FUEL INJECTION

by Norm Burger • *Don't reject GM's injector — it's a performance brain in an aluminum box*

Chevrolet owners with the Rochester fuel injection systems have encountered their share of trouble over the years in getting these units serviced. Difficulties even come in trying to diagnose the various operating ailments that crop up from time to time. Installation of one of these units will give horsepower gains of up to 10% with no appreciable loss of gas mileage, and, in most instances, mpg gains. There are many of these units around by now, and if you have a chance to pick one up, do it because the rigs are not as complicated as you may have heard. Pay close attention and we'll try to explain the how's and why's of the Rochester system of fuel injection while passing along a few bits and pieces regarding maintenance and trouble-shooting.

There are three types of fuel injection units available for automotive use. Timed injection, used by Mercedes on both their gas and diesel models, injects a charge under pressure into either the manifold, valve port, or directly into the cylinder. Injection comes at just the proper moment before top dead center (TDC). Constant-flow injection uses a fixed bypass, as in a dragster or Indy-type car, where engine speed varies pump output and thus determines the amount of fuel being delivered to the spray nozzles at the intake ports. In this setup, proper fuel ratio is maintained by bypassing a fixed portion of the total flow back to the fuel tank. Interchangeable jets are used in the bypass-return line to vary the flow to the injector nozzles. This system works fine where the engine is to be run at a relatively constant speed; usually wide open.

The third type of injection unit utilizes a *variable* jet in the return line. The Rochester system falls into this category. By utilizing a variable orifice in the return line, the amount of fuel being supplied to the engine can be changed as speed and load requirements vary, thereby retaining an efficient air/fuel ratio throughout the engine's operating range. A little oversimplification may help in explaining this method. As an analogy, we will discuss a garden hose with a large hole located somewhere along its length. Now, if we want a full flow at the end of the hose, we must *close* the bypass completely. Actually, any flow desired can be achieved by varying the size of the bypass opening from full open to full closed. This is essentially what the Rochester unit does by constantly changing the bypass orifice, thereby controlling fuel flow to the valve ports.

Two vacuum sources created within the engine are used to monitor the fuel flow system and maintain the correct fuel/air ratios for the varying fuel requirements of the engine. The first vacuum used is manifold vacuum, measured in inches of mercury and variable from 21 inches to as little as ½-inch. The second vacuum source is venturi vacuum, so minute that it must be measured in inches of water. Venturi vacuum is created by a diffuser cone in the intake on the air-metering side of the "doghouse." This weak vacuum varies from 10 to as low as a ¼-inch of water. One inch of mercury is equal to 13.6 inches of water, thus the ratio of 13.6 to 1. As an example, the vacuum created when you draw on a cigarette is just about 10 inches of water.

There are two vacuum diaphragms used to control the fuel-meter portion of the Rochester unit. The large, main fuel

ROCHESTER STYLE

photography: Eric Rickman

control diaphragm is positioned almost horizontally, is actuated by the weak venturi vacuum, and is the controller of the fuel bypass valve or spill-plunger. A smaller enrichment-control diaphragm, positioned vertically, is actuated by the strong manifold vacuum, thereby adjusting the leverage ratio of the axle and linkage assembly. The fuel-meter is composed of the following parts: main fuel-control diaphragm, enrichment diaphragm, axle and linkage, float bowl and cover, high-pressure fuel pump, spill-plunger, and pump-drive cable and housing. Check the accompanying illustrations for component identification and relationships as we examine the various functions of each.

The spill-plunger is our variable bypass (hole in the hose), and determines just how much fuel is to be delivered to the "octopus" nozzle lines before spilling the excess fuel back into the float bowl. The high-pressure pump is submerged in fuel at the bottom of the bowl and delivers a variable supply of fuel under pressure to the spill-plunger. The pump is driven by the engine's ignition distributor and delivers fuel in amounts relative to engine speed – more speed, more fuel. Under high engine output (maximum venturi vacuum, minimum manifold vacuum), the spill-plunger is fully closed and delivers all the high-pressure fuel to the octopus. Under low output and/or idle conditions, a reverse situation will occur causing low venturi vacuum and high manifold vacuum. This will allow the spill-plunger to open almost fully and bypass the high-pressure fuel back to the float bowl, permitting very little fuel to go to the octopus and on to the ports. The spill-plunger is constantly varying its position in response to the vacuum-generated signals from the two vacuum diaphragms. Now let's look on the other side of the doghouse at the "air-meter."

