RAMJET FUEL INJECTION

ALTHOUGH the advantages of direct injection of fuel over conventional carburetion have long been a part of the hot rodder's store of knowledge, Chevrolet's move in making such a system a part of their passenger car engine equipment was both surprising and gratifying. Most laymen, even many mechanics, think of injection as extremely complex and difficult both to comprehend and work with. Even after five years of service and outstanding success in competition, the Ramjet layout is still regarded with some apprehension by rodders who should know better. But, there is no reason to not be thoroughly at home with the system.

Part of the problem stems from the fact that a thorough, simple explanation of its principles and practical aspect has been difficult to come by in any publication prior to last year. By presenting such a point by point analysis here, I hope that more modifiers will take advantage of injection's possibilities.

First, we know that the function of a carburetor is to meter the flow of fuel in relation to the flow of air inspired by the engine in order to maintain optimum proportions for various operating conditions. The vacuum below the carburetor provides the force necessary to lift fuel out of the bowl and into the air stream. The amount of fuel supplied is determined by the size of the jets and the relative amount of vacuum developed in the manifold. As a secondary effect, the fuel is vaporized as it leaves the jet orifices and travels in atomized droplets to the cylinder.

In order to maintain this atomized condition and to prevent the fuel from re-condensing and upsetting the correct fuel-air mixture ratio, it is necesary to provide manifold passages large enough for good engine breathing but small enough to maintain a high velocity. This is a delicate balance which must be struck and calls for a definite compromise where a high performance engine with a broad speed and power range is called for.

Moreover, for street use, particularly under fairly cool, high humidity weather conditions, carburetor heat must be supplied to prevent ice formation due to the heat-of-vaporization properties of gasoline. In vaporizing, fuel takes on heat from its surroundings, acting exactly like the refrigerant in the coils of your kitchen Coldspot. With high velocity, enough heat can be absorbed to make the carburetor and manifold ice-cold in a matter of seconds. The water vapor in the air and in the fuel itself is turned to ice and extremely poor performance or stalling occurs. To offset this effect a heat riser from the exhaust manifold must be employed. This, in turn, operates at all times and, after the engine is thoroughly warm, heats the incoming mixture to such a point that it causes loss of power because of expansion.

On the other hand, the injection system delivers fuel under pressure right up to the intake ports through individual fuel lines. The manifold carries only air and it can be designed to accommodate the greatest demand of the engine without regard for maintaining velocity sufficient to keep fuel vaporized at low speed because the gasoline is vaporized as it is sprayed from the nozzles.

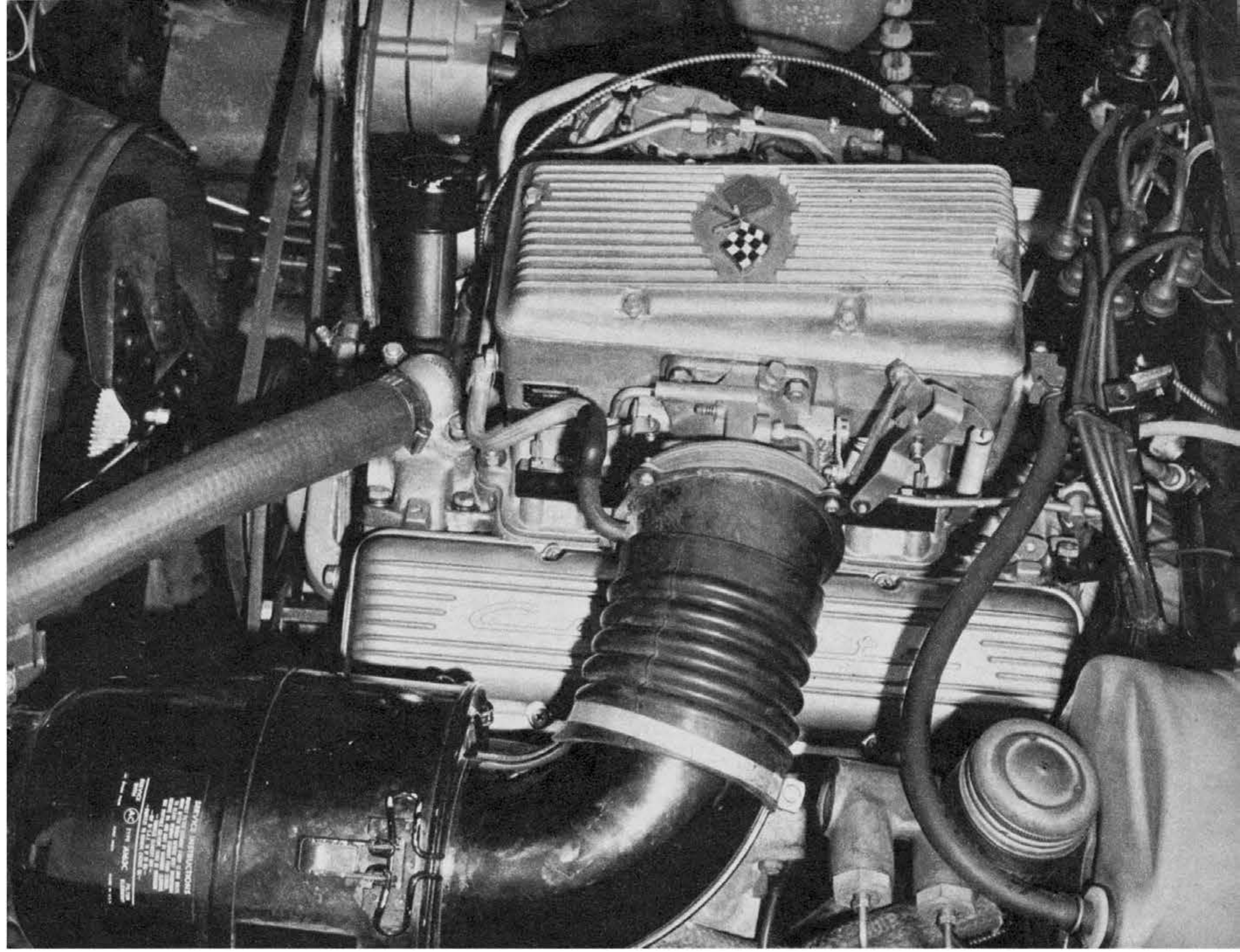
By metering the amount of fuel injected precisely at each nozzle, each cylinder is assured of receiving the exact amount of fuel required for the air coming in. In addition, since there is no vaporization in a chamber some distance from the port, there is no need for a heat riser to prevent refrigeration so volumetric efficiency is kept up.

