problems inherent in all of the "jet block" based carburettors, up to and including the "monobloc" range, was associated with the thin wall, split skirt, throttle valves necessary to accommodate the "slide" guide/s required to prevent rotation of the throttle valve. Slotting of the thin wall cylinder forming the lower section ("skirt") of the throttle valve gave rise to distortion in the cylindrical shape with possible "sticking" of the valve when fitted over the jet block insert in the body. Close manufacturing tolerances and intensive quality control, with their associated high costs, were necessary to ensure acceptable product operation.

2.1.5 Mark 1 "Concentric" Designs - 400, 600, 900 and 1000 Series Carburettors

These designs had the objective of removing, or at least reducing, all of the technical and manufacturing problems encountered in earlier Amal carburettor designs. The carburettors were first introduced into production for 1968 model year motorcycles and were the subject of an Amal Company management decision that would see all earlier similarly sized products withdrawn from Original Equipment engine applications as part of a rationalisation programme aimed at matching the needs a declining number of British motorcycle manufacturers and an increasingly demanding market. High performance and good fuel economy demands, together with imminent exhaust emission control legislation, gave rise to high revving multi-cylinder engines with close matching of the engine's fuel/air mixture requirements across the whole operating range of the engine, becoming essential.

Unfortunately, the British OE manufacturers were unable to match the aspirations of a rapidly changing market and the previous British dominance of the world market was eroded and overtaken by Japanese manufacturers. Although Amal attempted to provide additional tuning features in the "concentric" carburettor to satisfy the technical demand, by 1975 virtually all supplies to the true OE market had ceased and on-going production was limited to replacements, spares and aftermarket fitment. This limited production continues to the present day.

The "new" features made available within the "concentric" design were:

1. All major parts, (carburettor body, float bowl, throttle valve, air valve and throttle slide bore cover), manufactured as zinc based alloy castings for ease of manufacture and low cost.
2. Carburettor body only available with two bolt flange to engine/inlet manifold to reduce the incidence of air leaks engine to carburettor spigot mountings.
3. Hemispherical float chamber attached to the under-face of the carburettor body and positioned with its vertical centre line being also the centre line of the main fuel circuitry from the main jet to the discharge spray tube in order to remove cornering deficiencies of detachable float chambers, whilst achieving manufacturing cost reductions.
4. Pivoted nylon float of blow moulded manufacture for low cost, high quantity production, arranged concentrically around the main jet holder assembly and with integral float operating arm moulded to a pre-set height, making float height setting unnecessary.
5. Viton tipped float needle to prevent seating wear and needle sticking,
6. No jet block; zinc alloy throttle valve arranged to slide within and guided only by the main carburettor body. Throttle valve, designed with only small recess to accommodate spray tube projection, able to provide a variable venturi area at all throttle openings,
7. Throttle needles and needle jets available for four and two stroke petrol usage as well as for methanol fuelled engines.
8. Range of different spray tubes designs available, to enable various fuel metering slopes to be achieve from a given main jet size.

Mark 1 concentric carburettors bore diameters range from 12mm through to 32mm, with the 400 type covering 12 to 20mm; the 600 type covering 22 to 27mm and the 900 type covering 28 to 32mm.

A demand for larger carburettors than the 32mm bore available in the 900 series, did lead to the introduction of a 1000 series in 1970 with bore diameters of 34, 36 and 38mm and following identical design circuitry and production principles as the smaller 600 and 900 series, but with the rapid decline in OE motorcycle production in the UK and the differing demands of the Spanish OE producers, production ceased in 1975.

2.2 UK/Spain Collaborative Designs for Standard Road Machines

2.2.1 Mark 1½ Concentric Designs - 1600 & 1900 Series Carburettors

As the British OE motorcycle industry declined in the late 1960's and early 1970's, an increase in manufacturing activity in Spain led to Amal granting a manufacturing licence to a Spanish organisation (Talleres Arreche) for the manufacture in Spain of the Amal concentric carburettor range.

Initially, production was limited to the 400, 600 and 900 series carburettors as being produced in the UK, but the Spanish motorcycle manufacturer's demands for improvements led to changes being introduced to provide more control over the cold start/cold running operating modes.

