WAR DEPARTMENT

TECHNICAL MANUAL

AUTOMOTIVE BRAKES

March 8, 1941

TECHNICAL MANUAL
No. 10-565

WAR DEPARTMENT,
WASHINGTON, *March 8, 1941.*

AUTOMOTIVE BRAKES

Prepared under direction of
The Quartermaster General

SECTION I

MECHANICS

1. Purpose.—The purpose of the braking system is to reduce the speed of a vehicle or to stop the vehicle and hold it in place when stopped. Brakes must be so designed that they will readily retard a vehicle without causing the wheels to slip or skid. The importance of the braking system has been emphasized in recent years because of increased vehicle speeds. Present day demands for safe, rapid deceleration have led to the development of effective and dependable braking systems.

2. Terminology.—For purpose of clarity and ready reference the following terms are defined:

Accelerate.—To increase velocity or speed, as from 20 to 30 miles per hour.

Atmospheric pressure.—Pressure exerted in all directions upon all objects on the earth by the weight of air above the earth's surface. At sea level this pressure is 14.7 pounds per square inch.

Braking action.—Use of a controlled force to reduce the speed of or stop a moving vehicle, or to keep a vehicle stationary.

Coefficient of friction.—Ratio between the force required to move one surface over another and the pressure holding these surfaces together.

Decelerate.—To decrease velocity or speed, as from 30 to 20 miles per hour.

Electromagnet.—Magnet formed by passing a current of electricity through wire wound around a core (usually of soft iron).

Energy.—Capacity for doing work. Measured in work units.

Friction.—Resistance to relative motion between two surfaces in contact.

Fulcrum.—Support about which a lever turns.

Hydraulics.—Science of using liquids under pressure to do work.

Hydraulic pressure.—Pressure exerted by a liquid.

Kinetic energy.—Energy of motion. Increases with the square of the speed, and is the energy that must be overcome by the application of brakes.

Lever.—Rigid bar or beam of any shape capable of turning about one point called a fulcrum. Used for transmitting or modifying force or motion.

Leverage.—Mechanical advantage obtained by use of a lever; also an arrangement or combination of levers.

Linkage.—Any system of links or levers joined together.

Load arm.—Perpendicular distance on a lever from the direction of the load to the fulcrum.

Mechanical advantage.—Ratio of the force applied through use of mechanical means such as levers or gears to resistance to be overcome.

Mechanics.—Study of the action of force on bodies.

Mechanism.—System of parts or appliances which act as working agency to produce desired effect.

Power.—Rate at which work is done by transfer of energy.

Power arm.—Perpendicular distance on a lever from the direction of applied force to the fulcrum.

Reaction time.—Time elapsed between noting warning signal and taking the necessary action. For example, the time it takes a driver to apply the brake after the need of stopping is apparent.

Retard.—To slow down or to impede progress.

Self-energizing action.—Wedging action produced by nonrotating braking service forced against its support by rotating braking surface.

Vacuum.—Commonly termed a space from which air or gas has been partly exhausted resulting in a pressure below atmospheric pressure. A perfect vacuum, one from which all matter has been removed, resulting in no weight or pressure whatsoever, is not obtainable.

3. Action.—Braking action is the use of a controlled force to reduce the speed of or stop a moving vehicle, or to keep a vehicle stationary. When the braking force is applied it develops friction, which does the braking. Friction is the resistance to relative motion between two surfaces in contact. Thus by forcing a stationary surface into contact with a surface on a revolving wheel of a moving vehicle, the resistance to relative motion or the rubbing action between the two surfaces will slow down the wheel and retard the vehicle. Automotive vehicles are braked in this manner. Braking action may also be accomplished by establishing a rubbing contact with the roadway as is done by some trolleys which apply a braking surface to the rails.