These are advantages of the system. How the Chevrolet Ramjet layout acts to achieve them can be explained in a few words in broad outline, then a detailed analysis can be better followed.

The accelerator controls only the volume of air admitted to the engine. A mechanism in the system automatically measures the volume of incoming air and continually meters the precise amount of fuel to be mixed with the air. Other mechanisms enrich the mixture for acceleration, hill-climbing and warm up. They also insure instantaneous delivery of fuel for starting, provide for smooth idling and cut off fuel when decelerating against compression.

The cast-iron intake manifold on carbureted engines is replaced by two separate aluminum castings. The upper casting contains the plenum chamber, the intake, air metering and fuel metering systems. The lower casting forms the valley cover and provides for accessory mounts. Included in the system are a high pressure fuel pump driven off a special ignition distributor, a secondary fuel filter and a choke system for cold starts.

Although a number of different injection units have been fitted to Chevrolets since being introduced in 1957, and are identified by various part numbers: 7014800, 7104900, 7017300 and 7107300-R, 7017200, 7017250, etc., all are refinements of the 7014800 model. We will refer to these variations later, but each of them operates basically in the following manner.



1963 version of Ramjet fuel injection is distinguished by shape of plenum chamber. Unit is basically unchanged from first model.

AIR INTAKE

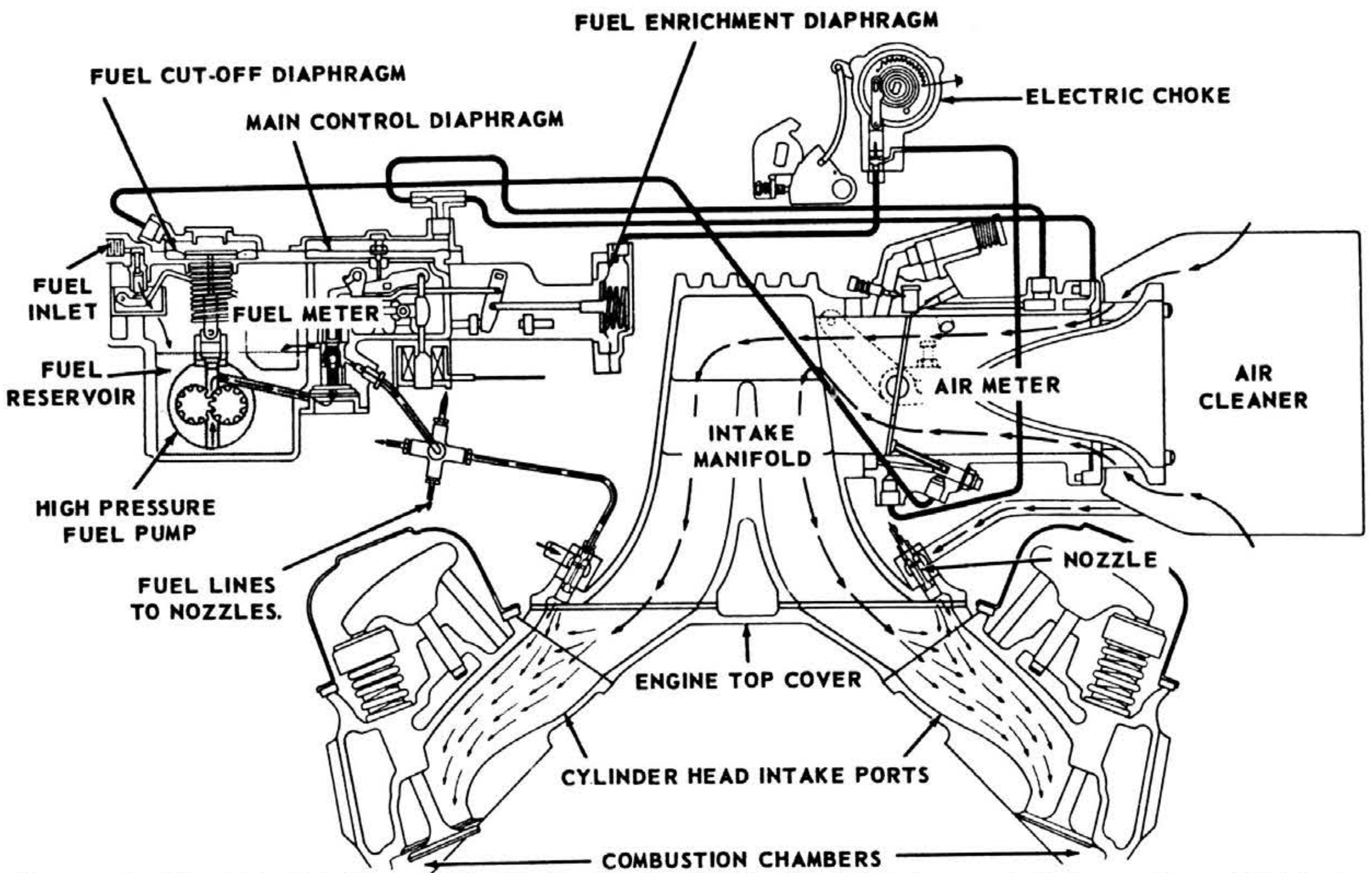
Outside air for the engine is routed through an air cleaner, where dust and foreign matter are filtered out, and then passes through an air meter, the intake manifold into the cylinder head combustion chamber. The entrance to the air meter is through a venturi or narrow passage. This passage also has a small opening leading to a vacuum tube. As the outside air rushes into the engine through the venturi, it tends to draw the air out of the tube, which creates a vacuum in the tube. The degree of vacuum is an accurate measure of the volume of air being drawn into the engine. A large volume of air creates high vacuum in the tube, while a small volume of air results in low vacuum.

FUEL INTAKE

A fuel meter is used to supply and regulate fuel to the engine. The regular engine fuel pump sends fuel through a fine filter and into a reservoir in the fuel meter housing. The quantity of fuel in the reservoir is maintained at a fixed level by a float-controlled valve. Another fuel pump, submerged in the reservoir fuel, is driven by the ignition distributor through a flexible cable. Fuel under high pressure from this pump passes into a central passage where it must lift a ball check before flowing through a series of small holes into a metering chamber. At this point the fuel can go either to the injection nozzles at the intake parts, or back to the reservoir, depending upon the position of a plunger. When the plunger is raised, fuel flows back to the reservoir. As the plunger is lowered, a portion of the fuel flows to the injection nozzles and the remainder returns to the reservoir. The ball check in the central passage permits fuel to flow from the pump when fuel pressure is about 15 pounds or higher so that any vapors which may have formed are compressed back into a liquid.

