CHAPTER 19

TURBOCHARGING AND SUPERCHARGING

OBJECTIVES

After studying Chapter 19, the reader will be able to:

1. Prepare for ASE Engine Performance (A8) certification test content area "C" (Fuel, Air Induction, and Exhaust Systems Diagnosis and Repair).
2. Explain the difference between a turbocharger and a supercharger.
3. Describe how the boost levels are controlled.
4. Discuss maintenance procedures for turbochargers and superchargers.

KEY TERMS

Bar (p. 326)
Boost (p. 326)
Bypass Valve (p. 328)
Compressor Bypass Valve (CBV) (p. 332)
Dry System (p. 334)
Dump Valve (p. 332)
Intercooler (p. 330)
Naturally (normally) Aspirated (p. 326)
Nitrous Oxide (p. 333)
Positive Displacement (p. 327)
Power Adder (p. 333)
Relief Valve (p. 332)
Roots-Type Supercharger (p. 327)
Supercharger (p. 326)
Turbo Lag (p. 330)
Turbocharger (p. 328)
Vent Valve (p. 332)
Volumetric Efficiency (p. 325)
Wastegate (p. 331)
Wet System (p. 334)

AIRFLOW REQUIREMENTS

Naturally aspirated engines with throttle bodies rely on atmospheric pressure to push an air–fuel mixture into the combustion chamber vacuum created by the downstroke of a piston. The mixture is then compressed before ignition to increase the force of the burning, expanding gases. The greater the mixture compression, the greater the power resulting from combustion.

All gasoline automobile engines share certain air–fuel requirements. For example, a four-stroke engine can take in only so much air, and how much fuel it consumes depends on how much air it takes in. Engineers calculate engine airflow requirements using these three factors:

- Engine displacement
- Engine revolutions per minute (RPM)
- Volumetric efficiency

Volumetric Efficiency

Volumetric efficiency is a comparison of the actual volume of air–fuel mixture drawn into an engine to the theoretical maximum volume that could be drawn in. Volumetric efficiency is expressed as a percentage, and changes with engine speed. For example, an engine might have 75% volumetric efficiency at 1000 RPM. The same engine might be rated at 85% at 2000 RPM and 60% at 3000 RPM.

If the engine takes in the airflow volume slowly, a cylinder might fill to capacity. It takes a definite amount of time for the airflow to pass through all the curves of the intake manifold and valve port. Therefore, volumetric efficiency decreases as engine speed increases. At high speed, it may drop to as low as 50%.

The average street engine never reaches 100% volumetric efficiency. With a street engine, the volumetric efficiency is about 75% at maximum speed, or 80% at the torque peak. A high-performance street engine is about 85% efficient, or a bit more efficient at peak torque. A race engine usually has 95% or better volumetric efficiency. These figures apply only to naturally aspirated engines, however, and turbocharged and supercharged engines easily achieve more than 100% volumetric efficiency. Many vehicles are equipped with a supercharger or a turbocharger to increase power. See Figures 19-1 and 19-2.

Engine Compression

Higher compression increases the thermal efficiency of the engine because it raises compression temperatures, resulting in hotter, more complete combustion. However, a higher compression can cause an increase in NO_X emissions and would require the use of high-octane gasoline with effective antiknock additives.

FIGURE 19-1 A supercharger on a Ford V-8.

FIGURE 19-2 A turbocharger on a Toyota engine.

SUPERCHARGING PRINCIPLES

The amount of force an air–fuel charge produces when it is ignited is largely a function of the charge density. Density is the mass of a substance in a given amount of space. See Figure 19-3.

The greater the density of an air–fuel charge forced into a cylinder, the greater the force it produces when ignited, and the greater the engine power.

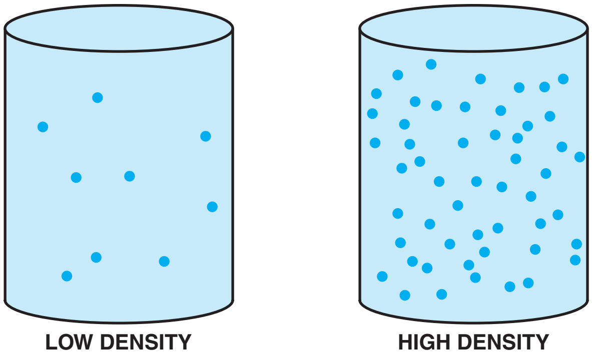

FIGURE 19-3 The more air and fuel that can be packed in a cylinder, the greater the density of the air–fuel charge.

An engine that uses atmospheric pressure for intake is called a **naturally (normally) aspirated** engine. A better way to increase air density in the cylinder is to use a pump.

When air is pumped into the cylinder, the combustion chamber receives an increase of air pressure known as **boost** and is measured in pounds per square inch (PSI), atmospheres (ATM), or **bar.** While boost pressure increases air density, friction heats air in motion and causes an increase in temperature. This increase in temperature works in the opposite direction, decreasing air density. Because of these and other variables, an increase in pressure does not always result in greater air density.

Another way to achieve an increase in mixture compression is called **supercharging.** This method uses a pump to pack a denser air–fuel charge into the cylinders. Since the density of the air–fuel charge is greater, so is its weight—and power is directly related to the weight of an air–fuel charge consumed within a given time period. The result is similar to that of a high-compression ratio, but the effect can be controlled during idle and deceleration to avoid high emissions.

