UNIT I SUPERCHARGING

Supercharging Basic concept

SUPERCHARGING
Definition and engine modification required. Effects on engine performance. Types of compressors - positive displacement blowers, centrifugal compressors - performance characteristic curves. Suitability for engine application. Matching of supercharger compressor and engine.

Definition:

Method of increasing the inlet air (charge) density, called supercharging, is usually employed to increase the power output of the engine.

Supplying air at a pressure higher than the pressure at which the engine naturally aspirates air from the atmosphere will increase density hence power output.

Pressure-boosting device is called 'supercharger'. Supercharger comprises of a compressor (positive displacement type or CF type).

Compressor provides a denser charge to the engine so that a greater mass of air is inducted inside the engine and more amount of fuel can be burnt. The compressor derives its power from the engine crankshaft.

Supercharging is also known as forced induction. When an engine is normally aspirated it relies on atmospheric pressure to push the air into the manifold (running under vacuum) and into the combustion chambers (cylinders) Due to internal flow restrictions along the air path, the normally aspirated cylinder is never able to completely draw in a full charge of air/fuel mixture.

Objectives of supercharging :

1. To increase the engine output without changing its weight and size. (increase in power to weight to ratio)

Supercharger: It is a device that helps in compression of additional air required for the efficient combustion of the fuel air mixture.The advantage of compressing the air is that it lets the engine stuff more air into a cylinder. At high speed and at high altitude there is a shortage of the intake air. At such times there is incomplete combustion which may lead to the loss of power. To avoid this loss, a device is installed in an automobile which increases the compression of air thus ensuring sufficient supply of air.

Effects on Engine performance:

Better mixing of air and fuel due to Increased turbulence.
• Higher temperature at the end of the compression process which helps in quick vaporization of fuel.
• The increased temperature is likely to increase the knocking tendency in SI engines and decreases the chances of knocking in CI engines.
• Supercharging system will absorb a fraction of power produced by the engine and therefore some of the gain in power output due to supercharging is lost and the mechanical efficiency is affected.

★ Thermodynamic cycle with supercharging

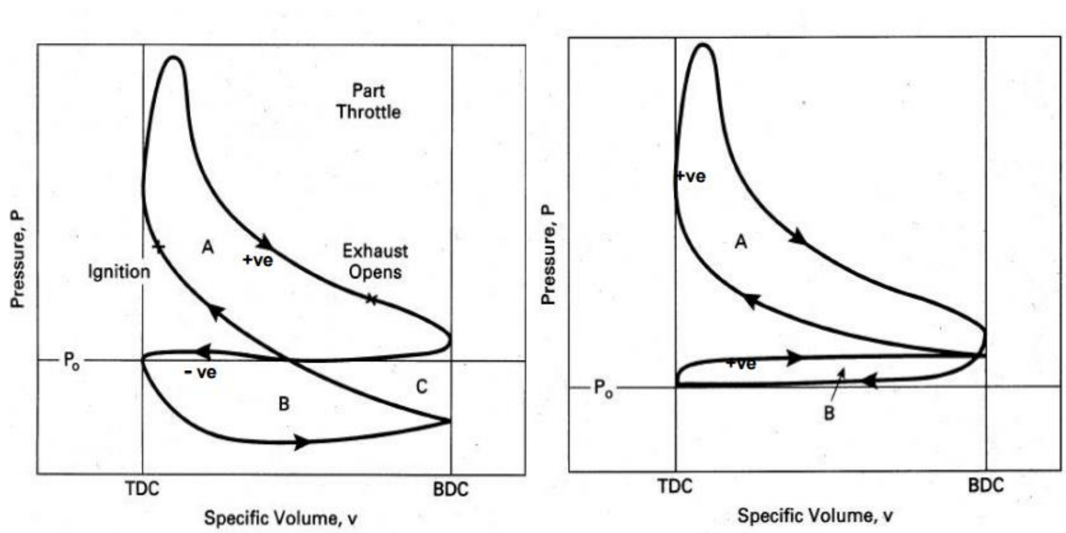


Figure. 1
a) P-V diagram of Naturally aspirated engines b) P-V diagram of Supercharged engines

Engine modification required :

Cylinder Head and Valve train Preparation

Weak valve springs or burned valves can lead to backfires. When an engine has more than 50,000 miles on it, it’s a good idea to inspect the entire valvetrain. If the valve springs require replacement, factory heavy-duty springs should be used.