The traditional Amal method of achieving cold running enrichment by restricting the intake air flow by a moveable air slide, whilst effective, was crude in operation and, contrary to cold engine operating requirements, gave increasing levels of enrichment with increasing air flow. In the redesign, the air slide was removed from the air intake region and a separate enrichment circuit, having its own fuel and air supplies, was introduced. By arranging this separate enrichment circuit to discharge into the carburettor region downstream of the throttle valve, it was subject to inlet manifold pressure and its effectiveness therefore decreased as the engine load (and therefore main air flow) increased. A manually controlled (lever or cable operated) valve in the circuit enabled the rider to open or close the circuitry. With the valve open, air flow through the circuit draws fuel from a separate, fixed size cold start fuel jet, to produce a fuel rich mixture, which is then fed into the main air/fuel mixture downstream of the throttle valve resulting in an enriched mixture entering the engine.

Unfortunately, in very cold start engine conditions requiring a very rich mixture for initial firing, the new circuit was limited in its effectiveness, as circuit mixture strength is dependent upon the circuit air velocity, which in turn is dependent upon pressure drop across the main throttle valve. Under the cold start conditions, engine load is higher than normal and cranking speeds lower, the resulting pressure drop across the throttle valve is low and air velocity within the cold start circuit is therefore at a low level and the potential for added enrichment is therefore limited until the manifold pressure decreases. To overcome this potential deficiency, the float chamber flooding (float "tickler") arrangement used in all previous Amal designs, was retained to enable the rider to achieve the initial fuel enrichment required for cold starting in very cold atmospheric conditions.

To suit many of the Spanish engine designs, the new carburettors were offered with the choice of carburettor mounting, either standard Amal two bolt flange or spigot. Contrary to earlier spigot mounted designs, this range utilised flexible connectors between the carburettor spigot and the engine inlet stub to eliminate air leakage from the earlier metal to metal spigot fixings and to reduce both heat transfer and the transfer of engine vibration to the carburettor.

Although the body, throttle valve, float chamber casting and cold start circuit components were different to those of the Mark 1 concentric design, they were interchangeable with those of the Mark 1 and virtually all other components were common.

To identify the modified carburettors, they were designated the Mark 1½ concentric carburettor range and given the series numbers 16- and 19--, with the last two digits of the four part number being the bore size in millimetres as had been the case for the Mark 1 concentric range.

2.2.2. Mark 2 Concentric Designs - 2000, 2600 and 2900 Series Carburettors

The Mark 2 concentric carburettor designs differed from earlier Amal OE production designs in that aluminium was used for all main castings (body, throttle valve and float bowl). Aluminium provided reduced carburettor weight with casting stability and at no detriment to casting cost.

All features available in the Mark 1½ designs, i.e. separate cold start circuitry, pilot circuitry with by-pass discharge port, air bled main fuel circuitry and a choice of throttle needles, needle jets and spray tubes to match engine types and fuelling requirements, were all made available in the Mark 2 arrangements. Only spigot mounting of the carburettor is catered for and the float bowl casting, although still arranged concentrically around the main jet circuitry, is of rectangular shape and attached to the carburettor body by attachment points at the four corners. To cater for inclined carburettor applications, alternative positions of the pilot jet are available to avoid fuel siphoning when the pilot outlet port is below the level of the fuel in the float chamber. As an end user tuning benefit and a manufacturing cost saving, the throttle bore cover is a threaded plastic moulding.

To cater for the demands of engine exhaust emissions controls, the tickler feature of the earlier float bowl was removed.

Carburettor bore sizes from 22 through to 38mm are available within the three body sizes:

2600 range covering 22, 24, 25, 26 and 27mm

2900 range covering 28, 30, 32 and 34mm

2000 range covering 34, 36 and 38mm.

2.3 Amal Carburettors for Racing Machines

A feature common to all Amal racing carburettors since the formation of the Company in the early 1920's, is the use of a "jet block" and associated "hollow" throttle slide in order to simulate a smooth venturi with minimum disturbance to the airflow through the carburettor body.

To ensure a smooth bore through the carburettor body and its inserted jet block, al! racing carburettors up to and including the GP2 type were machined as part assemblies, with the air bore through the carburettor body, jet block and any intake tube machined together and the parts identified by numbering to ensure that they remained as "matched" sets of parts.

2.3.1 Series 27 Carburettors

The first Amal carburettor specifically arranged for track racing engine usage was the 27 series unit. This was basically a spigot mounted "Amal standard" carburettor of $1^1/_{16}$" or $1^1/_8$" bore diameter choices and corresponding spigot (clip) fittings of $1^1/_4$" and $1^3/_8$" respectively, specifically jetted for alcohol fuels.

To eliminate the cornering fuel surge problems of the normal road usage "standard" carburettor with single rigidly mounted float chamber, the 27 carburettor was always used with two rigidly mounted float chambers, one on either side of the air intake.