This is where the two vacuum signals originate. As the name implies, the air-meter regulates the incoming air by way of a large butterfly in the intake duct. The high manifold vacuum that controls the enrichment diaphragm can be taken off at any point behind the butterfly, from either the duct or the doghouse, depending on the model of the injector. To obtain a vacuum reading proportional to the volume of air being used by the engine, a venturi effect is created in the air-meter duct by the installation of a diffuser cone in the duct's mouth. An annular groove in the venturi throat senses the amount of air flowing into the engine and transmits the information as a varying vacuum signal to the main fuel-control diaphragm. This is the low-vacuum circuit and requires a large diaphragm to obtain an adequate degree of control. By following the circuit as described, you should be able to see that the air flowing into the engine generates a weak vacuum which lifts the main fuel-control diaphragm and in direct proportion to the amount of air entering. In turn, the diaphragm raises a piano-wire link that is connected to the counterbalanced fuel control lever (axle-link assembly). This lever pivots on the end of the enrichment-ratio lever (we'll get back to this). The tip of the fuel control lever rests on the top of the spill plunger. High engine speeds will cause a large flow of air through the sensing venturi. This will transmit maximum vacuum to the diaphragm, lifting it and the end of the fuel

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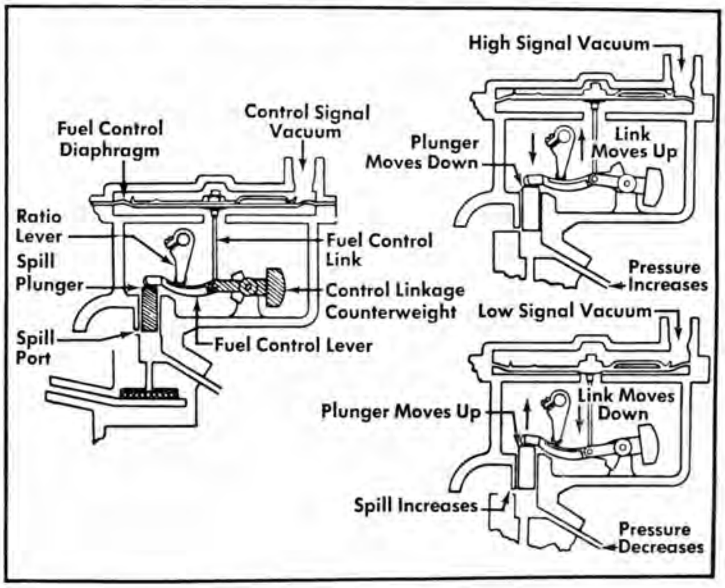
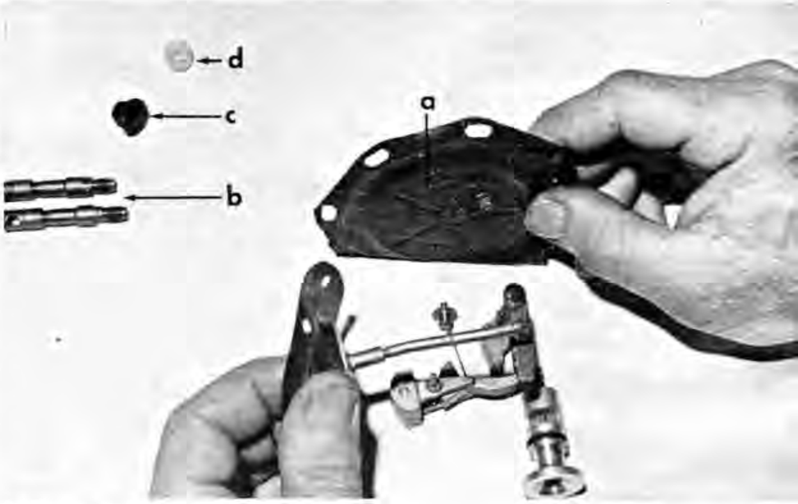
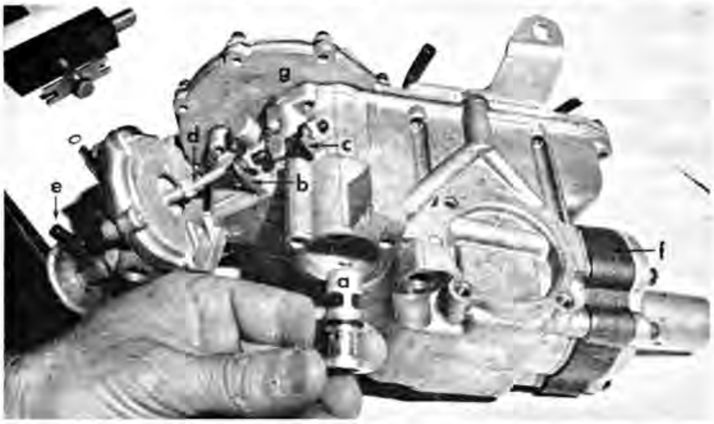
BELOW – Semi-schematic diagram shows the layout of the various fuel meter components for Rochester unit. Pic below the diagram shows the main-control diaphragm (a), new and old types of main-control diaphragm splash shields (d & c), and fuel nozzles (b). Bottom photo calls out '62-'64 main fuel control valve (a), lean and rich stops adjustments (b & c), enrichment diaphragm adjustment (d), cranking signal valve (e), high-pressure pump (f), and main fuel control diaphragm (g). Note the O-ring on main fuel control valve. This little ring, prior to assembly, should be coated with silicone lube to prevent leaks and fires.