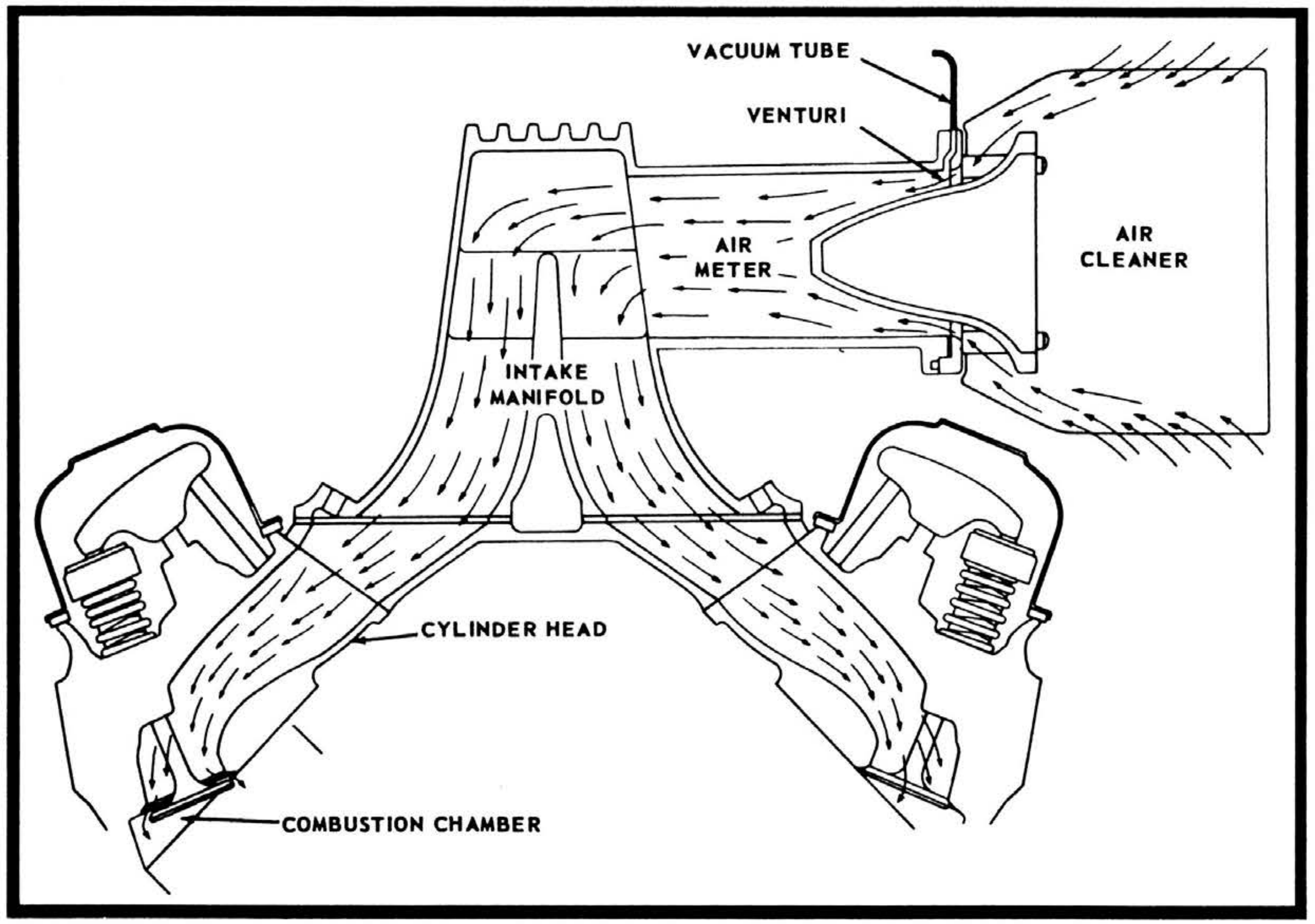
REGULATING FUEL TO MATCH AIR FLOW

As the incoming air passes through the venturi and is measured, it sends a vacuum signal to a main control dia-



Components of Ramjet fuel injection are defined in this drawing. Significant parts include separate fuel pump driven off distributor.

Unlike conventional carburetion, incoming air is not required to perform function of lifting and mixing fuel from float chamber.



phragm in the fuel meter. Depending upon the amount of vacuum, the diaphragm meters fuel by raising or lowering the plunger through a lever, thus delivering with high accuracy the precise quantity of fuel required by the engine for the volume of air being used.

All levers in the fuel metering system are counterbalanced so that their movements are unaffected by their own weight. Lever positions are determined only by forces exerted by the sensing devices.

FUEL MIXES WITH AIR AND IS DRAWN INTO THE COMBUSTION CHAMBER

The intake manifold has eight individual passages, called ram pipes, one for each cylinder. The fuel injection nozzles are mounted in plastic insulators in the lower part of the intake manifold, near the cylinder head intake ports. As the inlet valves open, fuel spray from the nozzles, which has mixed with the onrushing air, enters the combustion chamber where it is compressed and ignited in the same manner as in a conventional carburetor system. A throttle valve, controlled by the driver through the accelerator, determines the quantity of air, and as previously explained, the quantity of fuel supplied to the engine.

So that the amount of fuel injected is determined solely by the fuel metering system, and not influenced by variations in vacuum, the nozzles are designed to inject fuel into atmospheric pressure at all times. This is accomplished by supplying air from the air cleaner to a small chamber in each nozzle. The fuel injected from a small orifice passes through this chamber, and out a small opening to the intake port.

