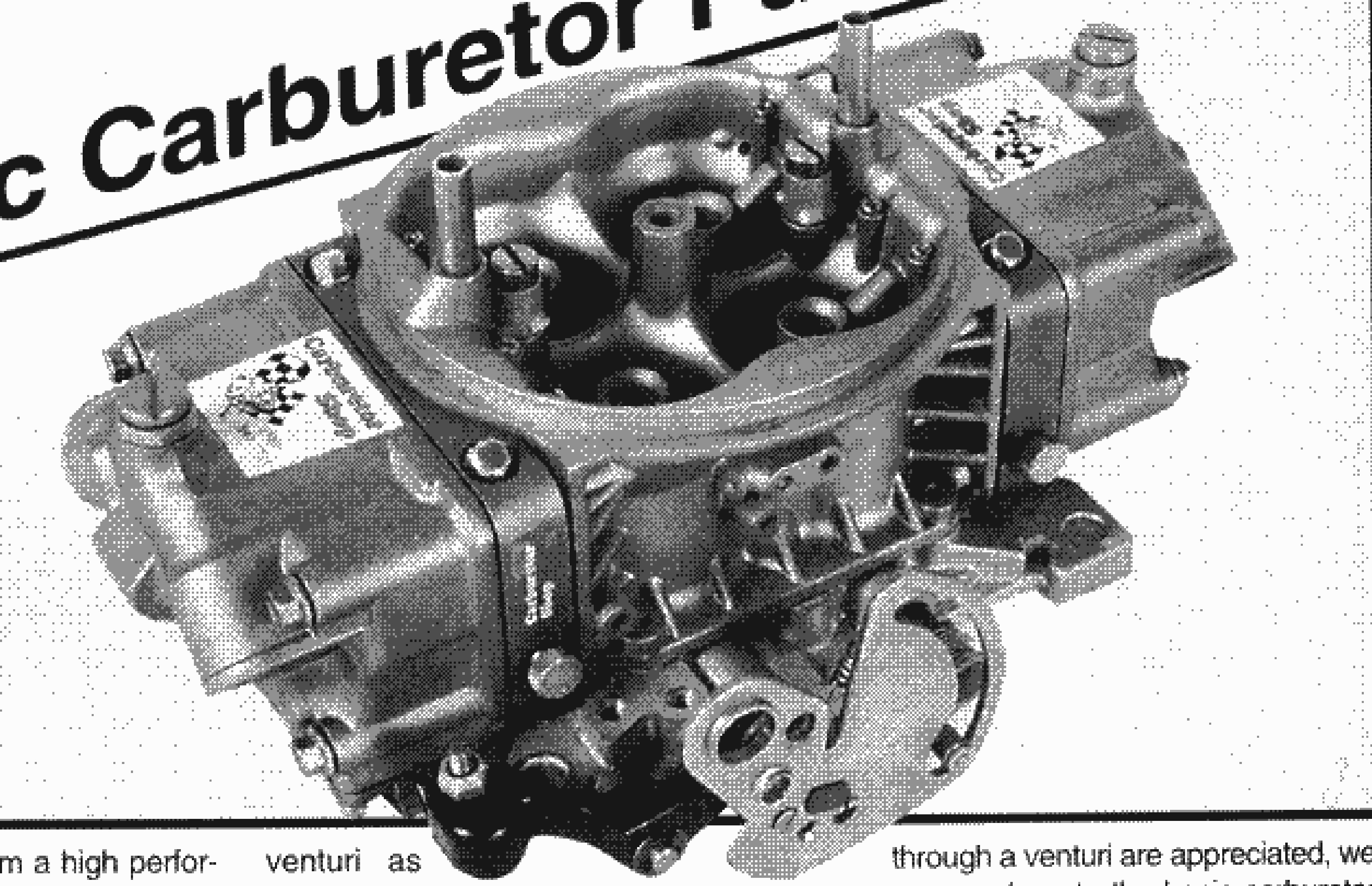
Basic Carburetor Function



To get the best from a high performance or race engine it is very important to have a working understanding of the carburetor. With the exception of its most basic functional parts like the throttle, the venturi, choke and a couple other minor details, the actual calibration and fuel circuitry seems to be a mystery for many engine builders. A hard look at the most successful engine builders often reveals a high priority on understanding the working principles of a fixed jet carburetor such as a Holley. Understanding these principles has proved to be a tool of great value for deciphering the fuel circuits of carburetors *regardless of type*—allowing the knowledgeable engine builder to swim where others would sink.

THE VENTURI

There is really no better place to start toward understanding a carb than the heart of the carburetor itself, the venturi. A venturi is no more than a streamlined orifice which has properties useful to the carburetor designer. Fig. 3-1, is a schematic showing what happens in a venturi as air passes through. At the minor diameter of the venturi, the air speeds up, and in so doing, the pressure at that point drops. This causes the liquid to be drawn farther up the tube connected to the minor venturi diameter than at any other point. The faster the air flow, the greater the draw on the connected tube.

Once the consequences of air flow through a venturi are appreciated, we can move along to the basic carburetor main jet function as shown in Fig. 3-2. If the fuel level in the reservoir is kept at the same level as the discharge nozzle in the venturi, then any pressure drop occurring here will cause fuel to flow. This crude means of mixing air and fuel only needs the addition of a main jet and a butterfly valve (Fig. 3-3) controlling air demand to produce the basis of a carburetor.