The main fuel circuitry of the unit was of the plain jet type with no needle jet or needle control of fuel after discharge from the main jet. Bleed air for the main fuel circuit was taken from outside the carburettor through an air jet positioned on the side of the body. This bleed air supply could either be fixed and operational under all conditions or manually controlled by means of a slide positioned by the operator to vary the amount of bleed air allowed to pass into the main fuel channel.

The pilot circuitry incorporated a throttle bypass port and its mixture control was by variation of the pilot air supply.

Part throttle mixture tuning was by means of throttle cutaway.

2.3.2 TT Carburettors - Series 175; Types 10TT, 15TT and 25TT

The TT racing carburettor series were introduced into production in 1932 as the racing version of the newly designed "standard" carburettor range and continued to be produced for OE application until 1954 when it was replaced by the Grand Prix (GP) series. The type/number included the year of the initial application, i.e. 10TT32 for a 1932 application, 10TT34 for a 1934 application, etc., but following the recommencement of production after the Second World War, the year designation was no longer used. After 1948, the type was re-designated as the TT9 range.

The TT was a progression on the 27 type in that a throttle needle and needle jet were re-introduced to provide the addition tuning facilities of a normal road machine and to satisfy the need to be able to use the carburettor with both petrol and alcohol fuels. Other than the main (primary) bleed air circuit, which was the same as that of the 27 type, the circuitry used was as that of the "standard" road machine carburettors. The carburettors were principally used with a single rigidly mounted float chamber.

Flange mounting of the carburettor was introduced to supplement the spigot mounting arrangement of its predecessor. Clamped spigot mountings, which had been popular up until this time, suffered from air leaks around the engine/carburettor spigot connection. Flanged carburettor mountings, especially when used with a gasket between the engine and carburettor flanges, were not susceptible to such air leaks and the introduction of a flanged mounting option on the TT range was viewed as a product improvement.

The series was manufactured in three body sizes covering a range of bore diameters from $^3/_4$" through to $^{15}/_{32}$", with the 25TT available with ¾" and $^{7}/_{8}$" bores,

the 15TT available with $^{15}/_{16}$" , 1" and $1^{1}/_{16}$" bores and

the 10TT available with $1^{1}/_{16}$", $1^{3}/_{32}$", $1^{1}/_{8}$" and $1^{5}/_{32}$" bores.

Whilst the 10TT and the 15TT types proved to be popular and continued in production throughout the period until the withdrawal from production of the "standard" carburettor range, the 25TT was of limited market appeal and OE related production ceased within 18 months of its introduction.

2.3.3 Remote Needle (RN) Carburettors - Series 185

The RN carburettor, although a development of the TT series, was to some extent a regression back towards the 27 series in that the throttle needle, needle jet and main jet circuitry were all moved to the side of the throttle bore in order to remove the needle from the bore and to once more offer a smooth airflow through the carburettor. Whilst the changes no doubt satisfied the racing fraternities desire for a smooth uncluttered venturi and air bore, attachment of the needle to the throttle valve was unnecessarily complex and the product did not prove as popular as its TT parent. Introduced into production in 1937, it continued to be used until the withdrawal of the "standard" carburettor range in 1954,

Initially, the RN types were considered to be within the TT series and were numbered accordingly, 10TT37KN being an example, but this was soon changed and the TT designation was dropped from the identification, although in other respects, the type numbering continued to follow the TT numbering with the two body sizes being 10 and 15.

Although the removal of the throttle needle from the air bore was obviously considered to be of technical benefit, since the principle continued to be followed in the later GP and GP2 designs, with hind-sight the benefits have to be questioned. Firstly, considering the physical obstruction to airflow resulting from the needle when operating across the venturi, such a restriction to flow area could normally be negated by increasing bore diameter by $^{1}/_{16}$". Secondly, with regard to any loss of airflow caused by turbulence downstream of the throttle needle; turbulence within the incoming air and especially behind the needle, is of benefit in ensuring adequate fuel distribution across the air stream (especially beneficial in single carburettor/twin cylinder applications) and also in assisting in the atomisation of the liquid fuel stream. Thirdly, if turbulence is considered detrimental to engine/carburettor performance, removal of the throttle needle does not eliminate surface turbulence resulting from airflow passing through and over the gap between the jet block and slide bore.

2.3.4 Grand Prix Carburettor Series 316 - 3GP, 5GP, 10GP and 15GP

The GP carburettor range was introduced in 1954 as a further development of the RN carburettor in that the needle, needle jet and main jet were all located to the side of the slide bore leaving the air bore as a smooth venturi except for the protruding spray tube and the slide clearance between the jet block and the slide bore. The major advance from the RN design was that the throttle needle, needle jet and main jet were all located at a distance from the vertical centre line of the throttle slide of less than the slide's external radius. This reduced significantly the complexity of the needle operating mechanism as the needle could now be clipped directly to the slide.

