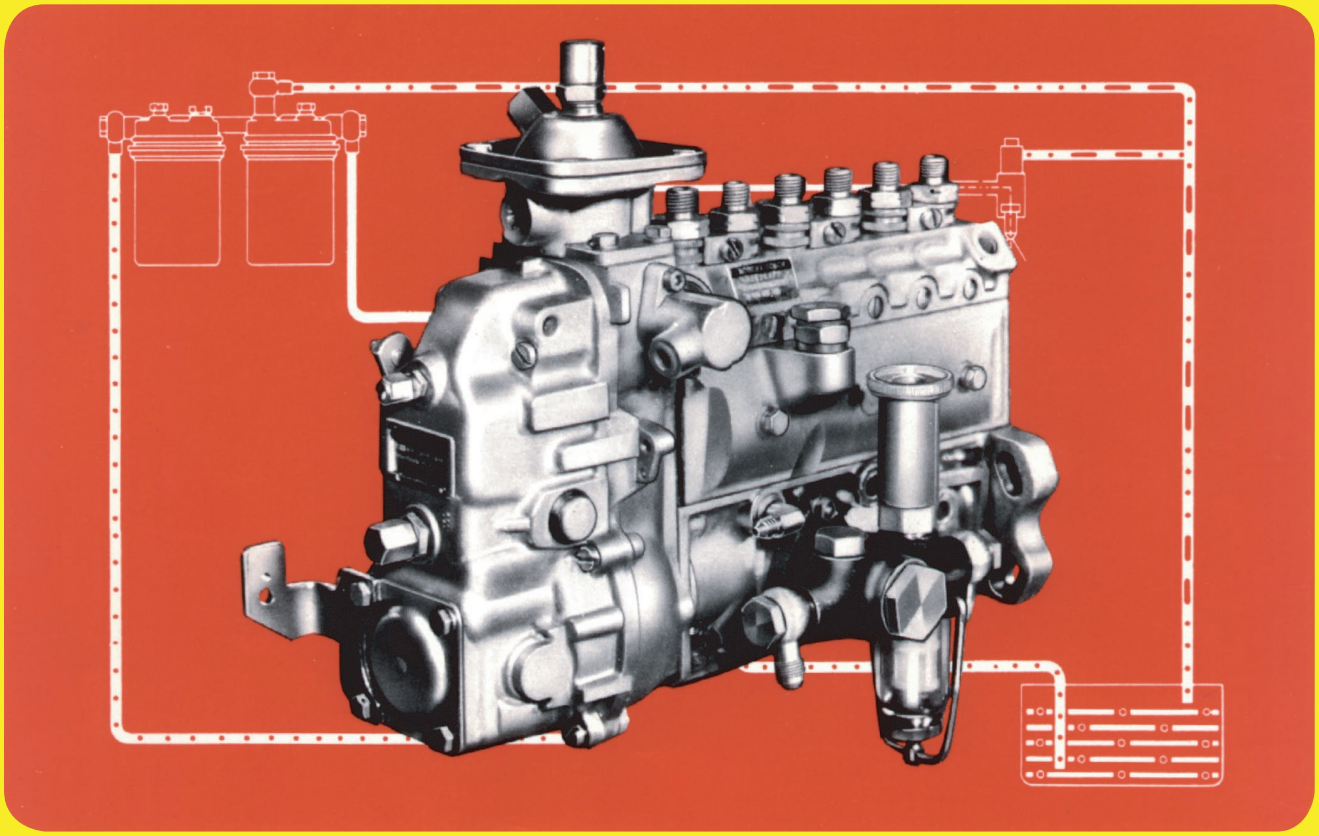
BOSCH

Module 4 (4)
VE - Pump Operation



Pre-Tech
Service Training

MODULE 4

VE-PUMP OPERATION

STPR VE 1
1/84

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INTRODUCTION

This audio-visual program, **VE Pump Operation** is a part of Module 4 of PRE-TECH, **Pump and Governor Operation.** You should have completed Modules 1 through 3 before you begin this program.

This module consists of eight audio-visual programs. Each program has a separate review guide and exercise. You will be required to complete from one to all eight programs, depending on the program track that you have been assigned to by your instructor or supervisor. These audio-visual programs will introduce you to the theory of operation for several selected pumps and governors. This program explains **VE Pump Operation** in terms of distributing, pressurizing, timing, and metering of fuel.

PROGRAM OBJECTIVES: VE PUMP OPERATION

When you have completed **VE Pump Operation** you will be able to:

1. State the applications and list the features of the VE Pump.

2. Describe distribution by rotation.

3. Describe how the fuel is pressurized and the operation of the camplate and rollers.

4. Describe port-closure and how it occurs.

5. Describe metering and effective stroke.

6. Explain governor control at start, low-idle, full-load, rated-speed, high-idle, and overrun.

7. Describe full-load adjustment and identify and explain the adjustments made on the test stand and on the vehicle.

8. Describe the injection timing mechanism and adjustments, including cold-start timing, and shut-off systems.

To complete this program you will need the **VE Pump Operation** audio-visual program, the appropriate play-back equipment, and this review guide. The different types of audio-visual presentations (formats) and the types of required equipment to view each format are listed below. Read the operating instructions for the equipment you will be using before attempting to view the programs.

Slide/Tape Format

You will need either an automatic slide/tape player or a manual slide projector and separate tape player. Side A of the cassette tape has inaudible pulses which trigger the advance mechanism of automatic slide/tape players. Side B of the tape has tone pulses which you can hear to indicate when you should advance to the next slide. Before you begin, be sure that you are using the correct side of the cassette tape for the equipment you are using and rewind the tape completely to be sure you are at the start of the program.

Filmstrip/Cassette Tape Format

You will need either an automatic filmstrip/tape player or a manual filmstrip projector and separate tape player. Side A of the cassette tape has inaudible pulses which trigger the advance mechanism of automatic filmstrip projectors. Side B of the tape has tone pulses which you can hear to indicate when you should advance the filmstrip to the next scene. Before you begin, be sure that you are using the correct side of the cassette tape for the equipment you are using and rewind the tape completely to be sure you are at the start of the program.

Film/Tape Cartridge Format

Because of the variety of film/tape cartridge players available, we have not included instructions for this equipment. Be sure to read the operating instructions that come with the equipment you are using before viewing the audio-visual program.

If you have any questions about how to use the audio-visual equipment, see your supervisor or instructor.

SPECIAL INSTRUCTIONS

DO NOT use or refer to the review guide until you have finished viewing the audio-visual program or you are instructed to do so. The visuals in the program are produced in colors which present important information. The black and white reproductions of these visuals used in the review guide may not show the discrimination between these colors and, therefore, may not completely present the information from the color visual. In addition, the audio-visual program may have been revised with updated visuals which may not be reflected in the review guide. These changes in visuals will not alter the meaning or content of the information contained in the review guide.

Start the audio-visual program, **VE Pump Operation**, at this time. Sit back and let the colors, motion, and sound help you learn. When the program ends, turn to page 3 and continue as instructed.

NOTE

The audio-visual program will STOP from time to time when viewed using automatic playback equipment. These stops are included to provide an opportunity to review the information that has been presented to that point. When you are ready to continue, press the START button on the playback equipment.

REVIEW EXERCISE: VE PUMP OPERATION

Now that you have finished viewing the audio-visual program, complete this review exercise. If you have a problem answering any of the questions, use this review guide to locate the correct answer. The numbers following each question indicate the range of scenes where the correct answer can be found.

Place a check to indicate the correct answer or answers to the following questions.

1. The VE Pump is a pump. (9-11)
   a. in-line
   b. distributor
   c. centrifugal

2. The VE Pump plunger operates with two motions. They are: (18-20)
   a. up and down
   b. rotation and stroke
   c. vertical and horizontal

3. The two functions of the plunger are: (21-23)
   a. delivery and injection
   b. pressurization and injection
   c. distribution and fuel metering

4. Effective stroke ends with: (34-37)
   a. port opening
   b. port closing
   c. the end of plunger travel

5. Zero pre-stroke is: (42-44)
   a. the lifting of the plunger for port closing
   b. determined by the position of the metering sleeve
   c. port closure occurring by rotation, before any plunger lift

6. The position of the metering sleeve is determined by: (48-50)
   a. the amount of cam lift
   b. the position of the plunger
   c. the position of the accelerator pedal or control lever

7. The greatest quantity of fuel is delivered at: (54-57)
   a. no load
   b. start-up
   c. full load

8. At start-up, spill occurs when: (55-58)
   a. the metering sleeve is turned
   b. the metering sleeve is at BDC
   c. the plunger takes its longest stroke to port opening

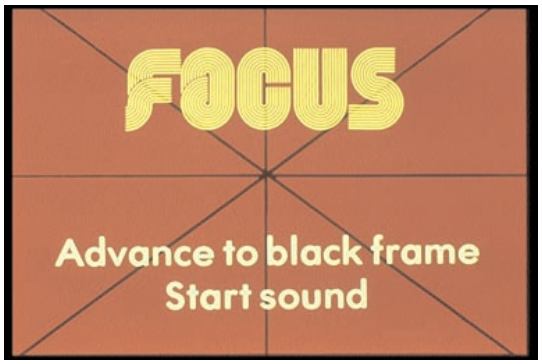
9. A zero delivery condition is when: (77-80)
   a. flyweights exceed spring force
   b. the accelerator is at idle during high engine RPM
   c. the metering sleeve nears BDC and no pressure developes

10. The full load adjustment screw should be adjusted: (80-82)
    a. on the test bench only
    b. on the engine at low idle
    c. on the engine at high idle

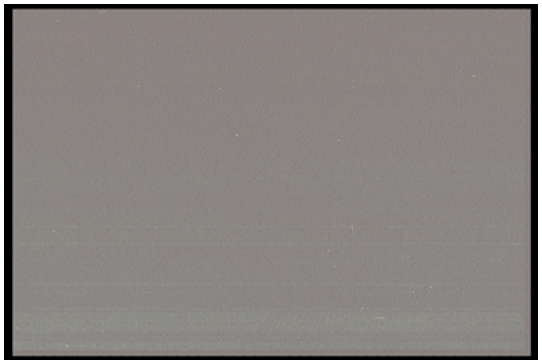
11. Injection timing is adjusted by: (90-92)
    a. changing cam lift
    b. moving the spill ports
    c. rotating the housing around the drive shaft axis

When you have finished this exercise, review your answers. Then show the completed exercise to your instructor or supervisor. Have your instructor or supervisor record your progress on the Student Progress Sheet.

Go on to the next audio-visual program or module assigned to your program track.