Air is drawn into a naturally aspirated engine by atmospheric pressure forcing it into the low-pressure area of the intake manifold. The low pressure or vacuum in the manifold results from the reciprocating motion of the pistons. When a piston moves downward during its intake stroke, it creates an empty space, or vacuum, in the cylinder. Although atmospheric pressure pushes air to fill up as much of this empty space as possible, it has a difficult path to travel. The air must pass through the air filter, the throttle body, the manifold, and the intake port before entering the cylinder. Bends and restrictions in this pathway limit the amount of air reaching the cylinder before the intake valve closes; therefore, the volumetric efficiency is less than 100%.

Pumping air into the intake system under pressure forces it through the bends and restrictions at a greater speed than it would travel under normal atmospheric pressure, allowing more air to enter the intake port before it closes. By increasing the airflow into the intake, more fuel can be mixed with the air while still maintaining the same air–fuel ratio. The denser the air–fuel charge entering the engine during its intake stroke, the greater the potential energy released during combustion. In addition to the increased power resulting from combustion, there are several other advantages of supercharging an engine including:

- It increases the air–fuel charge density to provide high-compression pressure when power is required, but allows the engine to run on lower pressures when additional power is not required.
- The pumped air pushes the remaining exhaust from the combustion chamber during intake and exhaust valve overlap.
- The forced airflow and removal of hot exhaust gases lowers the temperature of the cylinder head, pistons, and valves, and helps extend the life of the engine.

A supercharger pressurizes air to greater than atmospheric pressure. The pressurization above atmospheric pressure, or boost, can be measured in the same way as atmospheric pressure. Atmospheric pressure drops as altitude increases, but boost pressure remains the same. If a supercharger develops 12 PSI (83 kPa) boost at sea level, it will develop the same amount at a 5,000-foot altitude because boost pressure is measured inside the intake manifold. See Figure 19-4.

Boost and Compression Ratios

Boost increases the amount of air drawn into the cylinder during the intake stroke. This extra air causes the effective compression ratio to be greater than the mechanical compression ratio designed into the engine. The higher the boost pressure, the greater the compression ratio. See the following table for an example of how much the effective compression ratio is increased compared to the boost pressure.

SUPERCHARGERS

A supercharger is an engine-driven air pump that supplies more than the normal amount of air into the intake manifold and boosts engine torque and power. A supercharger provides an instantaneous increase in power without the delay or lag often associated with turbochargers. However, a supercharger, because it is driven by the engine, does require horsepower to operate and is not as efficient as a turbocharger.

In basic concept, a supercharger is nothing more than an air pump mechanically driven by the engine itself. Gears, shafts, chains, or belts from the crankshaft can be used to turn the pump. This means that the air pump or supercharger pumps air in direct relation to engine speed.

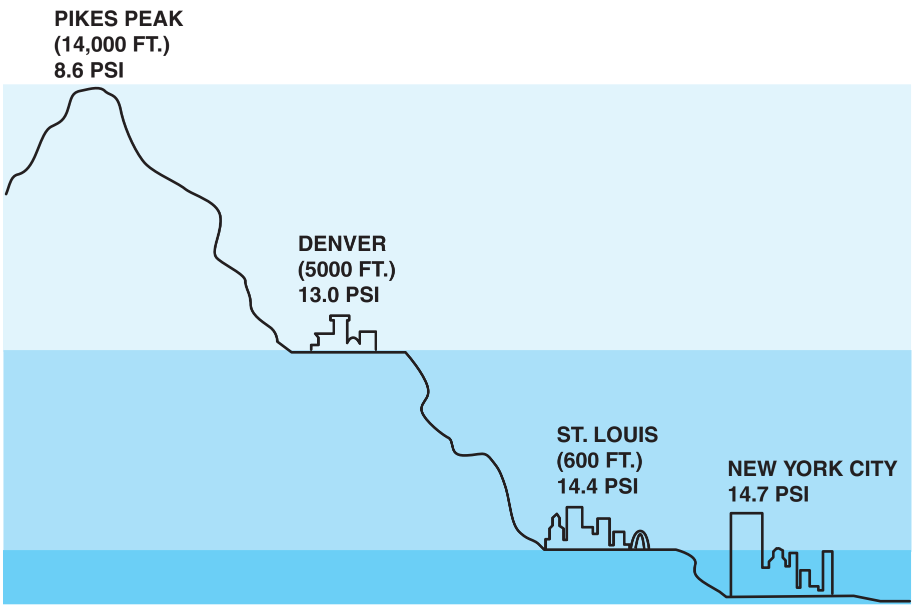

FIGURE 19-4 Atmospheric pressure decreases with increases in altitude.

Final Compression Ratio Chart at Various Boost Levels

Blower Boost (PSI)

Comp Ratio	2	4	6	8	10	12	14	16	18	20
6.5	7.4	8.3	9.2	10	10.9	11.8	12.7	13.6	14.5	15.3
7	8	8.9	9.9	10.8	11.8	12.7	13.6	14.5	15.3	16.2
7.5	8.5	9.5	10.6	11.6	12.6	13.6	14.6	15.7	16.7	17.8
8	9.1	10.2	11.3	12.4	13.4	14.5	15.6	16.7	17.8	18.9
8.5	9.7	10.8	12	13.1	14.3	15.4	16.6	17.8	18.9	19.8
9	10.2	11.4	12.7	13.9	15.1	16.3	17.6	18.8	20	21.2
9.5	10.8	12.1	13.4	14.7	16	17.3	18.5	19.8	21.1	22.4
10	11.4	12.7	14.1	15.4	16.8	18.2	19.5	20.9	22.2	23.6

There are two general types of superchargers:

