Horsepower testing is the mechanical measuring of the units of Power that an engine or machine is capable of producing. More specifically we are measuring Brake Horsepower - the effective horsepower or the amount of work that is produced at its final output. One method of doing this is by the use of a dynamometer. A dynamometer is a device that measures Force. In one common type of dynamometer, the force is measured by braking action. One of the first such dynamometers was developed by the French mathematician, Gaspard de Prony (1755-1839) and is called a Prony Brake. The principle of the Prony Brake is that an engine or motor is directly coupled to a drum that has a tensioned, friction belt around it. As the drum revolves, the frictional force is measured. Before we explain the operation of the Prony Brake any further, lets define Horsepower and understand the equations we will be using.

Straight Line Horsepower

Horsepower is a British unit for Power defined as the equivalent to the force needed to move 550 pounds, one foot, in one second or one pound, 550 feet, in one second.

Power is defined as the rate of doing Work or work divided by time. P = W / t and the unit is (ft-lb/s)

Work is defined as the product of an applied Force and the distance through which the force acts. W = Fd

Force is more difficult to understand, it is defined as a push or a pull that tends to cause motion or tends to prevent motion. Force has both a quantity and a direction. Force equals mass times acceleration. F = ma
The British system is said to be a gravitational system and the unit of force or weight is the pound (lb). The unit Pound is then defined as a given mass called a slug, times the acceleration of gravity, equals 32 pounds. Force weight equals mass times acceleration of gravity. Fw = mg or 32 lb = (1 slug)(32 ft/s2) or 1 lb = (1 slug)(1 ft/s2).
In the Metric system the unit of force is the Newton. One might think that it would be the kilogram but the kilogram is actually a unit of mass.

The results: $$\mathbf{P} = \frac{\mathbf{F}\text{ (in pounds)} \times \mathbf{d}\text{ (in feet)}}{\mathbf{t}\text{ (in seconds)}}$$

If we factor out (time) and make distance a rate, or velocity, we have: P = F (in pounds) x v (in feet/second)

Then: $$\mathbf{HP} = \frac{\mathbf{F}\text{ lb} \times \mathbf{v}\text{ ft/s}}{550\text{ ft - lb/s}}$$

Origin of Horsepower

The unit, horsepower, was originated by James Watt (1736-1819), the Scottish engineer who developed the first practical steam engine. When Watt offered to sell his steam engines to farmers and miners, he was probably asked how many horses they would replace. The value of the horsepower was based on his experiments with strong dray horses that were able to do about 50 percent more work than a standard horse in a working day. He concluded that an average draft horse could steadily exert a 150 pound force while walking at a speed of 2.5 miles and hour. The horse thus performed work at the rate of 33,000 foot-pounds per minute, or 550 foot-pounds per second. Watt defined this rate as 1 horsepower.

In the Metric system the unit of power is the Joule/second or Newton-meter/second (J/s = N-m/s). However the derived unit is watt (W), in honor of James Watt.

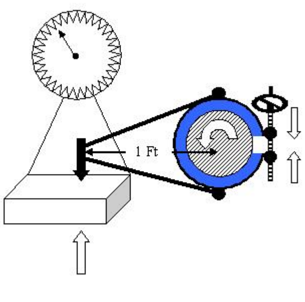
1 hp = 550 ft-lb/s = 33,000 ft-lb/min = 746 N-m/s = 746 J/s = 746 W

The Buckley Prony Brake


The Prony Brake used at the Buckley Show was constructed in 1988 by Larry Wichern and Nick Lederle, and other club members. Amos Rixmann had a love for the Prony Brake and for many years enjoyed announcing the action of tractors and steamers that were belted-up to the brake, to show their stuff. The Buckley, Prony Brake has been so successful that it has been used at other shows and used as a pattern for brakes built by other clubs. In recent years, many tractor shows use the Prony Brake as a means of competition, where owners will modify and soup up their tractors, to see who can develop the most horsepower. At Buckley however, the purpose of the test is to demonstrate the quality of the preservation or restoration of a tractor by attempting to achieve the rated horsepower based on the original Nebraska Tests for that model of tractor. In 1919, Nebraska passed a law that no tractors could be sold in that state unless one had been tested to provide unbiased information about its performance. The University of Nebraska Tractor Test Laboratory is the officially designated tractor testing station for the United States and tests tractors according to the codes of the Organization for Economic Co-operation and Development. Twenty-eight countries now participate in the tractor test codes. (Test Reports), requires Adobe Acrobat Reader. In 1996 a PTO input was added to the Prony Brake for testing later model tractors that no longer have a belt power take-off.

Horsepower from a Rotating Shaft

In determining horsepower from a rotating shaft; the same basis exists as in straight line horsepower. In a straight line system we define Force as a push or a pull. In a rotational system, we have a "twist", which we call torque. Torque is the tendency to produce change in rotational motion, it is equal to the applied force times the length of the torque arm. Torque is measured in foot-pounds (ft-lb) in the British System.



On a Prony Brake we can determine the input force or horsepower by measuring the opposing braking force applied. If we apply a brake band around a rotating shaft, with a tensioning device and an arm extending one foot from the center of the shaft, attempting to stop the rotation, we can measure the applied force on a weight scale. If this arm was allowed to rotate in would travel a distance of $2\pi \mathbf{r}$ (pi times twice the radius), or 6.2832 feet with each revolution. Since the speed of a rotating shaft is usually measured in revolutions per minute, we are going to use the HP rate of 33,00 ft-lb/min (550 ft-lb/s times 60 s/min). If we have this shaft turning at 500 RPM's and apply a braking force of 100 lbs, we have;

$$\mathbf{HP} = \frac{\mathbf{F}\text{ lb} \times \mathbf{d}\text{ per rev} \times \text{RPM's}}{33{,}000\text{ ft - lb/min}} = \frac{100\text{ lbs} \times 6.2832\text{ ft/rev} \times 500\text{ rev/min}}{33{,}000\text{ ft - lb/min}} = \frac{100\text{ lbs} \times 3141.6\text{ ft/min}}{33{,}000\text{ ft - lb/min}}$$ = 9.3 HP of braking being applied.

To simplify the equation we can factor out the fixed distance of the rotation (33,000/6.2832 = 5252.10084 or just 5252).

The equation becomes; $\mathbf{HP} = \frac{\mathbf{F}\text{ lb} \times \text{RPM's}}{5252}$

At Buckley we simplified things even further; we made the length of the arm 63 inches or 5.25 feet. Multiply that by 2 pi and you get 32.98680. Divide that into 33,000 and you get 1000.42442 or 1000.

Therefore the equation used at Buckley is: $\mathbf{HP} = \frac{\mathbf{F}\text{ (in lbs)} \times \text{RPM's}}{1000}$

Note: don't be confused and try to insert the values from the example into this last formula and expect to get the same braking horsepower. Remember we have increased the length of the arm, and if the RPM's and the brake tension remained the same the force required to prevent the arm from rotating would be less.

The maximum horsepower of an engine is determined by achieving a braking horsepower equal to the output of the engine and basically stalling the engine. During the test, tension is increased on the brake drum to increase the braking force in 10 pound increment for small tractors and engines, and up to 100 pound increments for large tractors and steam engines. Engines with good governors will maintain a reasonably constant RPM until the maximum Horsepower has been reached and then the speed will drop sharply. The highest Force and RPM's gives the maximum HP for the engine.