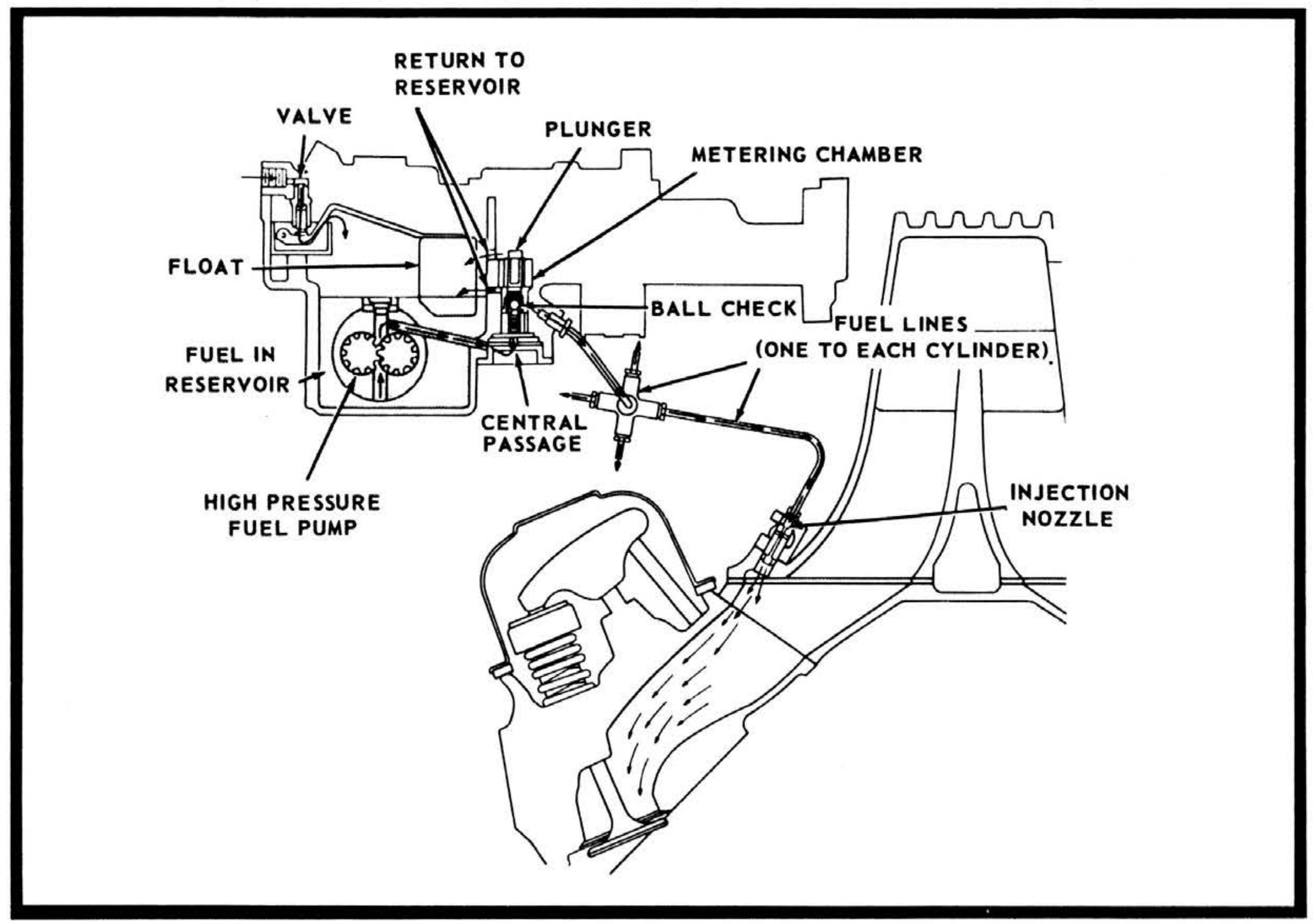
The arrangement has the added advantage of assuring a consistently accurate fuel air ratio for idling the engine. The volume of air passing through the chamber, although smaller when compared with the volume flowing through the intake manifold in normal driving, constitutes a major share of the air used by the engine during closed throttle or idling.

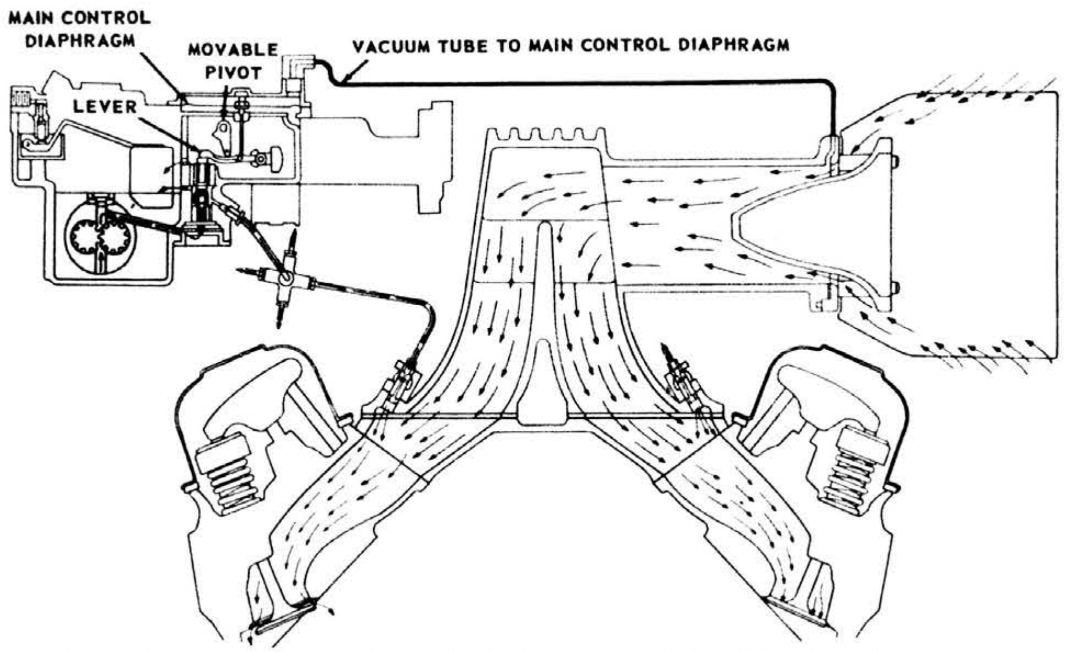
FAST ACCELERATION

The movable pivot in the fuel metering system is connected by a rod to the fuel enrichment diaphragm, and is normally held in a position which provides maximum economy of operation. The enrichment diaphragm is controlled by vacuum created when air rushes past the opening at the throttle valve. When the throttle valve is partially opened, air rushes through the small space of the opening on its way to the engine, and tries to draw air out of the enrichment vacuum tube. The resulting vacuum in the tube is strong enough to hold the diaphragm back against the opposing force of a spring. This holds the movable pivot in the fuel economy position.