- **Roots-type supercharger.** Named for Philander and Francis Roots, two brothers from Connersville, Indiana, who patented the design in 1860 as a type of water pump to be used in mines. Later it was used to move air and is used today on two-stroke cycle Detroit diesel engines and other supercharged engines. The **roots-type supercharger** is called a **positive displacement** design because all of the air that enters is forced through the unit. Examples of a roots-type supercharger include the GMC 6-71 (used originally on GMC diesel engines that had six cylinders each with 71 cu. in.) and Eaton used on supercharged 3800 V-6 General Motors engines. See Figure 19-5.
- **Centrifugal supercharger.** A centrifugal supercharger is similar to a turbocharger but is mechanically driven by the engine instead of being powered by the hot exhaust gases. A centrifugal supercharger is not a positive displacement pump and all of the air that enters is not forced through the unit. Air enters a centrifugal supercharger housing in the center and exits at the outer edges of the compressor wheels at a much higher speed due to centrifugal force. The speed of the blades has to be higher than engine speed

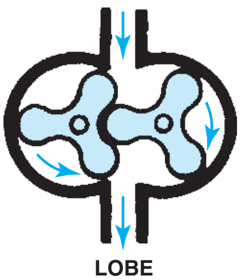

FIGURE 19-5 A roots-type supercharger uses two lobes to force the air around the outside of the housing into the intake manifold.

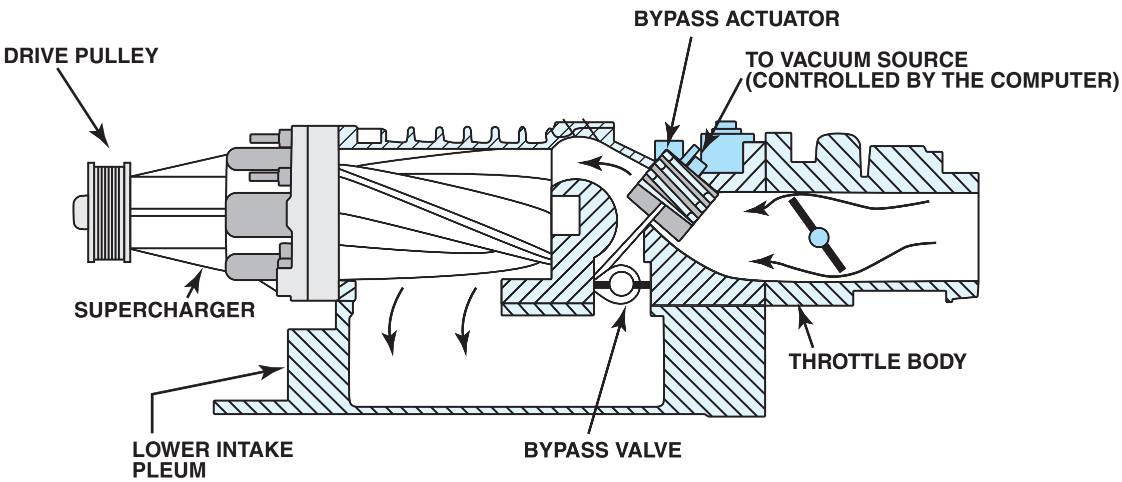

FIGURE 19-6 The bypass actuator opens the bypass valve to control boost pressure.

so a smaller pulley is used on the supercharger and the crankshaft overdrives the impeller through an internal gear box achieving about seven times the speed of the engine. Examples of centrifugal superchargers include Vortech and Paxton.

Supercharger Boost Control

Many factory-installed superchargers are equipped with a **bypass valve** that allows intake air to flow directly into the intake manifold bypassing the supercharger. The computer controls the bypass valve actuator. See Figure 19-6.

The airflow is directed around the supercharger whenever any of the following conditions occur:

- The boost pressure, as measured by the MAP sensor, indicates that the intake manifold pressure is reaching the predetermined boost level.
- During deceleration.
- Whenever reverse gear is selected.

Supercharger Service

Superchargers are usually lubricated with synthetic engine oil inside the unit. This oil level should be checked and replaced as specified by the vehicle or supercharger manufacturer. The drive belt should also be inspected and replaced as necessary.

TURBOCHARGERS

The major disadvantage of a supercharger is its reliance on engine power to drive the unit. In some installations, as much as 20% of the engine's power is used by a mechanical supercharger. However, by connecting a centrifugal supercharger to a turbine drive wheel and installing it in the exhaust path, the lost engine horsepower is regained to perform other work and the combustion heat energy lost in the engine exhaust (as much as 40% to 50%) can be harnessed to do useful work. This is the concept of a **turbocharger.**

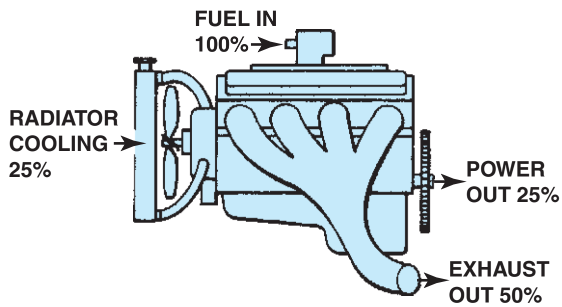

FIGURE 19-7 A turbocharger uses some of the heat energy that would normally be wasted.

The turbocharger's main advantage over a mechanically driven supercharger is that the turbocharger does not drain power from the engine. In a naturally aspirated engine, about half of the heat energy contained in the fuel goes out the exhaust system. See Figure 19-7. Another 25% is lost through radiator cooling. Only about 25% is actually converted to mechanical power. A mechanically driven pump uses some of this mechanical output, but a turbocharger gets its energy from the exhaust gases, converting more of the fuel's heat energy into mechanical energy.