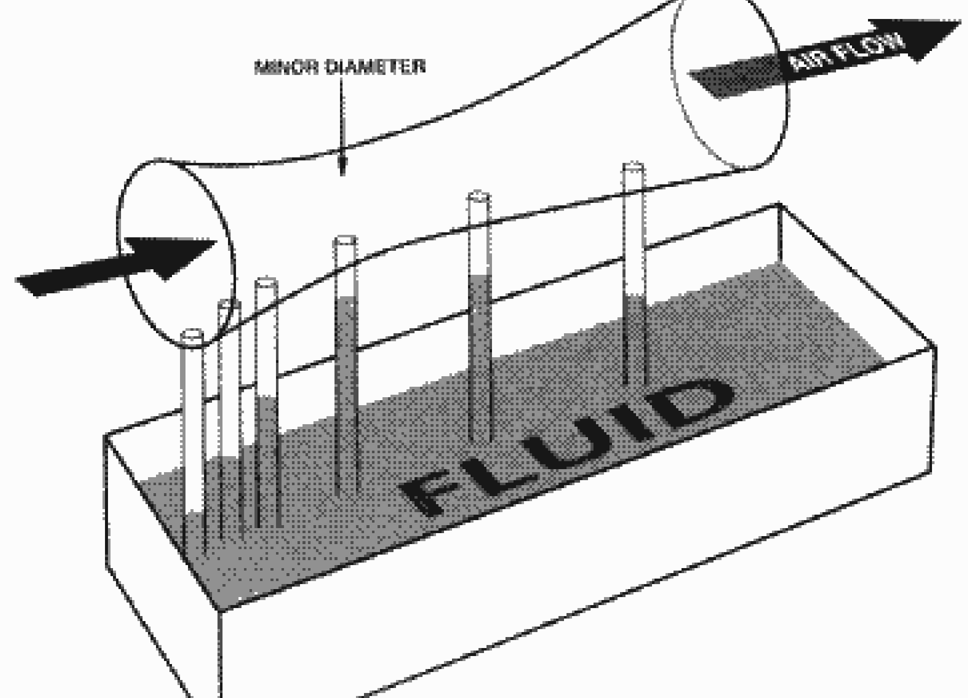


Fig. 3-1

Fig. 3-2

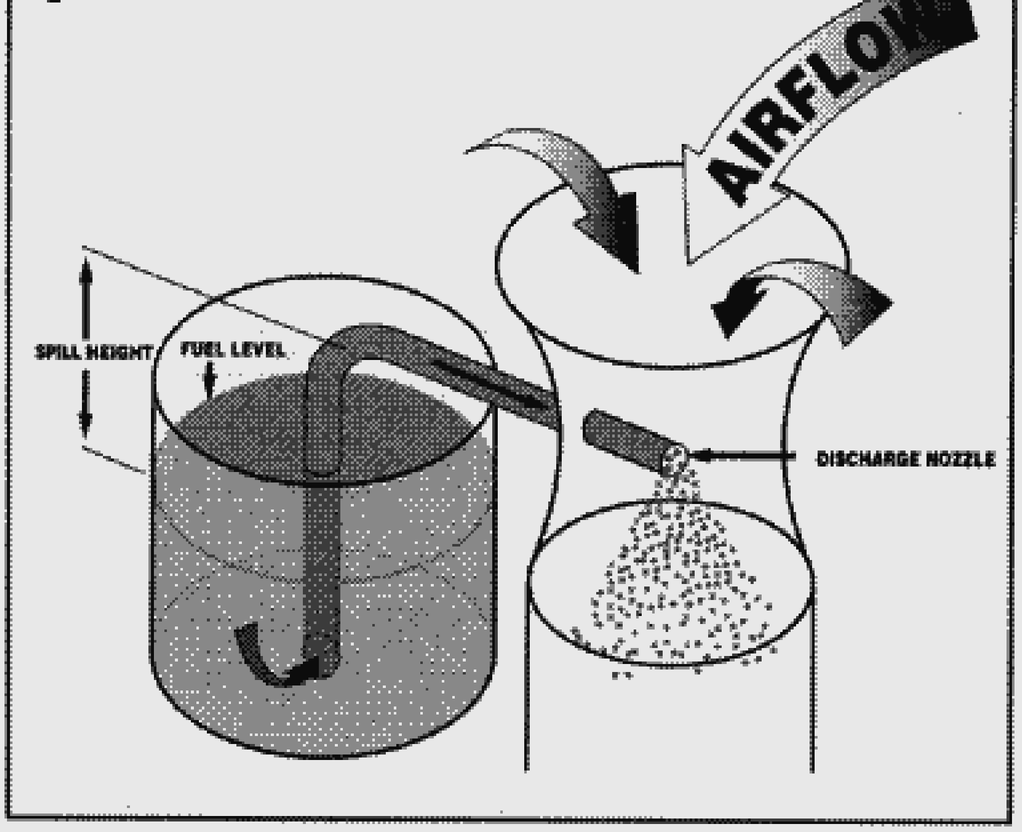
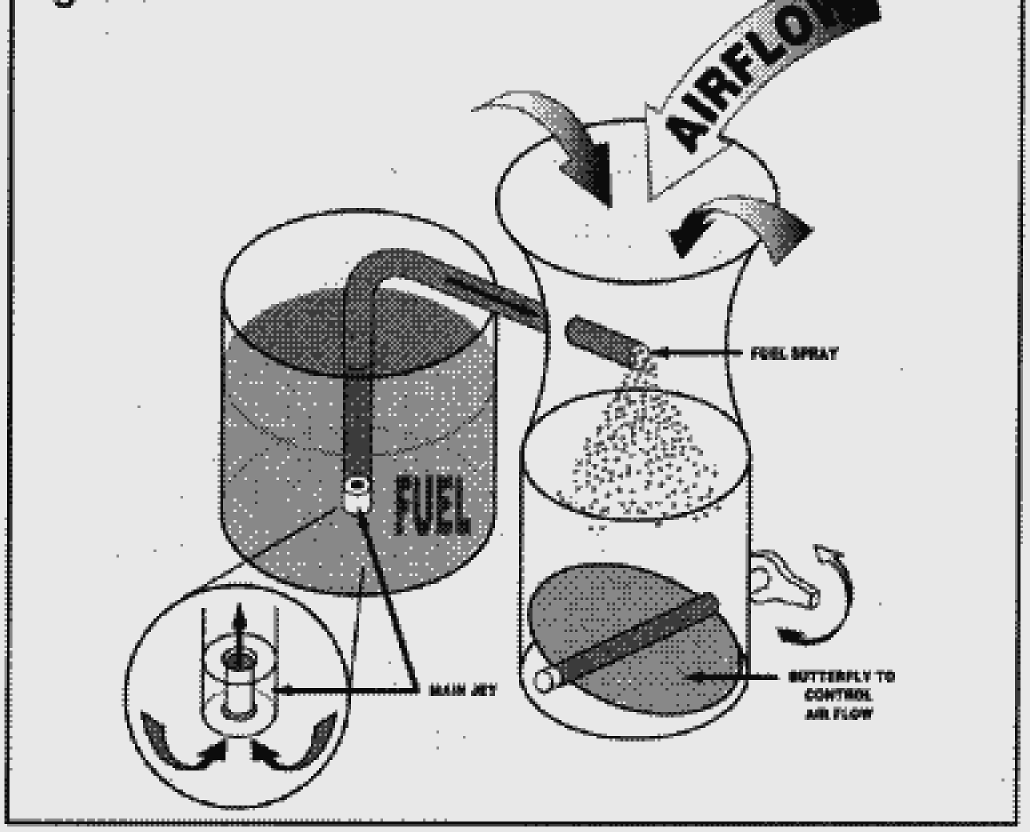
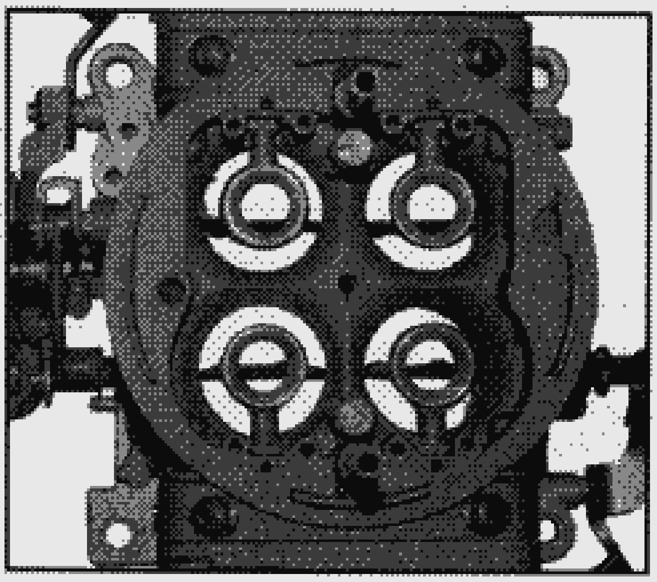


Fig. 3-3

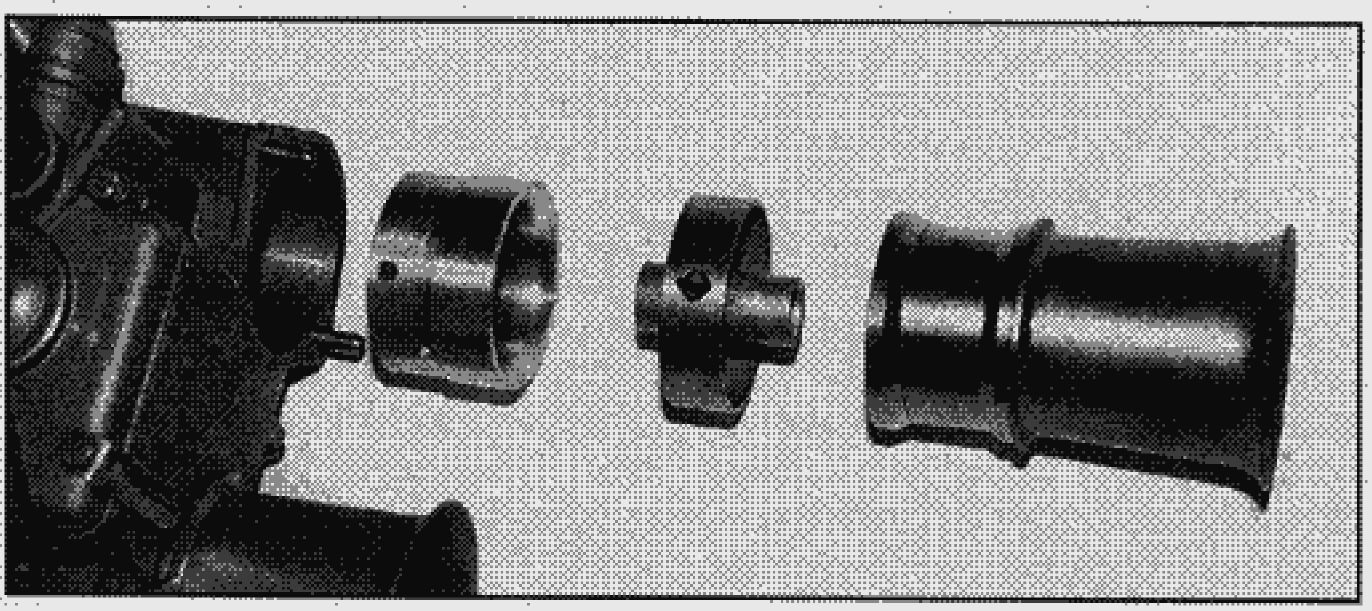




Most high-volume production carbs such as Holleys, have fixed size venturis. However, where production volumes are lower...

CORRECTION

At this point it looks like we have a functional carburetor. If so, why do real world ones seem so complicated by comparison? Although the carb in Fig. 3-3 would work, it would only do so at a fixed speed and if the balance of fuel levels between the reservoir and discharge nozzle were not upset by movement. To avoid spillage of fuel from the main jet into the venturi the fuel level must be set about a ¼ to ⅜ of an inch lower than the discharge point in the venturi. This is called the "spill height." Because of this and the fact that air is compressible and fuel is not, we find that when fuel finally does start to flow from the discharge point into the venturi, its flow rate increases faster than air flow. The result is that as demand increases, the mixture becomes progressively richer. Some sort of solution to this problem is obviously needed, and the technique used is to dilute the fuel with air prior to its arrival at the discharge orifice in the venturi. The problem is how to do this in such a way that it controls the air/fuel ratio or mixture so it is always within prescribed limits. This is done by introducing air into the fuel along the lines shown in Fig. 3-4 (next page). Introducing a calibrated air bleed at this point bleeds off a portion of the venturi signal to the fuel jet. This has two positive effects. First, it produces an air/fuel emulsion which atomizes far more readily, and secondly it allows a measure of control over high speed main jet enrichment.