When fast acceleration or more power is called for, the driver presses on the accelerator which opens the throttle valves wider. The incoming air now has a larger opening to pass through, and therefore draws less on the enrichment vacuum tube, reducing the vacuum. The spring now overcomes the reduced vacuum force and moves the diaphragm out. As a result, the movable pivot is plunged down. Therefore, fuel return to the reservoir is reduced and fuel flow to the injection nozzles increased. The richer mixture gives increased power for fast acceleration.

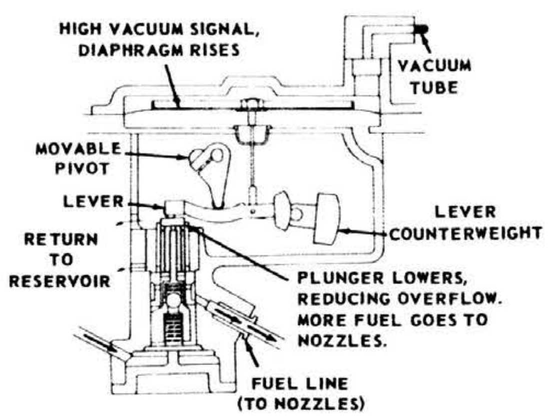
Ball check valve keeps pressure in system at 15 pounds so that vaporized fuel is re-condensed into liquid, returned to chamber.



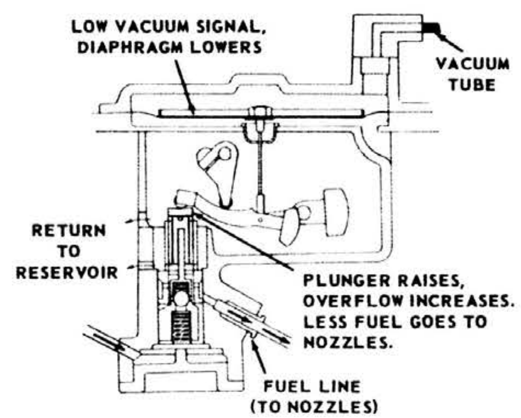


Air enters unit through cleaner and venturi air flow meter, which is linked to main control valve.

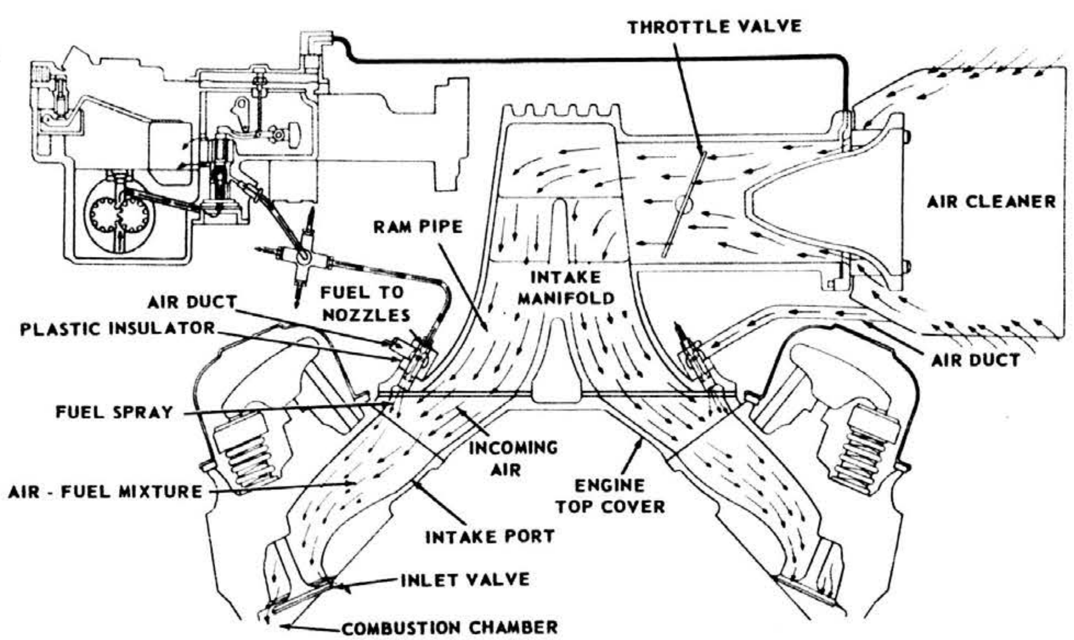
HIGH AIR FLOW CALLS FOR HIGH FUEL FLOW.



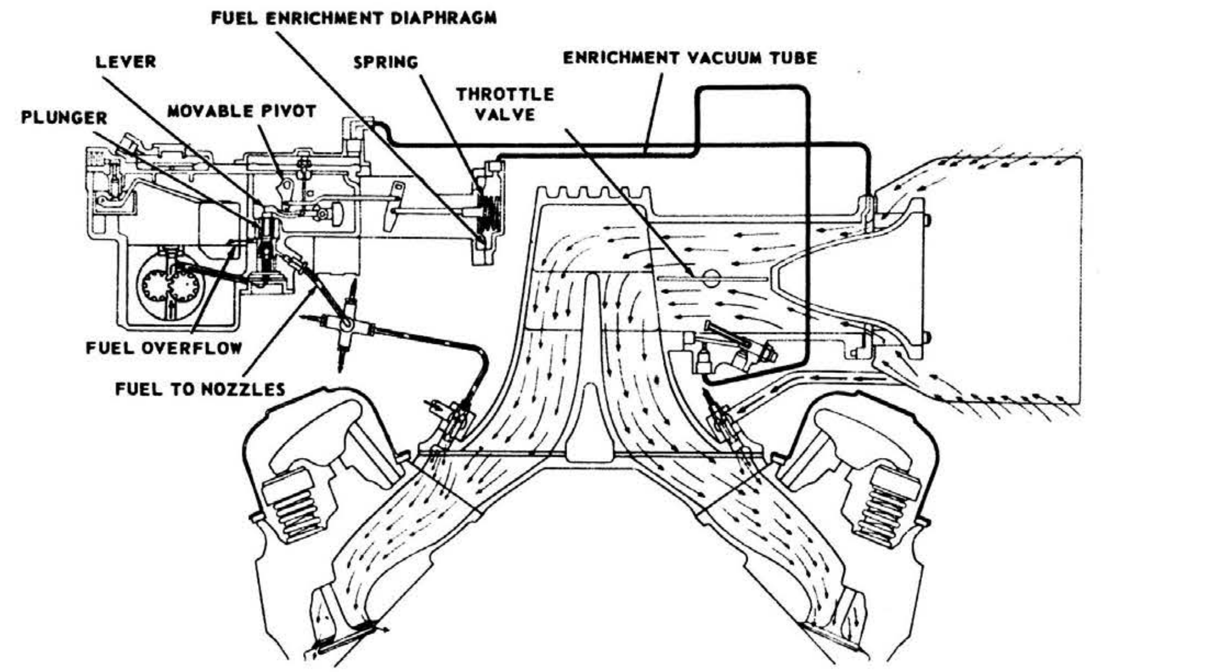
LOW AIR FLOW CALLS FOR LOW FUEL FLOW.