A turbocharger turbine looks much like a typical centrifugal pump used for supercharging. See Figure 19-8. Hot exhaust gases flow from the combustion chamber to the turbine wheel. The gases are heated and expanded as they leave the engine. It is not the speed of force of the exhaust gases that forces the turbine wheel to turn, as is commonly

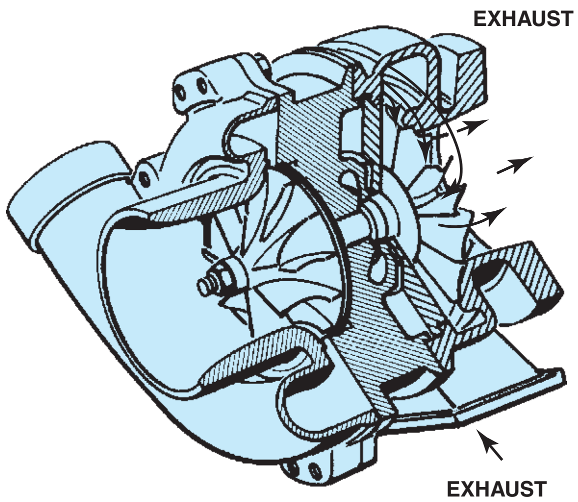

FIGURE 19-8 A turbine wheel is turned by the expanding exhaust gases.

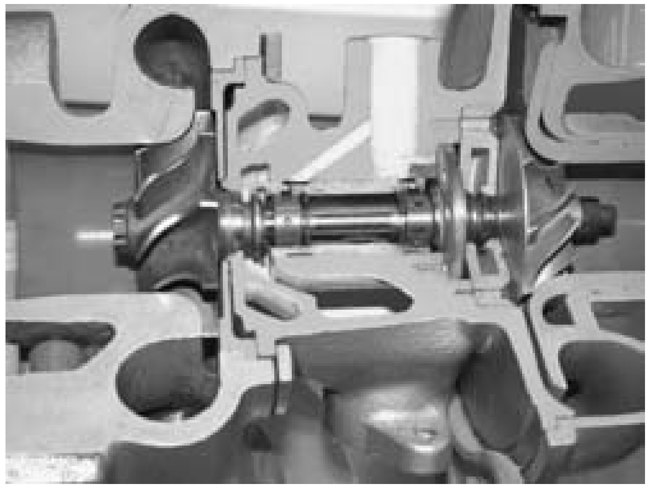

FIGURE 19-9 The exhaust drives the turbine wheel on the left, which is connected to the impeller wheel on the right through a shaft. The bushings that support the shaft are lubricated with engine oil under pressure.

thought, but the expansion of hot gases against the turbine wheel's blades.

Turbocharger Design and Operation

A turbocharger consists of two chambers connected by a center housing. The two chambers contain a turbine wheel and a compressor wheel connected by a shaft which passes through the center housing.

To take full advantage of the exhaust heat which provides the rotating force, a turbocharger must be positioned as close as possible to the exhaust manifold. This allows the hot exhaust to pass directly into the unit with a minimum of heat loss. As exhaust gas enters the turbocharger, it rotates the turbine blades. The turbine wheel and compressor wheel are on the same shaft so that they turn at the same speed. Rotation of the compressor wheel draws air in through a central inlet and centrifugal force pumps it through an outlet at the edge of the housing. A pair of bearings in the center housing support the turbine and compressor wheel shaft, and are lubricated by engine oil. See Figure 19-9.

Both the turbine and compressor wheels must operate with extremely close clearances to minimize possible leakage around their blades. Any leakage around the turbine blades causes a dissipation of the heat energy required for compressor rotation. Leakage around the compressor blades prevents the turbocharger from developing its full boost pressure.

When the engine is started and runs at low speed, both exhaust heat and pressure are low and the turbine runs at a low speed (approximately 1000 RPM). Because the compressor does not turn fast enough to develop boost pressure, air simply passes through it and the engine works like any naturally aspirated engine. As the engine runs faster or load increases, both exhaust heat and flow increases, causing the turbine and compressor wheels to rotate faster. Since there is no brake and very little rotating resistance on the turbocharger shaft, the turbine and compressor wheels accelerate as the exhaust heat energy increases. When an engine is running at full power, the typical turbocharger rotates at speeds between 100,000 and 150,000 RPM.

Engine deceleration from full power to idle requires only a second or two because of its internal friction, pumping resistance, and drivetrain load. The turbocharger, however, has no such load on its shaft, and is already turning many times faster than the engine at top speed. As a result, it can take as much as a minute or more after the engine has returned to idle speed before the turbocharger also has returned to idle. If the engine is decelerated to idle and then shut off immediately, engine lubrication stops flowing to the center housing bearings while the turbocharger is still spinning at thousands of RPM. The oil in the center housing is then subjected to extreme heat and can gradually "coke" or oxidize. The coked oil can clog passages and will reduce the life of the turbocharger.

The high rotating speeds and extremely close clearances of the turbine and compressor wheels in their housings require equally critical bearing clearances. The bearings must keep radial clearances of 0.003 to 0.006 inch (0.08 to 0.15 mm). Axial clearance (end play) must be maintained at 0.001 to 0.003 inch (0.025 to 0.08 mm). If properly maintained, the turbocharger also is a trouble-free device. However, to prevent problems, the following conditions must be met:

- The turbocharger bearings must be constantly lubricated with clean engine oil—turbocharged engines should have regular oil changes at half the time or mileage intervals specified for nonturbocharged engines.

