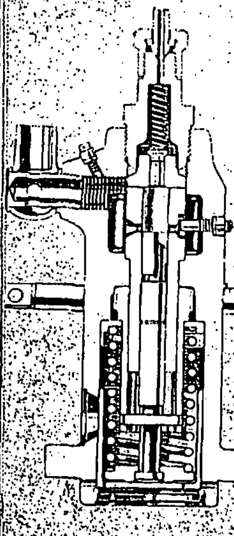
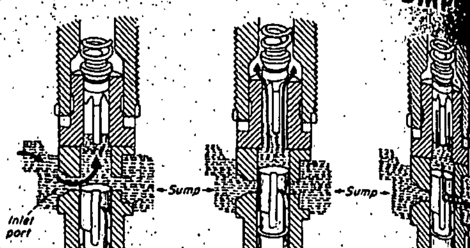
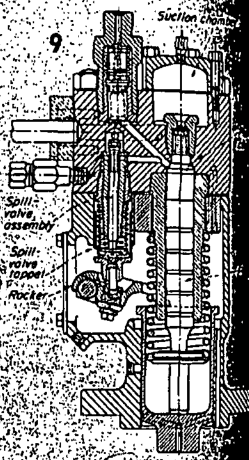
TYPICAL CONSTANT-STROKE FUEL-INJECTION PUMP



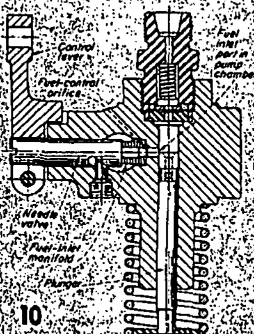
7 Typical constant-stroke pump has a plunger with a helix cut in it. Helix controls opening, closing of ports, thus metering the fuel and timing injection. Helix position is determined by a governor-controlled rack which turns plunger in pump barrel



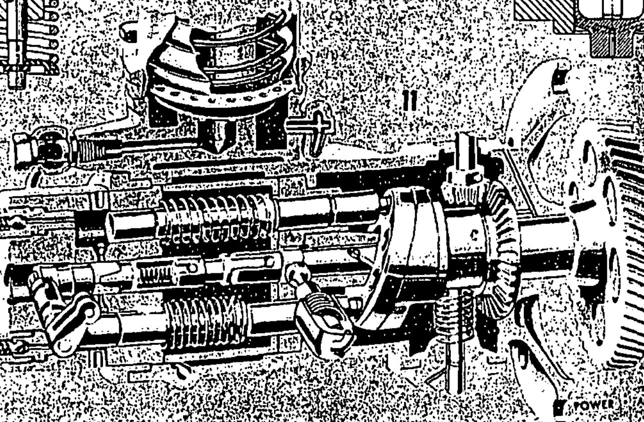
8 Cutaway views of three stages in pumping operation show principle of constant-stroke port-controlled pump. With plunger all the way down, fuel fills the pump chamber. As plunger rises, it closes ports and puts oil under pressure until delivery valve opens. As stroke continues, helix opens bypass port, pressure drops and delivery valve snapped shut. Turning plunger changes time when helix uncovers bypass



9 In constant-stroke valve-controlled pump, plunger upstroke delivers fuel through discharge valve until spill valve opens and relieves pressure. Control shaft, governor-actuated, adjusts clearance between spill-valve tappet and stem



10 In another constant-stroke valve-controlled pump, a needle valve determines fuel quantity discharged. Control lever acts on helix of needle valve to move it in or out, changing area of the inlet orifice and thus quantity pumped



11 Individual pump cylinders stand radially around central rotary valve. Wobble plate drives pump plungers. Central valve carries a triangular land to control port opening and closing. Moving valve endwise changes position of land

tion of this helix in relation to ports in the barrel determines amount of fuel discharged, as will be seen later. Action of a cam, located below the pump, lifts plunger and spring action returns it. A bushing encloses the pump barrel, carrying a pinion which engages a rack actuated by the governor. With this arrangement, *governor* action can change angular position of plunger without interfering with its reciprocating action. A transfer pump keeps injection-pump suction line filled with oil so ports are always submerged.

Operating Principle. As shown in Fig. 8, both inlet and bypass ports are open when plunger is at bottom of its stroke. *Fuel fills space above plunger* and flows through vertical groove to fill helical recess. As plunger starts upward it closes ports and traps oil above. Pressure builds up in pump, spring-loaded discharge valve opens and fuel flows to the nozzle. When pressure at nozzle reaches desired injection level, its spring-loaded needle valve opens and injection starts. It continues until plunger has risen enough to cause upper edge of helical recess to uncover the bypass port, which releases pressure. Both nozzle valve and pump delivery valve snap shut and cycle repeats.