1. FOCUS



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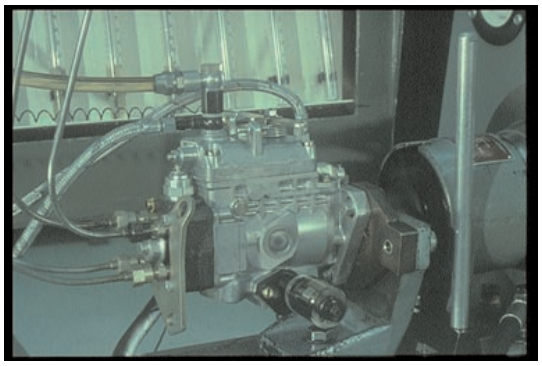

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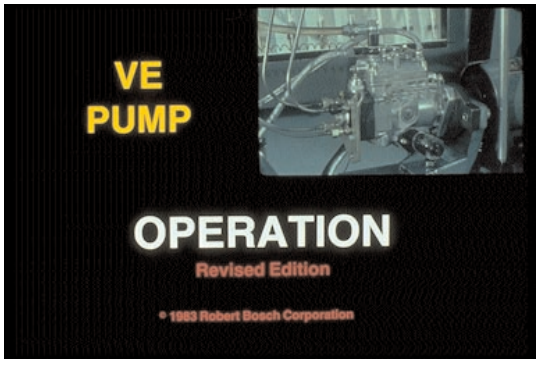

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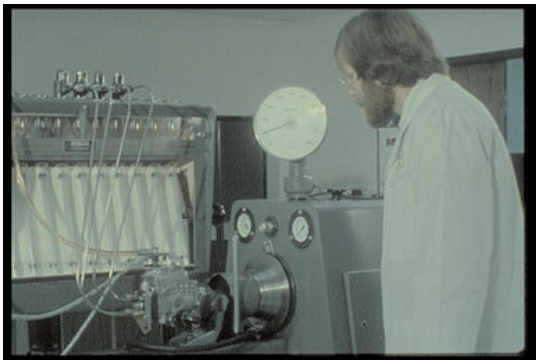
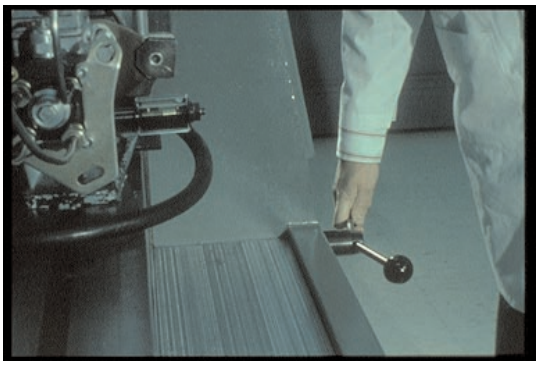
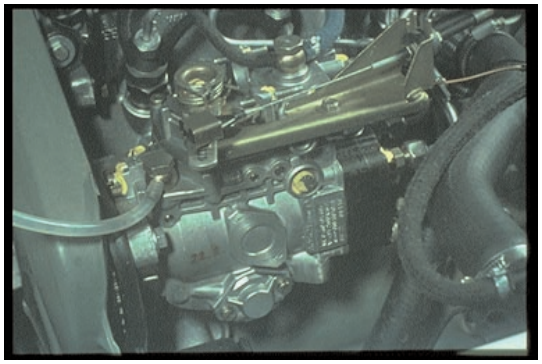


6. When you finish this program, you will understand the operation of the VE pump so you can relate to service and trouble-shooting instructions.

7. Some of you will repair or calibrate this pump on the test bench. Some of you will make minor pump adjustments on the vehicle.



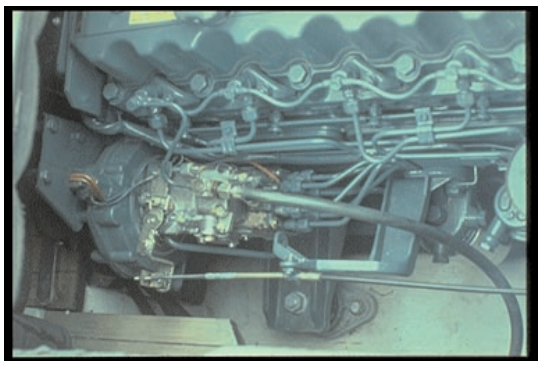
8. All of you will know what you are doing and why. Why is the VE pump important to you?



9. This late model distributor type pump will be found in growing numbers . . .

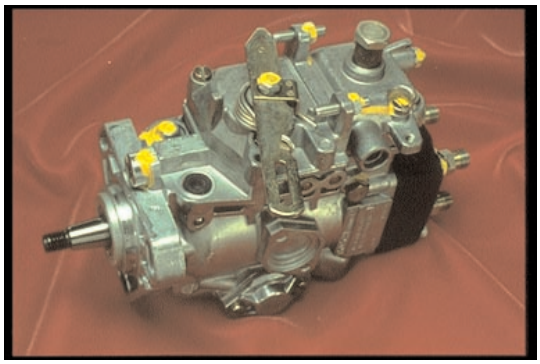
10. . . . in passenger cars, imported and built in the United States . . .

11. . . . in other applications such as light marine, small industrial, and agricultural.

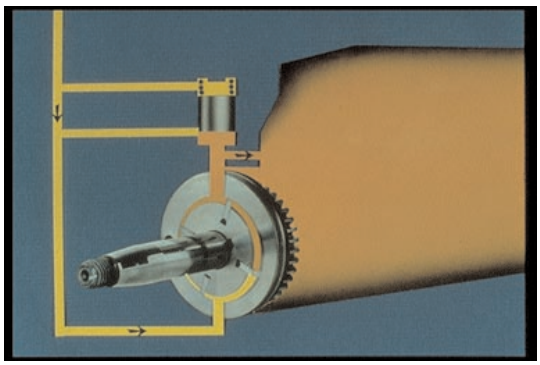


12. Yes, you'll be seeing more and more diesels and more VE pumps to service.

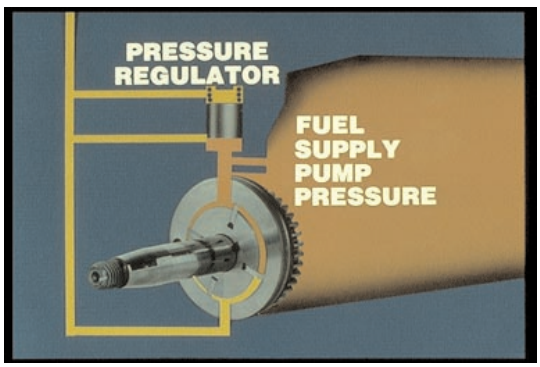
13. What is a VE pump? The "V" comes from Verteiler, meaning "Distributor." It's also called a rotary pump.



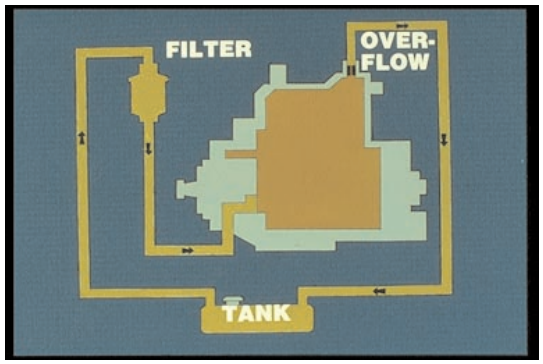
14. It's more compact than most familiar diesel injection pumps. The governor and supply pump are not external; they're inside the VE.



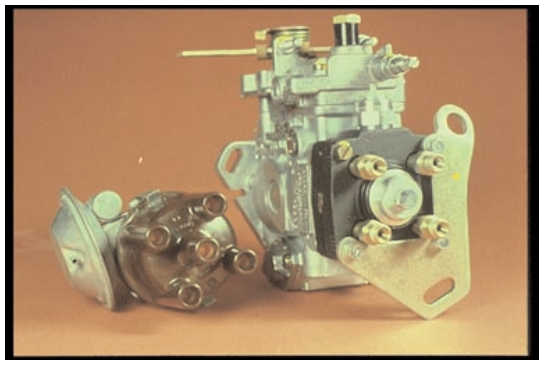
15. The integral supply pump keeps the interior filled with diesel fuel, not lubricating oil, but fuel under pressure; we'll show that in orange.



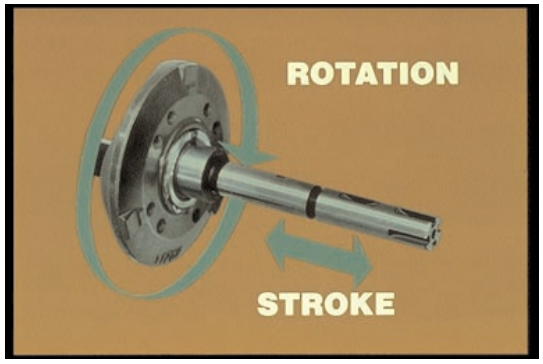
16. Under control of the pressure regulator, supply pump pressure rises with RPM to as much as 100 PSI, about seven bar.



17. The VE pump can lift fuel directly from the tank through the filter. Some fuel bleeds through an overflow, to carry away heat back to the tank.

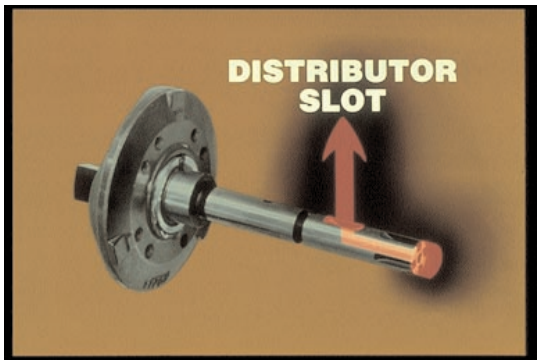


18. Like a spark ignition distributor, the diesel pump starts the power stroke with proper timing and distributes to each cylinder in firing order.