Required amount of fuel is sent to ports in response to vacuum signals; excess returns to chamber.



Additional air at atmospheric pressure is introduced at injection ports to insure velocity at idling.



At full throttle or acceleration, vacuum is signal for enrichment diaphragm to add more gasoline.

EASY COLD STARTING

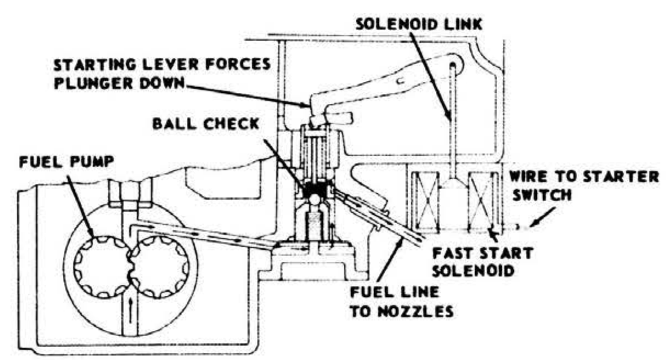
For fast engine starting, it is necessary to get fuel to the nozzles quickly when the starting motor is turned on. Since it would take from 20 to 30 seconds at cranking speed for the fuel pump to build up enough pressure to unseat the ball check, a solenoid is used to open a direct fuel passage to the nozzles.

When the starting motor is engaged, the solenoid, which is automatically energized at the same time, forces a solenoid link upward. This, in turn, pushes the starting lever which forces the plunger down, unseating the ball check. Fuel is then routed directly from the fuel pump to the nozzles. The solenoid is de-energized when the driver releases the key-turn starting switch.

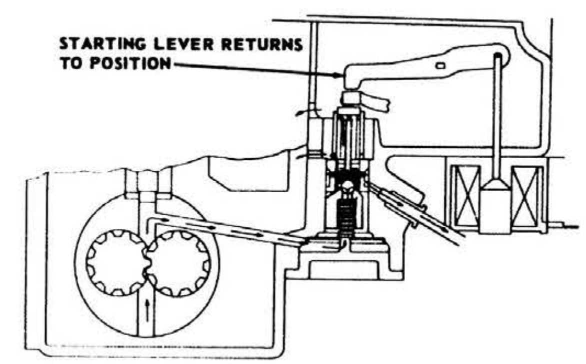
ENGINE WARM-UP

After starting and during warm up, it is desirable to furnish slightly richer fuel mixtures than would normally be supplied. This is accomplished by changing the position of the pivot in the fuel metering system to call for more fuel. The fuel enrichment system and an electric choke are used for this purpose. The enrichment vacuum route from the air meter to the fuel enrichment diaphragm passes through the electric choke housing. On cold starts, vacuum in the housing pulls a check ball upward against a seat, cutting off the vacuum to the enrichment diaphragm. As a result, the spring moves the pivot toward the end of the lever, routing fuel to the nozzles. In the choke housing the vacuum is then applied to the bottom of a piston. At the top end, the piston is linked to a thermostat heated by an element which carries electric current whenever the ignition switch is on. As the thermostat is heated, it relaxes and allows vacuum to pull the piston downward to its seat, returning the fuel enrichment system to normal operation.

The electric choke also controls linkage which holds the throttle valve slightly open for fast engine idling after cold starts. As the thermostat heats up, the linkage and engine idle speed return to their normal settings.

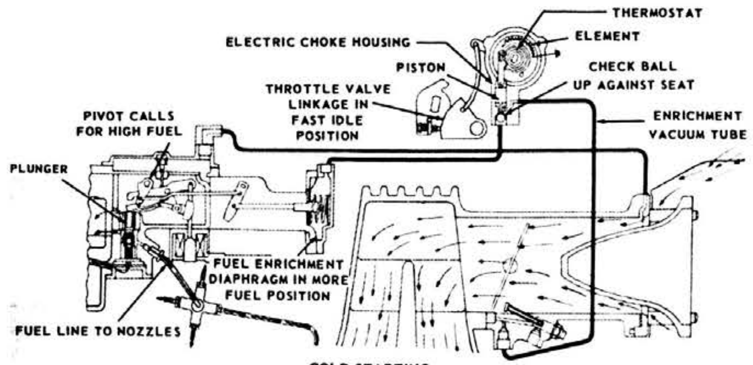


STARTING FUEL

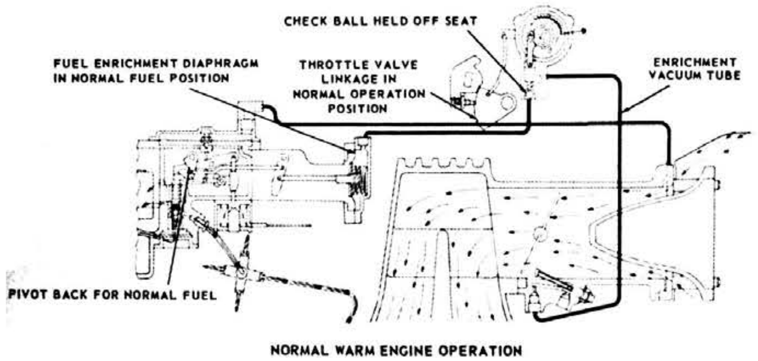


RETURN TO NORMAL

To provide instant fuel supply to engine being cranked by starter, ball check valve is lifted off seat by solenoid unit.



Cold starting arrangement has been altered on various models, but principle remains the same: additional richness for start.



As engine warms up, fast idle position of throttle and enrichment diaphragm return to normal and vacuum signal opens.