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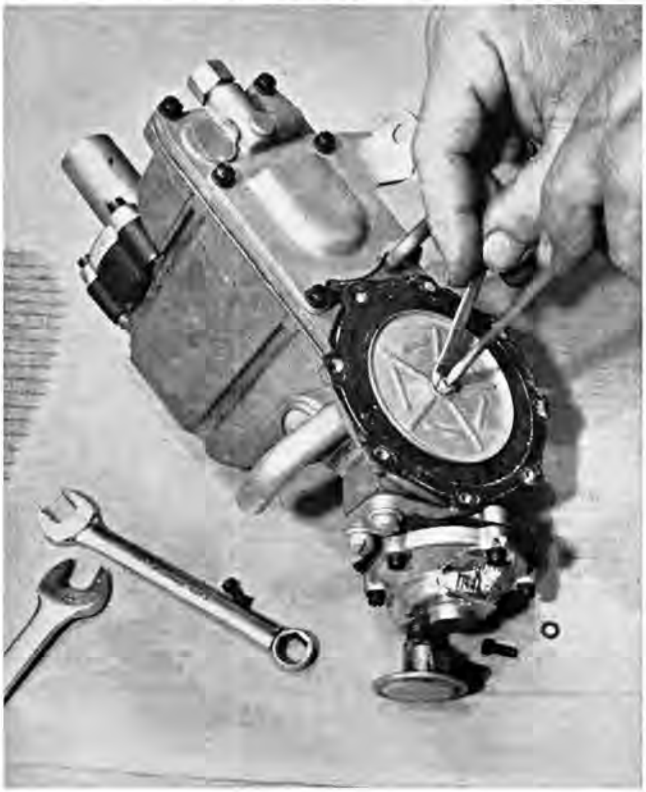

control lever so that the other end of the lever will drop, close the spill-plunger, and force all the fuel to the octopus and engine ports. At idle, no vacuum is created at the incoming-air duct. The diaphragm will drop of its own weight, thereby lifting the tip of the fuel control lever and allowing the spill-plunger, under pressure, to open fully and bypass almost all the fuel back to the float bowl.

While the engine is running, we will go back to the enrichment-ratio lever. This lever is connected to and actuated by the small, vertically mounted, high manifold-vacuum controlled diaphragm. The roller tip of this arm serves as a fulcrum for the main fuel control lever. High manifold-vacuum (low or idle engine speeds) moves this arm back to the lean stop, thus changing the leverage ratio of the main fuel control lever, and, in effect, slightly increasing the stroke at the spill-plunger end. All this serves to open the bypass even more. Low manifold-vacuum (wide-open throttle positions) allows

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SERVICE MAINTENANCE TIPS

Owner Preventive Maintenance:

Pump-Drive Cable — Remove and lubricate the cable every 5000 miles with a good grade of moly grease, wheel-bearing grease, or Delco distributor grease. Don't use any of the white brake lubes because these dry out quickly and lose their greasing properties.

Fuel Filter — The in-line filter element should be replaced at 6000- to 10,000-mile intervals. The same is true for the replaceable cartridges used on pre-'62 Corvettes.

Air Filter — The air filter should be replaced every 10,000 miles. The re-usable types (foam units) can be washed in a clean solvent, air-dried, and re-oiled. Dirty air elements will alter fuel-meter calibrations. NEVER operate the injection unit without the air cleaner and ducting.