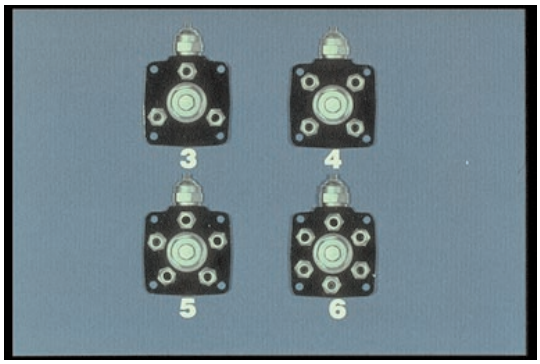


19. In the VE pump the single plunger operates with two motions — rotation and stroke.

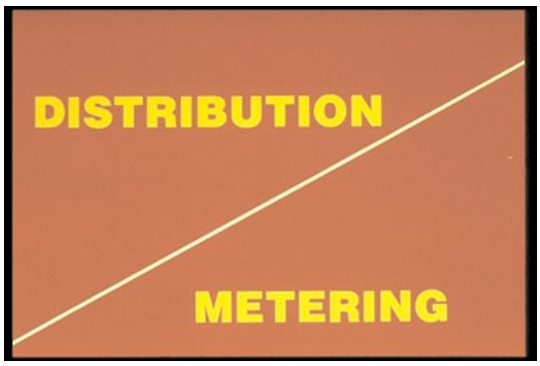
20. In the center of the distributor head, the rotating plunger distributes high pressure fuel shown in red, to one outlet passage every 90° in this four-cylinder application. High pressures may average around 2800 PSI, about 200 bar.



21. As the distributor slot lines up with each passage, it delivers high pressure fuel from the center of the plunger.

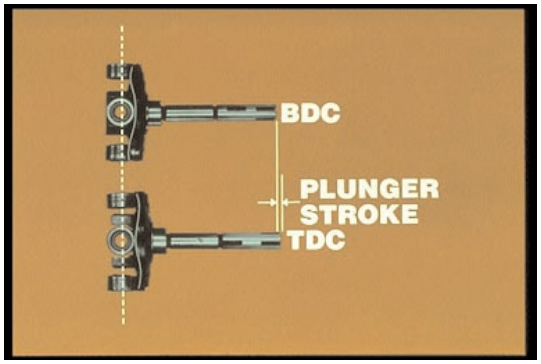


22. You'll find various models of VE pumps with distributor heads and outlets matching the number of engine cylinders.

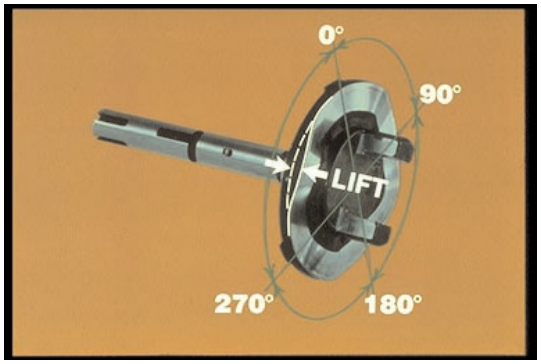


23. So, distribution by rotation is one job of the plunger system. Fuel metering is another job. To understand fuel metering, let's look at the stroke motion.

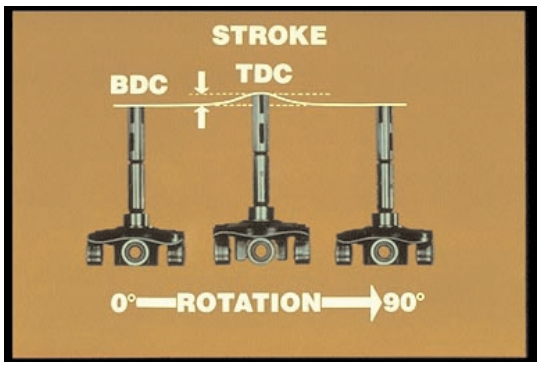
24. Plunger stroke is constant in the VE pump, but the rollers don't lift on the cam. It's really the other way around. As the plunger and cam plate rotate, they lift on the rollers and are returned by the springs.



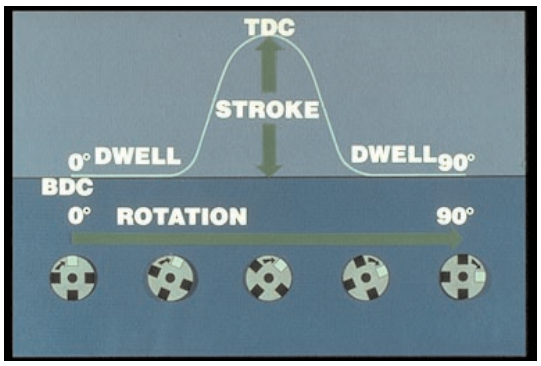
25. From bottom dead center you can see the constant plunger stroke as cam plate and plunger lift on the rollers to top dead center.



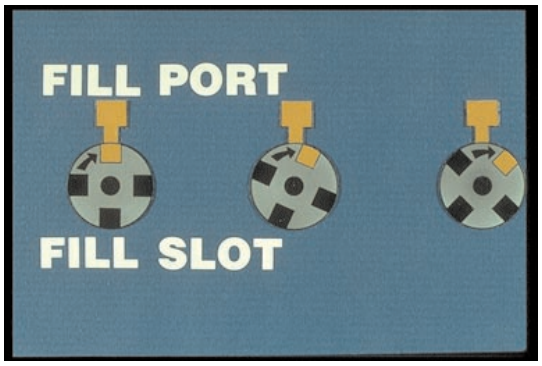
26. In our four-cylinder cam plate there's a cam lobe lift within each 90^{o} sector.



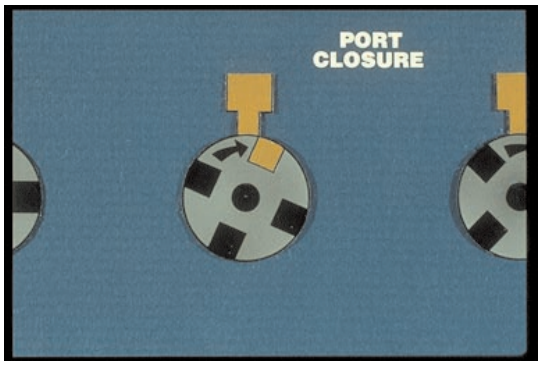
27. If you consider the rollers as fixed, you can see the cam plate and plunger rise up on the rollers to TDC and return to BDC.



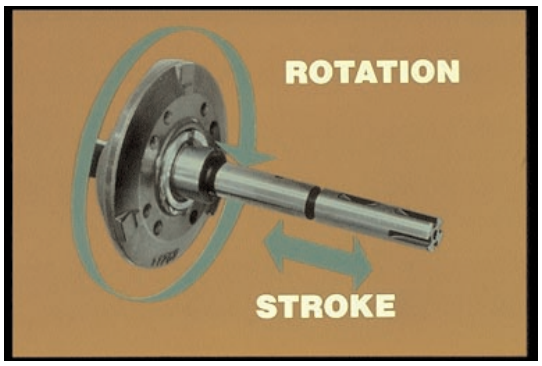
28. Look again at the two motions of the plunger, stroke, and rotation. You can see the plunger may dwell at BDC before and after the stroke; but even during the dwell, plunger rotation is continuous. That's important because . . .



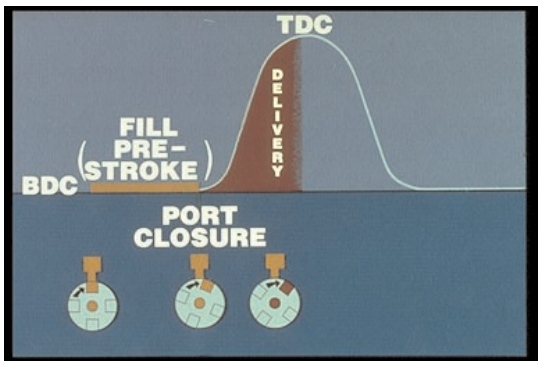
29. . . . during the rotation, the fill port lines up and opens one of the fill slots, bringing in fuel for one cylinder. The port then closes.



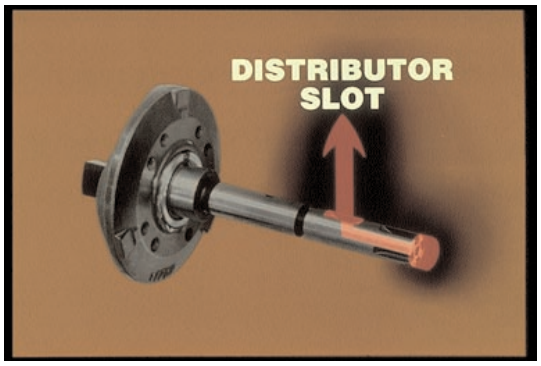
30. We know that port closure is related to timing and metering of fuel delivery. Let's see how.



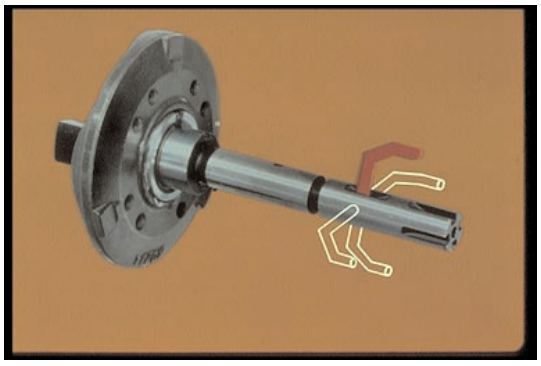
31. Remember the motion of the plunger? Its stroke to TDC and return, and its continuous rotation?



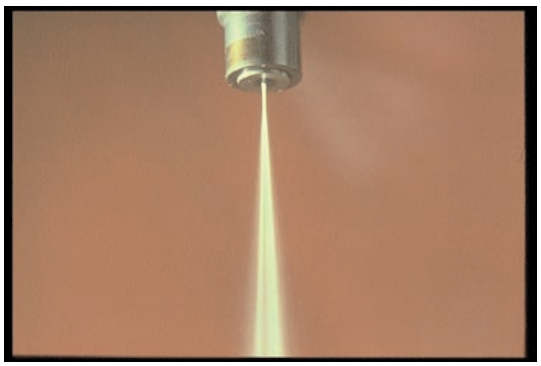
32. The plunger fills with supply pump fuel — shown in orange — during pre-stroke, while it's still at BDC. After rotation to port closure, the plunger lifts from BDC and begins delivery at high pressure, shown in red.



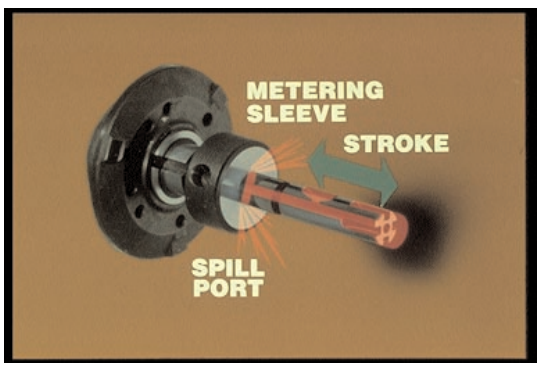
33. The distributor slot delivers high pressure fuel . . .