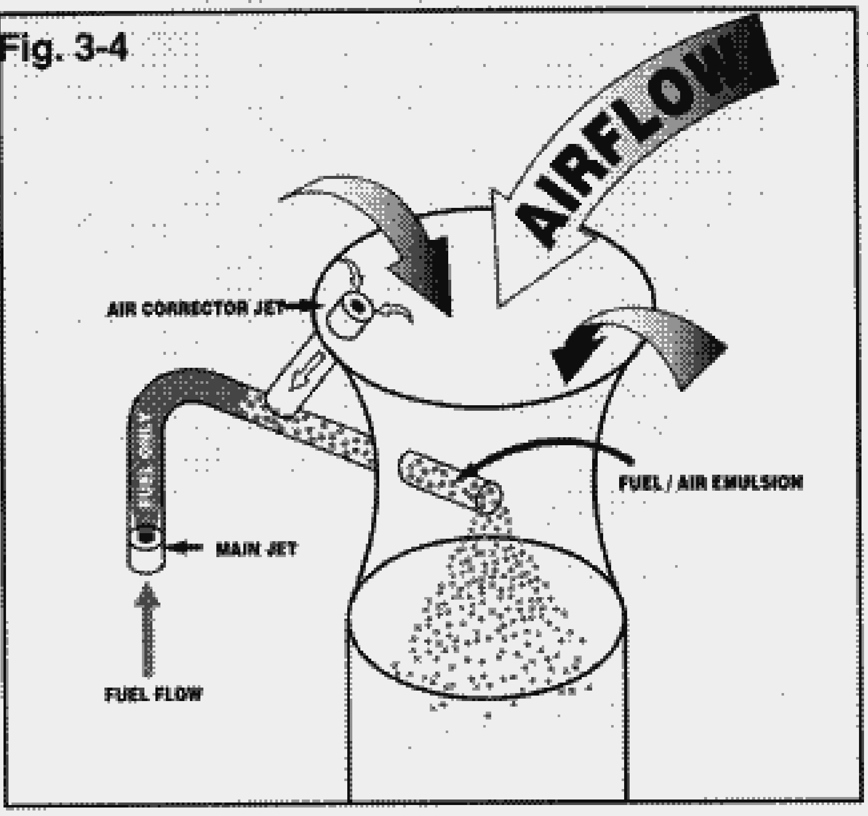


...some carb manufacturers, such as Dellorto and Weber, find it easier to make only a few throttle body sizes and have replaceable venturis so the best size can be selected.

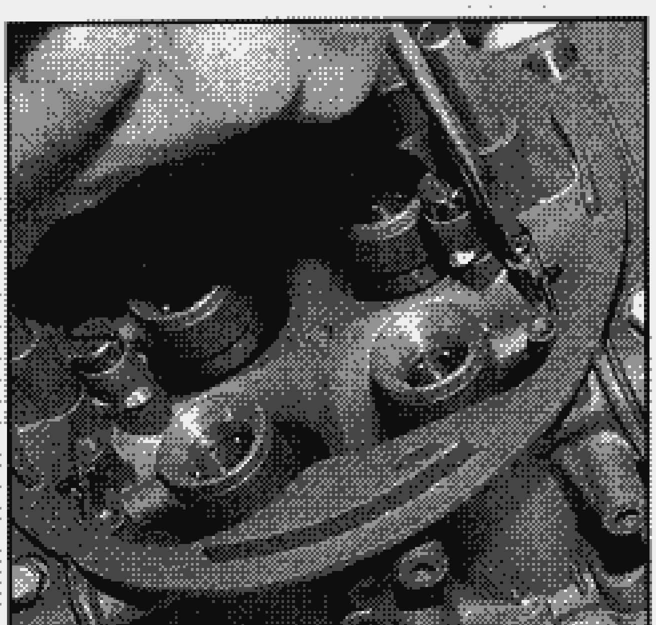
TRIMMING THE FUEL CURVE

The form of fuel delivery in relation to the air is commonly known as the "fuel curve," and the addition of an air jet has allowed us to reduce the mixture strength for any given main jet size. In practice, what is needed is an air bleed system that becomes more active as air flow through the venturi increases. This can be achieved in a number of ways, the simplest being to position the air bleed at the venturi entrance where a slight pressure rise occurs. By picking the right spot and appropriately sizing the air corrector jet, the amount of air bled into the fuel becomes progressively larger and counters the increasing richness normally seen in an uncorrected system. On the face of it this system fix looks pretty good, a little juggling here and there and we appear to be in business. Unfortunately, this type of carburetor assumes steady air flow and does not take into account that a high performance or race engine can have a strongly pulsating intake air flow. At certain RPMs, resonant pressure waves will affect the flow at the main jet to the air corrector jet differently, thus upsetting the mixture calibration. Abnormally strong reversionary pulses can occur when intake, cam and exhaust in a race engine are poorly matched. Air may momentarily

Fig. 3-4



reverse direction through the venturi. A pressure drop occurs at the venturi regardless of the flow direction. This means when the air reverses flow, it picks up fuel in addition to that picked up in the forward direction. When the correct flow direction is resumed, yet more fuel is picked up. While all this is going on, the air corrector will inevitably have added less air than needed so the mixture will go rich. The bottom line is that a far more sophisticated air correction system is needed. Now it is time to introduce a calibration item, the design and selection of which is often viewed as a black art. This is the emulsion tube, but to cover its function we also need to consider the main jet well and associated air corrector. We will need to look at these parts as a single working component. Fig. 3-5 is a schematic of a simple system. Because it is important to understand exactly what's going on here, we will take things one step at a time.



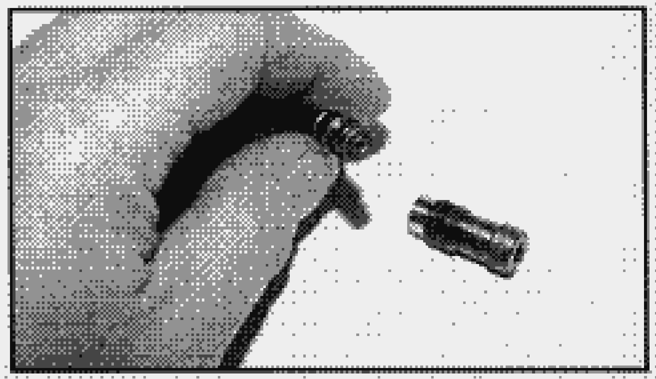
Air corrector jets or air bleeds for the Holly are positioned here. The outer ones, are for the idle circuit and the inner ones, the main circuit.

THE EMULSION TUBE

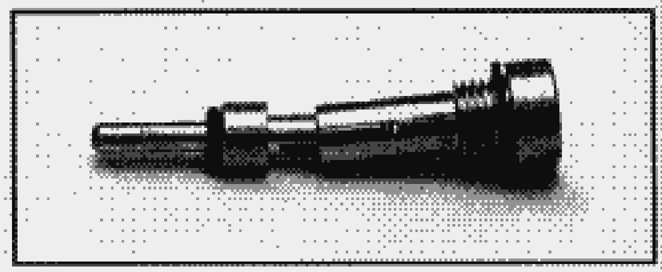
The emulsion well is an aptly named section of the carburetor, and under static conditions it sees the same fuel level as exists in the float bowl. Fuel enters the well via the main jet and exits via the discharge nozzle in the venturi. In essence, the well is nothing more than a substantial expansion of the tube that joins the main jet to the discharge nozzle. With that basic concept of the well in mind, let us add an emulsion tube and air corrector. The function of the air corrector is just as described earlier, it produces air dilution of the fuel to compensate for the RPM-induced overrichness of an uncorrected main jet. From Fig. 3-5 you can see that the air corrector is now connected directly to the bore of the emulsion tube. If the emulsion tube were to have no holes in its walls, the air corrector would be unconnected to the main jet and so have no effect on the mixture. Now let us add some holes to the emulsion tube as per the drawing. What happens now is that at static conditions, fuel fills up the emulsion tube until it gets to the same level as the fuel in the well in the float chamber. When the engine is running at low RPM, fuel in the main jet/emulsion well is drawn off by the suction produced by the venturi at the discharge nozzle. This causes the fuel in the well to drop slightly and the fuel in the emulsion tube to drop a greater amount. However, so long as no holes in the tube are uncovered the fuel being discharged at the nozzle will not be diluted by any air.

Let's now increase the RPM and consequently the engine's air demand. The situation is now similar to that being shown in the drawing. The air being drawn into the emulsion tube has caused the fuel level in it to drop below the first series of holes. There is now a measure of air bleeding into the well, forming an air/fuel emulsion, and by this means the mixture is leaned out. At this point, you may begin to discern how the emulsion tube functions. By varying the pattern of the holes in the emulsion tube it will be possible to vary the fuel curve delivered by the carburetor to suit the engine's characteristics. If we're dealing with a typical V8, it will, in most cases, use one four-barrel carburetor to feed all eight cylinders. Often, the type of manifold used, is of the plenum variety, where all 8 cylinders can draw from all four barrels. Under normal circumstances, the air flow pulses through the carburetor are relatively well damped or smoothed, either by the number of overlapping induction pulses or by the manifold's plenum volume. This aspect cuts the sensitivity of the emulsion tube to the system it has to work with. In other words, since the carb sees almost a constant flow, the need for much in the way of emulsion tube fudging to get the mixture right is minimal. This is fortunate because it means that as long as a unit based on the carburetor manufacturer's recommendations is selected, it is unlikely to be far off what is needed. However, what may need to be done to get the calibration of the main circuit right, is to deal with main jets and to a lesser extent, air correctors.

If the emulsion tube design for a four barrel can be considered simple, the same cannot be said for one barrel per cylinder installations. The heavily pulsating flow makes emulsion tube design for a given application far more critical. If you intend to run a carburetor set-up, such as Dellortos, Webers or Mikunis, chances are you will need to go through an emulsion tube selection routine. Without the information you are about to read, your selection will be strictly on a hit-and-miss basis.



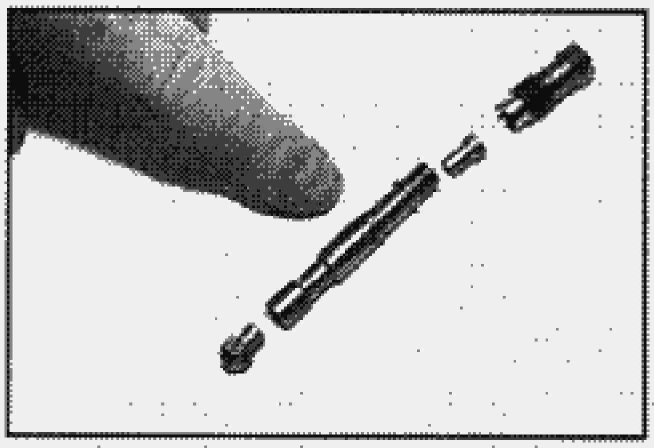
The Weber air correction system for the main jet circuit is like other carbs of this ilk, housed in the top of the emulsion tube and ...