For higher boost applications, consider a three-angle, “street-type” valve grind to promote better cooling. With the additional combustion temperatures normally generated in a supercharged engine, the wider valve seats will provide better cooling of the valves, and the three-angle valve grind will provide better sealing of the valves.

When any port work is being done to your cylinder heads, most of the effort should be directed to the exhaust ports. The supercharger will overcome most minor restrictions on the intake side of the cylinder head. The use of O-ring head gaskets requires receiver grooves in the heads and block milled by a competent machine shop.

Carburetor and Induction Considerations

At full throttle a blown engine can require 50 percent more air than an unblown engine and as a result needs a larger carburetor(s) in order to make maximum power and boost. If your blown engine is primarily driven on the street at moderate engine speeds (under 4,000 rpm) you won’t need a larger carburetor(s).

Typically the carburetors(s) will need to be enriched by 5 to 10 percent on the primaries and 10 to 20 percent on the secondaries. The idle mixture screws may need to be enriched by one or two turns. In either case, the carburetors need to be jetted properly to prevent a lean condition. A lean condition can lead to overheating and detonation.

For initial start-up, it's better to have a slightly rich condition to help prevent the engine from overheating. After initial start-up, check the spark plugs for proper reading (color) and adjust the carburetor(s) accordingly. You want to see a medium to dark tan color.

If you're installing a supercharger on a fuel-injected application, you may need to upgrade to larger fuel injectors and fuel rails to deliver the added fuel you may need based on BSFC (brake-specific fuel consumption). Contact your supercharger manufacturer to calculate your fuel needs or see our fuel injector post to learn more about BSFC. You should also make sure you have a good-flowing air cleaner and exhaust system to allow your supercharged engine to breath easily.

Camshaft Selection

A supercharger can overcome inadequacies in a stock cam up to about 4,500-5,000 rpm. You will typically find that performance with a blower will not be significantly enhanced below these speeds with a cam change. However for optimum performance at higher rpms, a more aggressive camshaft will provide substantial power increases.

For best performance with a blower, you should look for a cam that has higher lift and longer duration on the exhaust side. Street performance with a blown engine is usually best with a cam that is ground with a 112- to 114-degree lobe separation. With the use of an aftermarket camshaft, follow the camshaft manufacturer's recommendations for valve springs. Blower cams can typically be run "straight up." Note that a blower has tendency to lessen the rough idle of radical cams.

Ignition System Settings

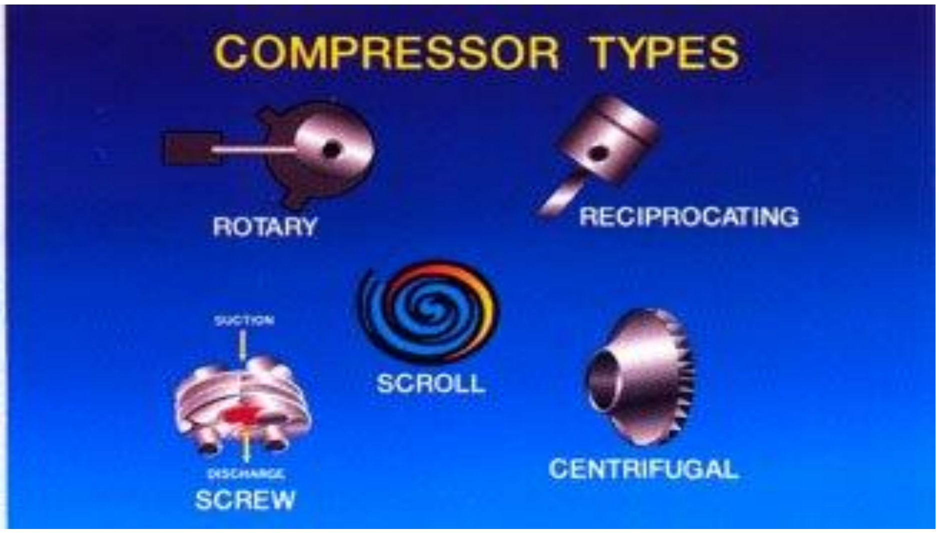
Blown engines make great power in the low-and mid-rpm range. That means most late model OEM electronic ignition systems have the capability of working well with a supercharger and will be fine if you keep your driving under 5,500 rpm.

