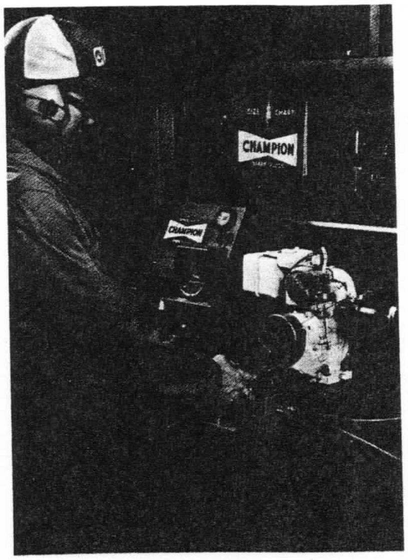

unit 12

size and performance measurement

Small engines are described and compared by a number of measurements related to size and performance. Measurements of engine size are concerned with an engine's bore, stroke displacement and compression ratio. These measurements determine how much power an engine can develop. The amount of power an engine actually develops is specified in terms of performance measurement called *horsepower*. The concept of horsepower is based upon a number of scientific principles such as force, work, power, energy and efficiency. Each of these principles is explained below.

LET'S FIND OUT: **When you finish reading and studying this unit, you should be able to:**

1. **Understand the size measurements based on bore, stroke, displacement and compression ratio.**
2. **Identify the elements of small-engine performance measurement for linear horsepower.**
3. **Recognize the elements of engine rotary horsepower measurement.**
4. **Describe the way horsepower is measured, charted and rated.**
5. **Explain the different types of efficiency ratings used with small engines.**

ENGINE SIZE MEASUREMENTS

Engines are manufactured in different sizes to meet different requirements. A lawnmower may have a small engine and an outboard a large one. Engine size comparisons are not based on the outside dimensions of an engine but on the size of the area where power is developed.

Bore and Stroke

The bore is the diameter of the cylinder, Figure 12-1. The larger the bore, the more powerful the engine. The stroke is the distance the piston moves from the bottom of the cylinder to the top or from the top to the bottom. The size of the stroke is determined by the distance between the

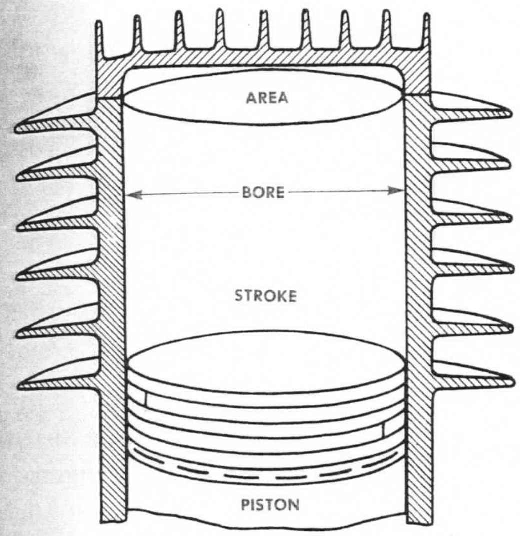

Figure 12-1. The bore is the distance across the cylinder. (Briggs & Stratton Corp.)

centerline of the crankshaft and the centerline of the connecting rod where it attaches to the crankshaft. The longer the stroke, generally speaking, the more powerful the engine. The bore and stroke are given in inches or millimeters, e.g., a bore of 3½ inches and a stroke of 4 inches, or a bore of 84 mm and a stroke of 88mm. Sometimes just the numbers are given: 3½ × 4, for example. In this case, the bore is always the first number.

Displacement

The bore and stroke of an engine are used to find its displacement. Displacement is the size or area of the cylinder, Figure 12-2. Displacement is measured when the piston is at the bottom of the cylinder. The bigger the bore, the larger the cylinder area or displacement. The longer the stroke, the larger the cylinder area or displacement. If the engine has more than one cylinder, the displacement of all the cylinders is added together. This gives us the total displacement for the engine.

The displacement of an engine may be given in two ways. It may be measured in cubic inches or in cubic centimeters. We often just call cubic centimeters cc's. Usually the larger an engine's dis-

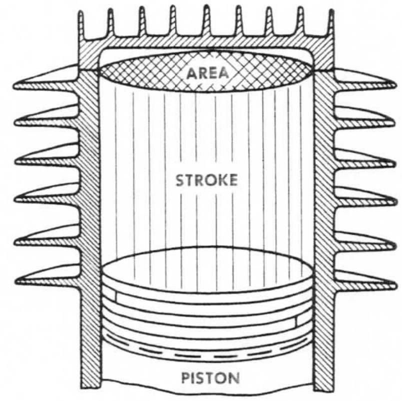

Figure 12-2. Displacement is the area of the cylinder when the piston is at the bottom of its stroke. (Briggs & Stratton Corp.)

placement, the more powerful the engine is. The displacement of many small engines is 6 to 8 cubic inches. A car engine may have a displacement of more than 200 cubic inches.