FUEL IS CUT OFF WHEN COASTING

When coasting downhill or decelerating from higher engine speeds, an automatic fuel cut-off system stops fuel waste and discharge of exhaust fumes containing unburned fuel. Other gains are quiet engine operation and the elimination of exhaust sputtering.

When going downhill with the foot off the accelerator, the throttle valve is closed, but the engine being pushed by the vehicle, tries to pull in large quantities of air. This creates an unusually high vacuum at the closed throttle valve. This vacuum is used to send a signal, through a tube, to a diaphragm located above the high pressure fuel pump. The high vacuum raises the diaphragm and a connecting link opens a valve over the fuel pump, and discharges the fuel directly back to the fuel reservoir. As a result, all of the fuel from the pump is discharged in the fuel reservoir, none going to the injection nozzles or engine. The high vacuum diminishes as the vehicle slows down, closing the valve over the fuel pump, and fuel again flows to the nozzles. The transition from coasting fuel cut-off to normal operation is so smooth that the driver and passengers are not aware of the change.

VARIATIONS ON A THEME

The 7014900 fuel injection differed from the original model by eliminating a starting cut-off switch, the starting solenoid, an idle vacuum signal tube and a signal boost tube and transmitted all vacuum signals through a single line . . . with the exception of starting. This was a simplification made possible by applying the manifold vacuum created during cranking to give an enriched fuel delivery via a normally open diaphragm valve to the main diaphragm and positioning the spill plunger to provide fuel meter pump delivery to the nozzles whereas on the 4800 the enrichment was accomplished mechanically by a solenoid which triggered the spill plunger to full depressed and allowed the engine fuel pump to deliver to the nozzles by way of a separate by-pass fuel line.

Two part numbers, 7014900 and 7014900-R are used on this model. The designation applies to units calibrated for the 290 bhp engine which are 6% to 8% richer on the power stop than the 4900 units calibrated for the 250 horsepower hydraulic lifter engine. Otherwise they are identical.

Units designated 7017200 and 7017250 are calibrated, respectively, for hydraulic tappet and mechanical tappet engines. They are like the 7014900 model except that a safety device, a siphon-breaker, has been incorporated to prevent the possibility of fuel leaking through the unit and filling up the cylinders while garaged for a period of time.

7017300 and 7017300-R are hybrids introduced in 1959. They have the fuel meter and intake manifold of the 7014800 and the air meter of the 7014900 and, are thus a further move toward simplification. The R suffix in this case means that the unit is for the hydraulic tappet engine.

7017310 and 7017320 are still another variation of the 4900 unit recognizable by the fact that there are no fins on the plenum chamber. A number of non-visible and non-mechanical revisions in the intake manifold were made on this model to improve efficiency and performance. The 310 number is for engines with hydraulic lifters, 320 for the higher output mill.

The identification of each unit is made from a plate atop the plenum chamber and, while the two part numbers designate the original usage for the injectors, they can all be recalibrated for whatever engine they may be fitted to. Fuel delivery is controlled by the main diaphragm and any small alteration to it will greatly affect the mixture. In Chevrolet shops the method used to set economy and power stops is with a manometer, a sensitive vacuum gauge consisting of a U-shaped tube partially filled with mercury and calibrated in 0.1 psi graduations.

The need for such close calibration may not be readily apparent, but the delicacy of the vacuum exerted on the diaphragm by the signal tube at 3,000 rpm is only 1/40th the pressure created by inhaling a cigarette!

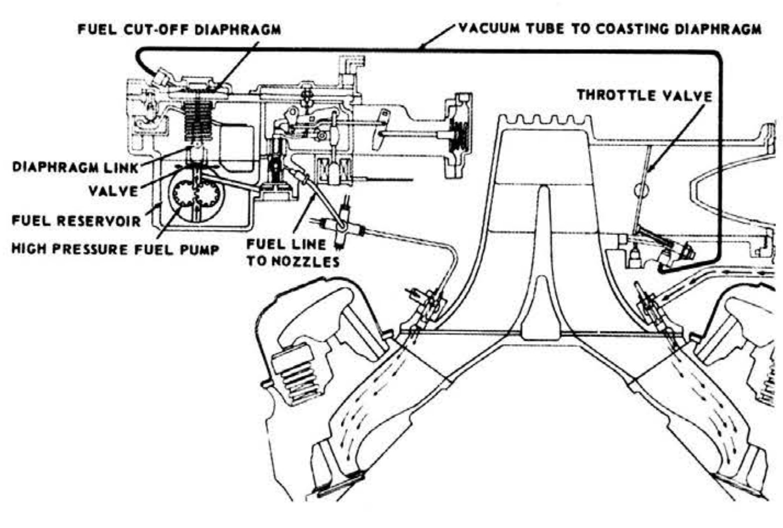
Using the manometer in the field is more difficult, of course and the mixture adjustment is carried out on the basis of spark plug readings, just as it is with carbureted engines. The adjustments are made at the enrichment lever, a small bell crank between the diaphragm and the ratio lever, by screwing stop screws in and out. The screw on the plenum side is the power stop, the opposite one is the economy stop.

If a plug reading taken under high speed operation reveals that the mixture is too rich, a turn of the screw in *toward* the economy stop would be indicated. If too lean, a turn in the other direction, and so forth.

Once the injector is understood, the rodder can take advantage of its potential, particularly in such areas as sports car road racing where the abrupt and sweeping turns in both directions cause some carburetion problems based on float levels. The attitude of the car or engine has no effect on fuel delivery or metering.

In another sensitive situation, where even distribution of mixtures to all cylinders (particularly in big engines) is a problem, injection can eliminate the multiple carburetor setup which often gives headaches under anything but all-out use. Whereas a variation of as much as 15% in mixture strength can be found at different cylinders in a carbureted engine, the injector delivers an equal amount of fuel to each port.

During coasting and deceleration, air for idle mixture is supplied directly at ports, fuel cut off diaphragm reduces fuel.



MODIFICATIONS

As with any automotive product, no sooner is it on the market than some original thinker sees a chance to improve it. So it has been with Ramjet fuel injection.

