valve stem meet it must be provided on push-rod side. In many cases, fulcrum bearing and push-rod and valve-stem contact points are pressure lubricated.

Scavenging. There are three basic methods of supplying low-pressure air for scavenging. In *crankcase scavenging*, the crankcase and underside of the piston act as an air compressor. In a somewhat similar scheme, *power-piston scavenging*, a separate chamber is connected to the space under the piston and separated from the crankcase in such a way that piston downstroke compresses air drawn into the chamber on the upstroke. Scavenging air is, however, most commonly provided by a pump or blower, either driven directly from the engine or by an independent source of power.

Crankcase Scavenging. In crankcase-scavenging engines, partitions between cylinders divide crankcase into separate compartments. As shown in Fig. 6, the slight vacuum created by piston upstroke draws air in through filters, and valves in partition walls. Downstroke of piston compresses air slightly. Near end of downstroke, piston uncovers exhaust ports and then scavenging-air ports. Air from crankcase flows into cylinder, displacing burned gas and charging cylinder.

Ports, Valves. Engines scavenged with air from a pump or blower may be classified according to the way air enters the cylinder and exhaust leaves. The commonest arrangement is *port scavenging;* air enters and gas leaves by ports alternately covered and exposed by the piston. In Fig. 5, ports are at same level and uncovered simultaneously. Automatic air valves keep exhaust gas from flowing out through the air ports until cylinder pressure falls below air pressure. Then air valves open and scavenging air flows in to expel burned gas. Air valves remain open while piston moves to bottom center, reverses travel and moves upward, until cylinder pressure again exceeds that in air manifold. Shape of ports directs flow of scavenging air in a loop, as shown.

In a *valve-scavenged* engine, Fig. 7, blower forces air into manifold and into cylinder when piston uncovers the ports, which are arranged around the entire cylinder periphery. Scavenging air flows upward and out through the exhaust valves. This is known as a *uniflow* system.

Scavenging Pumps. Reciprocating pumps form a common means of supplying scavenging air. In one design, Fig. 8, pump cylinders are at right angles to power cylinders, with pistons driven from the same crankshaft. Pumps may be single or double acting; one scavenging cylinder usually supplies two or more power cylinders.

More frequently, a vertical pump, Fig. 9, is mounted at one end of the engine and driven from an extension of the crankshaft. These are usually double-acting. To save space, two pistons may be used, one above the other on the same rod. Valves are usually of the automatic ring or feather type.

Scavenging Blowers. The positive-displacement blower finds wide use as a device for supplying scavenging air. Such blowers consist of two closely fitted rotors carrying two or three lobes, Fig. 10, 11. Meshing action of the rotors transports air to a region of higher pressure where it is compressed by back-flow effect. The two-lobed impeller gives maximum capacity from minimum blower size and weight and with lowest power consumption. More than two lobes, either of straight or spiral design, are used where a different pulsation frequency is desired or where it is necessary to meet a noise limitation with little or no muffling.

The familiar centrifugal blower also finds use in scavenging. Because such units operate best at relatively high speeds (upwards of 4000-5000 rpm) they are usually driven from a separate motor or turbine instead of from the engine, which is common practice with moderate-speed positive-displacement blowers.

Supercharging. Supercharging should not be confused with scavenging, although in 2-cycle engines it may be hard to tell where one ends and the other begins. The purpose of supercharging is to cram more air into the cylinder so more fuel can be burned and engine output boosted without increase in cylinder size. This is accomplished by forcing air into the cylinder under pressure substantially above atmospheric (up to 10 psi or more in some cases). In this country, supercharging has been applied only to 4-cycle engines; 2-cycle engines have been successfully supercharged in Europe (see POWER, June 1946, pp 68-70).

Supercharged engines usually show somewhat better fuel economy than unsupercharged units. Increase in output depends on a variety of factors; capacity boosts from 30 to 80% have been reported and 40% may be taken as a conservative figure. Superchargers may be added to existing engines and a number of users report that capacity gained in this way was substantially less expensive than installation of additional engines.

Because air at high altitudes is less dense, a given cylinder full of air contains fewer pounds at high altitude than low. This means less fuel can be burned and engine capacity suffers. Superchargers may be used to overcome this loss of capacity.

Engine Changes. Application of supercharging to an engine involves some small changes. It is customary, for example, to increase clearance volume, thus reducing compression ratio and keeping maximum pressure down near the unsupercharged condition. This avoids unduly increasing bearing loads and stresses in the engine.

In the normal 4-cycle engine, valve *overlap* is about 30-40 deg. This means that inlet valve opens before top center and exhaust valve closes after. During this period when both valves are open, air blows through the cylinder from inlet manifold to exhaust, scavenging burned gas that would otherwise be trapped in the clearance volume, valve pockets, etc. It also provides some cooling effect, particularly on exhaust valves. Longer valve overlap is generally beneficial but requires more air and at high supercharge pressures this may mean excessive power consumption. Designer thus must balance gains against losses. Overlaps in the neighborhood of 130-160 deg are common in supercharged engines.