The formula used to calculate displacement is:

$$\text{Displacement} = \frac{\text{Bore}^2 \times \pi \times \text{Stroke}}{4}$$

The bore is squared, or multiplied by itself. The symbol π stands for 3.14. An engine with a bore of 3 inches and a stroke of 3 inches would have a displacement calculated as follows:

$$\text{Displacement} = \frac{3^2 \times 3.14 \times 3}{4} =$$

$$\frac{9 \times 3.14 \times 3}{4} =$$

21.20 cubic inches

The displacement in one cylinder is multiplied by the number of cylinders to find the displacement for the entire engine. If the engine in the example above has two cylinders, the displacement is 42.4 cubic inches.

Compression Ratio

An engine's compression ratio is another important engine measurement.

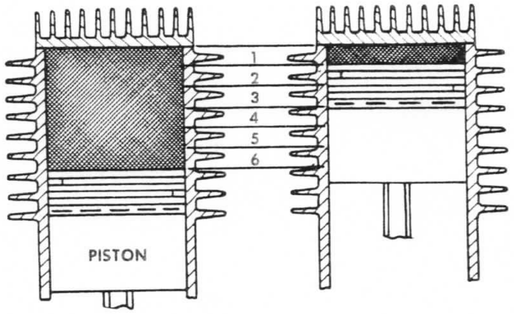

Figure 12-3. This engine has a compression ratio of 6 to 1. (Briggs & Stratton Corp.)

You may remember that one of the four strokes of the four-stroke-cycle engine is called a *compression stroke*. On this stroke the piston moves up. Both the intake and exhaust valve are closed. The piston squeezes the air-fuel mixture in the top of the cylinder. The tighter the mixture is squeezed, the higher the compression an engine has. The higher the compression, the more power the engine can develop.

We need a way to measure how much compression an engine has. The measurement we use is called *compression ratio*. Compression ratio is measurement of how tightly the air-fuel mixture is squeezed in the cylinder. We find the compression ratio by measuring the area of a cylinder. First we measure the area when the piston is at the bottom of its stroke. The piston is then moved to the top of its stroke. The small area above the piston is measured.

Let's see how this works. In Figure 12-3, the piston on the left is at the bottom of its stroke. If we measure the area we find there are six cubic inches. The piston is moved to the top of its stroke (right). We find there is only one cubic inch of space now. This means we squeeze six inches of air-fuel mixture into a one-cubic-inch area. We call this a compression ratio of 6 to 1.

ENGINE PERFORMANCE MEASUREMENTS

More than two hundred years ago an engineer and practical instrument maker at Glasgow University was conducting experiments to improve the steam engine. The experiments were so successful that a practical steam engine was developed. The engineer, James Watt, went on to form a company to sell the engines. The engines were designed to be used in the coal mines in England. Up to this time, the mine operators did all the lifting of coal with horses. To sell his engines, Watt had to develop a system for comparing his engines to the horse. The biggest achievement of James Watt was to establish a unit for power. He thought up the term *horsepower* after establishing by experiment the amount of work an average horse could do.

The idea of horsepower is based upon a number of simple scientific principles: force, work, power, torque, energy and efficiency. Each of these important principles and its relationship to horsepower is discussed below.

Force

In simple terms, a force is a push or pull. If a man pushes against a door, he has exerted a force on the door. In scientific terms, a force is explained as an action against an object that tends either to move the object from a state of rest or to change the direction or speed of an object already in motion. The amount of force exerted can, of course, be measured. In the customary system, force is measured in pounds. To open a door, a person must push against the door with a force of so many pounds. In the metric system, force is measured in newtons.

Work

The term *work* is familiar to everyone. In scientific terms, however, work is done when a force travels through a distance. Work is done only if

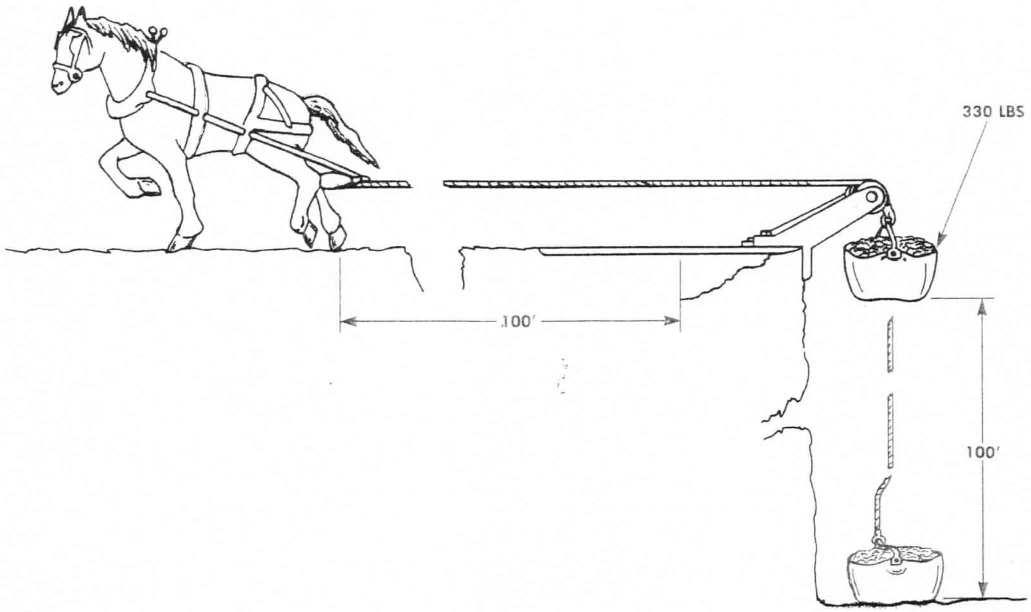

Figure 12-4. Work is force times distance.

the force results in movement. Someone who pushes against a door that is locked exerts a force. If the door is not moved, no work is done.