Smog-Control Valves — These should be blocked off or re-routed to operate through the air cleaner. Oil fumes and combustion residue will clog the nozzles and form carbon in the doghouse. The result could be lean mixtures and blown pistons.

Water Residue — Commercially available additives can safely be used to decrease the amount of water in the float bowl. You can add a pint to the gas tank every 5000 miles.

Trouble Shooting:

Engine will not start —

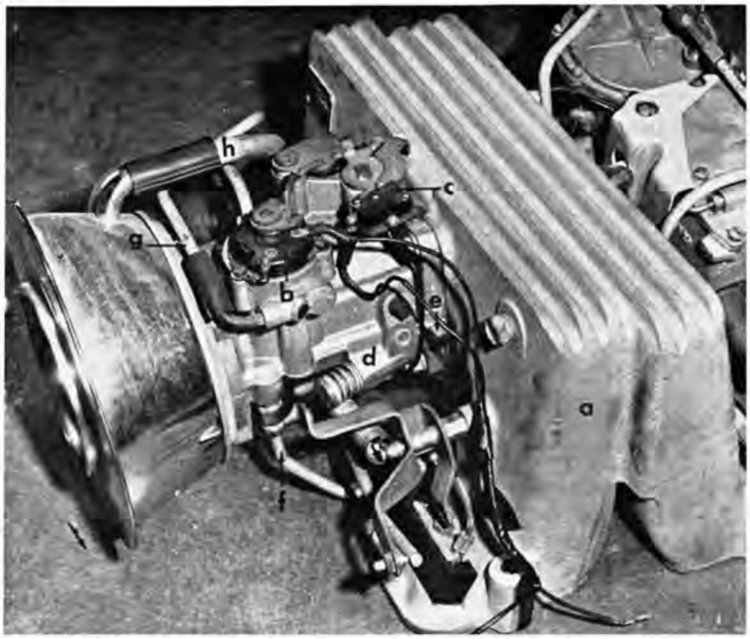
1. Broken pump drive-cable. No fuel is pumped to the nozzles.
2. Cranking-signal valve sticking. If stuck, the valve will prevent the main control diaphragm from moving the spill-plunger to the rich position for starting. To check, remove the valve with a 7/16-inch wrench and suck through the threaded or "outlet" end. You'll hear a "hissing" if the valve is operating properly. If you suck through the other end (small end), the valve should close.
3. Ignition failure. Here's the cause, nine times out of ten. Commonly, the ballast resistor breaks or burns out. This will allow the engine to fire momentarily when the key is in the "start" position, but die when the key is returned to the "run" position. With a jumper wire, short-out the resistor to see if it is functioning. Don't run the engine for any period of time without the resistor or you'll damage the ignition points and condenser.
4. Broken axle-linkage assembly. This linkage connects the main control diaphragm to the spill-plunger, so if the link is broken, the fuel valve will remain in the wide-open position and cut off the fuel to the nozzles. You can check this by removing the main control diaphragm cover and gently pulling up on the diaphragm link and nut. If the link is broken, the diaphragm will pull all the way out. The counterbalance assembly could also be broken, although the condition is not visible unless the bowl cover is removed.
5. Punctured main control diaphragm. If the diaphragm has a hole in it, the vacuum will not lift it to the raised position and operate the spill-plunger. The diaphragm must be removed and checked with a light source for pin-holes.
6. Vehicle out of gas. There is always the possibility that you've run out of gas. Check before you get too involved.

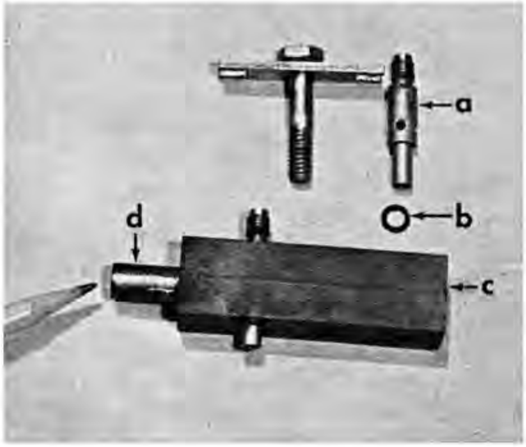
Engine runs but misses under load or at idle—

1. Defective spark plugs.
2. Plugged nozzles. This condition is difficult to determine without removing all of the nozzles. A check of the spark plugs will show a lean condition in one cylinder and point you in the right direction. On an ignition oscilloscope, a high "spike" or high "firing line" will indicate high electrical resistance (lean fuel mixtures). Gasoline is a conductor of electricity, so if a lean fuel condition exists, high resistance will be indicated on the 'scope. When all else fails, check the compression of each cylinder for a burned or warped valve.
3. Plug wires. Burned or shorted plug wires can also cause a miss. A burned rotor and/or a defective distributor cap can also create high electrical resistance and subsequent missing.

