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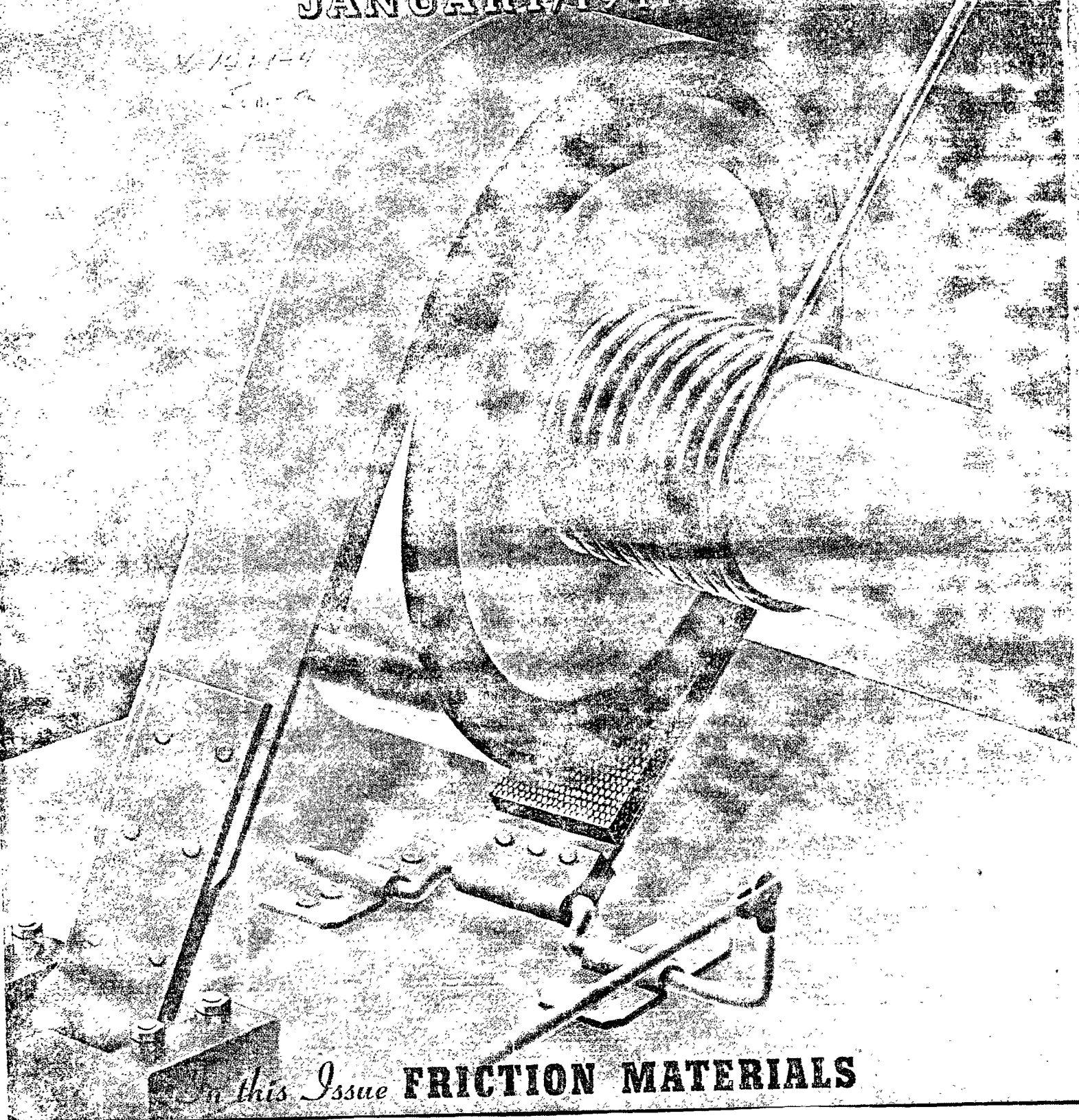
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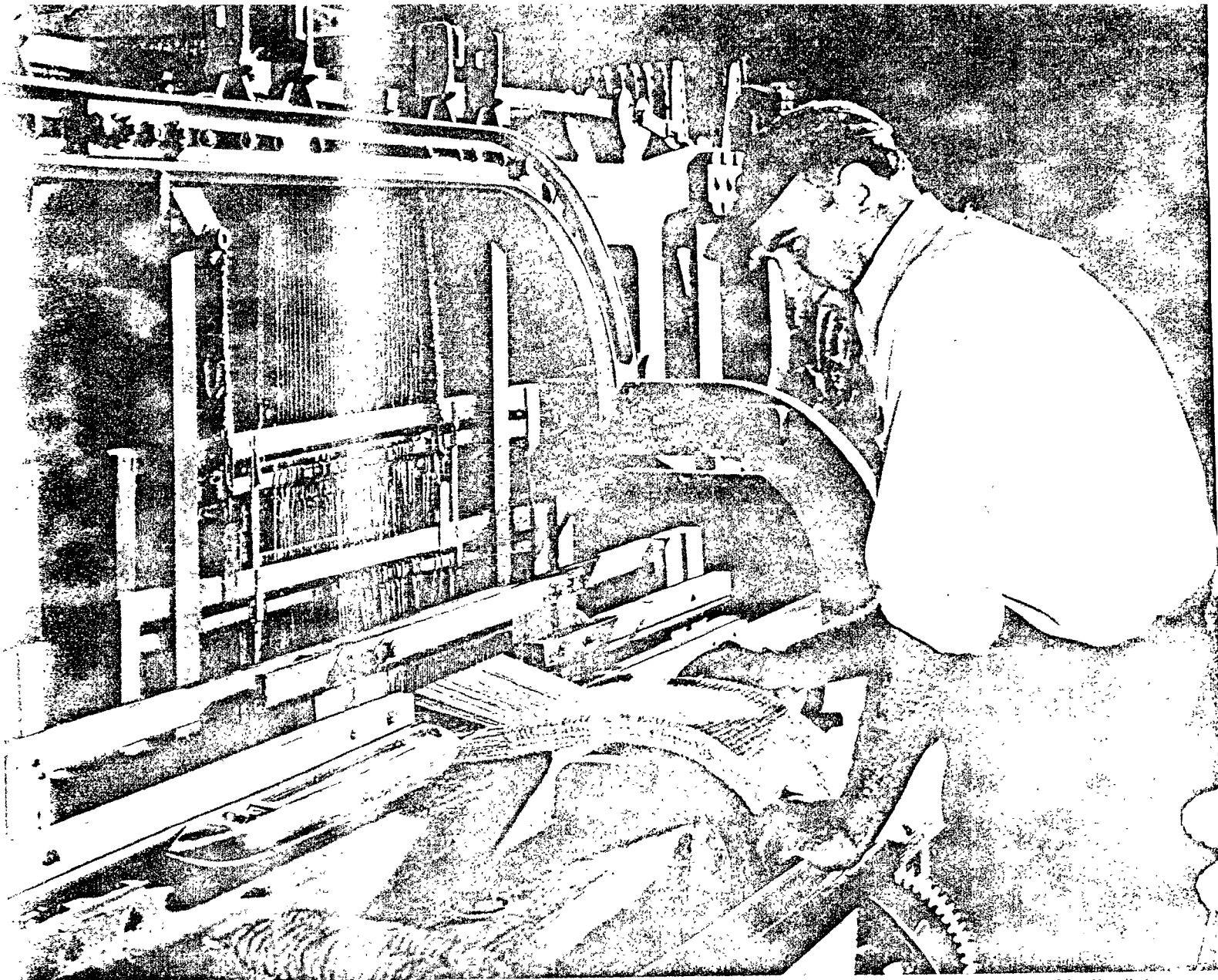
DOCUMENT DESCRIPTION: Trade Journal Article - Friction
Materials