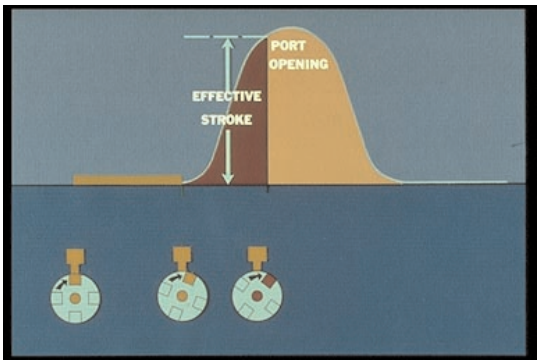
34. . . . through a delivery passage and line to each cylinder in firing order.



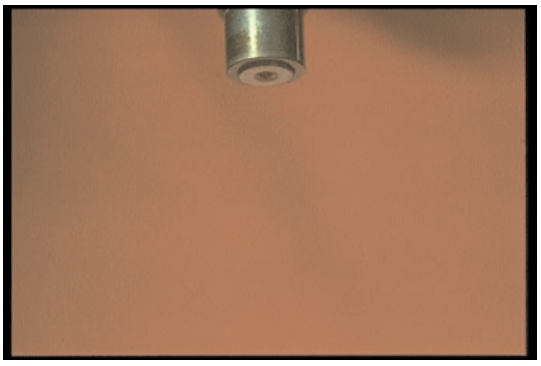
35. There, the fuel injector needle opens and fuel is delivered. How does this delivery stop? That's the job of . . .



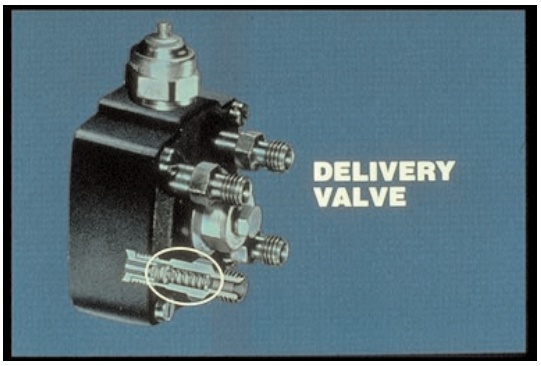
36. . . . the metering sleeve. As the plunger strokes through the metering sleeve, the movement uncovers a spill port, opening the high pressure circuit and spilling the remaining fuel into the pump interior.



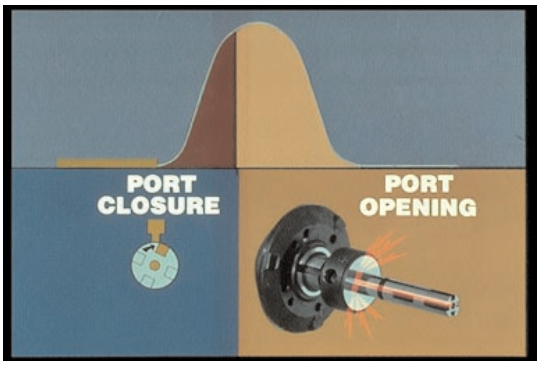
37. This is called port opening, or spill. Effective stroke ends with port opening even though plunger stroke continues.



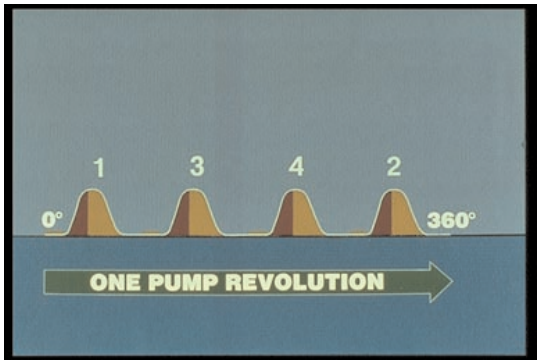
38. With the drop in pressure, the injector cuts off delivery . . .



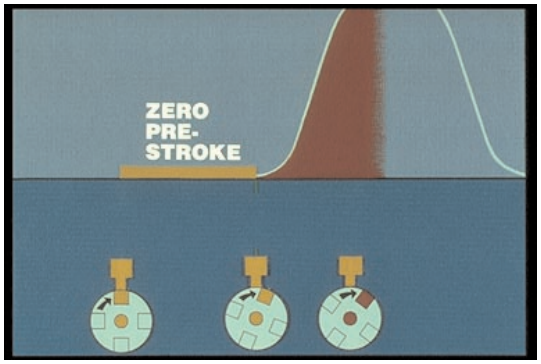
39. . . . aided by its delivery valve at the pump distributor head.



40. So, for each plunger rotation and stroke, we have "fill" to port closure, "delivery" to port opening and "spill."

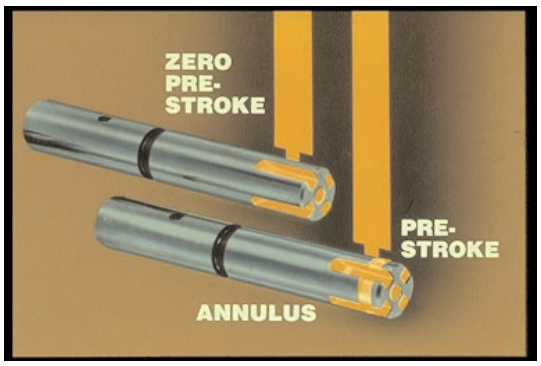


41. For a four-cylinder engine, we have four plunger strokes in one pump revolution, 360° which is, of course, 720 engine degrees.

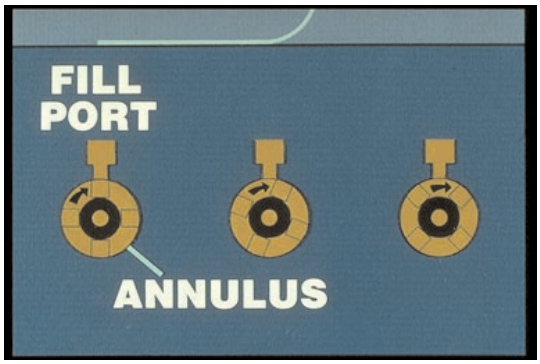


42. The VE pumps we've been discussing are called "zero pre-stroke" because port closure occurs by rotation, before the plunger lifts from BDC. You can identify these pumps . . .

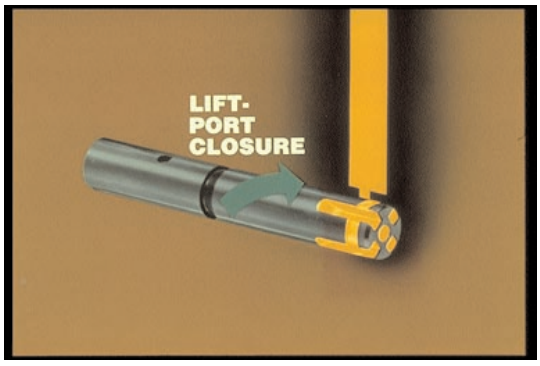
43. . . . by the simple fill slots which port close by rotation.



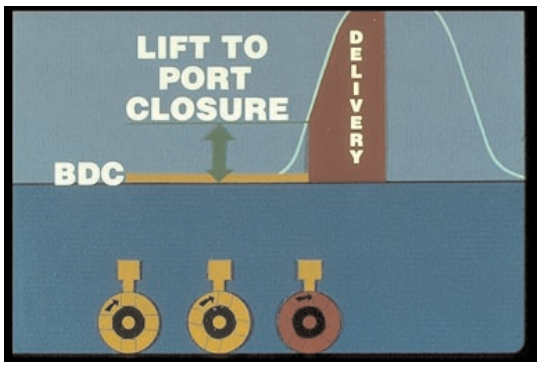
44. Contrast the zero pre-stroke with the plunger of a different pump which has a pre-stroke. Because of this annulus or circular slot . . .



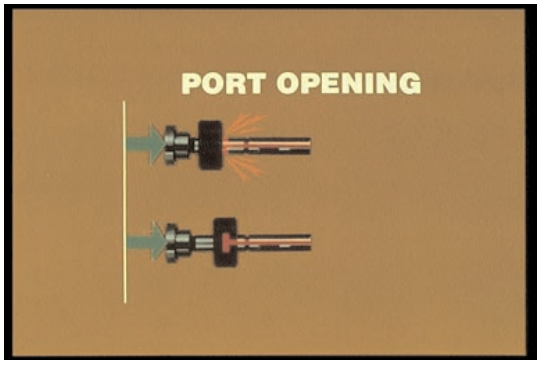
45. . . . the fill port cannot close by rotation alone.



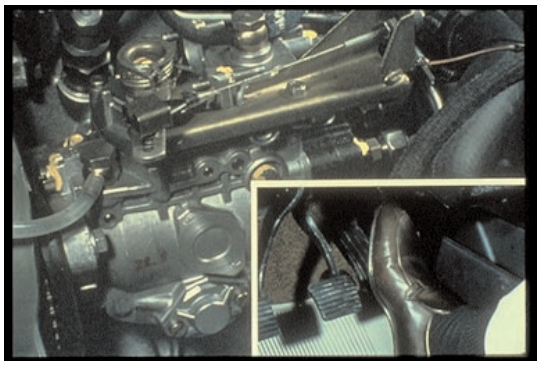
46. Instead, the plunger must lift for port closure. Only after the annulus lifts beyond the fill port do we have port closure.



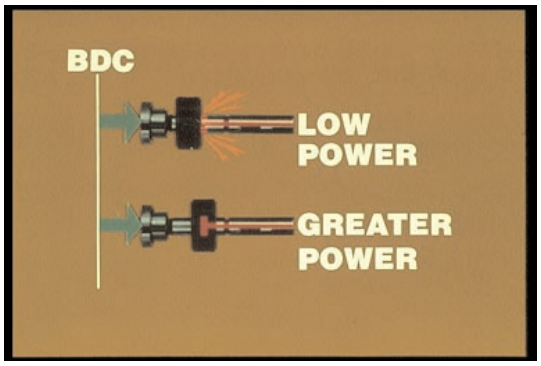
47. For this type of VE pump, lift to port closure settings are important because delivery does not begin until a specified lift from BDC. Regardless of port closure . . .