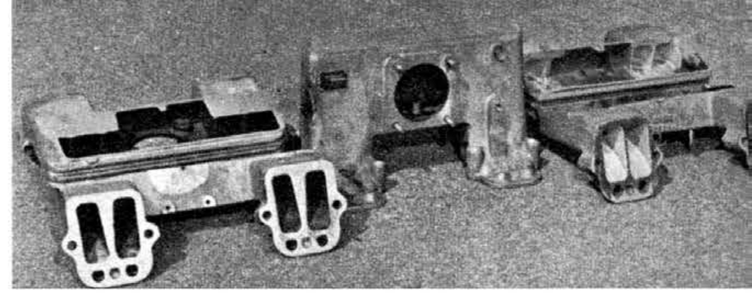
Bill Thomas, West Coast Corvette expert began experimenting with the units almost as soon as they were released. After a great deal of tribulation, he evolved some highly successful modifications which added 17 to 24 horsepower (at the rear wheels) to 283 Corvettes with no other engine changes.

The principle is no secret but the actual revisions and exact dimensions to be attained are included is a set of blueprints which Thomas markets for $1.00, so it isn't cricket to reveal them here. However, the technique is exactly the same as that which you would follow if you wanted to increase the breathing on a carbureted engine: Enlarge the venturi.

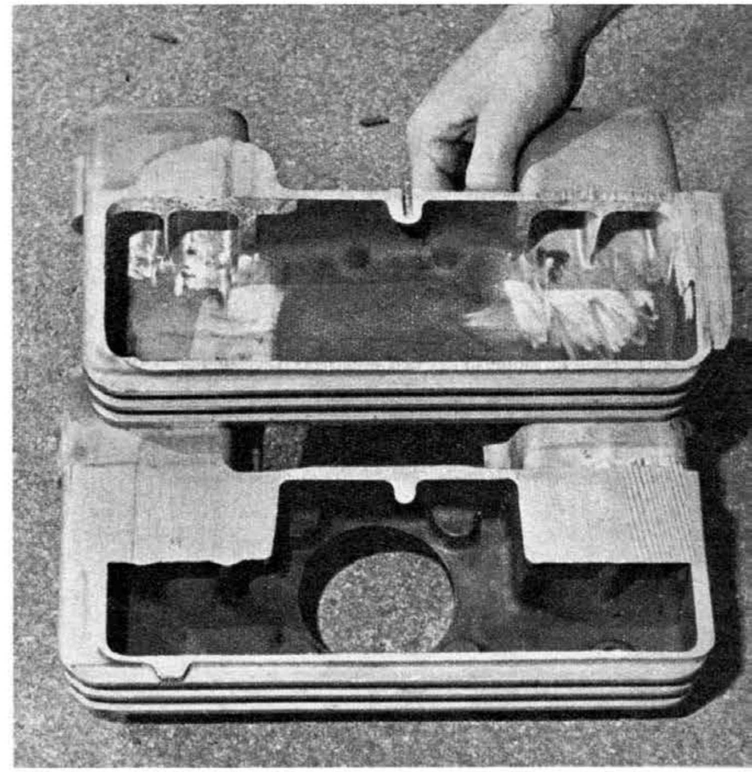
Like any street engine induction system, the Ramjet is a compromise. If your principal aim is high performance you must remove the compromising portions. In this case it is the size and length of the ram tubes, analagous to the carburetor venturi. Thomas cuts off the top of the plenum chamber (on the pre-1963 models), increases the size of the ram tubes and shortens them to improve the flow capacity. So that port velocity will not be too greatly reduced for low end performance, he re-shapes the tube for a greater venturi effect. The top of the plenum chamber is then heli-arced back into position and the whole unit sandblasted to an attractive finish. Port delivery nozzles are specified in the instructions, for those who have access to the tools and equipment necessary to carry out the alterations themselves.

For the not-so-well-equipped, Thomas sells modified injectors on an exchange basis ready to be slapped onto the Chevrolet engine. If you want to put the injector on a Chevy not originally in a Corvette, it is necessary to use a Delco Remy Distributor (Part No. 1110914 up to 1962, Part No. 1111011 for '62's) which incorporates an injector pump drive.

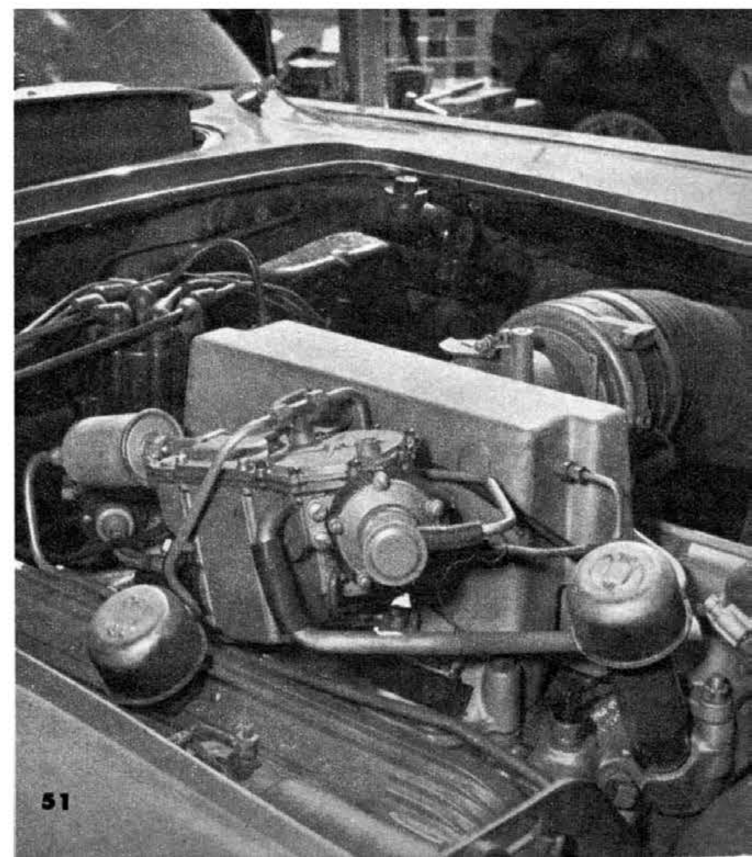
The 1963 injectors have been improved at the factory in much the same fashion as Thomas' modified models, though not to the same extent. It is reasonably safe to predict that they too will be altered upward in the next few months. ■



Comparison of stock fuel injection ports (left) and Bill Thomas' much re-worked version (far right) reveals enlargement.



Shortening of the ram tubes and re-shaping of the entry is part of Thomas' treatment. Plenum chamber must be cut, welded.



Re-installed injector has the same outward appearance as stock, but adds much horsepower and increases performance.