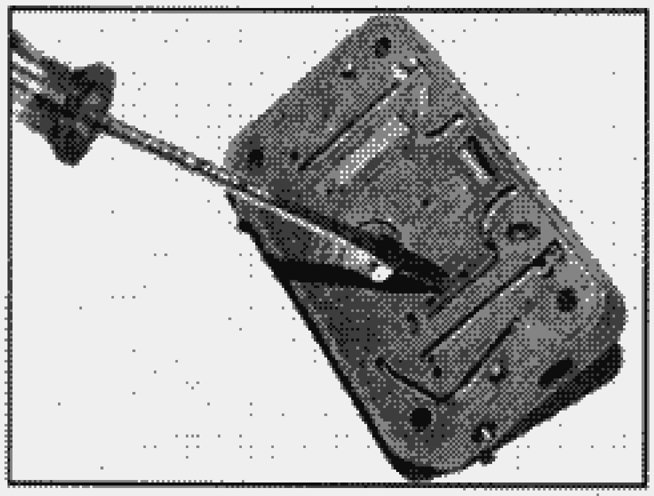
...the idle air corrector is built into the idle jet holder.

EMULSION TUBE SELECTION

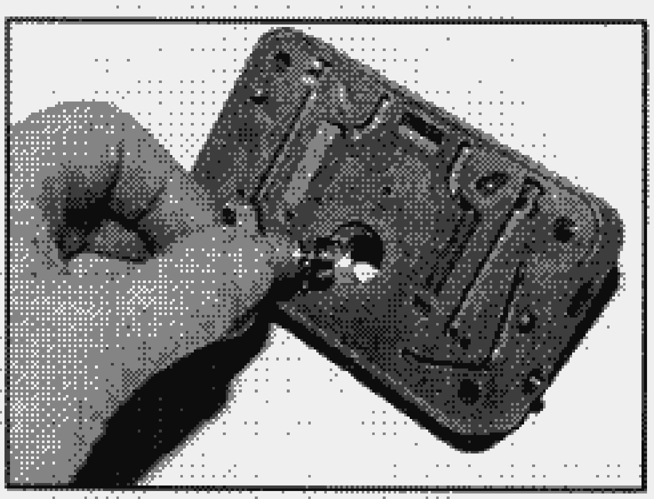
Refer back to the drawing of Fig. 3-5 showing the function of the emulsion tube and well assembly. Here you can see that



Emulsion tubes for IR type induction systems are complex affairs because of the pulsating nature of the induction stroke. As airflow becomes less...



...pulsating and more even because a number of cylinders are connected to common plenum, the emulsion tube becomes less critical and simpler to determine. On a Holley, the channel here is in effect an emulsion tube, although some have a more conventional one in the main jet well.



The power valve, when connected to a vacuum source, is held closed. When the throttle is opened wide, the vacuum goes away and the power valve opens to allow auxiliary jets to introduce more fuel to the system, thus giving the full power rich mixture required.

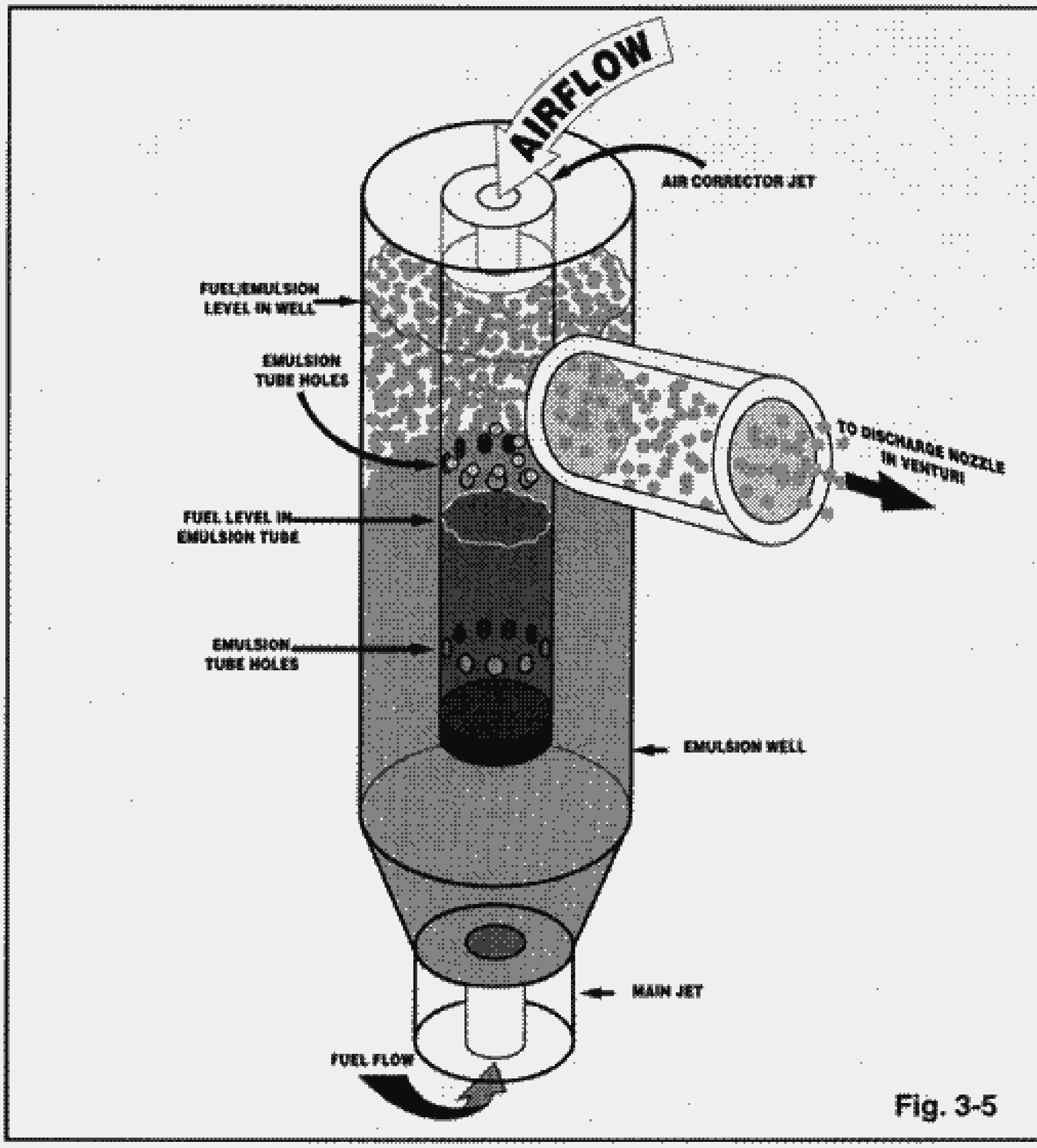


Fig. 3-5

the emulsion tube now has a series of holes getting more plentiful toward the lower end. What this does, in essence, is introduce more and more air into the fuel as air demand increases to combat the increasing richness that would otherwise exist. The function of the air corrector jet in the assembly is to control just how much or little the mixture is leaned out.

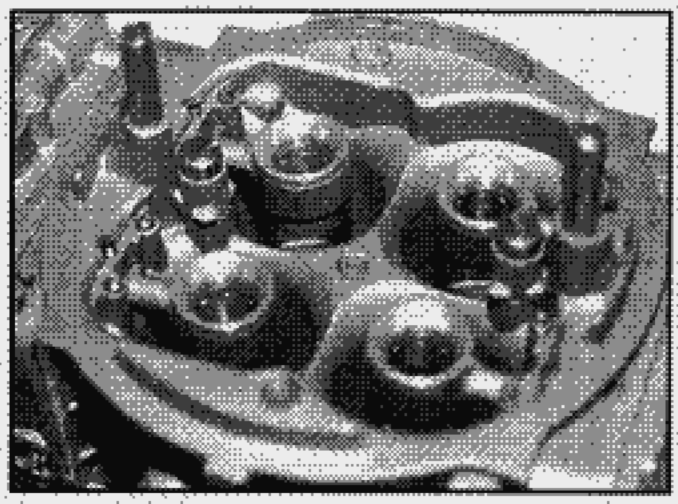
The components we've looked at are the main jet, the well, the emulsion tube and air corrector. Starting at the main jet, it will be pretty obvious that putting in a bigger main jet will make the mixture richer everywhere in the rev range and a smaller main jet will lean it out. The effect of the emulsion tube will depend on the hole pattern. The more holes there are at the lower end of the emulsion tube, the more it will lean out top end mixture. The higher up the emulsion tube the holes occur, the sooner the effect of the air corrector comes in. The effect of the air corrector itself is to lean out the mixture the more it is increased and to richen the mixture when reduced in size. Its effect being greater as RPM increases, but the measure of control is also influenced by the hole pattern in the emulsion tube.

Although it was mentioned earlier, one other aspect you must appreciate is that the emulsion tube serves another useful purpose apart from its metering function. It is so named because it turns the fuel in the well into an emulsion of air and fuel. An emulsion atomizes far better than straight fuel when it's discharged from the nozzle in the venturi.