- Dirt particles and other contamination must be kept out of the intake and exhaust housings.
- Whenever a basic engine bearing (crankshaft or camshaft) has been damaged, the turbocharger must be flushed with clean engine oil after the bearing has been replaced.
- If the turbocharger is damaged, the engine oil must be drained and flushed and the oil filter replaced as part of the repair procedure.

Late-model turbochargers all have liquid-cooled center bearings to prevent heat damage. In a liquid-cooled turbocharger, engine coolant is circulated through passages cast in the center housing to draw off the excess heat. This allows the bearings to run cooler and minimize the probability of oil coking when the engine is shut down.

Turbocharger Size and Response Time

A time lag occurs between an increase in engine speed and the increase in the speed of the turbocharger. This delay between acceleration and turbo boost is called **turbo lag.** Like any material, moving exhaust gas has inertia. Inertia also is present in the turbine and compressor wheels, as well as the intake airflow. Unlike a supercharger, the turbocharger cannot supply an adequate amount of boost at low speed.

Turbocharger response time is directly related to the size of the turbine and compressor wheels. Small wheels accelerate rapidly; large wheels accelerate slowly. While small wheels would seem to have an advantage over larger ones, they may not have enough airflow capacity for an engine. To minimize turbo lag, the intake and exhaust breathing capacities of an engine must be matched to the exhaust and intake airflow capabilities of the turbocharger.

BOOST CONTROL

Both supercharged and turbocharged systems are designed to provide a pressure greater than atmospheric pressure in the intake manifold. This increased pressure forces additional amounts of air into the combustion chamber over what would normally be forced in by atmospheric pressure. This increased charge increases engine power. The amount of "boost" (or pressure in the intake manifold) is measured in pounds per square inch (PSI), in inches of mercury (in. Hg), in bars, or in atmospheres. The following values will vary due to altitude and weather conditions (barometric pressure).

1 atmosphere = 14.7 PSI
1 atmosphere = 29.50 in. Hg
1 atmosphere = 1.0 bar
1 bar = 14.7 PSI

FIGURE 19-10 The unit on top of this Subaru that looks like a radiator is the intercooler, which cools the air after it has been compressed by the turbocharger.

The higher the level of boost (pressure), the greater the horsepower potential. However, other factors must be considered when increasing boost pressure:

1. As boost pressure increases, the temperature of the air also increases.
2. As the temperature of the air increases, combustion temperatures also increase, which increases the possibility of detonation.
3. Power can be increased by cooling the compressed air after it leaves the turbocharger. *The power can be increased about 1% per 10°F by which the air is cooled.* A typical cooling device is called an **intercooler** and is similar to a radiator, wherein outside air can pass through, cooling the pressurized heated air. See Figure 19-10. Some intercoolers use engine coolant to cool the hot compressed air that flows from the turbocharger to the intake.
4. As boost pressure increases, combustion temperature and pressures increase, which, if not limited, can do severe engine damage. The maximum exhaust gas temperature must be 1,550°F (840°C). Higher temperatures decrease the durability of the turbocharger *and* the engine.

Wastegate

A turbocharger uses exhaust gases to increase boost, which causes the engine to make more exhaust gases, which in turn increases the boost from the turbocharger. To prevent overboost

TECH TIP

BOOST IS THE RESULT OF RESTRICTION

The boost pressure of a turbocharger (or supercharger) is commonly measured in pounds per square inch. If a cylinder head is restricted because of small valves and ports, the turbocharger will quickly provide boost. Boost results when the air being forced into the cylinder heads cannot flow into the cylinders fast enough and "piles up" in the intake manifold, increasing boost pressure. If an engine had large valves and ports, the turbocharger could provide a much greater *amount* of air into the engine at the same boost pressure as an identical engine with smaller valves and ports. Therefore, by increasing the size of the valves, a turbocharged or supercharged engine will be capable of producing much greater power.

and severe engine damage, most turbocharger systems use a wastegate. A **wastegate** is a valve similar to a door that can open and close. The wastegate is a bypass valve at the exhaust inlet to the turbine. It allows all of the exhaust into the turbine, or it can route part of the exhaust past the turbine to the exhaust system. If the valve is closed, all of the exhaust travels to the turbocharger. When a predetermined amount of boost pressure develops in the intake manifold, the wastegate valve is opened. As the valve opens, most of the exhaust flows directly out the exhaust system, bypassing the turbocharger. With less exhaust flowing across the vanes of the turbocharger, the turbocharger decreases in speed and boost pressure is reduced. When the boost pressure drops, the wastegate valve closes to direct the exhaust over the turbocharger vanes and again allow the boost pressure to rise. Wastegate operation is a continuous process to control boost pressure.

The wastegate is the pressure control valve of a turbocharger system. The wastegate is usually controlled by the onboard computer through a boost control solenoid. See Figure 19-11.