Some distributors with computer controlled advance curve and timing may not be compatible with a supercharger because of the preset timing and sensors they require. However, any of the aftermarket high performance standard or electronic distributors should function well when properly calibrated. A quality electronic unit would be the preferred choice for best all around performance and reliability.

Set initial ignition timing at 6 to 10 degrees BTDC. The distributor advance curve should be calibrated to give a total advance of 28 to 34 degrees by 2,500 rpm. If detonation is encountered, a boost/retard system that works with manifold vacuum and pressure is recommended. It is also a good idea to run your spark plugs one or two heat ranges colder than normal with a blower to reduce the chances of detonation.

Keep in mind, these are general suggestions–there are no hard and fast rules. Bottom line is you can benefit from supercharging a stock, mild, or wild engine with the right tuning and modifications.

Types of compressor :



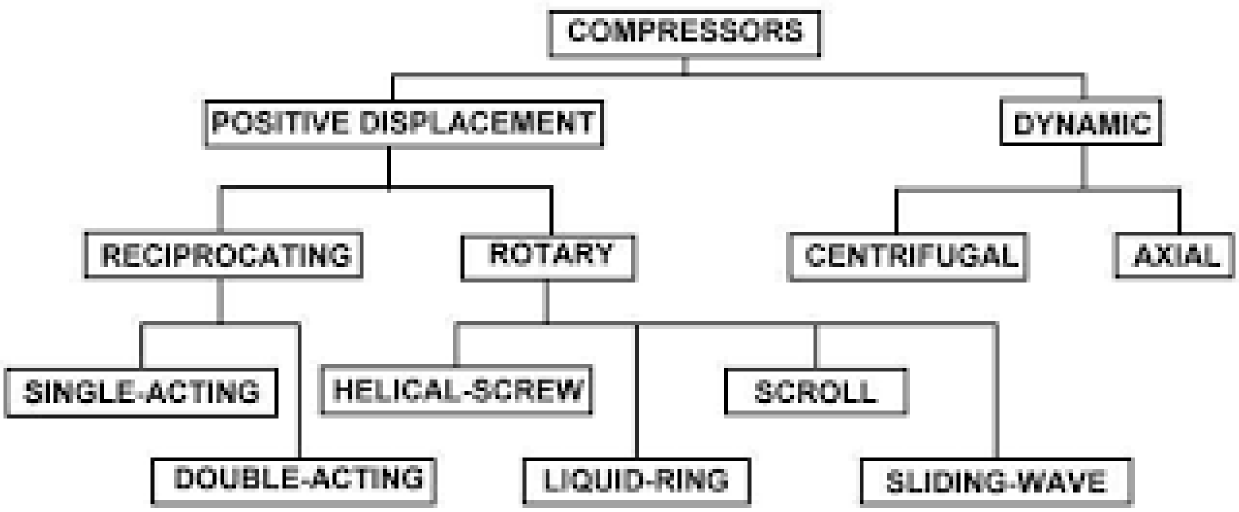
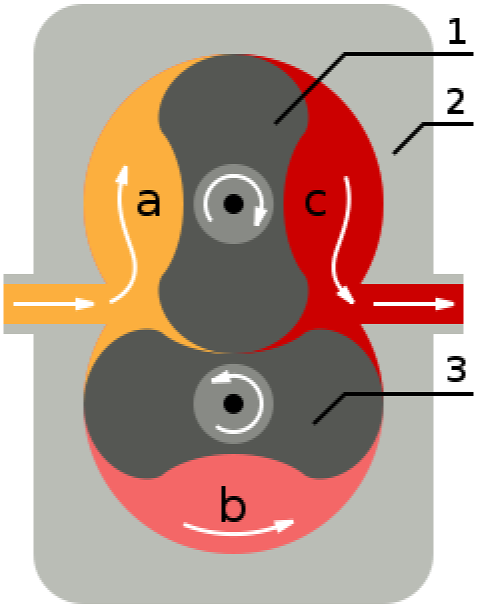