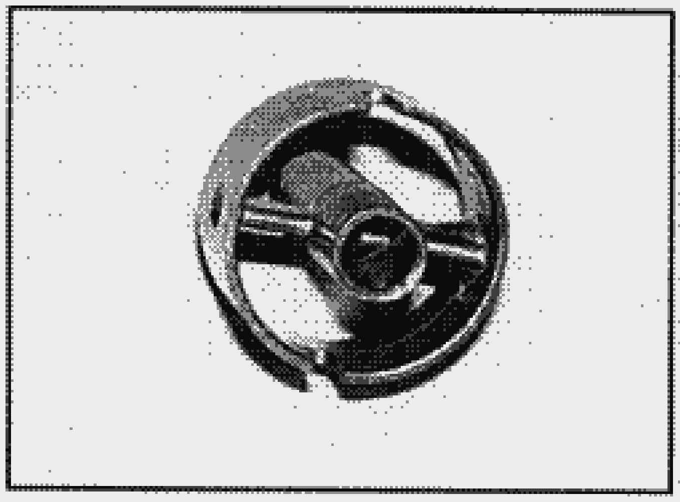
Fuel should be delivered to an engine in fine enough droplets to produce complete vaporization of the charge toward the end of the compression stroke. Any vaporization taking place in the manifold takes up more room and cuts the volumetric efficiency of the engine. It's a good idea to keep in mind the atomization aspect of an emulsion tube/air corrector assembly, because it can prove significant in the performance of your engine.

THE POWER VALVE & MIXTURE SPREAD

For a typical single four-barrel equipped V8 engine to produce maximum horsepower, the gasoline air/fuel ratio, by weight, needs to be around 12.5:1 to 12.9:1. That is 12.5 lbs. of air to 1 lb. of fuel. If perfect fuel distribution is achieved, the optimum ratio tends to be a little leaner at around 13.0/1 to 13.1:1. The chemically correct mixture varies slightly dependent on the fuel blend, but, is typically around 14.7:1 to 15:1. From this you can see that to



The booster or auxiliary venturi amplifies the signal produced at the main venturi. In most carbs, such as the Holley shown here, this is a factory fixed entity. With some carbs...



...such as Webers, Dellortos and a few others, the type of booster venturi can be selected by the end user. With variations in gain and atomization characteristics, this allows a higher degree of tuning to an engine's individual requirements.

deliver maximum power the air/fuel ratio must be on the rich side, i.e. only 13 lbs. of air to 1 lb. of fuel means there is now excess fuel in relation to the air. The major reason an engine makes maximum power with a rich mixture is that the excess fuel cools the air, allowing a denser charge to enter the cylinders. Second, and to lesser extent, it also makes up for manifold distribution and fuel droplet size problems.

LEAN CRUISE MIXTURE

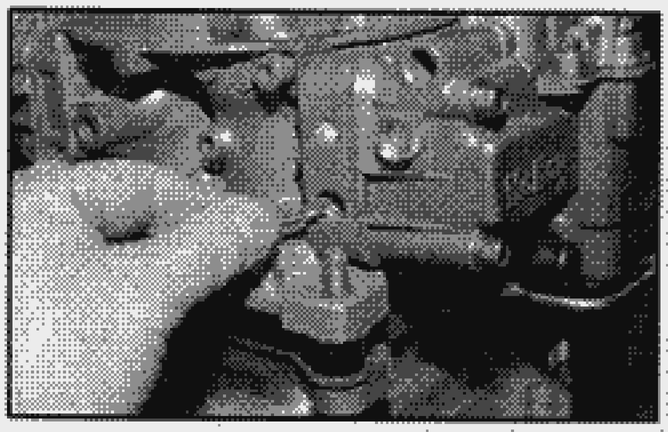
A full-power rich mixture at cruise would produce very poor fuel consumption. With a fixed jet carb, such as the Holley, the main jets are used not to calibrate for maximum power, but to set the air/fuel ratio for good part throttle fuel economy. For this, a lean mixture, typically around 16-17:1 air/fuel ratio is required. However, using a mixture ratio this lean can cost a considerable amount of horsepower at full throttle. Fig. 3-6 shows how the horsepower changes as the air/fuel ratio is varied. To get the best results at both part and full throttle, the carburetor must be capable of varying the mixture ratio between lean for economy and rich for full power. To satisfy these demands the carb must be able to deliver leaner ratio's for cruise, idle and any circumstances which don't require a maximum power rich mixture ratio. This can be done in a number of ways, but the method typically employed is to have what is known as a power valve enrichment circuit. This device is essentially nothing more than an additional main jet that is brought into operation by a vacuum sensitive switch. When an engine is operating at part throttle, a considerable amount of vacuum exists in the intake manifold. This vacuum is used to keep the power valve closed so fuel flow to this extra main jet is shut off. Opening the throttle causes the vacuum in the intake manifold to largely disappear. When this happens, it is obvious that the driver is demanding power. Under these conditions, the vacuum supplied to the power valve disappears, allowing this additional main jet to open. This jet, known on Holley carbs as a Power Valve Restriction Channel (PVRC), allows more fuel to be fed into the metering well, supplying fuel in addition to that passing through the main jet. Net result: an instant enrichment of the mixture. The drawing, Fig. 3-7, shows the power valve system built into our basic carburetor.

BACK TO VENTURIS

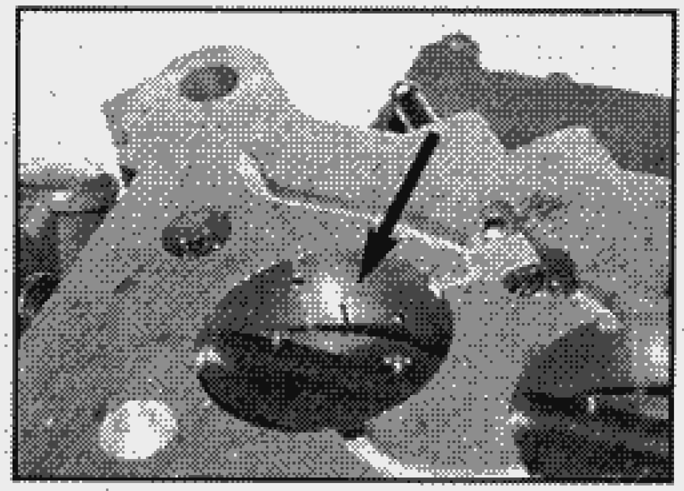
To get an adequate signal from the venturi at low RPM, it is necessary to make the venturi relatively small. This means at high engine RPM, it is virtually strangling the engine and preventing anything like the engine's true maximum power from being developed. Fortunately, there is at least a partial solution to this problem and it takes the form of a booster venturi. The solution employs a second venturi located with its end at about the same position as the point maximum depression occurs in the main venturi. This causes the air to go through the booster venturi faster than through the main venturi, providing an increased signal. A good booster design can increase the signal developed at the main venturi by 50 to 100%. By employing a booster venturi, the carburetor designer can increase the size of the main venturi to deal with top end flow requirements without the big compromise in low speed performance. Some carburetors, such as certain models of Q-Jet, employ a triple venturi, in-as-much as the booster venturi has an additional booster within it.

IDLE SYSTEM

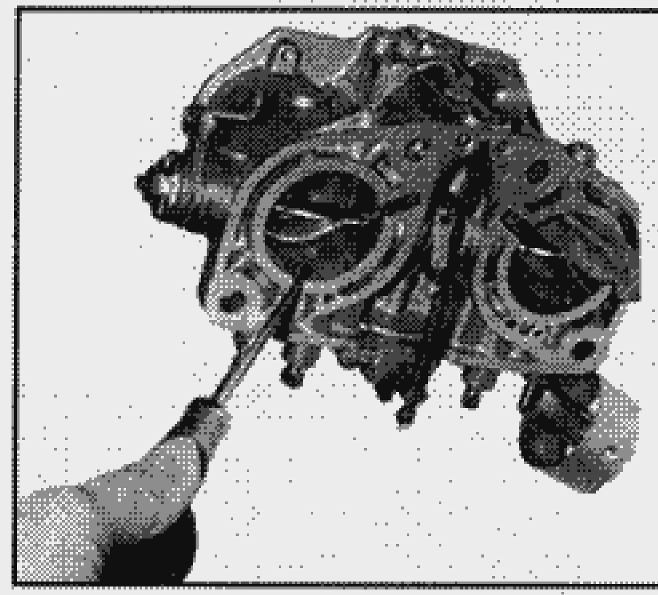
From the foregoing, it won't come as much of a surprise to realize that a venturi, even with a triple booster, isn't going to meter the fuel accurately enough for an engine at idle where the air demand is minimal. Because of the minimal air flow rates at idle, a carburetor circuit specifically tailored for the needs of low RPM/high vacuum is necessary. Hence, the idle circuit of a carburetor. Fig. 3-8 shows the breakdown of a typical idle circuit. The signal required to draw the fuel from the float bowl is supplied by the engine. With the throttle plate closed, there is a considerable amount of vacuum existing in the intake manifold. This vacuum is used to draw fuel from the float bowl, or the main jet well, via an idle jet. This same passage is also joined by an air bleed, so an emulsion is formed. This emulsion is then routed down to an orifice below the butterfly, which is controlled in size by a tapered needle. From this, you can see that screwing the needle in will reduce the amount of fuel passing out through the orifice and backing it out will increase it. (Although there are some Holley carburetors which control the air to operate in the reverse mode). From this diagram you can see that most of the air required for the engine to idle is going past the butterfly and only a small amount of air is passing via the air bleed into the fuel to form an emulsion. This system works just fine until the throttle is opened slightly. When an increase in air flow takes place, the vacuum in the manifold drops. Net result: the engine stalls. So the idle circuit tends to be self-canceling, and is only any good when the engine is truly idling and doing nothing else. It is, in essence, a totally steady-state circuit and, unless it can be modified in some way, will not cope with anything other than idle circumstances.