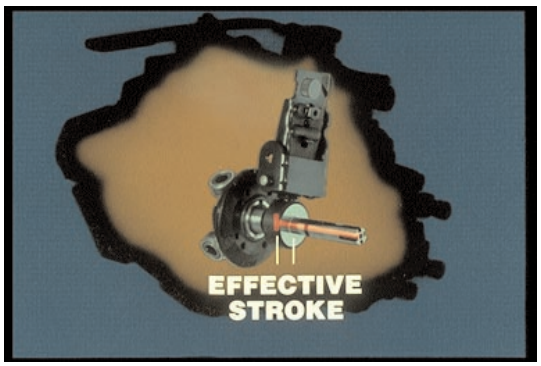
48. . . . port opening is determined by the position of the metering sleeve as the plunger and spill port move through it. The metering sleeve position determines the amount of fuel delivered. What positions this sleeve?



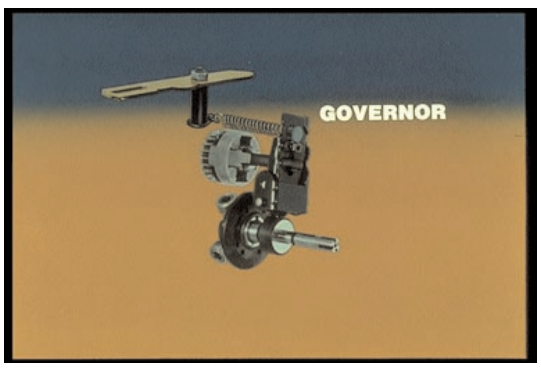
49. It is usually the accelerator pedal, some form of power control lever.



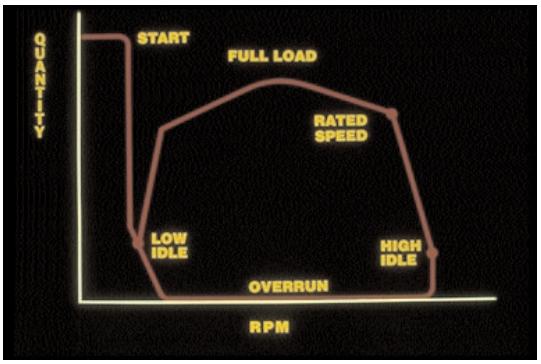
50. For low power — light accelerator pressure — the sleeve is closer to BDC so the spill port opens sooner by plunger stroke. For greater power, the sleeve is farther from BDC, so the spill port does not until later in the plunger stroke.



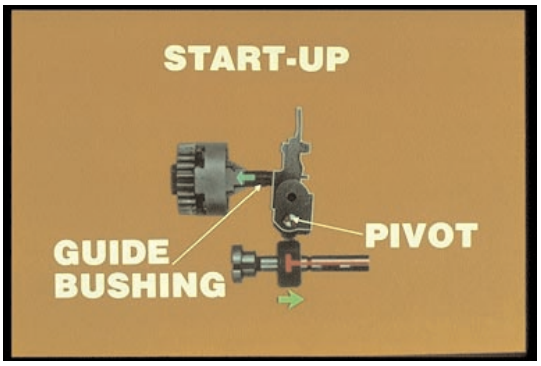
51. So as this lever positions the sleeve, it determines the effective stroke. The effective stroke is always less than full plunger stroke.



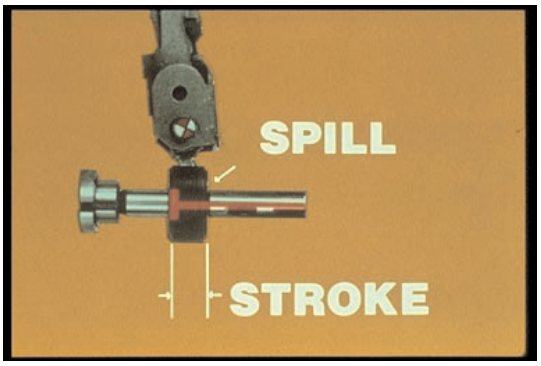
52. It is the spring and flyweights which determine the force on the governor lever and sleeve. When does the governor control?



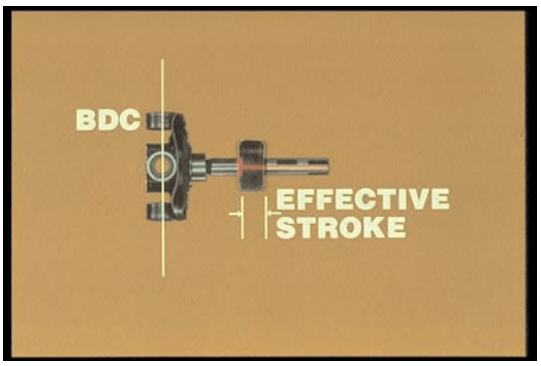
53. You may recall it controls at start, low idle, full load, rated speed, high idle and overrun or coasting. For each case, let's see how.



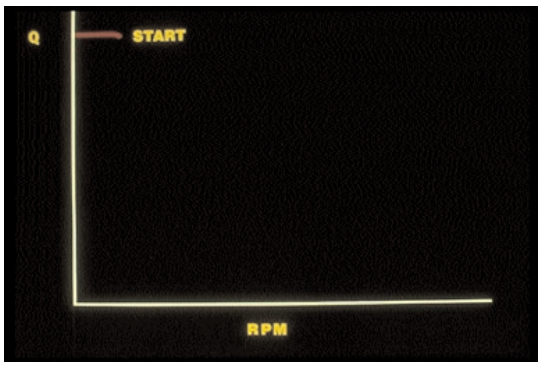
54. At start-up, the flyweights are at rest. So the guide bushing is pushed back to the left in this picture. The governor lever pivots to move the metering sleeve the other way away from BDC. Then, how does that affect fuel delivery for start-up?



55. That's right, maximum delivery; at start-up, spill occurs only after the plunger takes its longest stroke to port opening.

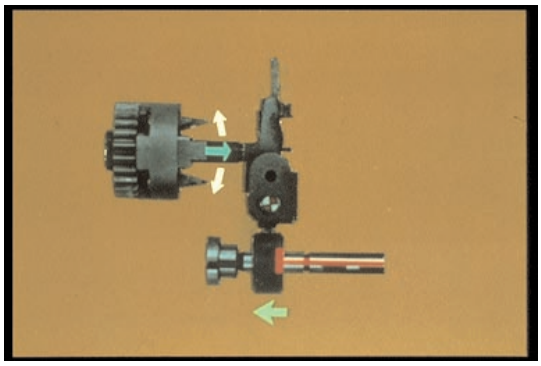


56. When the metering sleeve is farthest from BDC, the effective stroke is longest.



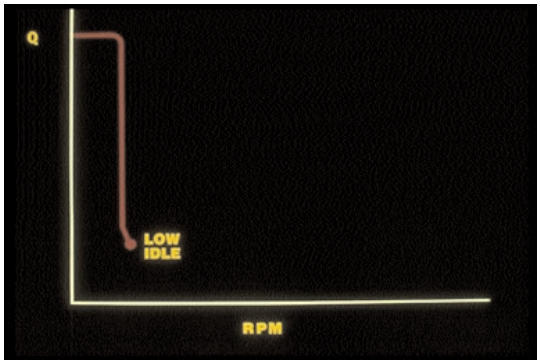
57. So for start-up, the greatest quantity of fuel is delivered. Greater even than at full load.

58. Now, as the engine starts . . .

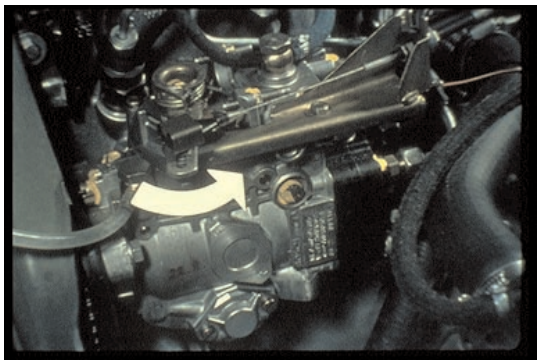


59. . . . the flyweights open out, moving the guide bushing to the right. So the governor lever pivots the sleeve to the left, shortening the effective stroke.

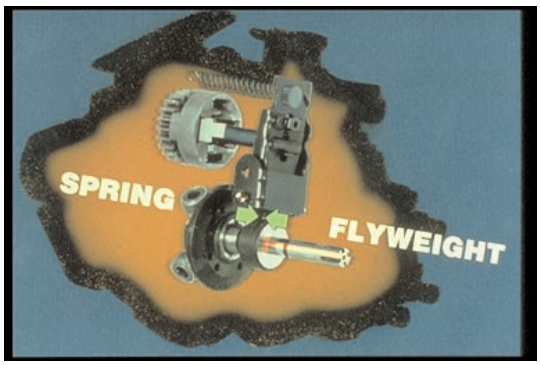
60. With the sleeve close to BDC, the plunger moves only a minimum distance before the spill port opens. Thus, a minimum effective stroke.



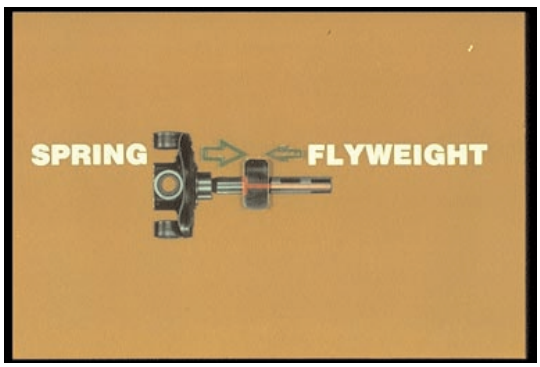
61. At low idle, the governor controls fuel injection at the idle RPM, tending to compensate for temperature and load changes.



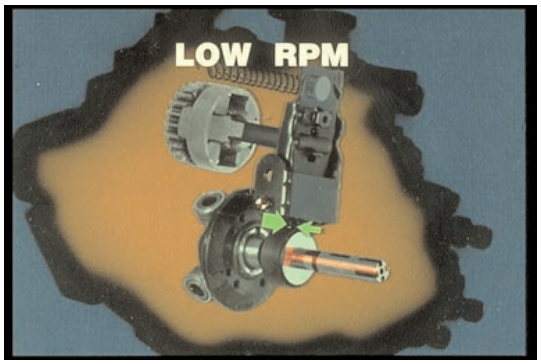
62. When you increase power, move from low idle to high speed stop. What happens?



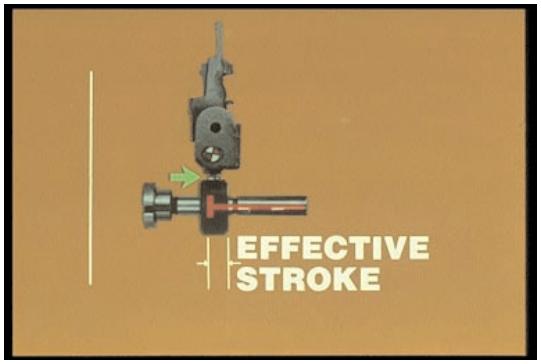
63. Fuel delivery depends on a balance of forces, spring forces balancing flyweight forces, pivoting the lever to move the metering sleeve.