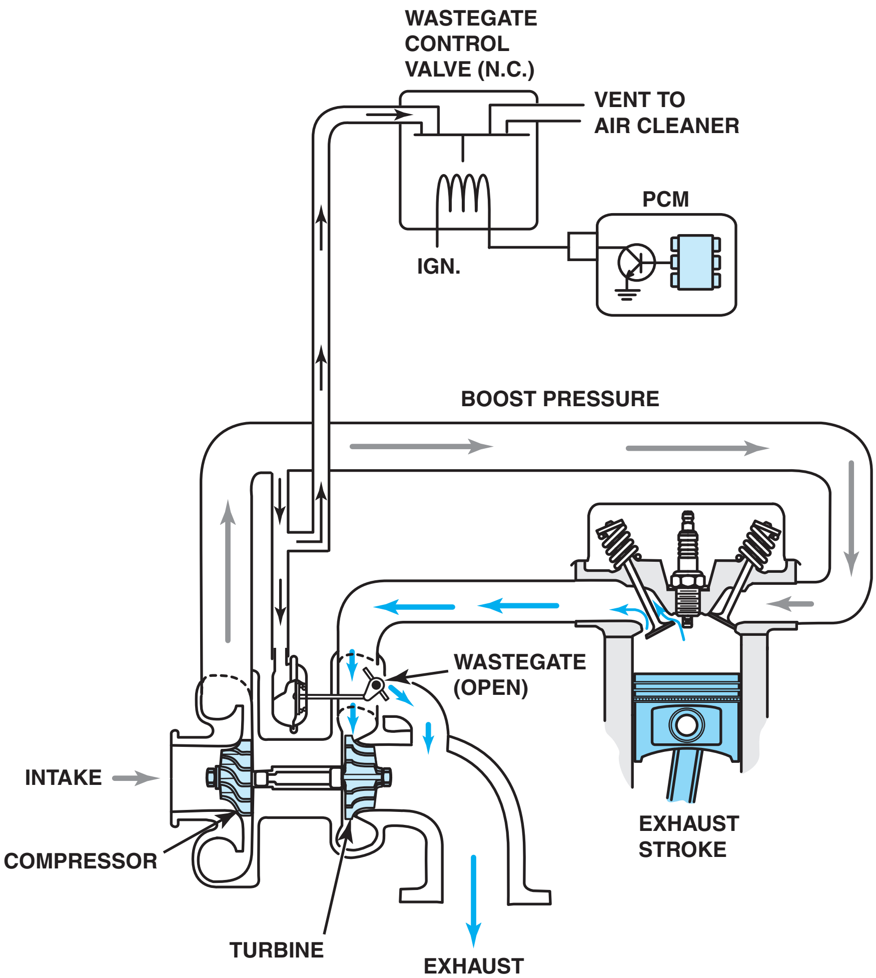

FIGURE 19-11 A wastegate is used on the first-generation Duramax diesel to control maximum boost pressure.

Relief Valves

A wastegate controls the exhaust side of the turbocharger. A relief valve controls the intake side. A **relief valve** vents pressurized air from the connecting pipe between the outlet of the turbocharger and the throttle whenever the throttle is closed during boost, such as during shifts. If the pressure is not released, the turbocharger turbine wheel will slow down, creating a lag when the throttle is opened again after a shift has been completed. There are two basic types of relief valves including:

- **Compressor bypass valve** or **CBV** This type of relief valve routes the pressurized air to the inlet side of the turbocharger for reuse and is quiet during operation.
- **Blow-off valve or BOV** This is also called a **dump valve** or **vent valve** and features an adjustable spring design that keeps the valve closed until a sudden release of the throttle. The resulting pressure increase opens the valve and vents the pressurized air directly into the atmosphere. This type of relief valve is noisy in operation and creates a whooshing sound when the valve opens. See Figure 19-12.

TECH TIP

IF ONE IS GOOD, TWO ARE BETTER

A turbocharger uses the exhaust from the engine to spin a turbine, which is connected to an impeller inside a turbocharger. This impeller then forces air into the engine under pressure higher than is normally achieved without a turbocharger. The more air that can be forced into an engine, the greater the power potential. A V-type engine has two exhaust manifolds and so two small turbochargers can be used to help force greater quantities of air into an engine, as shown in Figure 19-13.

TURBOCHARGER FAILURES

When turbochargers fail to function correctly, a drop in power is noticed. To restore proper operation, the turbocharger must be rebuilt, repaired, or replaced. It is not possible to simply remove the turbocharger, seal any openings, and still maintain decent driveability. Bearing failure is a common cause of turbocharger failure, and replacement bearings are usually only available to rebuilders. Another common turbocharger problem is excessive and continuous oil consumption resulting