Poor fuel economy —

1. Incorrect injector calibration. Always tune the engine thoroughly before calibration adjustments. When adjustments **are** necessary, here's what to do. Use the Kent-Moore gauges (check with your Chevy dealer) or an exhaust-gas analyzer in conjunction with a dyno. If you prefer to use the gauges, a few important steps should be followed to prevent gauge damage. When the gauges are installed, make sure you don't rev the engine when it starts. If you forget this, the red gauge oil will be sucked out of the gauges.





ABOVE – Partial view of complete unit reveals doghouse (a), electric choke (b), micro-switch for fuel control (c), idle-speed adjustment (d), idle-speed mixture adjustment (e), main fuel control vacuum line (f), enrichment diaphragm control vacuum (g), equalizing line vents main diaphragm (h).

ABOVE RIGHT – Inside the fuel meter with enrichment diaphragm assy. (a), ratio lever (b), axle-linkage assy. (c).

FAR LEFT – This illustrates the use of a screwdriver when removing nut from main fuel control diaphragm. Should you fail to do this, you'll shear the screw inside the diaphragm.

LEFT – New and old ("good-guy") types of valves (a & b).

RIGHT – Nozzle block (c) with nozzle (a), O-ring gasket (b), vent and idle air tube (d). Always replace old O-ring.

Gauge hook-up is explained in the 1960 Chevrolet shop manual or in the book of instructions included with the gauge kit. The air cleaner should not be disconnected because fan air-wash will affect calibration by acting on the airmeter intake. Beginning settings which will give you a fairly close adjustment for the various models of injectors follow: 1957-1961 (early), lean stop .8 pounds fuel pressure and rich stop 2.2 pounds pressure; late 1961 and 1962 (using "thumb-tack" fuel valves), lean stop .5 pounds and rich stop 2.2-2.5 pounds; 1963-1965, lean stop .5 pounds and rich stop 1.6 pounds. (All settings at ½-inch "water vacuum.") If you change the fuel-valve in the '63-'65 units to the old or "good-guy" type, throttle response will be almost instantaneous. Calibration specs should remain the same regardless of the valve used.

For dyno calibrations, note the following: At 3500-4000 (wide-open throttle and dyno-loaded) set the rich stop for a fuel/air mix of 11-11.5:1; the lean stops should be set for a ratio of 14-14.5:1 with about a 10 hp, 40 mph loading (2000-2500 rpm). Enrichment diaphragm adjustments are made by hooking a vacuum source to the feed-line on the diaphragm cover. The ratio lever should hold on the lean stop at 9 inches of mercury, and as the vacuum source is decreased, the ratio lever will hit the rich stop near 3 inches of mercury. The lever will be half the distance between the rich and lean stops at 6 inches of mercury. Don't forget, these adjustments are made AFTER the stops are calibrated.