Figure 1-2, Compressor Family Tree

<u>**positive displacement blowers:**</u>


1
2
a
c
3
b

The **Roots type blower** is a positive displacement lobe pump which operates by pumping a fluid with a pair of meshing lobes not unlike a set of stretched gears. Fluid is trapped in pockets surrounding the lobes and carried from the intake side to the exhaust. The most common application of the Roots type blower has been as the induction device on two-stroke Diesel engines, such as those produced by Detroit Diesel and Electro-Motive Diesel. Roots type blowers are also used to supercharge Otto cycle engines, with the blower being driven from the engine's crankshaft via a toothed or V-belt, a roller chain or a gear train.

The Roots type blower is named after the American inventors and brothers Philander and Francis Marion Roots, founders of the Roots Blower Company of Connersville, Indiana USA, who patented the basic design in 1860 as an air pump for use in blast furnaces and other industrial applications. In 1900, Gottlieb Daimler included a Roots-style blower in a patented engine design, making the Roots-type blower the oldest of the various designs now available. Roots blowers are commonly referred to as air blowers or PD (positive displacement) blowers,[1] and can be commonly called "huffers" when used with the gasoline-burning engines in hot rod customized cars

For any given Roots blower running under given conditions, a single point will fall on the map. This point will rise with increasing boost and will move to the right with increasing blower speed. It can be seen that, at moderate speed and low boost, the efficiency can be over 90%. This is the area in which Roots blowers were originally intended to operate, and they are very good at it.

Boost is given in terms of pressure ratio, which is the ratio of absolute air pressure before the blower to the absolute air pressure after compression by the blower. If no boost is present, the pressure ratio will be 1.0 (meaning 1:1), as the outlet pressure equals the inlet pressure. 15psi boost is marked for reference (slightly above a pressure ratio of 2.0 compared to atmospheric pressure). At 15 psi (1.0 bar) boost, Roots blowers hover between 50% and 58%. Replacing a smaller blower with a larger blower moves the point to the left. In most cases, as the map shows, this will move it into higher efficiency areas on the left as the smaller blower likely will have been running fast on the right of the chart. Usually, using a larger blower and running it slower to achieve the same boost will give an increase in compressor efficiency.

The volumetric efficiency of the Roots-type blower is very good, usually staying above 90% at all but the lowest blower speeds. Because of this, even a blower running at low efficiency will still mechanically deliver the intended volume of air to the engine, but that air will be hotter. In drag racing applications where large volumes of fuel are injected with that hot air, vaporizing the fuel absorbs the heat. This functions as a kind of liquid aftercooler system and goes a long way to negating the inefficiency of the Roots design in that application.

The different types of superchargers:

Roots Superchargers

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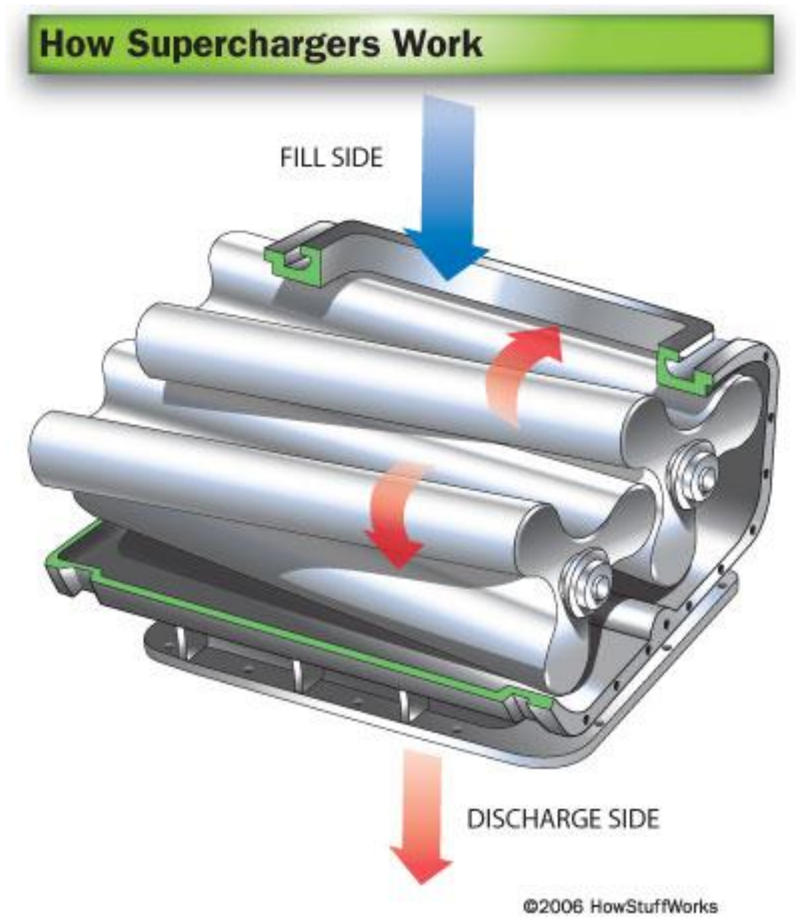
Photo courtesy HowStuffWorks Shopper

The Eaton supercharger, a modified Roots supercharger.

There are three types of superchargers: Roots, twin-screw and centrifugal. The main difference is how they move air to the intake manifold of the engine. Roots and twin-screw superchargers use different types of meshing lobes, and a centrifugal supercharger uses an impeller, which draws air in. Although all of these designs provide a boost, they differ considerably in their efficiency. Each type of supercharger is available in different sizes, depending on whether you just want to give your car a boost or compete in a race.

The Roots supercharger is the oldest design. Philander and Francis Roots patented the design in 1860 as a machine that would help ventilate mine shafts. In 1900, Gottleib Daimler included a Roots supercharger in a car engine.



Roots supercharger

As the meshing lobes spin, air trapped in the pockets between the lobes is carried between the fill side and the discharge side. Large quantities of air move into the intake manifold and "stack up" to create positive pressure. For this reason, Roots superchargers are really nothing more than air blowers, and the term "blower" is still often used to describe all superchargers.

Photo courtesy Sport Truck

A 1940s Ford pickup with a Roots supercharger.

Roots superchargers are usually large and sit on top of the engine. They are popular in muscle cars and hot rods because they stick out of the hood of the car. However, they are the least efficient supercharger for two reasons: They add more weight to the vehicle and they move air in discrete bursts instead of in a smooth and continuous flow.