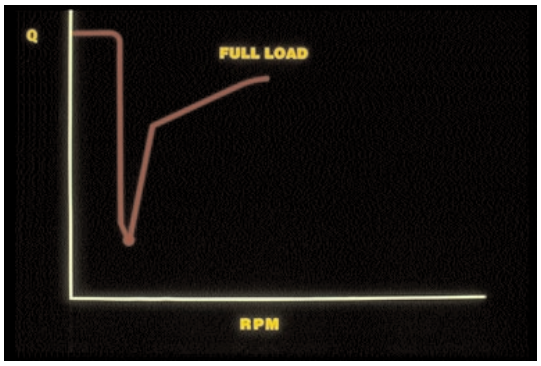
64. When you are increasing power, spring force tends to move the sleeve away from BDC, against the opposing flyweight force.



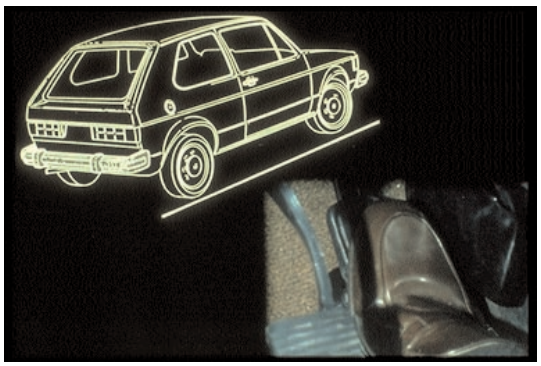
65. The flyweights are collapsed at low RPM, and at full load, the spring force is greater than the flyweight force.



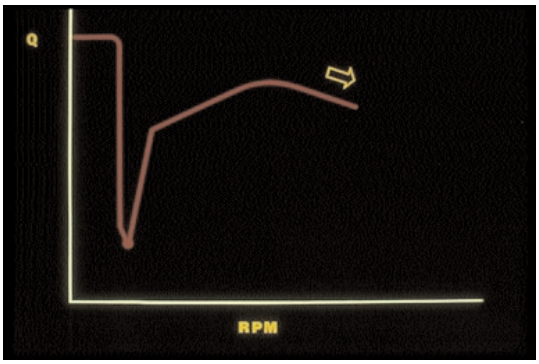
66. The metering sleeve is moved away from BDC, so the effective stroke is longer.



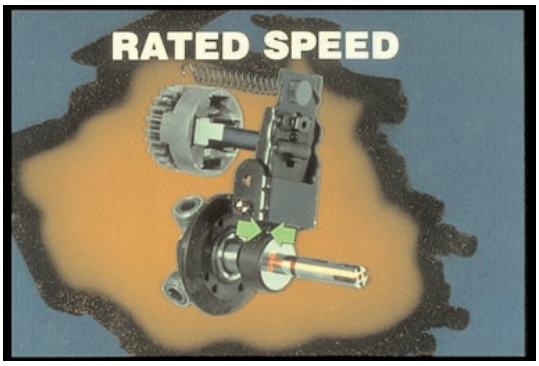
67. The fuel quantity per stroke is greater. The engine accelerates and the vehicle gains speed.



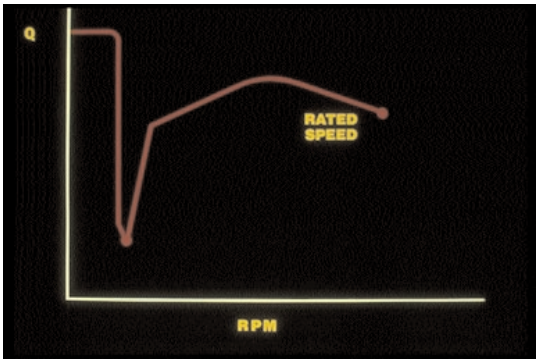
68. In part, speed is determined by load. Climbing a hill, full load may be at some partial speed between minimum and maximum.



69. As the RPM approaches rated speed, what happens?

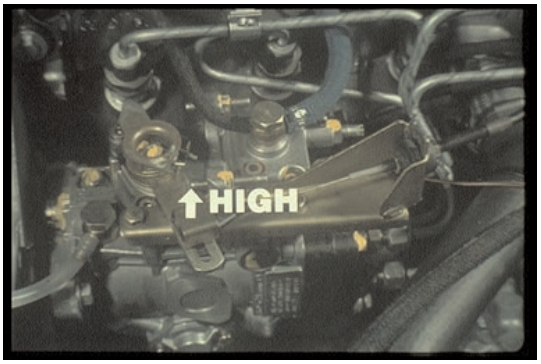


70. At rated speed and full load, the spring force just balances the flyweight force, holding the metering sleeve for rated speed delivery.

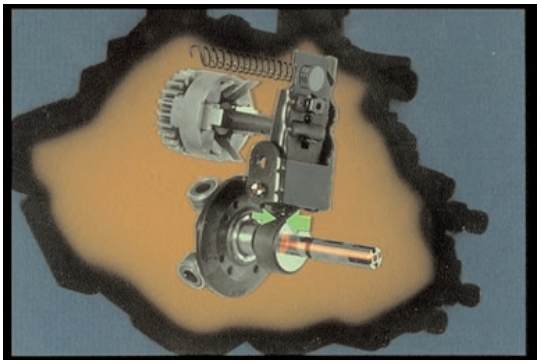


71. Full load continues at rated speed, but no more.

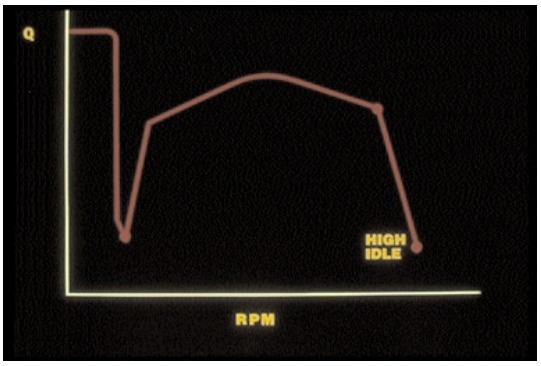
72. Now, suppose you run the engine at no load, as with the clutch down and accelerator full down . . .



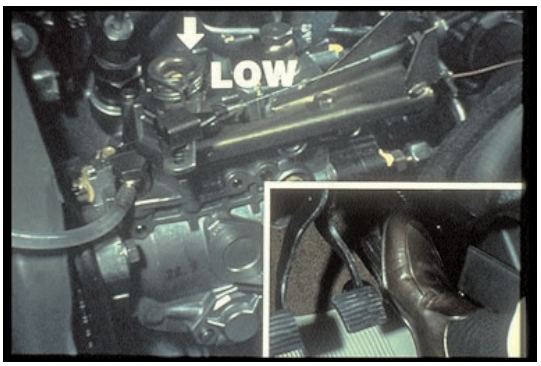
73. . . . holding the control lever against the high idle or maximum RPM stop.



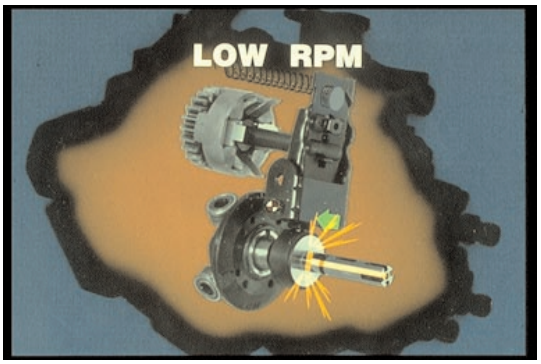
74. At high RPM, the flyweights move out opposing the spring. The flyweight force is stronger, so through the lever, it moves the metering sleeve to reduce effective stroke.



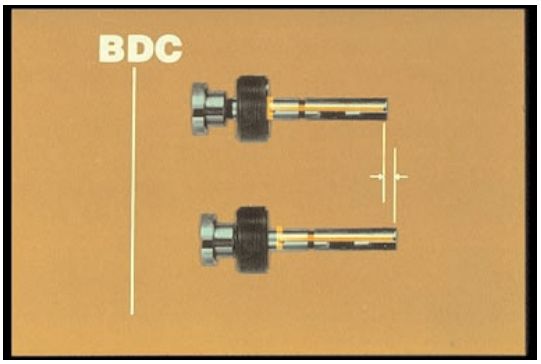
75. This reduced fuel flow is called high idle. Notice this no load condition produces a maximum RPM, faster than rated speed but at a fraction of the fuel delivery.



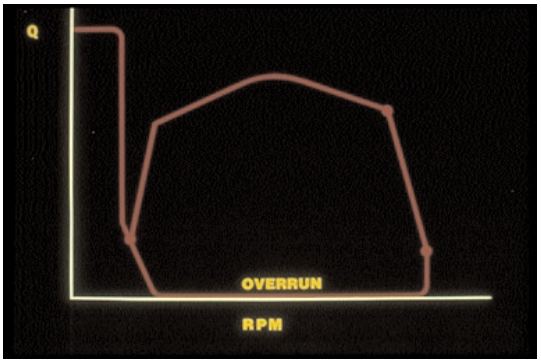
76. Finally, suppose you release the accelerator and coast, returning the governor lever to the low idle stop. What happens?



77. At high RPM, with accelerator at idle, the flyweight force overcomes the relaxed spring. The metering sleeve moves so close to BDC that injection pressure never develops. A zero delivery condition.