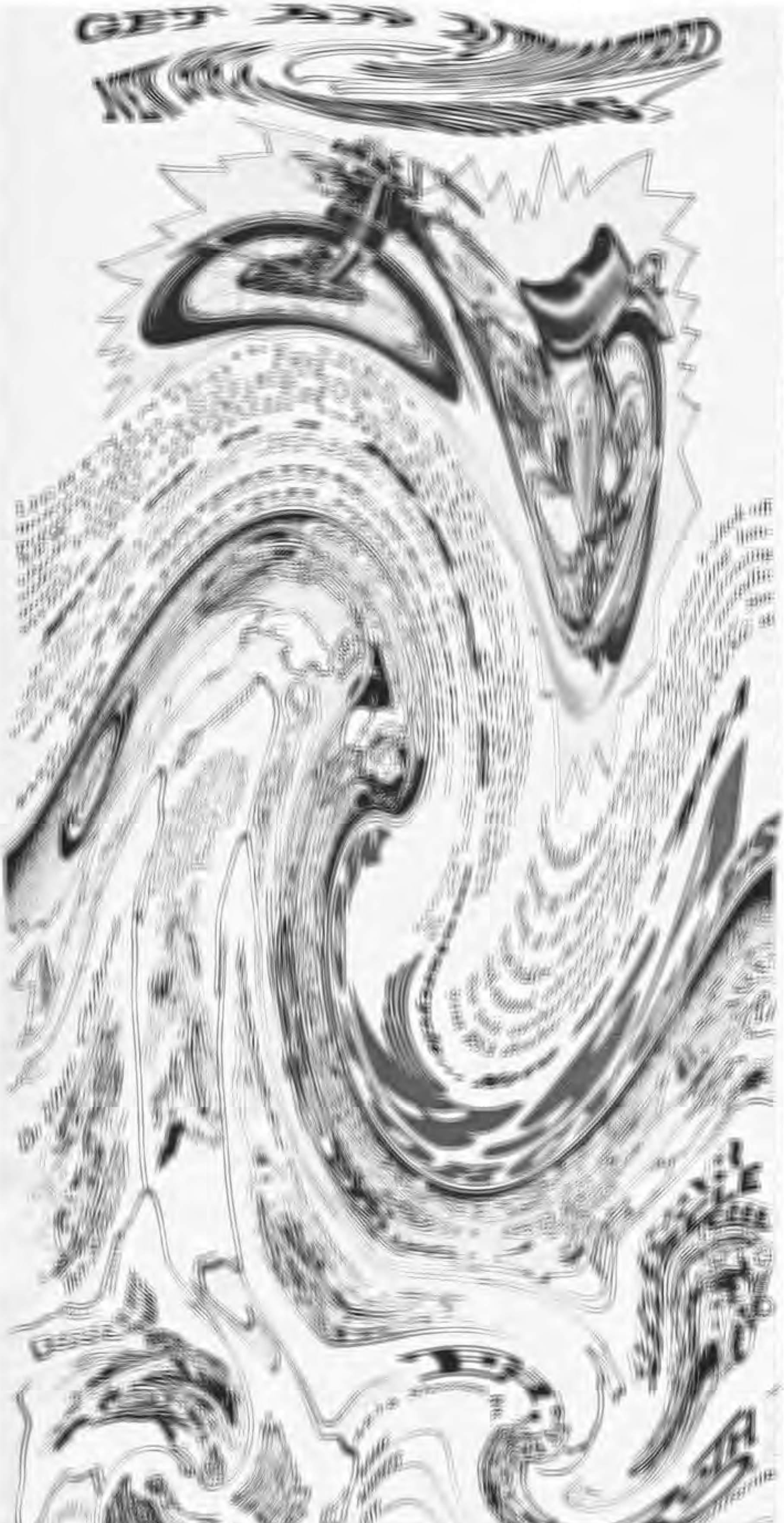
2. Cranking-signal valve rupture. If the diaphragm is punctured or stuck in the open position, the cranking-signal valve will allow full manifold vacuum to operate on the main control diaphragm. The unit will then run full-rich at all times. A check of this valve can be made by removing the valve and sucking on the "inlet" end to see if the valve will close. An emergency repair would be to block off the valve after the engine is started.
3. Sticking fuel valve or spill-plunger. Foreign material in the system can cause the fuel valve or plunger to stick in either the rich or lean position. For the repair of this, the injection unit must be removed from the car and disassembled.
4. Restricted air cleaner. A dirty or clogged air cleaner will act as an automatic choke and cause rich mixtures.
5. Improper calibration. Settings made "by ear" can cause a lot of headaches. Use either the Kent-Moore gauges or an exhaust-gas analyzer.
6. Shrunken main control diaphragm. The most common problem here is the contraction of the neoprene diaphragm due to high heat and/or ambient temperatures in the engine compartment. You can check the diaphragm after removing its cover. As previously mentioned, it is to be installed loose so that it will "flop" under its own weight.

Surging at medium speeds —

1. Diaphragm vent-tube trouble. Sometimes, when the diaphragm vent-tube (the tube that runs from the air-meter to the area just below the main control diaphragm) is displaced or improperly installed, engine fan-wash will force the diaphragm to operate independently of its regular controls. You may also find the rubber connecting hoses broken or loose. Surging here is usually noticed at speeds from 30 to 50 mph.
2. Incorrect ignition timing. If the ignition timing (at the crank) is too far advanced, a surge at speeds around 20 to 40 mph, in high-gear, will result. A vacuum advance unit operating in conjunction with a distributor in this mal-timed condition will compound the problem.