James Watt was interested in the amount of work a horse could do. He hitched a horse to a container of coal that weighed 330 pounds. He had the horse pull the container of coal 100 feet Figure 12-4. The formula for work is:

Work = Distance × Force

Using the example of the horse:

Work = distance (feet) × force (pounds)
Work = 100 feet × 330 pounds
Work = 33,000 foot-pounds

The horse, then, accomplished 33,000 foot-pounds of work. In the United States, the measurement of work is the foot-pound. One foot-pound equals the force of one pound moved through a distance of one foot. In the metric system, work is measured in joules. One joule is equal to a force of one newton moved through a distance of one meter. These ideas can be expressed as an equation:

Work = Distance × Force
foot-pounds = feet × pounds
joules = meters × newtons

Power

Power is the rate or speed at which work is done. Power adds the idea of time. The faster work is done, the more power is involved. Consider again the example of the horse. If the horse is able to pull the container of coal one hundred feet in one minute, two horses might be able to pull the container of coal one hundred feet in half a minute, Figure 12-5. The same amount of work is done in both cases, but the amount of power involved is different. The formula for power is:

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

$$\text{Power} = \frac{\text{distance} \times \text{force}}{\text{time (minutes)}}$$

$$\text{Power} = \frac{100 \text{ feet} \times 330 \text{ pounds}}{1 \text{ minute}}$$

$$\text{Power} = \frac{3{,}000}{1}$$

Power = 33,000 foot-pounds per minute

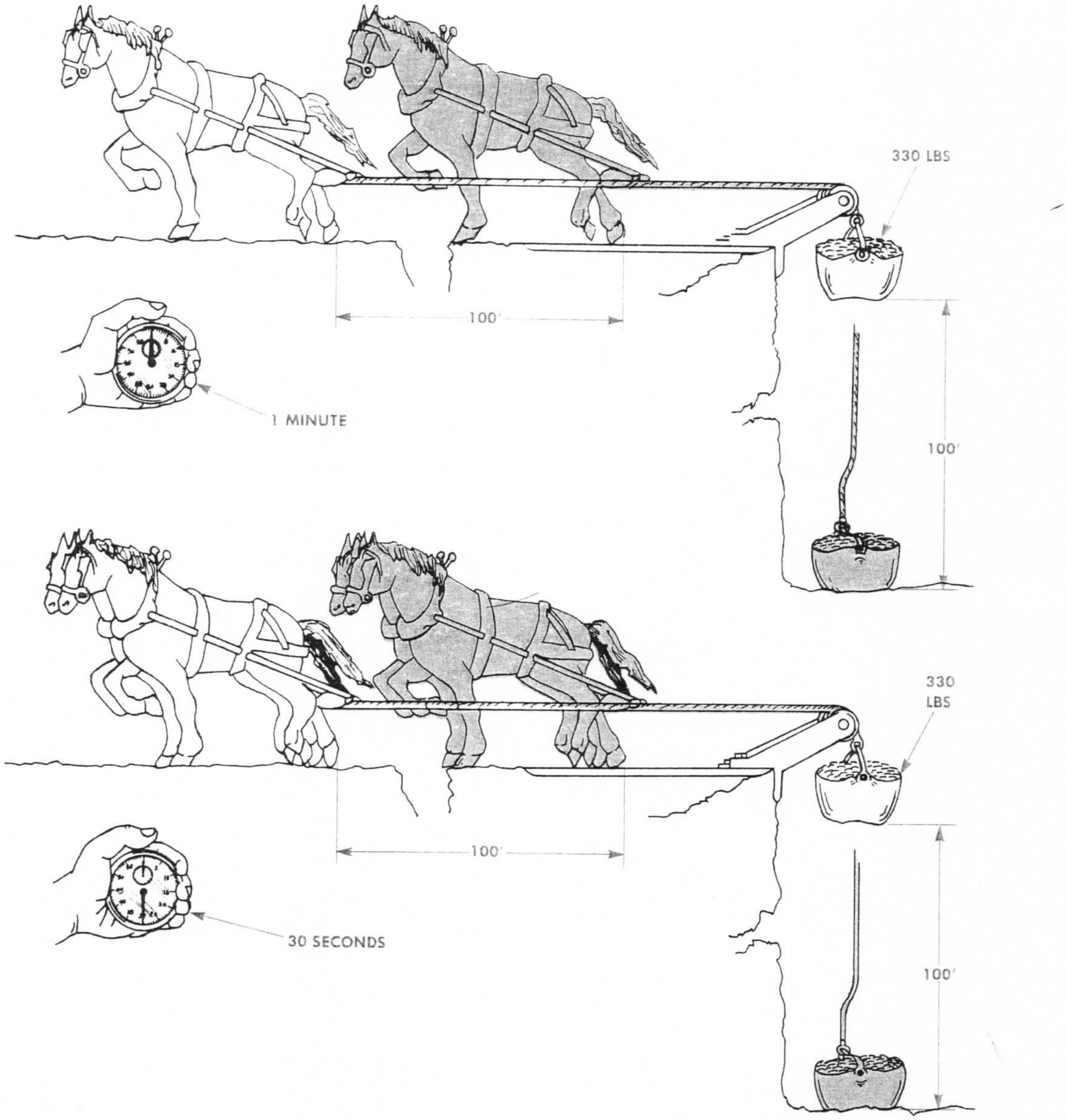

Figure 12-5. Power is the rate or speed of doing work.