The use of a tapered screw to set the idle mixture is almost universal amongst carburetor designs and little difference will be found from one brand to another.



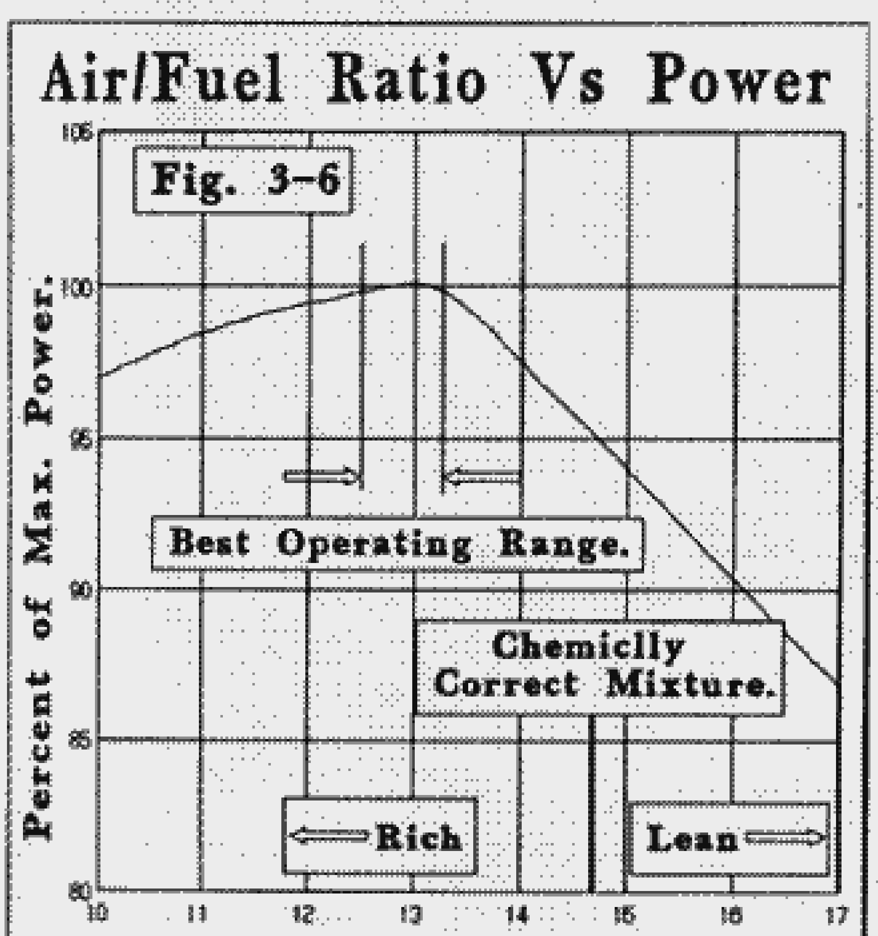
The transition, or progression as it is termed in Europe, from the idle circuit to the main circuit is accomplished by means of a transition slot on most U.S .carb designs and a...



...series of holes on most European carbs. Whichever way it is done, the operational principles are the same.

TRANSITION CIRCUIT

The transition circuit takes care of the engine's fuel and air requirements just off idle. It is incorporated into the idle circuit for a smooth progression from idle to small throttle cruise conditions. This modifies the idle circuit by drilling into the idle circuit fuel supply hole just above the position that the butterfly will be at idle. In reality, some carburetors employ drilled holes at this point and others, such as Holley, utilize a slot as per Fig. 3-9. When the throttle is closed at the idle position, vacuum from underneath the butterfly not only draws fuel through the idle circuit but also pulls in air through the transition slot to better emulsify the fuel being discharged from the idle orifice. As the butterfly opens, it begins to uncover the transition slot, and, instead of drawing in air, it starts to draw more fuel. This change over from air to fuel occurs because the length of the slot above the butterfly is reduced so less air is drawn through it. However, a great deal more air is passing around the now more open butterfly. As we continue to open the butterfly so the amount of fuel drawn in from the transition slot increases, and to a certain extent, so does the fuel being discharged by the idle orifice. By the time the butterfly has reached the end of the transition slot, sufficient air is being drawn into the system to bring the main jet into action. Although the transition circuit on most carburetors is simple in function, it is very important because most street driving, especially in traffic, is done from the middle to the end of the transition circuit. If this circuit isn't correctly calibrated it will bring about poor drivability and high fuel consumption. In most systems the idle jet is the biggest influence on the transition circuit calibration. In this respect the idle jet is probably misnamed since most of the mixture at idle is controlled by the idle mixture adjustment screw.



ACCELERATOR PUMP JET CIRCUIT

Under idling conditions, a considerable amount of vacuum exists in the intake manifold. This vacuum reduces the boiling point of the fuel, causing the fuel to vaporize much easier under high-vacuum conditions than under low conditions. This is a very useful aspect as it helps fuel distribution at idle considerably. The same situation applies at cruise. When running down the freeway at 2 to 3000 RPM and 15 to 17-inches of vacuum, a lot of the fuel being drawn into the engine is vaporized before it reaches the cylinders. However, when you stand on the throttle suddenly, the fuel that is held in suspension in the air in vapor form suddenly condenses on the walls of the intake manifold. Although a fresh charge of air is entering the engine and carrying its associate fuel, for a moment the engine goes very lean because the fuel that was in the manifold air is now on the manifold walls and for a moment at least, going nowhere. This causes an enormous flat spot which, unless countered, cannot be driven through. To offset fuel condensing on the walls of the intake manifold, an accelerator pump system is added. What this does is physically squirt in additional fuel to cover the would-be hole in the carburetion. Fig. 3-10 is a basic schematic of a typical pump jet system. Here a piston is shown injecting the fuel, but most often a diaphragm, such as on Holleys is used. Calibration of the accelerator pump fuel system is not only by means of jets to control the rate at which it goes in, but also with various springs, cams, and piston/diaphragm sizes to control the amount that's injected.

THE COLD START SYSTEM

All cold start systems work by enriching the fuel/air ratio until the engine warms up enough for fuel to be sufficiently vaporized for more effective combustion. The simplest cold start system is the "choke," (Fig. 3-11) so called because it literally chokes the air supply to the engine.

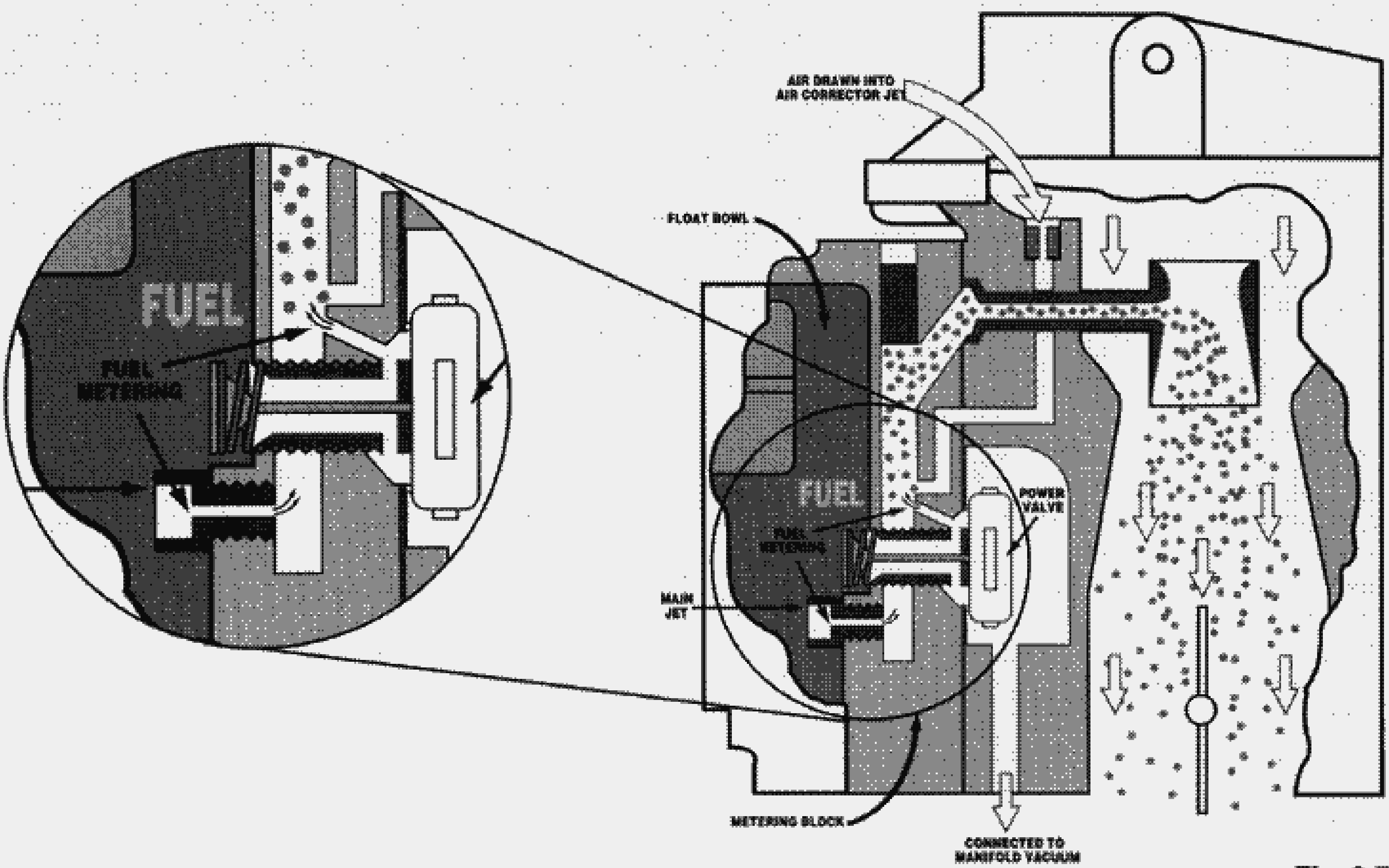
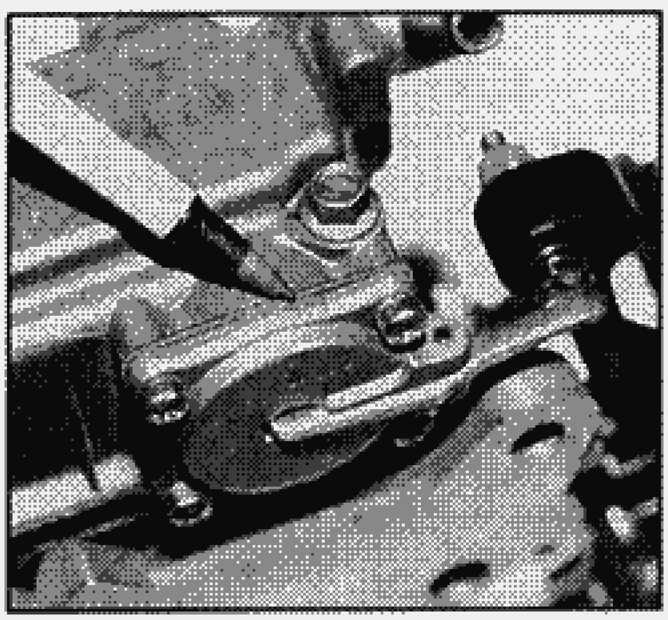
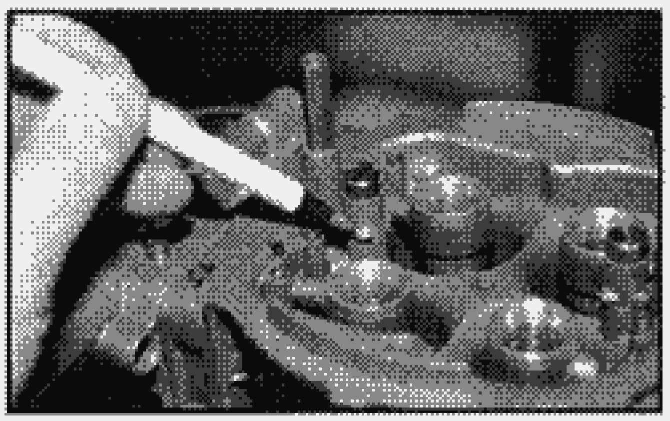