4. Requirement.—*a.* Vehicle operators usually realize that to increase a vehicle's speed requires an increase in the power output of the engine. It is equally true although not so apparent that an increase in speed requires an increase in the braking action necessary to bring a vehicle to a stop. A vehicle, just as any other body, has energy due to its motion known as kinetic energy. This kinetic energy, which increases with the square of the speed, must be overcome by braking action. If the speed of a vehicle is doubled, its kinetic energy is increased fourfold; four times as much energy must therefore be overcome by the braking action.

b. Brakes must not only be capable of stopping a vehicle but must stop it in as short a distance as possible. The faster kinetic energy is overcome, the more is the power required. Because brakes are expected to decelerate a vehicle at a faster rate than the engine can accelerate it, they must be able to control a greater power than that developed by the engine. This is the reason why well-designed, powerful brakes have to be used to control the modern high speed motor vehicle. A comparison between the horsepower developed by the engine and the horsepower required by the brakes of a passenger car is shown in figure 1.

c. It is possible to accelerate an average passenger car with an 80-horsepower engine from a standing start to 80 miles an hour in 36 seconds. By applying the full force of the brakes, such a vehicle can be decelerated from 80 miles an hour to a full stop in 4.5 seconds. The time required to decelerate to a stop is one-eighth the time required to accelerate from a standing start, hence the brakes handle eight times the power developed by the engine. Thus, about 640 (8×80) horsepower has to be expended by the friction surfaces of

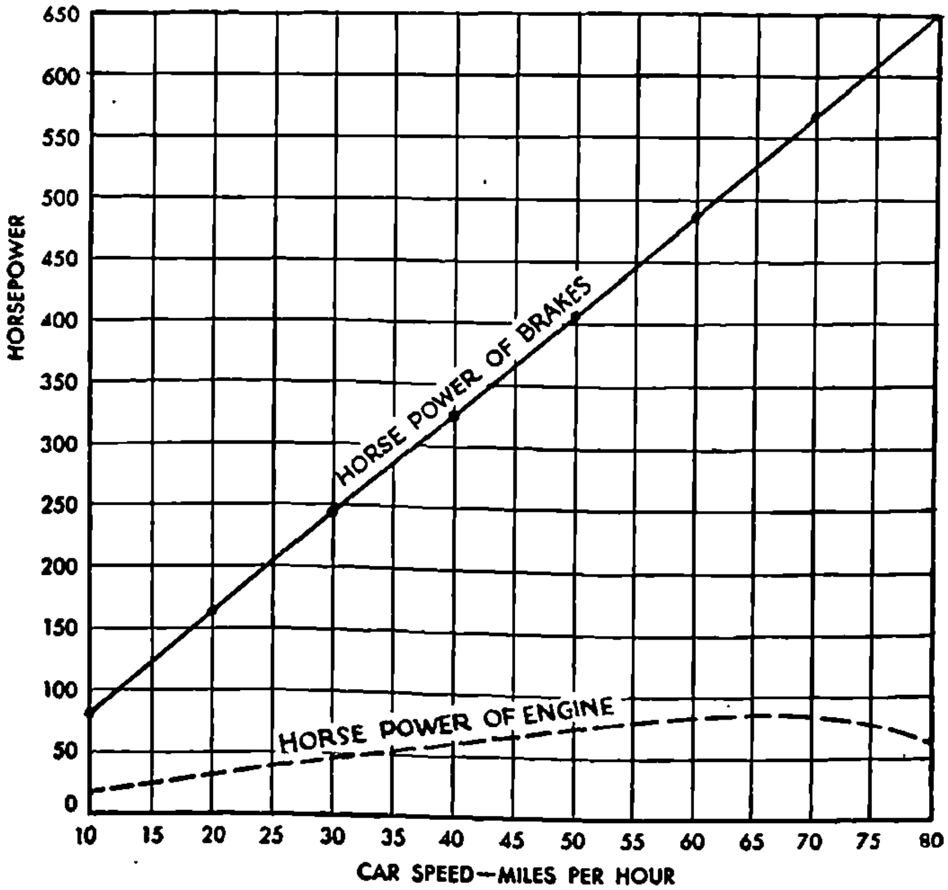

FIGURE 1.—Comparison of horsepower developed by engine and horsepower required by brakes on passenger car.

the brakes of an average passenger car to bring it to a stop from 80 miles an hour in 4.5 seconds.