The GP design was arranged to provide the minimum air bore area just downstream of the throttle valve, rather than at the spray tube cross-section.

Air for the pilot system was supplied from outside via a drilling through the body casting, located directly beneath the pilot outlet hole. Pilot mixture adjustment was achieved by varying the volume of fuel before it is mixed with the pilot emulsion air and discharged into the air bore downstream of the throttle valve.

The design catered only for flange fixing of the carburettor to the engine to remove the manifold air leak problems of the alternative clamped spigot connections.

Initially, the GP castings were produced in zinc alloy as previous series carburettors, but increased industrial usage of aluminium with it weight and stability advantages over zinc alloy, led the Amal design engineers to adopt the use of aluminium for the racing carburettor castings, in the late 1950's.

The GP series was produced in four body sizes, each of which were available with a range of bore diameters. As with the RN and TT series which preceded the GP; the "15" body size covered bore diameters from $^{7}/_{8}$" to $1^{1}/_{16}$" in $^{1}/_{16}$" stages; the "10" body size covered bore diameters from $1^{1}/_{16}$" to $1^{3}/_{8}$" in $^{1}/_{32}$" stages. Additional body sizes "5" and "3" covered bore diameters from $1^{7}/_{32}$" to $1^{3}/_{8}$" and from $1^{3}/_{8}$" to $1^{1}/_{2}$" respectively. $^{1}/_{32}$" size steps were available up to $1^{7}/_{16}$"

Significant service problems were encountered with the GP pilot system design, as control of pilot mixture strength by varying pilot fuel flow unfortunately leads to excessive adjustment sensitivity. The pilot circuit problems were aggravated by the location of the pilot air bleed, which was vulnerable to dirt contamination.

Another major defect of the GP carburettor was the inability to use the carburettor when any substantial downdraught angle was required by the engine installation. This defect was again due to the pilot circuit geometry with fuel siphoning from the pilot outlet occurring if installations angles greater than 20° were used,

2.3.5 Grand Prix 2 Carburettor Series 516 - 3GP2, 5GP2, 10GP2 and 15GP2

The GP2 series, introduced into production in 1962, was designed to eliminate the pilot circuit inconsistencies of the original GP series, whilst retaining all other features and perceived technical advantages.

In the GP2 design, the pilot circuit was effectively moved to the intake end of the carburettor and the method of mixture adjustment reverted to the more acceptable fixed fuel jet and adjustable air bleed. Sourcing the pilot air from the air intake region and making its control adjustable, removed the susceptibility to dirt contamination. With the pilot fuel jet located at the air intake end of the carburettor, the carburettor was able to be used with greater installation inclinations than the earlier GP and in some instances was used as a fully downdraught carburettor.

Available carburettor sizes and numbering remained as the GP series except for the inclusion of the 2 after the GP.

2.3.6 Mark 2 Smoothbore Concentric Carburettors - Series 2000

After the GP2 series, no further dedicated racing carburettor designs were produced by Amal until the Mark 2 "smoothbore" carburettor designs resulting from the collaborations between Amal and Talleres Arreche in 1973.

The Mark 2 smoothbore design was an off-shoot of the 2000 series carburettors with bore sizes covering 34, 36 and 38mm diameters. It incorporated the main design feature of earlier racing series, i.e. a jet block for a smooth air bore through the carburettor and a thin wall brass slide operating over the jet block. Manufacturing problems associated with the guide slot in the throttle slide wall, prevalent throughout the Amal racing carburettor production, continue to be present in the "smoothbore" slide design. All of the later beneficial improvements present in the Mark 2 series road machine carburettors, i.e. the use of aluminium castings for low weight and improved casting stability; concentrically arranged float chamber with pivoted float and lever operated float needle; screwed plastic slide bore cover for ease of slide removal and low cost; separate fuel/air circuitry for cold engine start and run; main jet circuitry with jet controlled emulsion air bleed; separate and easily removable pilot and cold start fuel jets; pilot mixture control by adjustment of pilot air bleed; with pilot fuel jet location able to be moved from the engine manifold side to the air intake side of the rectangular float chamber cover, etc. have been incorporated into the smoothbore designs.

Although, not benefiting from major OE manufacturer usage, the smoothbore series has proved popular with smaller specialist racing engine/motorcycle preparation operations and continues to have a "new engine" market some 30 years after its initial introduction into the marketplace.