Fig. 3-7

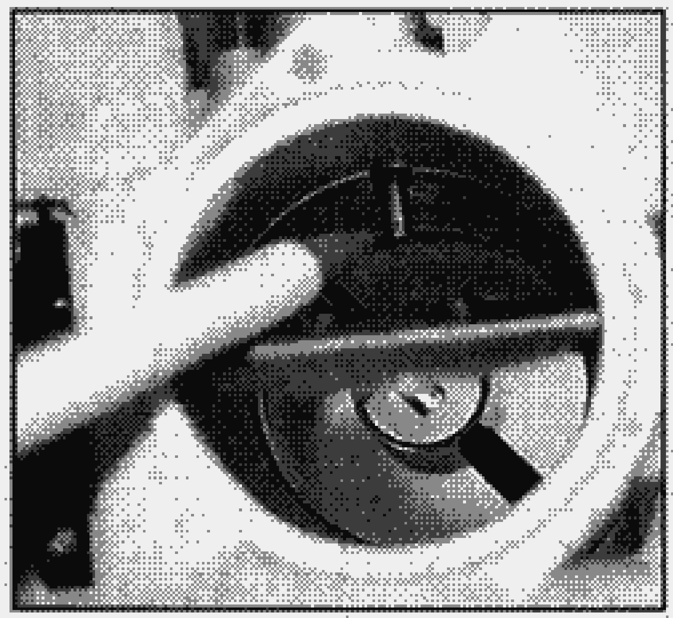
This causes the engine to draw harder on the transition and main jet circuit, resulting in less air flow and more fuel flow for a richer mixture. Any complexity we may see in the choke system stems from making it automatic in operation. When self-operated, the choke may be applied and shut off by either an exhaust heat activated bi-metal strip system or, as many of the newer carbs are, by an electrically heated system. Since none of these choke systems contribute to performance, no great detail will be gone into concerning their function. Suffice to say that several other SA books cover in detail the overhaul of these systems on popular carbs such as the Holley.



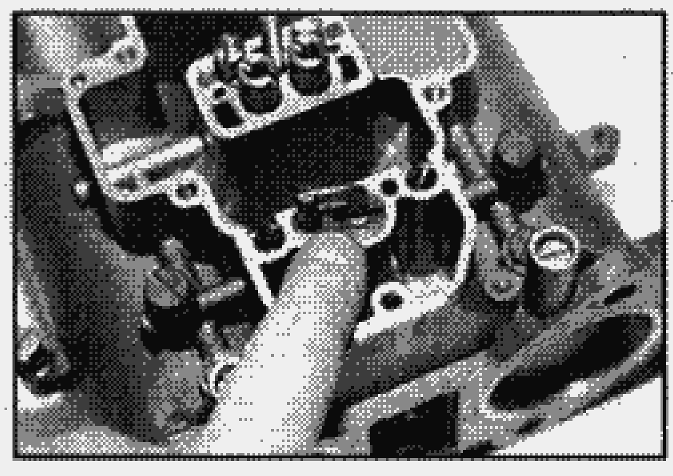
The use of a diaphragm as the means of injecting fuel into the engine to cover the acceleration lean out is about the most common way of doing the job. Fuel from here...



... enters the induction system via these pump jets, which are required to be appropriately sized.



On carbs intended for IR usage, the pump jets can also act as a high speed fuel bleed, which at high airflow values starts to feed fuel into the system for power enrichment.



Unlike many other designs such as the Dellorto, the Weber uses a piston as a pump system for acceleration enrichment.