Because the basic purpose of supercharging is to increase the air charge so more fuel may be burned, rate of fuel injection must be increased. This may mean larger fuel-pump plungers.

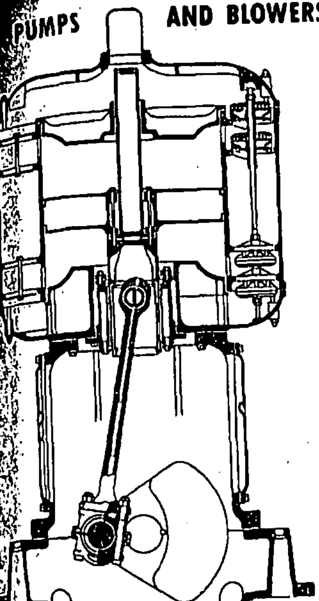
Turbocharging. The energy in hot exhaust gas from a diesel can be recovered in a gas turbine to drive a centrifugal blower supplying air at supercharging pressure. Usually turbine and blower rotors are mounted on a common shaft in a single casing, Fig. 13. Such a unit is called a turbocharger.

In the Buchi turbocharging system, valve timing, exhaust manifolding and turbine design are coordinated to create timed pressure pulsations. Engines of four cylinders and over employ a multiple exhaust manifold arrangement, Fig. 14, to permit complete scavenging of one cylinder before exhaust valve opens on another. No controls are needed; speed, air quantity and charging pressure follow engine load and speed changes.

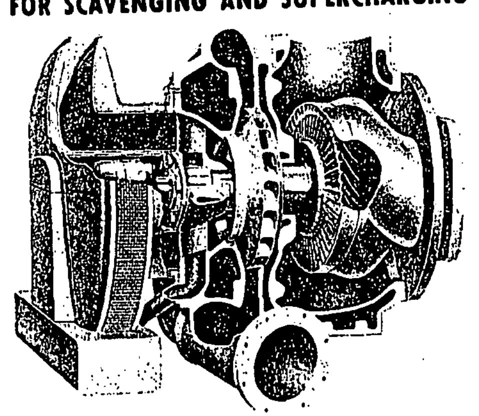
Engine-Driven Chargers. Supercharging blowers can be driven from the engine or, for that matter, from a separate power source. Positive-displacement blowers are widely used; centrifugals may be used also. The positive-displacement type, Fig. 12, finds favor in applications where full torque over a wide speed range is required.

Intercooling. Insertion of an air cooler between supercharger and engine reduces manifold temperature. This increases air density and thus gives greater weight of air per unit volume, increasing supercharging effect.

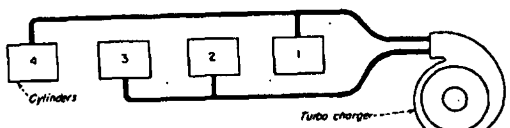
PUMPS AND BLOWERS FOR SCAVENGING AND SUPERCHARGING



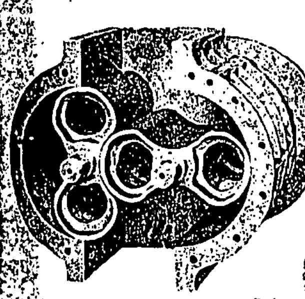
9 Reciprocating pump for supplying scavenging air is usually mounted at one end of engine frame and driven from crankshaft extension. The cylinder is double-acting. Some have two pistons



13 Cutaway view of turbocharger shows exhaust-gas-turbine blading at right; centrifugal charging compressor at center; air intake, left

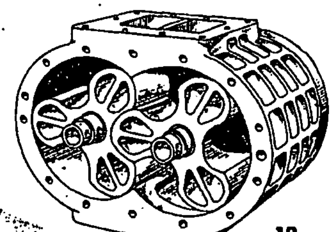


14 The Buchi system of turbocharging employs a divided exhaust manifold to permit complete scavenging of one cylinder before the exhaust valve opens on another. An engine firing 1-2-4-3 is connected as above so no two cylinders exhaust consecutively into one manifold



10 Positive-displacement blowers find wide use in supplying scavenging air. They operate with little pressure pulsation, volume of air is proportional to speed, power need drops as speed drops, and output is not affected by change in atmospheric conditions. Working efficiently at from one to three times engine speed, positive-displacement blowers are usually gear or chain driven from engine

11 Three-lobe impellers, straight or spiral, (below) may be used to give different frequency of pulsation or to meet noise limit with no muffler or little muffling



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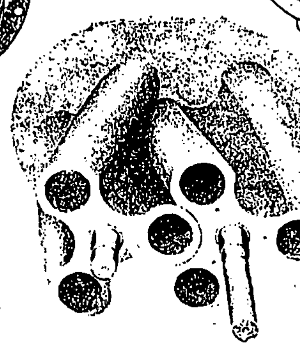

12 Positive - displacement blower, with 3-lobed, straight impellers, used as supercharger. Driven from engine by chain, V-belt or gears, supercharger of this type proportions air supply to engine speed, making it particularly suited to automotive and mobile applications with variable-speed operation