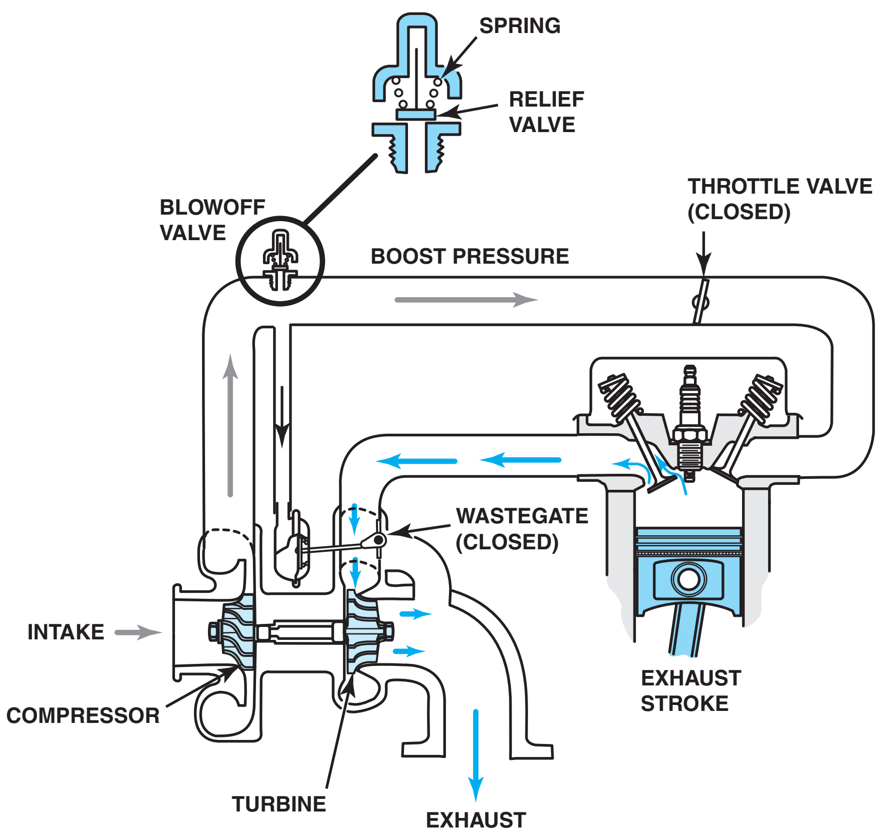

FIGURE 19-12 A blow-off valve is used in some turbocharged systems to relieve boost pressure during deceleration.

FIGURE 19-13 A dual turbocharger system installed on a small block Chevrolet V-8 engine.

in blue exhaust smoke. Turbochargers use small rings similar to piston rings on the shaft to prevent exhaust (combustion gases) from entering the central bearing. Because there are no seals to keep oil in, excessive oil consumption is usually caused by:

1. A plugged positive crankcase ventilation (PCV) system resulting in excessive crankcase pressures forcing oil into the air inlet. This failure is not related to the turbocharger, but the turbocharger is often blamed.
2. A clogged air filter, which causes a low-pressure area in the inlet, which can draw oil past the turbo shaft rings and into the intake manifold.
3. A clogged oil return (drain) line from the turbocharger to the oil pan (sump), which can cause the engine oil pressure to force oil past the turbocharger's shaft rings and into the intake *and* exhaust manifolds. Obviously, oil being forced into both the intake and exhaust would create lots of smoke.

NITROUS OXIDE (N_2O)

Principles

Nitrous oxide is a colorless and nonflammable gas. Nitrous oxide was discovered by a British chemist, Joseph Priestly (1733–1804), who also discovered oxygen. He found that nitrous oxide caused a person to be light-headed when it was breathed and soon became known as *laughing gas*. Nitrous oxide was used in dentistry during tooth extraction to reduce the pain or at least make the patient forget what occurred.

Nitrous oxide has two nitrogen atoms and one oxide atom. About 36% of the molecule weight is oxygen. Nitrous oxide is a manufactured gas because, even though both nitrogen and oxygen are present in our atmosphere, they are not combined into one molecule and require heat and a catalyst to be combined.

Engine Power Adder

A **power adder** is a device or system added to an engine such as a supercharger, turbocharger, or nitrous oxide to increase power. When nitrous oxide is injected into an engine along with gasoline, engine power is increased. The addition of N_2O supplies the needed oxygen for the extra fuel. By itself, N_2O does not burn, but rather provides the oxygen for additional fuel that is supplied along with the N_2O to produce more power.

NOTE: Nitrous oxide was used as a power adder in World War II on some fighter aircraft. Having several hundred more horsepower for a short time saved many lives.

Pressure and Temperature

It requires about 11 pounds of pressure per degree Fahrenheit to condense nitrous oxide gas into liquid nitrous oxide. For example, at 70°F it requires a pressure of about 770 PSI to condense N_2O into a liquid. To change N_2O from a liquid under pressure to a gas, all that is needed is to lower its pressure below the pressure it takes to cause it to become a liquid.

The temperature also affects the pressure of N_2O. See the following chart.

Temperature (°F/°C)	Pressure (PSI/kPa)
−30°F/−34°C	67 PSI/468 kpa
−20°F/−29°C	203 PSI/1,400 kpa
−10°F/−23°C	240 PSI/1,655 kpa
0°F/−18°C	283 PSI/1,950 kpa
10°F/−12°C	335 PSI/2,310 kpa
20°F/−7°C	387 PSI/2,668 kpa
30°F/−1°C	460 PSI/3,172 kpa
40°F/4°C	520 PSI/3,585 kpa
50°F/10°C	590 PSI/4,068 kpa
60°F/16°C	675 PSI/4,654 kpa
70°F/21°C	760 PSI/5,240 kpa
80°F/27°C	865 PSI/5,964 kpa
90°F/32°C	985 PSI/6,792 kpa
100°F/38°C	1,120 PSI/7,722 kpa

Nitrous oxide is stored in a pressurized storage container and installed at an angle so the pickup tube is in the liquid. The

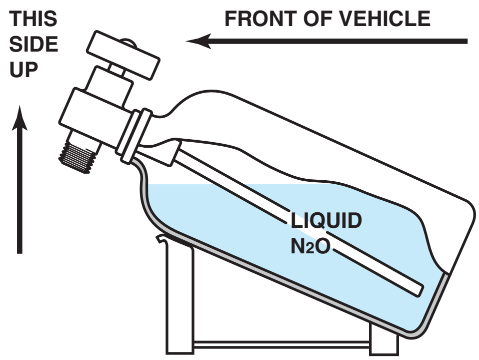

FIGURE 19-14 Nitrous bottles have to be mounted at an angle to ensure that the pickup tube is in the liquid N_2O.

front of the discharge end of the storage bottle should be toward the front of the vehicle. See Figure 19-14.