When two horses pull the same weight 100 feet in 30 seconds or .5 minute, the amount of power is:

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

$$\text{Power} = \frac{\text{distance} \times \text{force}}{\text{time (minutes)}}$$

$$\text{Power} = \frac{100 \text{ feet} \times 330 \text{ pounds}}{.5 \text{ (minute)}}$$

$$\text{Power} = \frac{33{,}000}{.5}$$

Power = 66,000 foot-pounds per mintue

From this example, it can be seen that the faster work is done, the more power is developed. In the customary system of measurement, power commonly is described in foot-pounds per minute. In the metric system, the unit of power measurement is the watt. One watt is equal to one joule per second. A joule is equal to a newton moved through one meter.

Horsepower. The steps used above to determine the amount of power a horse could develop are like those James Watt used. After watching the power produced by draft horses, Watt decided that 33,000 foot-pounds per minute was about what the average horse could do. A horsepower is the ability to do 33,000 foot-pounds of work in one minute. He then was able to write a formula for horsepower. The formula became:

$$\text{Horsepower} = \frac{\text{Distance (feet)} \times \text{Force (pounds)}}{\text{Time (minutes)} \times 33{,}000}$$

Again, using the example of the horse:

$$\text{Horsepower} = \frac{100 \text{ feet} \times 330 \text{ pounds}}{1 \text{ minute} \times 33{,}000}$$

$$\text{Horsepower} = \frac{33{,}000}{33{,}000}$$

$$\text{Horsepower} = 1$$

This idea of horsepower allowed James Watt to compare the steam engines he was trying to sell to the common power-producer of his day — the horse. This proved to be a very useful idea, but the formula was limited to power used for pulling a weight a straight distance. The rotating crankshaft of an engine, however, does not develop a pulling force. Instead, it develops a force through a circle as it turns.

Rotary Horsepower (Torque). To measure power developed by an engine crankshaft, a rotary unit of force is necessary. The rotary unit of force is called *torque*. Torque, in simple terms, is turning or twisting effort. A mechanic using a wrench to tighten a bolt is applying torque to the bolt. When the bolt is tight, the mechanic may not be able to turn it any more. Even though the bolt does not turn, the mechanic is applying torque. Torque, then, is a force that produces or tries to produce rotation. If the torque results in rotation, work is done.

The formula for determining torque is:

$$\text{Torque} = \text{Force} \times \text{Radius}$$

The term *force* is used exactly as it is in the concept of work. The radius is the distance from the

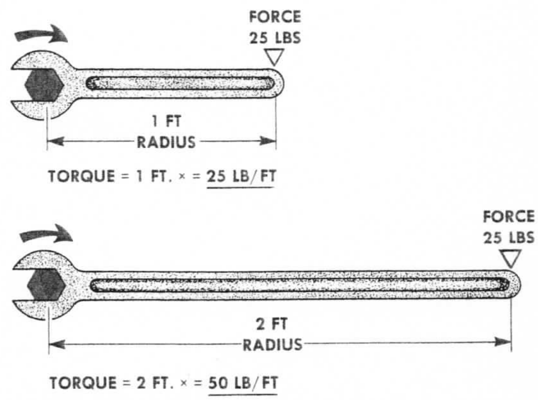

Figure 12-6. The longer the radius the more torque you can get with the same force.

point at which the force acts to the center of rotation of the shaft. The push or pull the mechanic exerts on the wrench is the force. The distance from the center of the bolt to the part of the wrench handle where the mechanic applies the force is the radius. It is called a radius because as the wrench goes around it describes a circle. The wrench takes up one-half the diameter of the circle, or the radius.

If the wrench the mechanic is using, Figure 12-6, has a 1-foot radius and the force exerted is 25 pounds, the torque may be calculated as follows:

$$\text{Torque} = \text{Force} \times \text{Radius}$$
$$\text{Torque} = 25 \text{ lbs} \times 1 \text{ ft}$$
$$\text{Torque} = 25 \text{ lbs ft}$$

Should the mechanic choose a longer wrench with a 2-foot radius and exert the same amount of force, the torque will be increased.

$$\text{Torque} = \text{Force} \times \text{Radius}$$
$$\text{Torque} = 25 \text{ lbs} \times 2 \text{ ft}$$
$$\text{Torque} = 50 \text{ lbs ft}$$

In the customary system, torque always is expressed in pounds-feet. This causes a good deal of confusion because the unit of measurement for work is foot-pounds. In both formulas, pounds are multiplied by feet. Remember that torque always is specified in pounds-feet and work in foot-pounds. In the metric system, torque is measured in newton-meters. The formulas are:

Torque = Force × Radius
Customary system: Torque = Pounds × Feet
Metric system: Torque = Newtons × Meters

The power produced by an engine is rotary. Like linear horsepower can be measured. Rotary horsepower measurement is based upon the formula Watt developed. The formula for rotary horsepower is:

$$\text{Horsepower} = \frac{\text{RPM} \times \text{Torque}}{5252}$$

Torque is the turning effort developed by the engine. RPM means revolutions per minute. RPM gives us the time element in the formula. The 5252 is simply a number called a constant by which we divide to get the correct units.