5. Stopping distance.—Because of the physical laws of nature, no vehicle can be decelerated by brakes quicker than a definite rate even under ideal conditions. Therefore the minimum distance in which a vehicle can be stopped by brakes at any definite speed is limited. During the time that the driver is thinking of applying the brakes and moving his foot to do so the vehicle has moved a certain distance, depending on its speed. This time required for a mental response before the brakes are actually applied is the driver's reaction time. Thus, total stopping distance of a vehicle is the total of the distance covered during driver's reaction time and the distance during which brakes are applied before the vehicle stops. Figure 2 gives total stopping distance required at various vehicle speeds, assuming an average reaction time of three-fourths second and that good brakes are applied under most favorable road conditions.

6. Levers.—*a.* The force exerted or controlled by the driver in applying brakes is increased by use of a lever, irrespective of the system of braking used. The lever, a simple machine, is a rigid bar or beam of any shape capable of turning about one point called a fulcrum and containing points for applying force. The fulcrum may be at any point on the lever depending upon how the force is to be applied. Figure 3① illustrates action of a lever. On the brake pedal lever the fulcrum is usually located at one end and the force

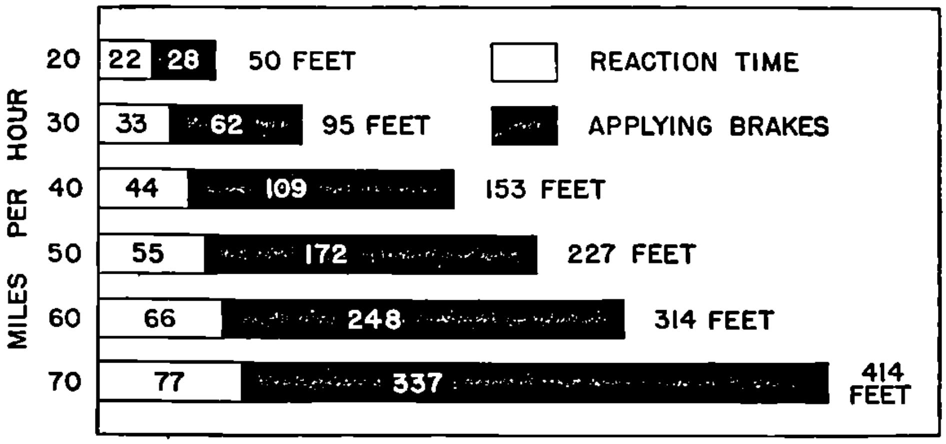

FIGURE 2.—Total stopping distance of vehicle.

is applied to the pedal on the other, as in figure 3② in which the load is between the fulcrum and the point at which the force is applied. The bar in figure 3① demonstrates action that occurs at the brake pedal.

b. The perpendicular distance from the direction of force to fulcrum is called the power arm. The perpendicular distance from the direction of load to fulcrum is called the load arm.

c. A small force can overcome a much larger resisting force or load with the aid of a lever. The force required to overcome the load depends upon the mechanical advantage of the lever. The mechanical advantage obtained from a lever depends upon the ratio of power arm to load arm. Thus if the ratio of power arm to load arm is 4 to 1, only one-quarter of the resisting force of the load is required at the end of the power arm to overcome the load. The mechanical advantage to be gained by use of a lever is shown in figure 4.