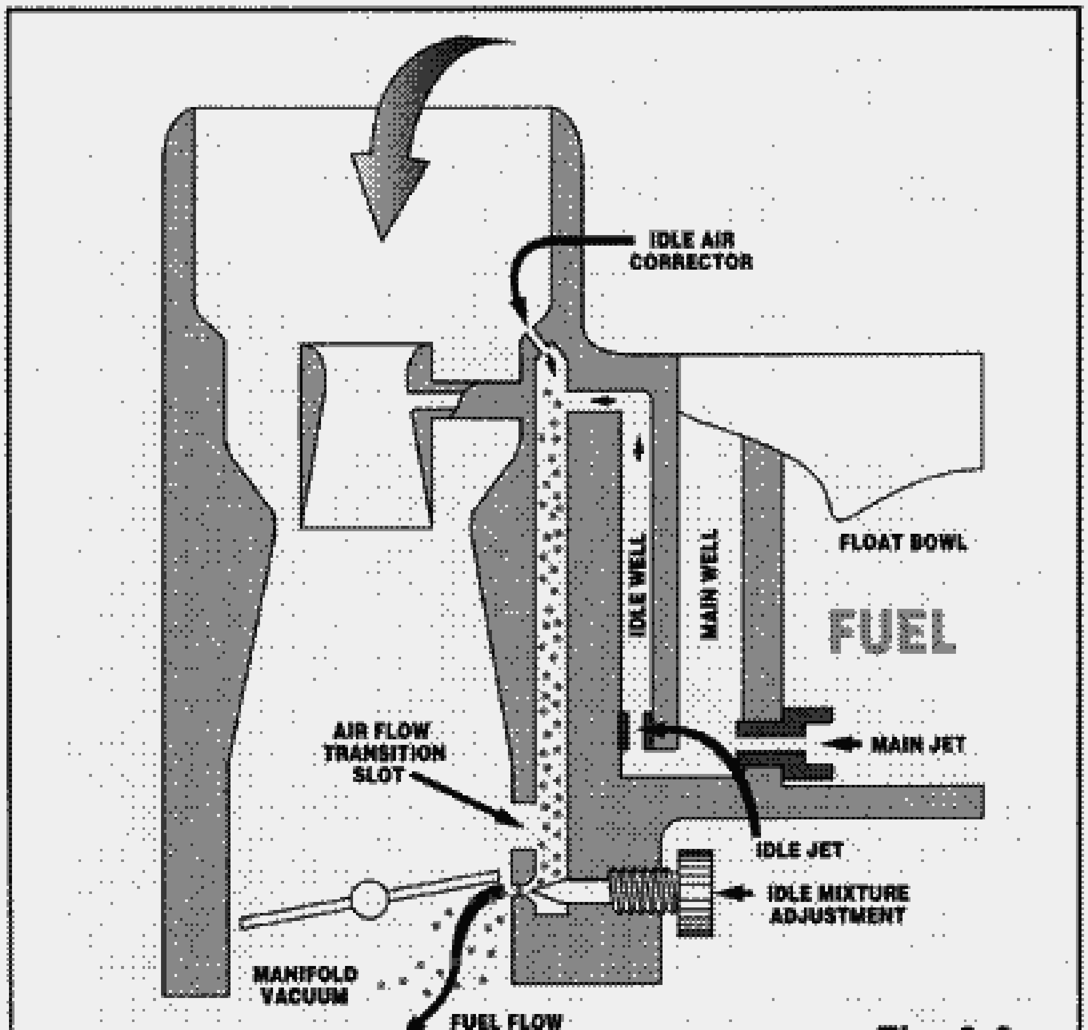


Fig. 3-8

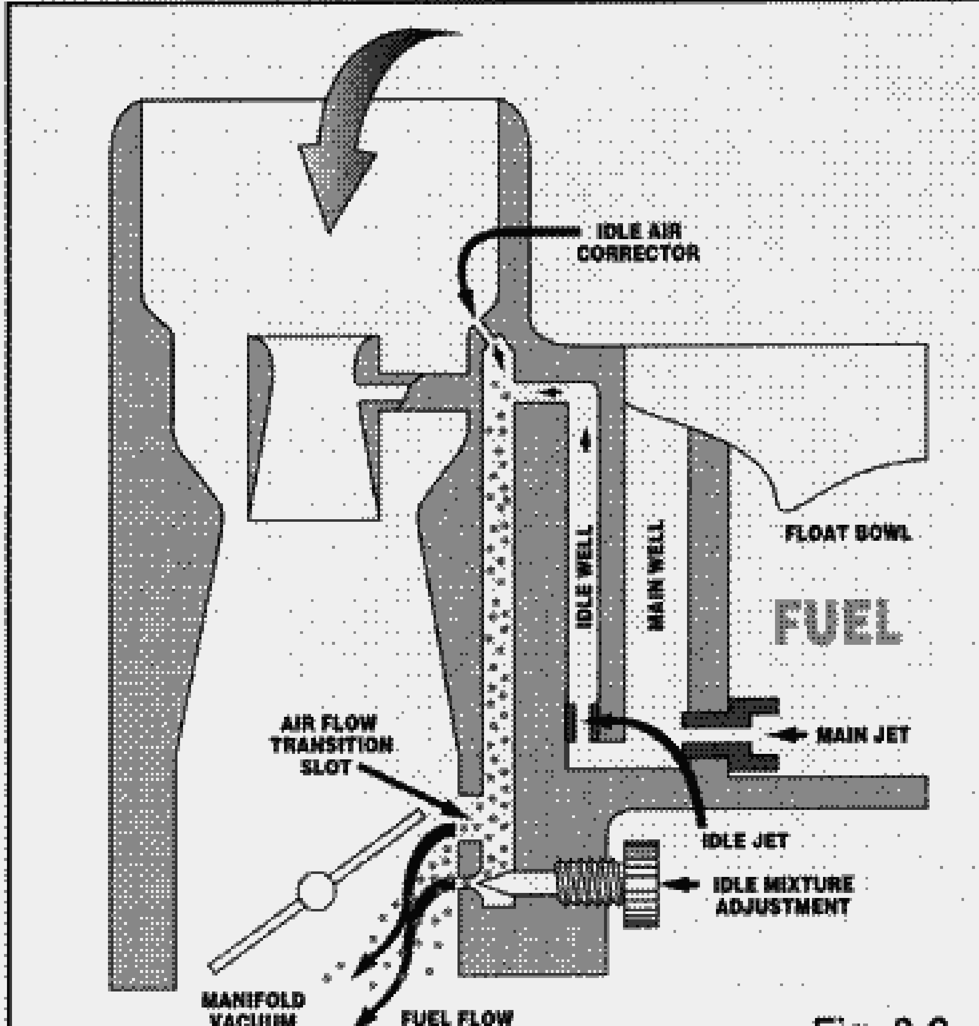


Fig. 3-9

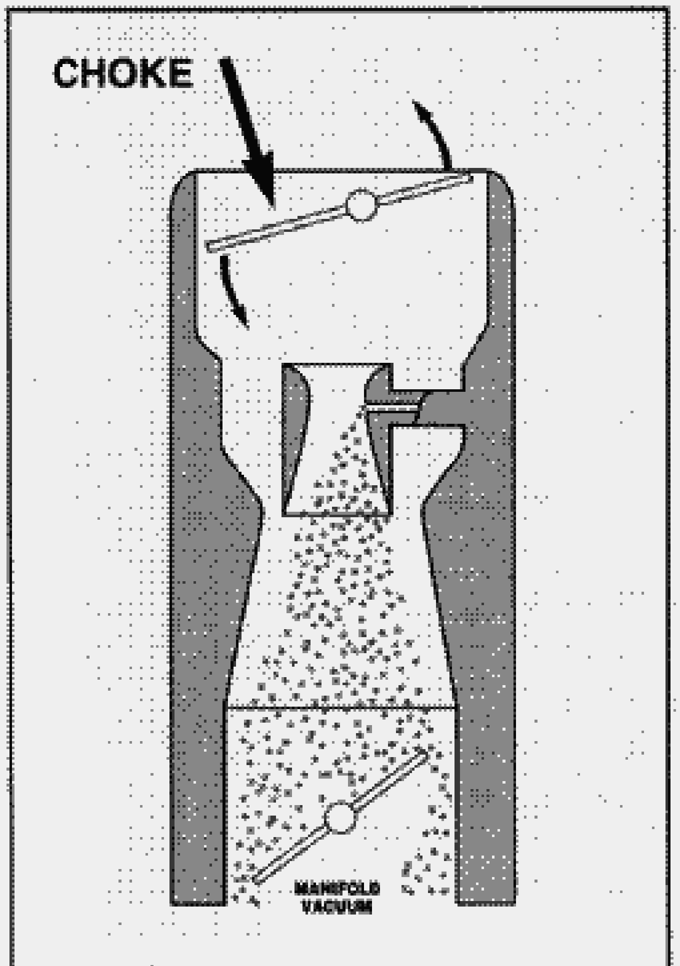


Fig. 3-11

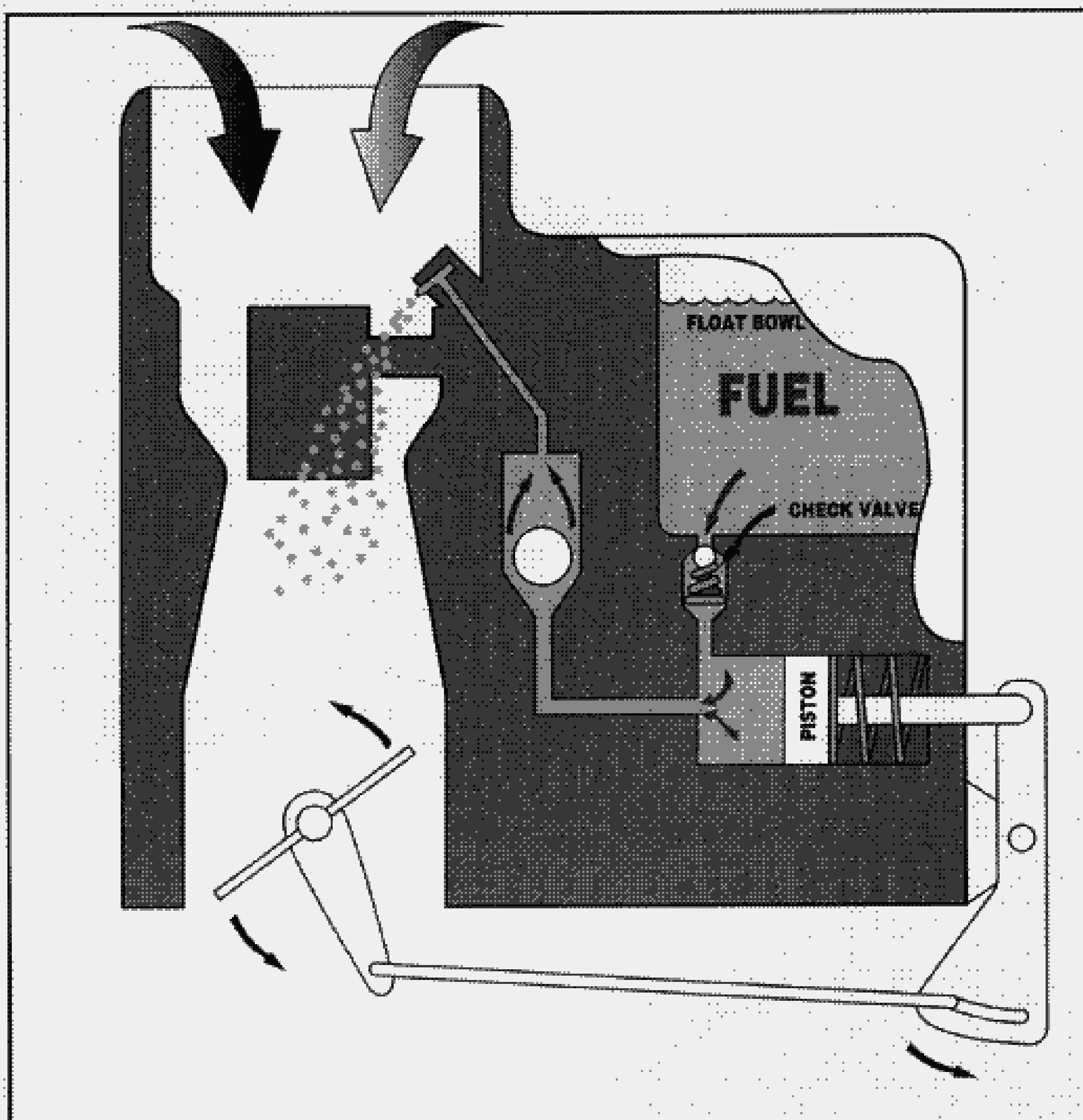


Fig. 3-10

On carbs like the high-performance Webers, the cold start system is not a choke. The mixture is actually enriched by means of a jet system, that is manually brought into operation for cold starting purposes. Although these systems can be calibrated, they rarely need anything other than the original "as produced" calibration settings.