MEASURING HORSEPOWER

The horsepower of an engine can be found if the engine's torque at any particular RPM is measured. A dynamometer, Figure 12-7, is a device used to measure engine torque. The dynamometer does not measure horsepower directly. It measures torque and RPM. These values are then put into the horsepower formula and horsepower is determined mathematically. Many dynamometers have the ability to do this math automatically and provide the operator with a horsepower figure.

There are many types of dynamometers. Most dynamometers measure torque of an engine by changing the rotating torque to a stationary torque. The stationary torque is then measured with a scale, a hanging weight, load cell strain gage or other force-measuring device at the end of a torque arm.

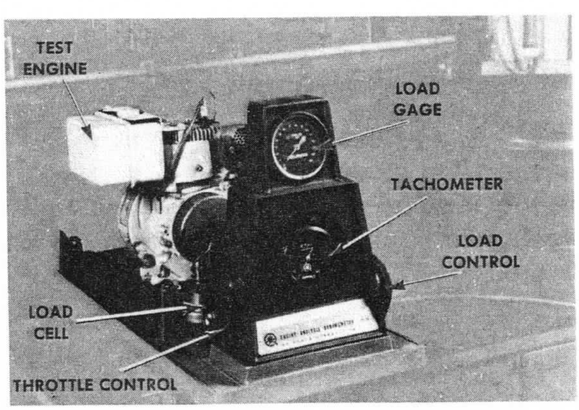

Figure 12-7. A small engine dynamometer.

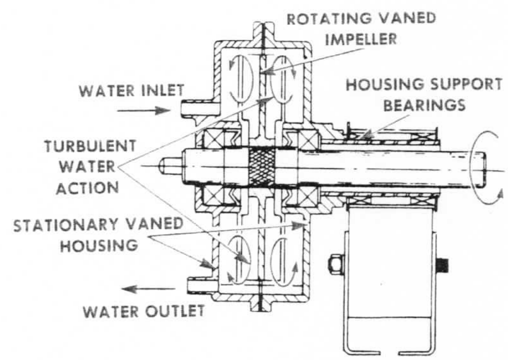

Figure 12-8. Cross section of a water brake unit. (Go-Power Corp.)

Most dynamometers use a hydraulic water brake to change rotating torque to stationary torque and absorb the power. The water brake absorption unit shown in Figure 12-8 consists of a vaned impeller that rotates in a stationary vaned housing. When the absorption unit is partly filled with water, the vaned impeller rotates and accelerates the water outward in the direction of rotation of the impeller until the water strikes the outer edge of the housing. The water is deflected against the stationary housing vanes. The force of the fast-moving water striking the stationary housing causes the housing to try to rotate. A force-measuring load cell, shown in Figure 12-9, is used to keep the housing from rotating and to measure the torque the water exerts on the housing. The torque being measured at any RPM is controlled by changing the amount of water in the absorption unit. A water valve controls the flow of water through the absorption unit and, as the water flow increases, the amount of water in the absorption unit also increases.

There are two general types of dynamometers. One is an *engine dynamometer* which tests the engine by itself. Engine dynamometers are used to make engineering and performance studies on the engine, such as measuring and rating its horsepower. An engine under test on a dynamometer is shown in Figure 12-10.

The other type of dynamometer is called a *chassis dynamometer*. This unit is used in many service facilities for tuneup and diagnostic work. Motorcycles often are tested on a chassis dynamometer.

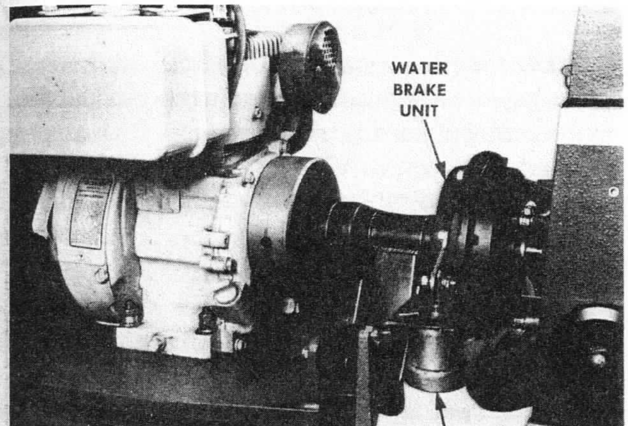

Figure 12-9. A force-measuring load cell.