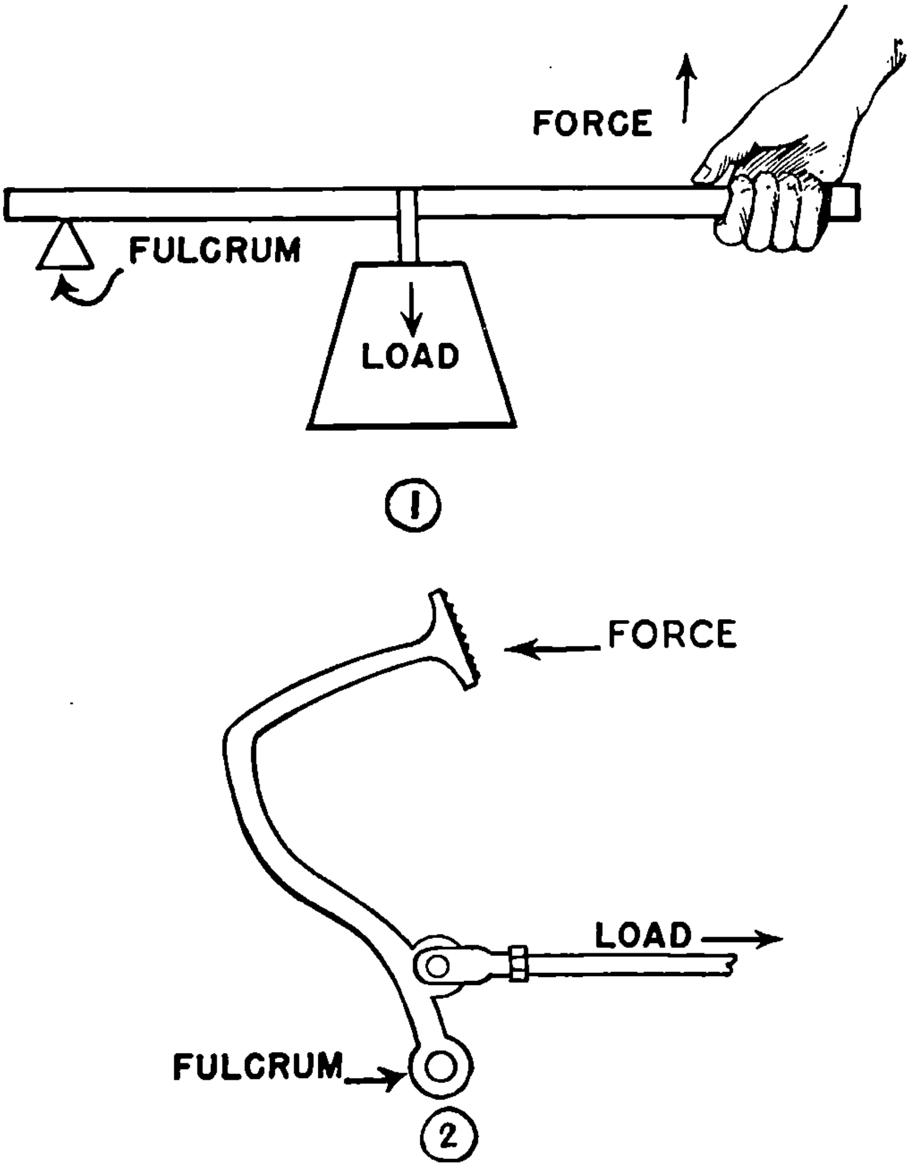

FIGURE 3.—Type of lever used for brake pedal.