Special camshaft installation —

The enrichment diaphragm requires a minimum of 9 inches of mercury to hold control on the lean stop during idle speeds. If you install any cam other than the stock shaft, the wilder timing can drop the idle vacuum below the required 9 inches. The engine will go to full rich, load up, and refuse to idle. To correct this condition, remove the diaphragm cover, break the lock-nut holding the diaphragm hub to the actuating shaft, and rotate the diaphragm one or two turns clockwise on the shaft. This reduces the loading of the spring pressure, and allows the diaphragm to hold control on the lean stop with less than the original requirement of 9 inches of mercury. If you over-adjust, the engine will hesitate slightly and backfire under acceleration. Each engine requires its own adjustment.



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the spring-loaded diaphragm to move the roller tip (fulcrum) of the enrichment-ratio lever forward to the rich stop, again changing the fuel-lever ratio. In effect, this closes the bypass (spill-plunger) even further, insuring a delivery of more fuel to the ports. The main fuel-control diaphragm system gives an approximate fuel/air ratio control throughout the engine's operating range, while the fine adjustments are made with the rich and lean stops that limit the travel of the enrichment-control lever. To lean the engine, the lean stop is backed off a turn or so. This moves the fulcrum back slightly, allowing the tip of the fuel-control arm to rise, thereby opening the spill-plunger to bypass a bit more fuel and deliver a bit less fuel to the ports. Backing off the rich stop will close the spill-plunger slightly and make it deliver more fuel to the ports. As the load on the engine varies and throttle position is changed, the attending variation in manifold vacuum will cause the fulcrum point to shift. This shift will produce the optimum fuel/air ratio by balancing the two vacuum signals against each other. Now that we have covered the basics, let's go back and analyze the several starting systems that Chevrolet has developed over the years.

Engineers seem to have had trouble in deciding which type starting system should be used, and as a result, there are several designs and combinations of designs in circulation. Basically, each consists of manual and/or electrical methods of increasing the fuel flow during engine starts. In '57 and '59, engineers installed a micro-switch on the throttle linkage. This switch closed when the throttle was about ⅓ open. With the ignition key in the start position, current flowed to the micro-switch and on to a solenoid on the fuel meter. This solenoid was linked to the axle-linkage so that it would close the spill-plunger for full-rich starts. When the key was returned to run position, the solenoid de-energized and allowed a return to normal fuel delivery. To keep the cold engine running, a valve was installed in the vacuum line to the enrichment diaphragm. This valve was thermostatically controlled by an electric heater connected to the low-voltage side of the ignition ballast resistor. When cold, this valve cut off manifold vacuum to the spring-loaded enrichment diaphragm and allowed the diaphragm to move to the full rich position for cold engine operation. As the valve warmed, it slowly opened the vacuum line and permitted the diaphragm to return the system to the idle (lean) position. The

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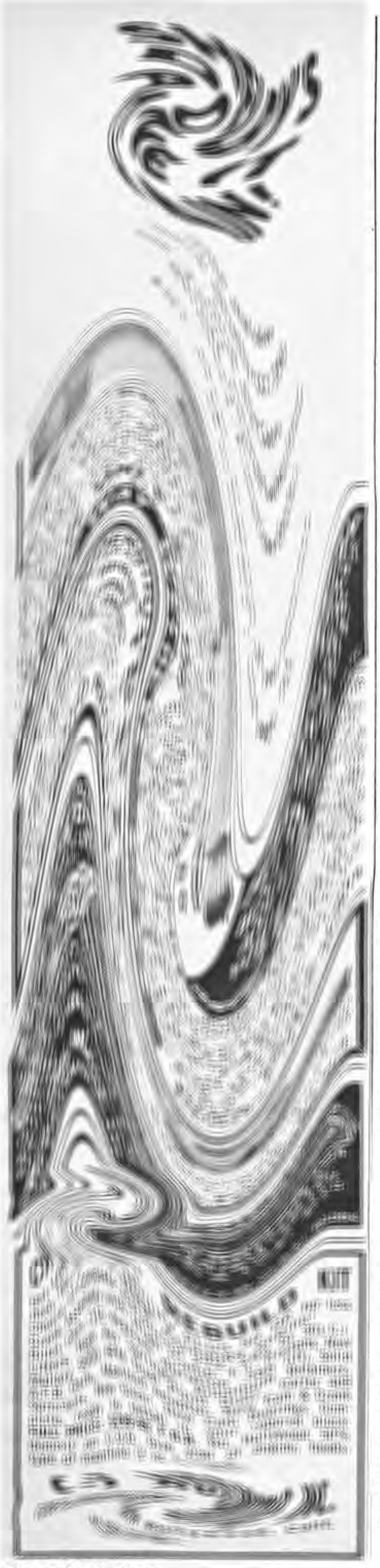