It can be seen that amount of fuel injected depends on how long it takes *for the helix to uncover the bypass* port. This in turn depends on the plunger's position in the barrel, which is controlled by the fuel rack and governor. With the plunger turned far enough to the right for the vertical groove to register with the bypass, the pump builds no pressure because there is always a connection between the space above the plunger and the bypass port. This is the *stop* position. As the control rack turns plunger to left, time between closing of ports by plunger top and uncovering of bypass by helical groove becomes longer, increasing duration and amount of injection. Pumps of this design are built as single units like Fig. 7, or with a number of barrels and plungers in a single housing.

VALVE-CONTROLLED PUMPS

Constant-stroke pump of Fig. 9 operates on the "spill-valve" principle. Fuel enters a suction chamber and flows through a suction valve into the pump barrel on the plunger downstroke. On the upstroke, pressure lifts the discharge valve and fuel flows into discharge tubing until a spill valve opens to bypass fuel back to suction chamber. This releases pressure and discharge valve snaps shut.

The rocker and tappet assembly for the spill valve is so arranged that the control rod, which is governor-actuated, changes clearance between tappet and valve stem. At full load, clearance is great and plunger moves a considerable distance before rocker opens spill valve. At partial loads, clearance becomes less and effective pump stroke decreases.

Wobble-Plate Design. Another valve-*controlled* constant-stroke pump is shown in Fig. 11. Individual pump cylinders stand radially around a central rotary valve. Drive unit has a vertical takeoff for the governor and powers a wobble plate which gives reciprocating motion to injection-pump-plunger push rods. Central valve turns at wobble-plate speed.

After passing through transfer pump, strainer and filter, fuel flows to a recess formed by a spool-like reduction in diameter of the rotary valve. Valve ends fit closely in the bore, preventing any escape of fuel endwise. The middle spool-like section of the valve has one triangular section or *land,* which has the same diameter as the spool ends.

Fuel flows from the valve recess to the space ahead of the injection-pump plunger, by way of a port, and excess fuel returns to the chamber in the same way. As the plunger moves in the discharge direction, the central valve rotates to a position where the triangular land starts to close the port. Plunger motion then builds up *pressure* until the delivery valve at the end of the plunger space opens and fuel flows into discharge tubing. Continued valve rotation puts triangular land past port opening, relieving pressure in plunger chamber. Excess fuel returns to the valve chamber through the port.

Quantity Control. Control of amount of fuel injected is effected by moving rotary valve endwise, thus changing position of triangular land in relation to port. When apex of triangle is opposite port, land closes port for a brief interval only and fuel delivery is short; when base of triangle comes opposite port, greater width of land closes port for a much longer time, and delivery is increased proportionately.

Operating from the main drive unit, rotary valve turns at same speed, while wobble-plate action is such that individual injection plungers stand at different stroke positions at any one time, and therefore in different relations to rotary valve. Wobble-plate action, and its timing with rotation of valve, permits the single valve to serve each injector in turn.

Needle-Valve Design. Fig. 10 shows another valve-controlled constant-stroke pump designed specifically for small engines. The plunger is cam operated. Fuel enters the pump chamber through an orifice whose area is regulated by a needle valve. Action of governor-actuated control lever moves needle valve in or out to pass more or less fuel to pump chamber.

After passing needle valve, fuel flows into the chamber as long as fuel-inlet port is left open by plunger. In its lowest position, upper edge of plunger opens inlet port approximately half way. Fuel delivery commences when upper edge of plunger, during upstroke, closes inlet port. Fuel injection terminates when *lower edge of plunger head* reopens inlet port and cuts off delivery. Fuel displaced by plunger after cutoff is returned to inlet manifold through drilled passage in plunger head.

Variable-Stroke Pumps. *Thus far all pumps pictured and discussed have* operated with a constant stroke. Changes in pump discharge required to meet variations in load can also be produced by altering length of pump stroke. In one design, for example, individual fuel pumps cluster around a single cam drive. By extending or withdrawing the single driving cam, governor changes pump stroke and amount of fuel delivered. Fuel cam can be moved to change injection timing.

In another case, individual pump cylinders mount above a camshaft that is really a shaft within a shaft; the center being movable longitudinally. This motion retracts or protrudes the cams to change pump stroke as needed.

UNIT INJECTORS

Unit injectors, a relatively recent development, combine the pump, fuel valve and nozzle in a single housing, thus eliminating discharge tubing. This permits extremely high injection pressures, up to about 20,000 psi in some designs.

The unit injector of Fig. 12 consists of a helix-grooved plunger in a barrel with ports: the plunger is driven down by a cam-actuated rocker arm against the resistance of a spring; a governor-actuated control rack turns the plunger to position the helix with respect to the ports. Below is the delivery valve and nozzle. Fig. 14 shows another unit-injector design and Fig. 13 illustrates its operation.

Unit-Injector Operation. As can be seen in Fig. 13, the plunger has a helical groove in its side, connected to the space under the plunger by a passage. There are two ports on one side, an inlet port and a bypass port above. With plunger in highest position, fuel enters inlet port until lower edge of plunger closes it and pressure rise begins. When pressure reaches proper level, oil discharges through the nozzle valve. As downstroke begins, lower edge of helix passes the bypass port, releasing pressure, and spring closes noz-