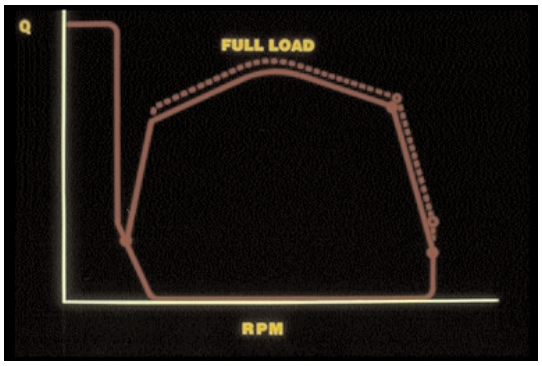


78. Zero, because the metering sleeve is so close to BDC that it never covers the spill port during the plunger stroke.

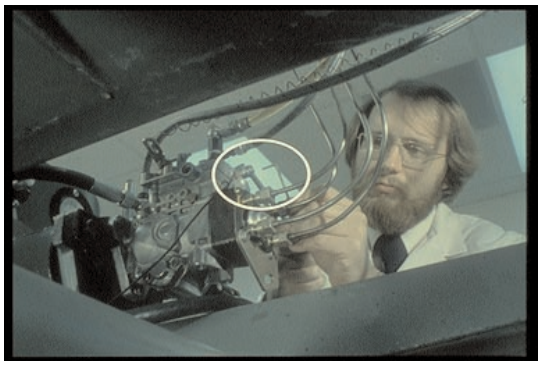


79. Zero delivery during overrun is one reason diesels are so economical during conditions such as city driving.

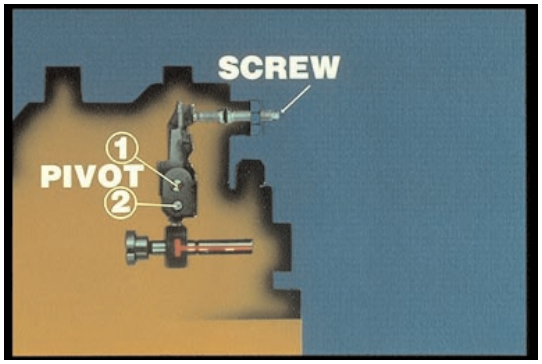
80. You've seen that at full load the governor lever moves the metering sleeve far from BDC.



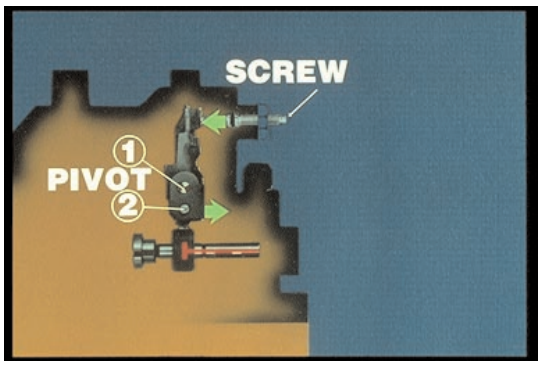
81. How can we make a full load adjustment, say, to increase our full load fuel quantity?



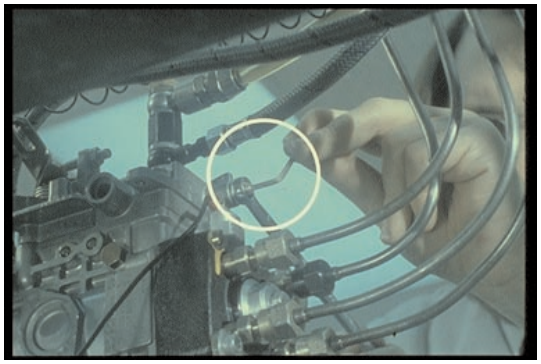
82. On the governor, you'll find a full load adjustment screw. You should adjust this screw only on the test bench, never on the vehicle.



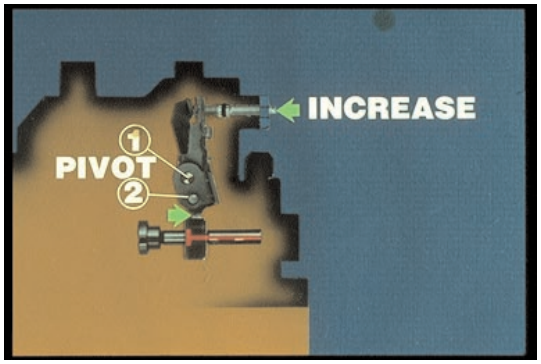
83. This screw adjusts a special lever called the correction lever, pivoting at point one. Notice this correction lever carries pivot two, the normal pivot point four you've seen for spring and flyweight force on the metering sleeve.



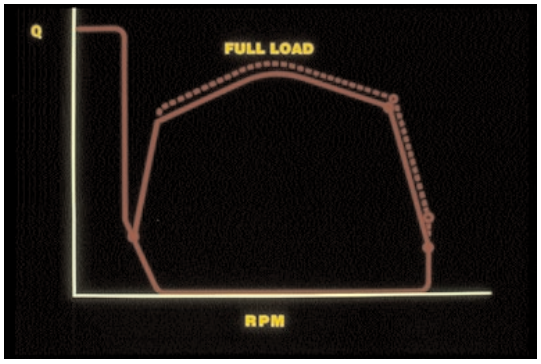
84. So, moving this full load adjustment screw shifts pivot two which has the effect of shifting the metering sleeve, and so changing our full load delivery.



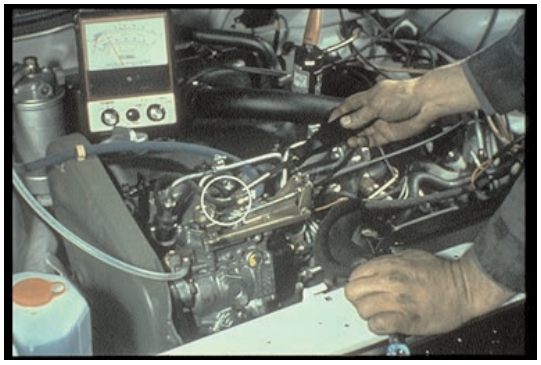
85. On the test bench you can turn this screw to move the correction lever inside the pump.



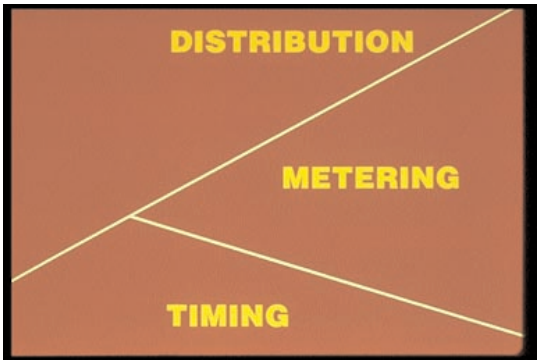
86. This movement, in to increase, pivots the correction lever at pivot one to move pivot two and the metering sleeve, increasing the effective stroke and, therefore, the full load fuel delivery.



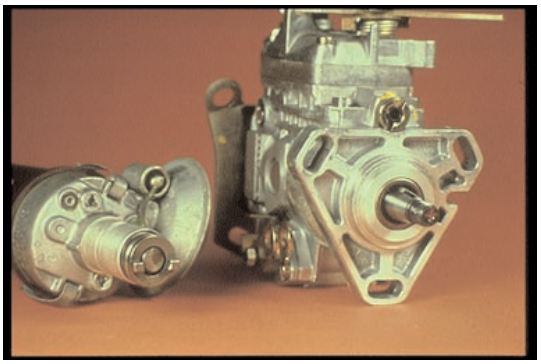
87. You can see why this full load fuel delivery must be adjusted before the other settings. High and low idle can be done on the test bench . . .



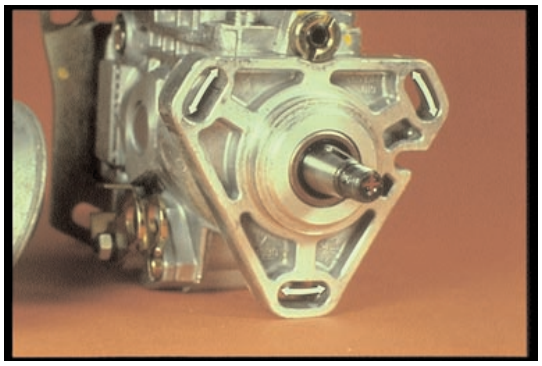
88. . . . or on the vehicle. In the shop, set idle RPM at the low idle stop. Set maximum RPM at the high idle stop. But leave the full load adjustment screw alone.



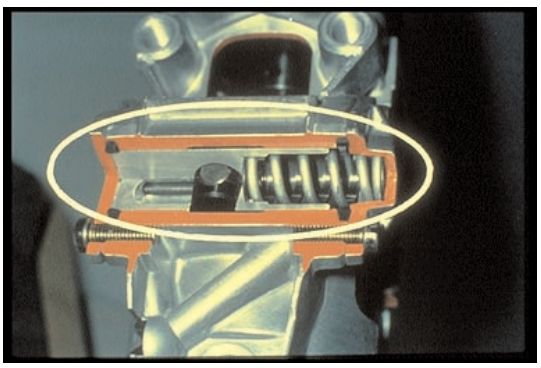
89. You've seen distribution and metering in the VE pump. We'll conclude with injection timing, the timing mechanisms, and the timing adjustments.



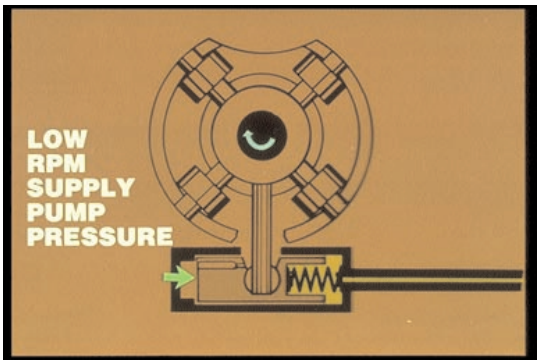
90. In a procedure similar to spark timing, diesel injection timing is adjusted to the engine by rotating the pump housing around the drive shaft axis.



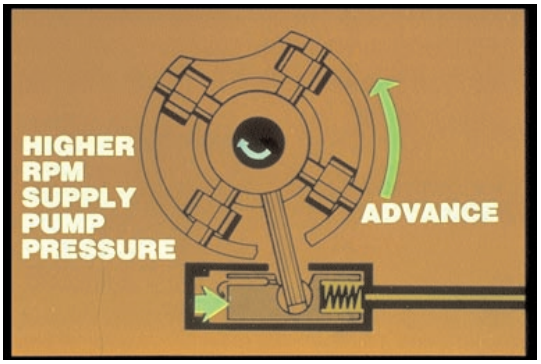
91. Timing is set by turning the pump in the mounting bolt slots so injection begins at the correct time.



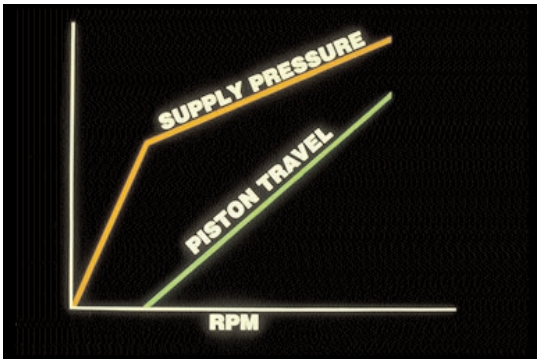
92. In this cutaway VE pump, you can see the timing device, the timing piston, and its opposing spring.