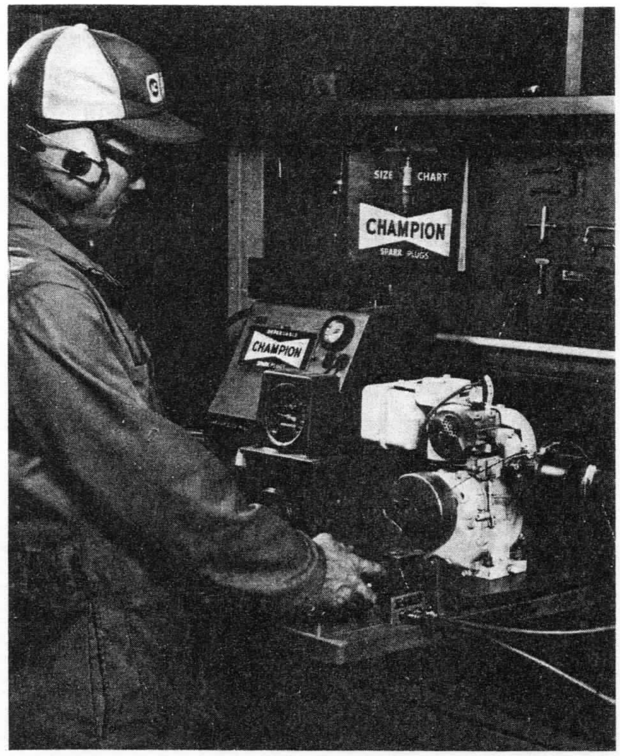

Figure 12-10. A small engine being tested on a dynamometer.

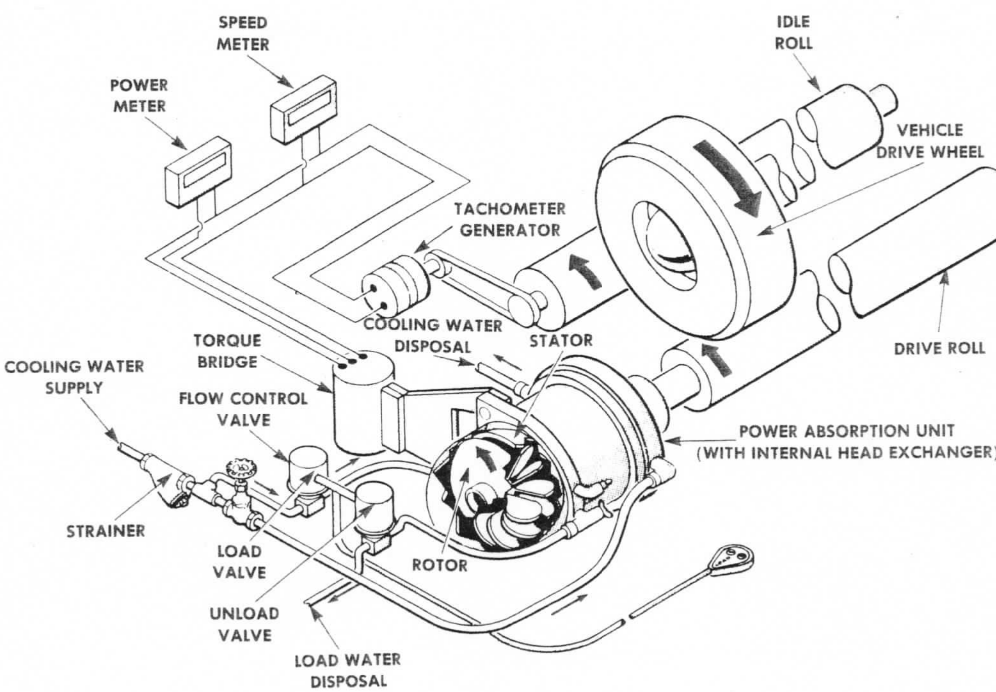

Figure 12-11. Operation of a chassis dynamometer. (Clayton Manufacturing Co.)

A chassis dynamometer allows the technician to duplicate road conditions and determine the vehicle's ability to perform on the road. It is useful for testing a number of motorcycle systems such as brakes, drive lines, and fuel systems as well as power output and engine condition. The chassis dynamometer puts the motorcycle to work exactly as it works on the road and continuously measures its ability to work.

The dynamometer is able to simulate road conditions by placing the rear wheel of the motorcycle between two large rollers. The shaft of the forward or drive roller is attached to a power absorption unit as shown in Figure 12-11. The power absorption unit works like a hydraulic fluid coupling. It has a rotor with blades which throws fluid forward. A stator with stationary blades receives the force of the fluid flow from the rotor. The power absorption unit acts like a brake. The more fluid in the unit, the more power required to revolve the rotor at any given speed. With a given amount of fluid, the faster the rotor revolves, the more power is required.

The motorcycle engine is started and the rider puts it in gear. The rear wheel drives the rollers. The operator, by maintaining a constant amount of fluid in the power absorption unit, may adjust any desired load on the rear wheels. The load may be changed by varying the amount of fluid within the system. The control is accomplished by two valves operated remotely from a portable control unit in the hand of the operator. By pushing an "on" button, the technician allows fluid to flow into the power absorption unit to simulate any type of road required from a level highway through moderate hills to the steepest grades. When the technician pushes the "off" button, fluid flows out of the power absorption unit, decreasing the load or steepness of the hill.

Torque and Horsepower Curves

When torque is measured on a dynamometer, it is recorded on a graph. Horsepower, calculated mathematically using torque and RPM also is charted on a graph. The graph shown in Figure 12-12 is typical. Horsepower figures are shown along one side of the graph and torque in pound-feet along the other side. The bottom of the graph has engine speed in revolutions per minute. This kind of graph allows both torque and horsepower to be compared to engine operating speed.