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valve remained hot and open as long as the key was on, regardless of engine temperature. In '58 and '60, the micro-switch and solenoid method was abandoned in favor of a manual system. This method utilized a third spring-loaded diaphragm called a cranking-signal valve. The unit was mounted on either the doghouse or the enrichment diaphragm cover. It was plumbed so that it permitted the low vacuum created when the engine was cranking to be routed from the doghouse to the main control diaphragm. This put the system on full rich for starting. As soon as the engine fired, the manifold vacuum overrode the spring in the cranking-signal valve and closed it, thus preventing the high manifold-vacuum from reaching the main control diaphragm. With the cranking-signal valve closed, the main control diaphragm is controlled by venturi vacuum. To keep the cold engine running, one of the aforementioned '57-'59 electrically heated valves was placed in the vacuum line. The '61 units retained the cranking-signal valve and abandoned the vacuum valve in favor of an automatic choke with a butterfly in the air-meter intake duct. Heat for control purposes was still supplied by the electrical resistor. In the '62-'63 models, the electrical heating system was discontinued and exhaust heat was used an in conventional automatic choke systems. The cranking-signal valve fuel control was retained in these units.

The result of all the re-design work is the present '64-'65 unit which utilizes a conventional automatic choke for cold engine operation, although engineers have gone back to the micro-switch controlled solenoid valve for starting. In the new unit, the valve is opened to allow low-pressure fuel from the engine's fuel pump to flow into the octopus for delivery to the ports. When the key is in the run position, the solenoid valve is closed and all fuel is delivered from the high-pressure system of the fuel meter.

The octopus assembly incorporates a spring-loaded check valve to decrease any fire hazard if the engine happens to backfire through the nozzles. The nozzles, incidentally, are mounted in pairs in plastic nozzle blocks and contain an idle air supply tube system which is connected to the air inlet duct on the doghouse. The doghouse contains the ram tubes which direct the incoming air to each port. The length of these tubes is carefully calibrated to create a ram effect at high engine speeds, thereby causing delivery of higher density charges to each cylinder. Two air meters are used on the 327-inch engines to permit proper engine breathing ability at speeds over 6000 rpm. Drilling out the

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nozzle discs or polishing the ram tubes will be of little help.

When installing the injector system on the engine, check the intake manifold gasket very carefully. The '57-'60 heads have a small gasket opening, while the '61-'65 heads have a slightly larger port. An early gasket on a late model engine will cause oil to be sucked in from the valve chamber.

There are currently three types of fuel valves (spill-plungers) being used. The "late type" looks like it uses a thumb tack as a valve and is found in most '62-'65 units. The "old type" valve found in the '58 and '60-'62 units is the "good-guy" type and provides far better throttle response and fuel control than the newer version. The two types are interchangeable in any of the above units. The '57-'59 injectors use a different valve to which no alterations can be made. This valve is acceptable for street use only. A small alteration can be made to the late three-piece valve by grinding about .010-inch off the stem of the lower "T" portion of the valve. This will prevent the axle-link assembly from going "over center" and breaking off the roller tip of the control lever when adjustments for extra richness are incorporated. If you make this change, the unit will need to be recalibrated by adjusting the rich and lean stops since the entire operating arc of the enrichment control arm will be moved slightly toward the lean stop.

The Rochester Ram-Jet fuel injection is very economical to operate. It has been found that a Corvette can get over 21 mpg with 4.11 gears. This writer obtained over 33 mpg driving to Bonneville last year. (Of course, 2.90 gearing was used.) So if the unit is properly installed and calibrated, you can have virtually fool-proof injection. Everything is controlled by the driver's foot. The air-meter tells the fuel-meter what to do, and, having been told by the fuel-meter, the fuel-valve adjusts flow accordingly.

To facilitate understanding and provide information in "reference" form, the various ailments, remedies, and maintenance procedures are bunched in the accompanying tables. Maybe you can find room in the back of one of your shop manuals to paste this in. ■ ■