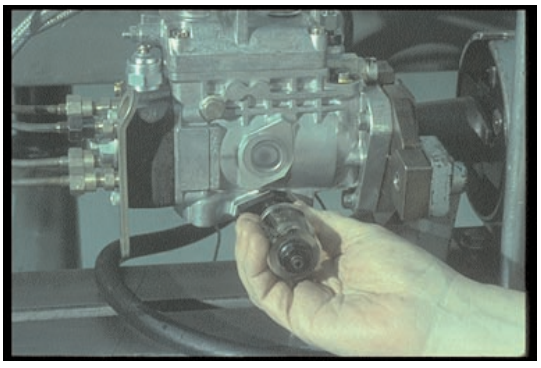
93. At low RPM, supply pump pressure has little effect on timing piston travel. As pressure rises with increasing RPM . . .



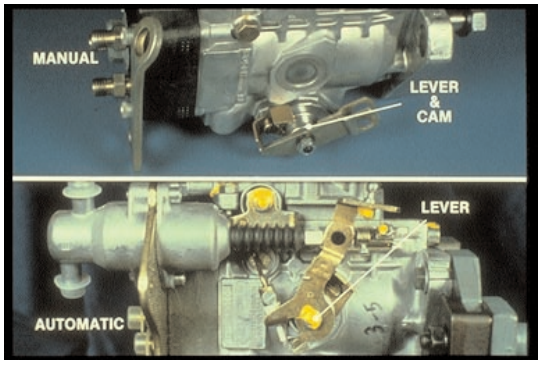
94. . . . piston movement advances the roller ring opposite to drive shaft rotation. This advances the time when the cam plate will lift from BDC to begin the stroke.



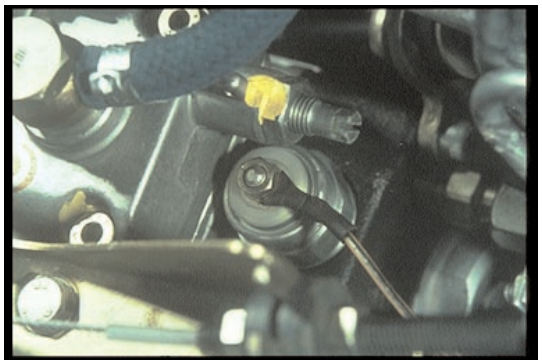
95. So, as supply pump pressure increases with RPM, the timing piston travels, advancing the time when injection begins. For this reason . . .



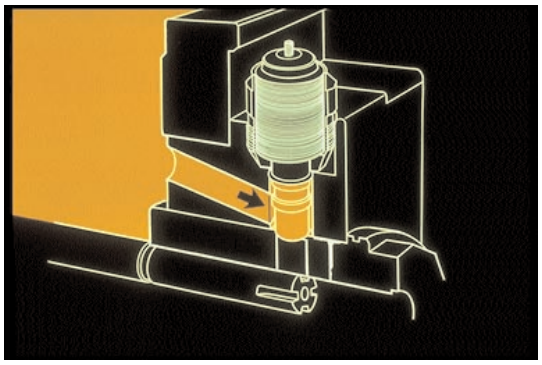
96. . . . procedures on the test bench include measuring the travel of the timing piston as the RPM changes.



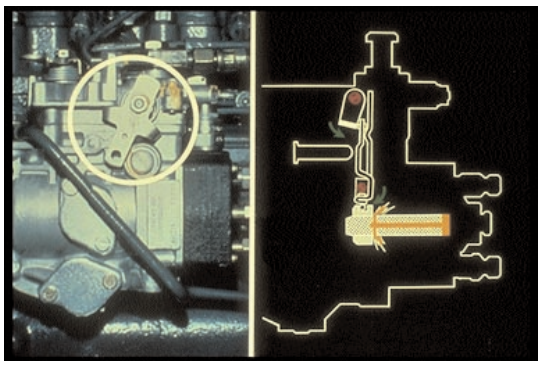
97. On some VE pumps, a cold start lever and cam advance the timing a few degrees, tending to reduce start-up smoke.



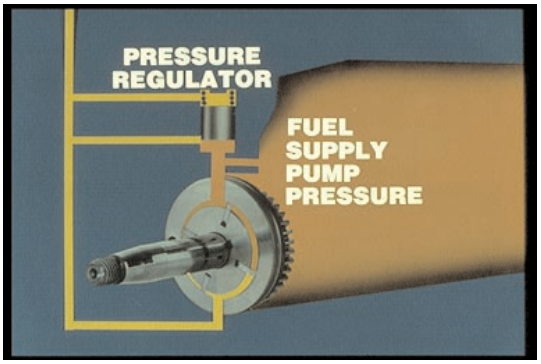
98. On most pumps, fuel shut-off is electrical. A solenoid valve . . .



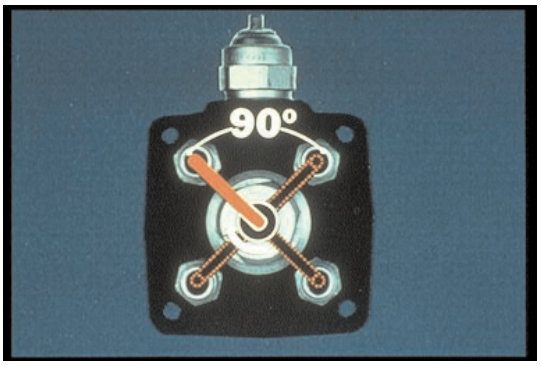
99. . . . closes the supply of fuel to the fill port and the plunger.



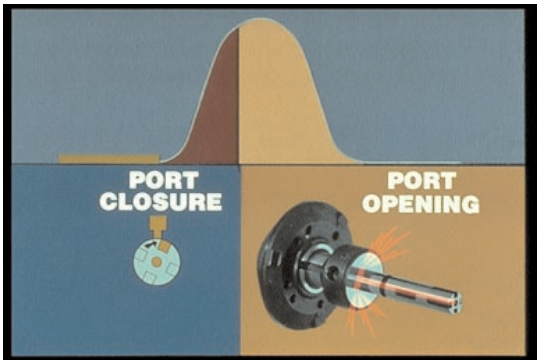
100. You may find a mechanical shut-off. The lever system overrides the governor spring to move the metering sleeve to zero delivery.



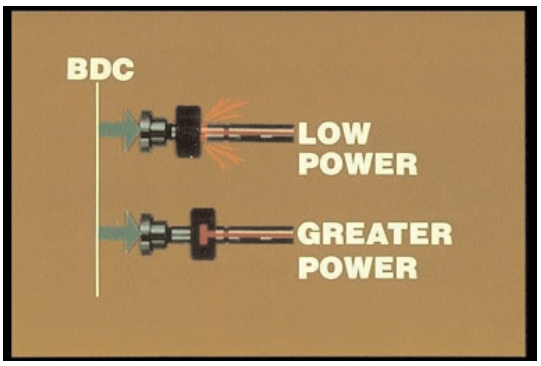
101. You've seen the compact VE pump pressurized by the integral supply pump . . .



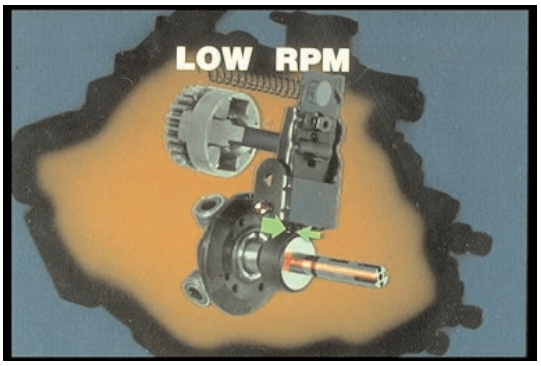
102. . . . the single plunger rotating for distribution of fuel to the cylinders in firing order . . .



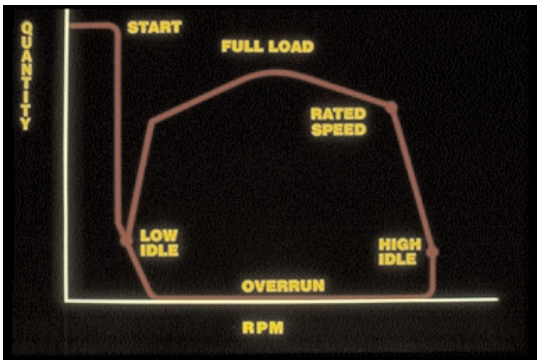
103. . . . you've seen the meter delivery to port opening and spill . . .



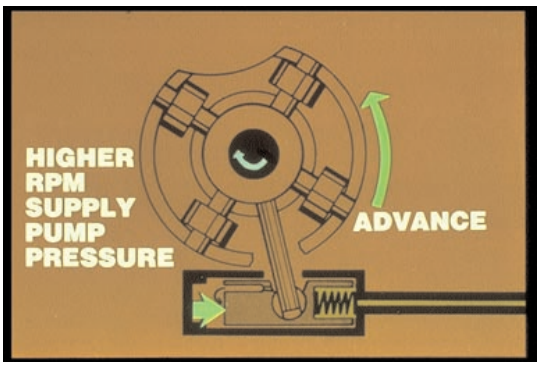
104. . . . the metering sleeve opening the spill port sooner for lower power requirements or set to open later for greater power . . .



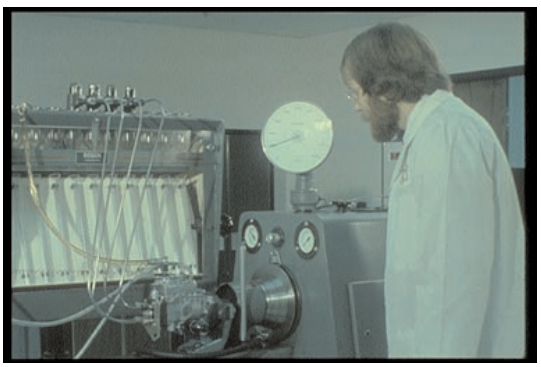
105. . . . positioned by the accelerator, spring forces and governor flyweights . . .



106. . . . governed for correct delivery quantity at various load and RPM conditions.



107. Finally, you've seen the timing and the timing piston travel.



108. Operating principles important to your service and trouble-shooting instruction . . .

109. . . . brought to you by Robert Bosch.

REVIEW EXERCISE ANSWER PAGE: VE PUMP OPERATION

1. b
2. b
3. c
4. b
5. c
6. c
7. b
8. c
9. b
10. a
11. c