Horsepower and torque curves result when horsepower and torque are measured or calculated on a dynamometer. When an operator observes a certain amount of torque on the dynamometer instruments at a particular RPM, the operator puts a mark on the graph that corresponds to the torque and RPM. When the test is complete, all the marks are connected together and curves such as those shown in Figure 12-12 result.

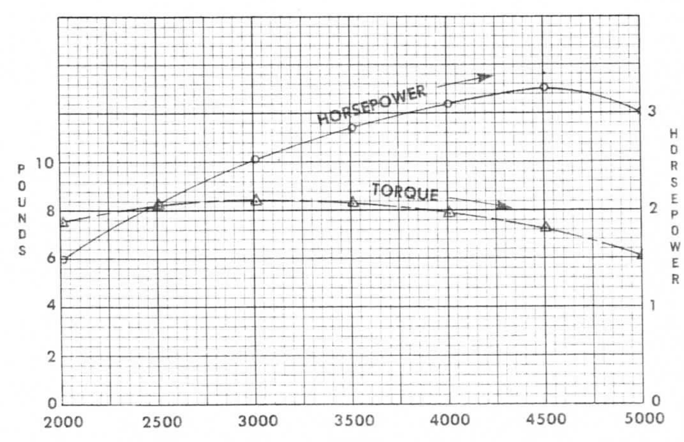

Figure 12-12. Horsepower and torque curve. (Go-Power Corp.)

The horsepower curve in Figure 12-12 is common to most engines. The horsepower does not start at zero because an engine will not run at zero speed. Therefore, the curve is cut off at the bottom. Horsepower increases as the engine speed and load increase. The graph shows that this engine reaches its maximum horsepower of 165 at 4,000 RPM. An engine is capable of running faster than the speed at which it reaches maximum horsepower. The horsepower begins to decrease after reaching the maximum point. The reasons for the decrease are related to the torque curve.

The torque curve shows the load-carrying ability of the engine at different speeds in pound-feet. The relationship between the torque curve and the horsepower curve shows how the engine will perform at different loads and speeds.

As shown in Figure 12-12, the horsepower curve continues to climb as the engine speed increases until maximum horsepower is reached. This is also true with the torque curve, but the torque curve will reach its maximum point much earlier. Notice in Figure 12-12 how the torque curve drops after it reaches its peak point (maximum) at 1500 RPM.

The torque of which most engines are capable will change widely over the normal range of crankshaft speeds. At very low speeds—200-300 RPM — an engine develops only enough torque to keep itself running without any extra load. The next torque — the reserve beyond what is needed to keep the engine running — is practically zero.

As engine speed and load increase, torque will increase until it reaches the speed where torque will peak. This is where the manufacturer rates the torque. It will be very near the most efficient operating speed of the engine. At this point the cylinders are taking in the biggest and most efficient air-fuel mixture, and the exhaust gases in the cylinder are being forced out most effectively.

The torque curve drops off rapidly after its peak. At higher engine RPM there is less time for the air-fuel charge to enter the cylinder and less time for the exhaust gases to leave the cylinder. This results in a weaker push on the pistons and less torque. Other factors contribute to the drop in torque, such as internal engine friction and effective loss of the energy used in pumping in air and fuel and exhausting it. These losses are described as pumping losses.

The horsepower curve is directly affected by the torque curve. This is due to the fact that torque is one of the elements in the horsepower formula:

$$\text{Horsepower} = \frac{\text{Torque} \times \text{RPM}}{5252}$$

. The reason that the horsepower curve does not directly correspond with the torque curve is that it also is affected by another element, time. Power, remember, is the speed or rate at which work is done. The horsepower curve is able to increase past the peak of the torque curve because the engine RPM increases beyond this point. Eventually, however, the torque drops off so much that even more RPM cannot hold the horsepower curve up.

Horsepower Ratings

Even though there is general agreement about what horsepower is, there are some differences of opinion about how it is to be rated or specified. When horsepower is measured at the flywheel of an engine, it is described as brake horsepower, abbreviated BHP. The term *brake* comes from a device invented in 1821 by a man named Prony. It was called a Prony friction brake dynamometer. The Prony brake was a device that was wrapped around an engine flywheel to absorb energy and to measure the amount of energy absorbed.

The brake horsepower of an engine can be measured on a dynamometer with all of the engine's accessories driven from an external power source. This results in the maximum obtainable horsepower. Horsepower measured this way is called *gross horsepower*.

On the other hand, the horsepower can be measured with the engine driving all the necessary accessories, such as the standard exhaust and air cleaner, alternator, water pump, fan and oil pump. Figures obtained in this way are called the *net rating* and naturally are lower than the gross figures.

The horsepower of an engine is affected by such things as barometric pressure and air temperature. Horsepower readings taken directly from dynamometer readings are called *observed horsepower*. Observed horsepower is corrected to standard atmospheric conditions. This is called *corrected horsepower*. The correction factors may be those set up by SAE (The Society of Automobile Engineers) for the customary system or DIN, for the metric system. Horsepower corrected in this manner is called SAE horsepower or *DIN horsepower*. Since the metric standard is smaller than the customary horsepower unit, DIN ratings are slightly higher for a given engine than SAE ratings.