Wet and Dry Systems

There are two different types of N_2O system that depend on whether additional fuel (gasoline) is supplied at the same time as when the nitrous oxide is squirted. If additional fuel is also injected, this type of system is called a **wet system.** A wet system is identified as having both a red and a blue nozzle with the red flowing gasoline and the blue flowing nitrous oxide. In a system such as an engine using port fuel injection, only nitrous oxide needs to be injected because the PCM can be commanded to provide more fuel when the N_2O is being sprayed. As a result, the intake manifold contains only air and the injected gaseous N_2O, which is called a **dry system.**

Engine Changes Needed for N_2O

If nitrous oxide is going to be used to increase horsepower more than 50 hp, the engine must be designed and built to withstand the greater heat and pressure that will occur in the combustion chambers. For example, the following items should be considered if adding a turbocharger, supercharger, or nitrous oxide system:

- Forged pistons are best able to withstand the pressure and temperature when using nitrous oxide or an other power adder.
- Cylinder-to-wall clearance should be increased. Due to the greater amount of heat created by the extra fuel and N_2O injection, the piston temperature will be increased. While using forged pistons will help, most experts recommend using increased cylinder-to-wall clearance. Check the instructions from the nitrous oxide supplier for details and other suggested changes.

FIGURE 19-15 An electrical heating mat is installed on the bottle of nitrous oxide to increase the pressure of the gas inside.

TECH TIP

INCREASE BOTTLE PRESSURE

To increase the pressure of the nitrous oxide in a bottle, an electrical warming blanket can be used as seen in Figure 19-15. The higher the temperature, the higher the pressure and the greater amount of flow of N_2O that will occur when energized.

CAUTION: **The use of a nitrous oxide injection system can cause catastrophic engine damage. Always follow the instructions that come with the kit and be sure that all of the internal engine parts meet the standard specified to help avoid severe engine damage.**

System Installation and Calibration

Nitrous oxide systems are usually purchased as a kit with all of the needed components included. The kit also includes one or more sizes of nozzle(s), which are calibrated to control the flow of nitrous oxide into the intake manifold. Installation of a nitrous oxide kit also includes the installation of an on/off switch and a switch on or near the throttle, which is used to activate the system only at the wide-open throttle (WOT) position.

SUMMARY

1. Volumetric efficiency is a comparison of the actual volume of air–fuel mixture drawn into the engine to the theoretical maximum volume that can be drawn into the cylinder.
2. A supercharger operates from the engine by a drive belt and, while it does consume some engine power, it forces a greater amount of air into the cylinders for even more power.
3. A turbocharger uses the normally wasted heat energy of the exhaust to turn an impeller at high speed. The impeller is linked to a turbine wheel on the same shaft and is used to force air into the engine.
4. There are two types of superchargers: roots-type and centrifugal.
5. A bypass valve is used to control the boost pressure on most factory-installed superchargers.
6. An intercooler is used on many turbocharged and some supercharged engines to reduce the temperature of air entering the engine for increased power.
7. A wastegate is used on most turbocharger systems to limit and control boost pressures, as well as a relief valve, to keep the speed of the turbine wheel from slowing down during engine deceleration.
8. Nitrous oxide injection can be used as a power adder, but only with extreme caution.

REVIEW QUESTIONS

1. What are the reasons why supercharging increases engine power?
2. How does the bypass valve work on a supercharged engine?
3. What are the advantages and disadvantages of supercharging?
4. What are the advantages and disadvantages of turbocharging?
5. What turbocharger control valves are needed for proper engine operation?

CHAPTER QUIZ

1. Boost pressure is generally measured in _____.
   - **a.** in. Hg
   - **b.** PSI
   - **c.** in. H_2O
   - **d.** in. lb
2. Two types of superchargers include _____.
   - **a.** Rotary and reciprocating
   - **b.** Roots-type and centrifugal
   - **c.** Double and single acting
   - **d.** Turbine and piston
3. Which valve is used on a factory supercharger to limit boost?
   - **a.** A bypass valve
   - **b.** A wastegate
   - **c.** A blow-off valve
   - **d.** An air valve
4. How are most superchargers lubricated?
   - **a.** By engine oil under pressure through lines from the engine
   - **b.** By an internal oil reservoir
   - **c.** By greased bearings
   - **d.** No lubrication is needed because the incoming air cools the supercharger
5. How are most turbochargers lubricated?
   - **a.** By engine oil under pressure through lines from the engine
   - **b.** By an internal oil reservoir
   - **c.** By greased bearings
   - **d.** No lubrication is needed because the incoming air cools the supercharger

6. Two technicians are discussing the term "turbo lag." Technician A says that it refers to the delay between when the exhaust leaves the cylinder and when it contacts the turbine blades of the turbocharger. Technician B says that it refers to the delay in boost pressure that occurs when the throttle is first opened. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
7. What is the purpose of an intercooler?
   - **a.** To reduce the temperature of the air entering the engine
   - **b.** To cool the turbocharger
   - **c.** To cool the engine oil on a turbocharged engine
   - **d.** To cool the exhaust before it enters the turbocharger
8. Which type of relief valve used on a turbocharged engine is noisy?
   - **a.** A bypass valve
   - **b.** A BOV
   - **c.** A dump valve
   - **d.** Both b and c
9. Technician A says that a stuck-open wastegate can cause the engine to burn oil. Technician B says that a clogged PCV system can cause the engine to burn oil. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
10. What service operation is *most* important on engines equipped with a turbocharger?
    - **a.** Replacing the air filter regularly
    - **b.** Replacing the fuel filter regularly
    - **c.** Regular oil changes
    - **d.** Regular exhaust system maintenance