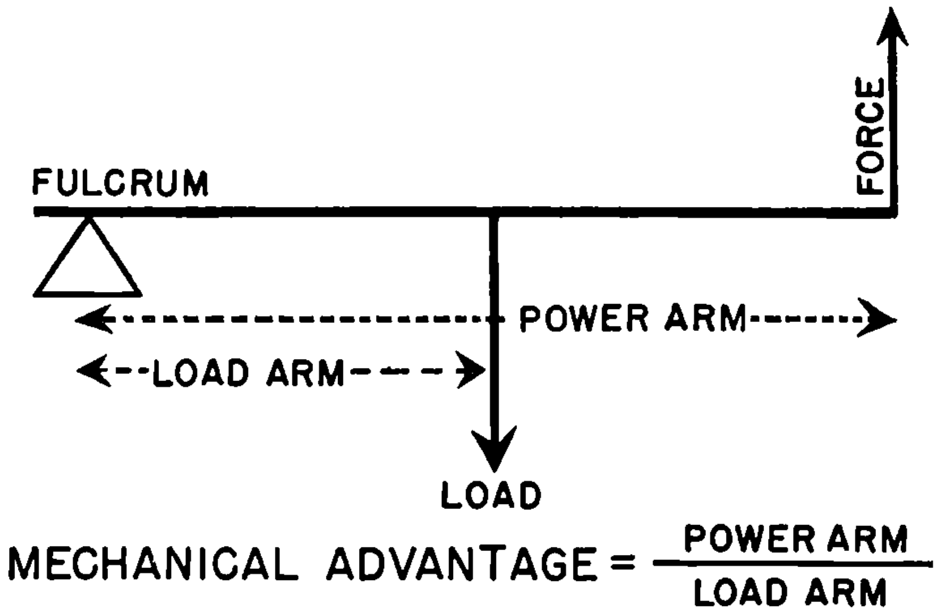

FIGURE 4.—Mechanical advantage of lever.

d. Length of the power arm varies with the angle between the line of applied force and the lever. Thus length of the power arm varies with position of lever as shown in figure 5. The power arm *P* reaches its greatest length when the lever is perpendicular (square) to the line of applied force. The brake system operates most effectively if each lever is set so that the power arm reaches its greatest length