Twin-screw Superchargers

Photo courtesy Superchargers Online

Twin-screw supercharger

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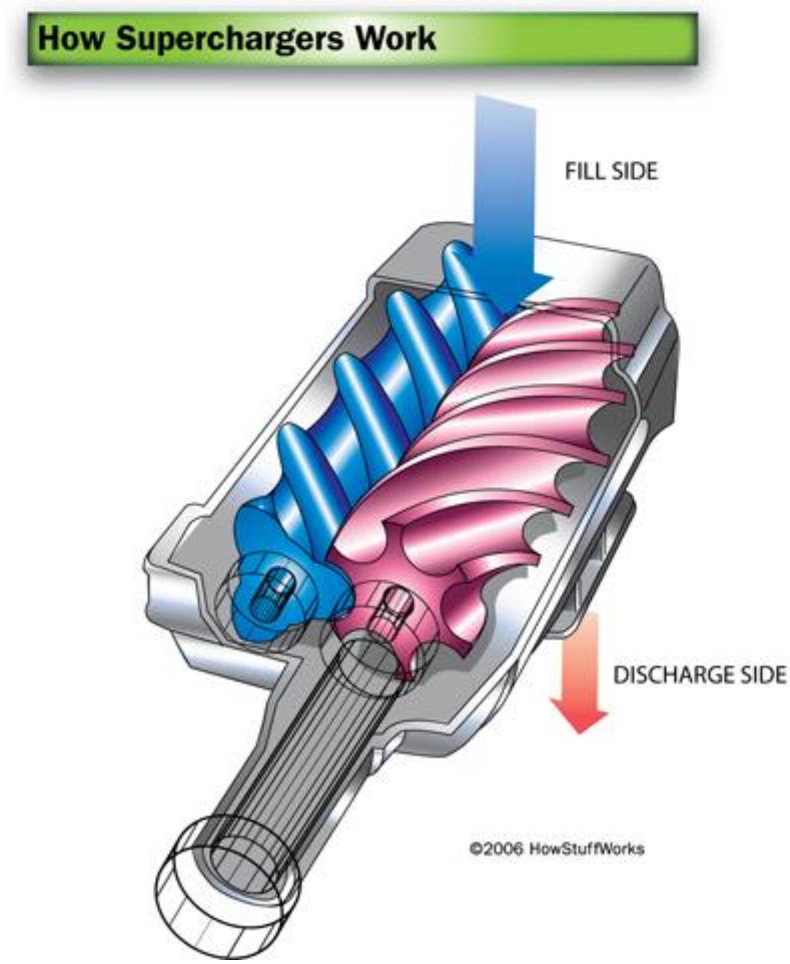
A twin-screw supercharger operates by pulling air through a pair of meshing lobes that resemble a set of worm gears. Like the Roots supercharger, the air inside a twin-screw supercharger is trapped in pockets created by the rotor lobes. But a twin-screw supercharger compresses the air inside the rotor housing. That's because the rotors have a conical taper, which means the air pockets decrease in size as air moves from the fill side to the discharge side. As the air pockets shrink, the air is squeezed into a smaller space.



Twin-screw supercharger

This makes twin-screw superchargers more efficient, but they cost more because the screw-type rotors require more precision in the manufacturing process. Some types of twin-screw superchargers sit above the engine like the Roots supercharger. They also make a lot of noise. The compressed air exiting the discharge outlet creates a whine or whistle that must be subdued with noise suppression techniques.

Centrifugal Superchargers

Photo courtesy Muscle Mustang

ProCharger D1SC centrifugal supercharger

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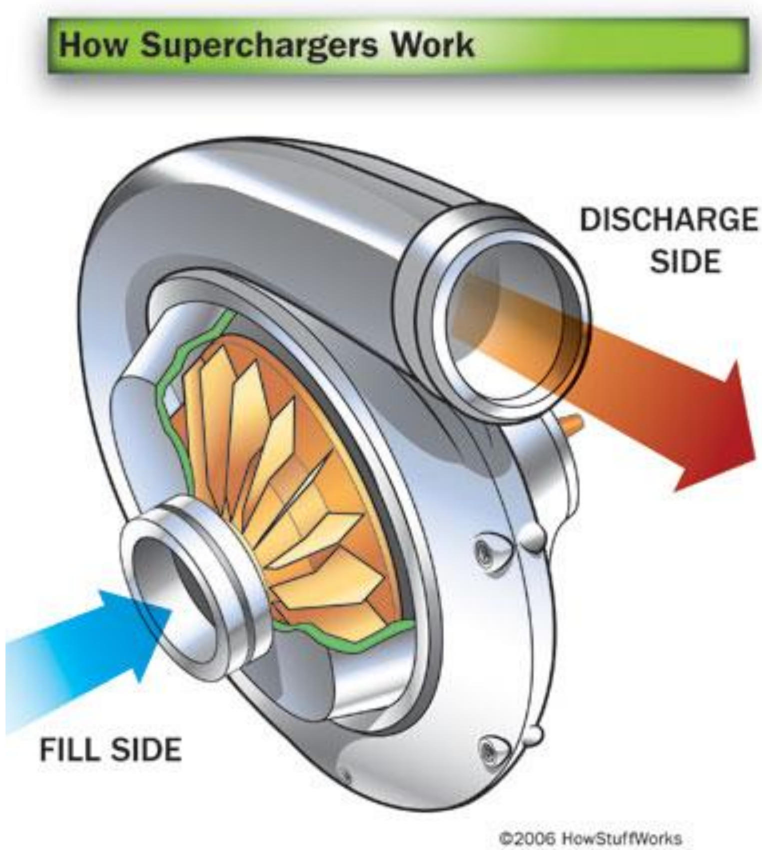
A centrifugal supercharger powers an impeller -- a device similar to a rotor -- at very high speeds to quickly draw air into a small compressor housing. Impeller speeds can reach 50,000 to 60,000 RPM. As the air is drawn in at the hub of the impeller, centrifugal force causes it to radiate outward. The air leaves the impeller at high speed, but low pressure. A diffuser -- a set of stationary vanes that surround the impeller -- converts the high-speed, low-pressure air to low-speed, high-pressure air. Air molecules slow down when they hit the vanes, which reduces the velocity of the airflow and increases pressure.