Indicated horsepower is an engineering measurement seldom used outside of a factory or laboratory. It is a measurement of the power delivered by the expanding gas to the piston inside the cylinder. It does not take into consideration the friction losses within the engine but is the total power developed in the cylinders. The usual formula is:

$$IHP = \frac{P\ L\ A\ N\ K}{33{,}000}$$

where P = means effective pressure in the cylinder in pounds per square inch.
L = length of stroke in feet
A = area of one cylinder
N = number of cylinders
K = a constant × RPM
(For a two-stroke, K = 1 × RPM, while for a four-stroke, K = 2 × RPM.)

The customary system of ratings known as taxable horsepower, which has been abandoned, bore almost no relationship to actual output. Taxable horsepower was based upon a calculation involving engine bore and number of cylinders. It was used for tax purposes.

Horsepower also may be measured with an engine installed in the vehicle. Horsepower measured at the rear wheels of a vehicle is described as *road* or *chassis horsepower*. This figure, of course, will be much lower than the engine ratings.

ENERGY

Energy in any form, is the ability to do work. The ability to do work is, of course, necessary to develop horsepower. The different kinds of energy are chemical, thermal and mechanical.

Mechanical energy is measured by the work a body can do. A raised weight has energy that is stored up for later use. If the weight is dropped, it can be made to do work. For example, the weight could be made to raise another weight, compress a spring or pull a rope or cable.

In an engine, the energy used to develop horsepower comes from the fuel. A fuel such as gasoline has a considerable amount of energy. The energy in gasoline is stored in the form of chemical energy. When the gasoline is burned with oxygen in the engine, the chemical energy is released as thermal energy.

Efficiency

The purpose of any engine or machine is to convert energy into useful work. How well the machine does at converting energy into work is a measure of its efficiency. Efficiency is the ratio of energy supplied to the work produced. The question is, how much work does a machine deliver for the amount of energy put into it? The basic equation for efficiency is:

$$\text{Efficiency} = \frac{\text{work output}}{\text{energy in}} \times 100\%$$

No machine or device is 100 percent efficient because of lost energy through heat and friction. In an internal combustion engine, only about 25 percent of the total energy of the fuel is converted into useful work.

Thermal Efficiency. The internal combustion engine converts the chemical energy of gasoline into thermal energy. It is important to know how efficiently this is accomplished. Thermal efficiency is a measure of the percentage of heat energy available in the fuel that actually is converted into power at the crankshaft.

Volumetric Efficiency. Another important type of efficiency rating in internal combustion engines is called *volumetric efficiency*. Volumetric efficiency is the relationship of the actual volume of a cylinder to the volume which is filled during engine operation. At high engine speeds, the valves are open for such a short time that the cylinders are not completely filled. This, plus friction temperature and inertia, causes the cylinders to be filled to less than their capacity. Volumetric efficiency may be calculated with an engine dynamometer and air flow equipment.

Brake Mean Effective Pressure. Another important measurement of engine efficiency is called *brake mean effective pressure,* abbreviated *BMEP.* BMEP is the average effective pressure exerted on the piston during one operating cycle. Pressure used in drawing fuel into the cylinder and compressing it, pressure required to exhaust the burnt exhaust gases, and internal friction are subtracted from the power delivered during the power stroke. The result is BMEP. BMEP may be calculated on a dynamometer.

NEW TERMS

bore: The diameter of the cylinder.

brake horsepower: Horsepower measured at the engine's flywheel. Abbreviated BHP.

brake mean effective pressure: The average pressure exerted on the piston during one operating cycle. Abbreviated *BMEP.*

compression ratio: The amount the air-fuel mixture is compressed during the compression stroke, compared to its original volume.

displacement: The volume swept or displaced by the pistons of an engine.

dynamometer: Equipment used to measure torque and calculate horsepower.

efficiency: How well a machine such as an engine converts energy into useful work.

energy: The ability to do work.

force: A push or a pull.

horsepower: Term used to describe the power developed by an engine. One horsepower is equal to 33,000 foot-pounds of work per minute.

horsepower ratings: Different ways in which horsepower is measured and specified.

indicated horsepower: A laboratory horsepower measurement based upon the power developed in the engine's cylinders.

linear horsepower: Horsepower used to pull in a straight line.

power: The speed at which work is done.

rotary horsepower: Horsepower developed in a rotary motion such as by an engine's crankshaft.

stroke: The movement of the piston in the cylinder, controlled and measured by the offset of the crankshaft.

thermal efficiency: How well an engine changes the chemical energy in gasoline to heat energy.

torque: A turning or twisting effort or force.

volumetric efficiency: The ratio of an engine's cylinder volume to the volume filled by air and fuel during engine operation.

work: What is done when a force travels through a distance.

SELF CHECK

1. Define the term *bore.*
2. Define the term *stroke.*
3. Explain the term *displacement.*
4. Define *compression ratio.*
5. Define *force.*
6. Write the formula for work.
7. Define the term *power.*
8. Define a *horsepower.*
9. What is rotary horsepower?
10. Explain how horsepower is measured on a dynamometer.
11. What is a torque curve?
12. What is a horsepower curve?
13. What is efficiency?
14. Define *thermal efficiency.*
15. Define *volumetric efficiency.*

DISCUSSION TOPICS AND ACTIVITIES

1. Look up the horsepower and torque specifications for a small engine you own. At what RPM is horsepower the highest? Where is torque highest?
2. What limits the horsepower and torque of an engine? How could they be increased?