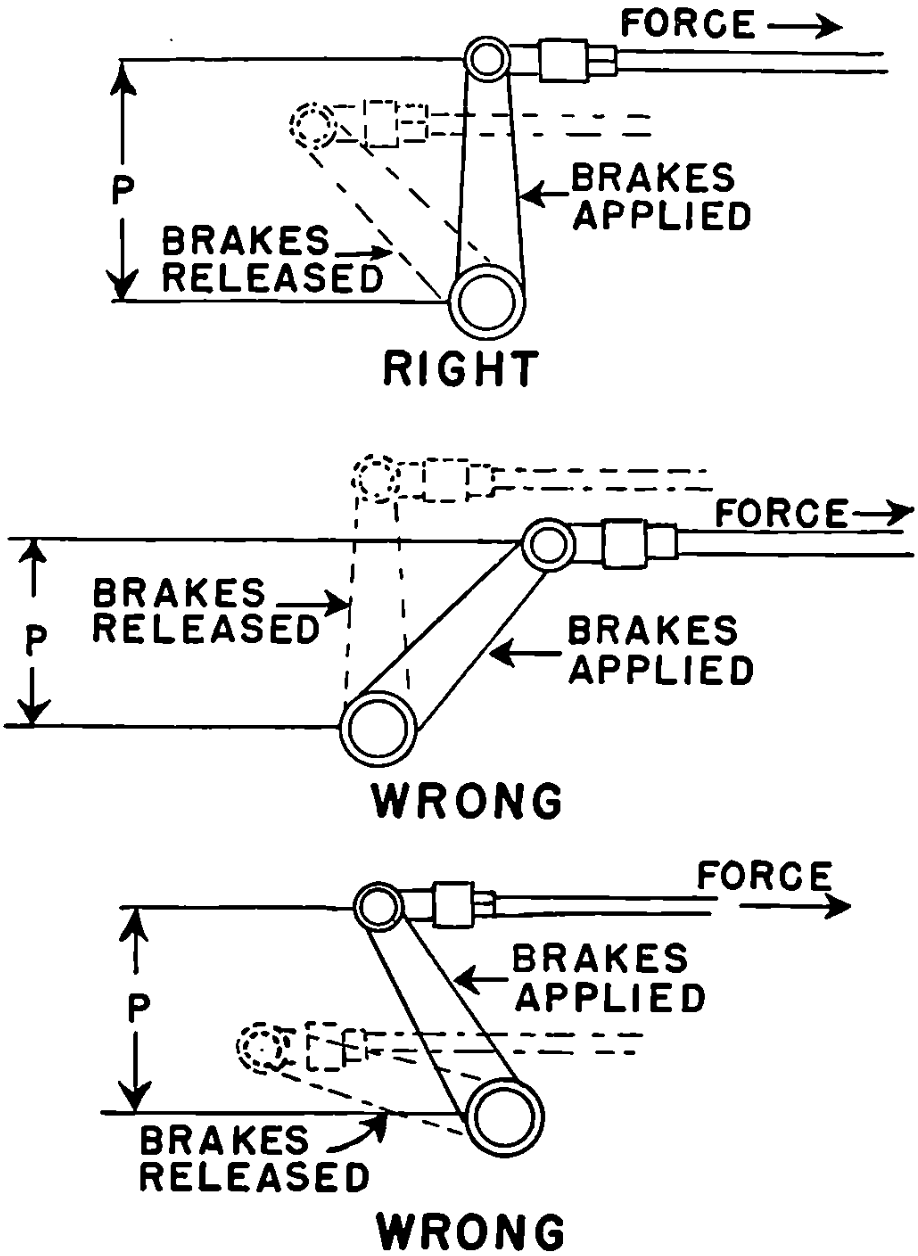

FIGURE 5.—Proper lever adjustment.

(lever is perpendicular to the force) when brakes are fully applied. The greatest mechanical advantage is then obtained from the system when it is most needed, that is, at full application of the brakes.

7. Friction.—*a. Amount.*—Value of the friction used for braking action depends upon the design of the brake. The two outstanding factors that govern the amount of friction developed between two surfaces in contact are pressure holding the surfaces together and materials used for the surfaces. The more pressure applied the tighter the surfaces will grip each other and resist any relative motion. Rough-surfaced materials will grip and resist relative movement more than smooth-surfaced materials. For instance, there is a great deal of friction between a tire and dry pavement while there is very little friction between a tire and ice.

b. Coefficient.—The coefficient of friction is the ratio between the force required to move one surface over another and the pressure holding these surfaces together. For example, if it requires a force of 400 pounds to move a box weighing 1,000 pounds over a concrete floor, the coefficient of friction between box and floor is $400/1000=0.4$. As another example, suppose that the weight on one wheel of a vehicle is 750 pounds and that a force of 350 pounds acting on the tread of the tire is required to lock the wheel so that it will skid on the road. Coefficient of friction between the tire and the road is then $350/750=0.466$. The higher the coefficient of friction between two surfaces the greater is the amount of friction developed between them.

c. Design factor.—When any two surfaces move against each other, the friction between them develops heat and tends to wear them away. By increasing contact area between two surfaces effect of friction is spread, thereby preventing excessive heat and wear over a small area. The factors resulting from friction as well as those affecting the amount have to be taken into account when designing a braking system.

8. Factors affecting retardation.—*a.* The amount of retardation obtained by the braking system of a vehicle is affected by several factors. For wheel brakes used on motor vehicles these are—

(1) Pressure exerted on braking surfaces (lining and drum).

(2) Weight carried on wheel.

(3) Overall radius of wheel (distance from center of wheel to outer tread of tire).

(4) Radius of brake drum (rotating member).

(5) Coefficient of friction between braking surfaces.

(6) Coefficient of friction between tire and road.

b. For a definite amount of retardation, exerted pressure required on braking surfaces will become greater when weight carried on the wheel or overall radius of the wheel is increased. These factors are not affected by the design of the braking system and are generally a fixed value. However, limitations of these factors, particularly the weight of the vehicle to be carried by the wheel, must