Centrifugal supercharger

Centrifugal superchargers are the most efficient and the most common of all forced induction systems. They are small, lightweight and attach to the front of the engine instead of the top. They also make a distinctive whine as the engine revs up -- a quality that may turn heads out on the street.

Photos courtesy HowStuffWorks Shopper
Both the Monte Carlo and the Mini-Cooper S are available with superchargers.

Any of these superchargers can be added to a vehicle as an after-market enhancement. Several companies offer kits that come with all of the parts necessary to install a supercharger as a do-it-yourself project. In the world of funny cars and fuel racers, such customization is an integral part of the sport. Several auto manufacturers also include superchargers in their production models.

Surging in compressor:

Surge occurs when there is no forward flow of gas through the compressor and a reversal of flow occurs. The gas that is being compressed gets pushed backward through the centrifugal compressor. When this surge (flow reversal) occurs, which can happen in milliseconds, the rotor is affected.

Surge is defined as the operating point at which centrifugal compressor peak head capability and minimum flow limits are reached. Choking: Stonewall or choke point for a centrifugal compressor occurs when the resistance to flow in the compressor discharge line drops significantly below the normal levels.

Performance characteristic curves :

Performance curve

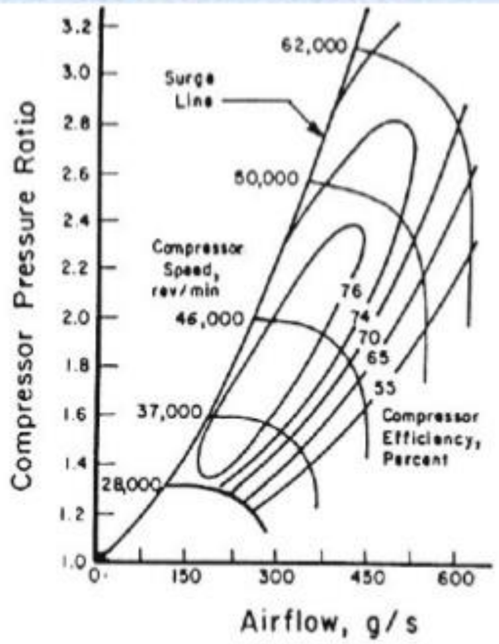


Figure 8. A compressor performance map.

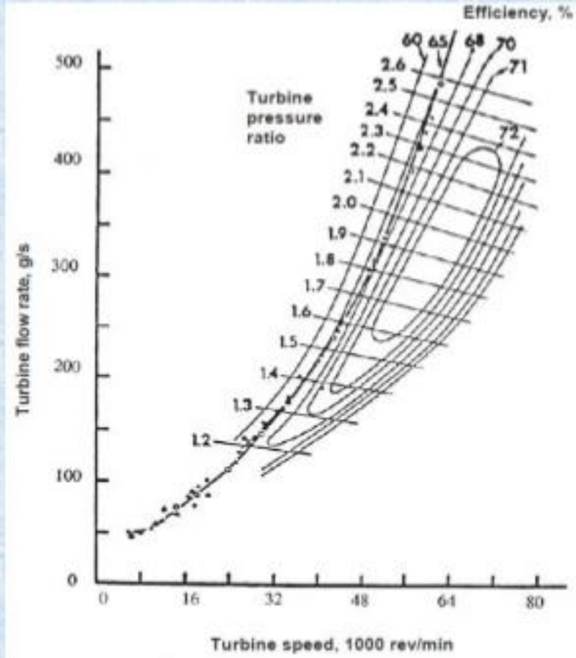
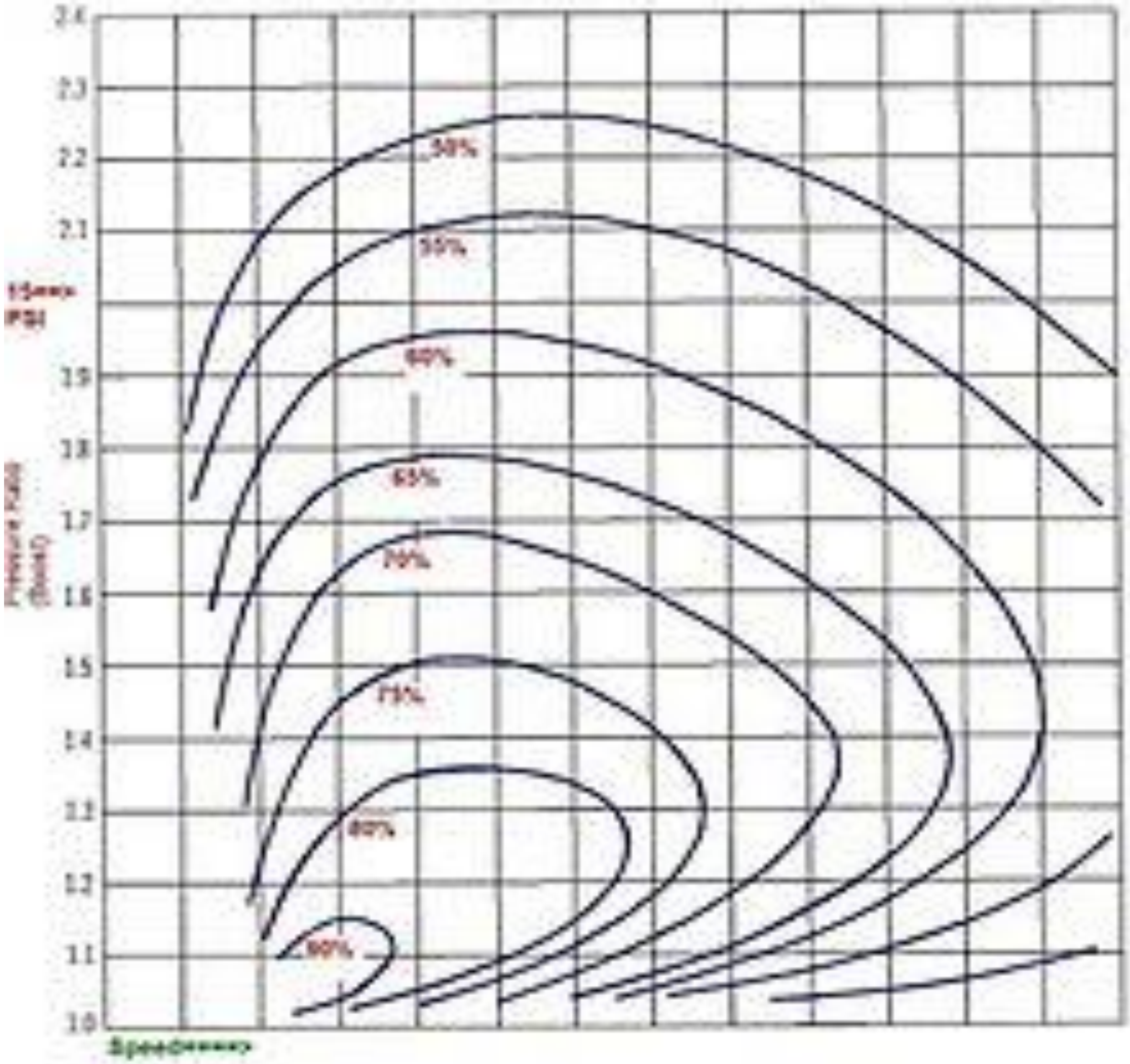


Figure 9 . A turbine performance map.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