PRODUCT ENGINEERING

JANUARY, 1941



In this Issue **FRICTION MATERIALS**



Johns-Manville Corporation

Weaving thick asbestos lining on a giant loom, after which the lining is impregnated and molded to size by heat and pressure

FRICITION MATERIALS—I

Linings and Blocks for Brakes and Clutches

FUNDAMENTALLY any type of band, shoe, disk brake, or clutch is designed with the objective of retarding rotation in order to decrease or to stop the relative motion between brake or clutch members, by converting the kinetic energy of the moving system to heat energy.

A major consideration in the solution of braking or clutching problems is concerned with the variation of the coefficient of friction of the friction

material during deceleration or acceleration. Factors which must be considered in determining the operating characteristics and capacity of a brake or clutch are the effects on friction values caused by temperature rise, maximum operating pressure, moisture, rubbing speed, wear, condition of brake drum surface, and length of time between operations.

No single friction material can meet the widely different conditions of brake

temperatures, loads, drum materials and finishes, deceleration rates, and frequencies of application encountered in the various services. In the industrial field some services require flexible lining, others require dense rigid blocks.

The quantity of heat generated at the contacting surfaces of the brake lining and the drum for any given braking operation has a definite value dependent upon the difference in the kinetic energy in the moving system

before and after deceleration, regardless of the time taken to stop or decelerate the moving load. The brake factors on which converting the kinetic energy into heat energy depend are the coefficient of friction between the lining or block and the drum, the total normal contact pressure, and the rubbing speed.

Friction linings are good heat insulators, metal drums are good conductors and therefore readily absorb the heat produced by the frictional forces with an accompanying rise in temperature. Naturally the maximum temperature developed in the drum will depend upon the frequency of operation, the mass and type of material of which it is made, the exposed area of the drum and its ability to radiate heat.

The high resistance to heat possessed by friction materials made with an asbestos base, as compared with similar properties of wood, paper, fiber and leather, are the chief reasons for the preference shown asbestos friction materials in the automotive, industrial and construction machinery fields. The typical values of operating factors shown in Table I are for asbestos composition linings and blocks.

Effect of Temperature

Coefficients of friction for asbestos composition materials at temperatures above 500 deg. F. become erratic, rising to high values or dropping to low values with consequent lack of control of the rate of deceleration. Therefore, for satisfactory operation brake drums must have the ability to dissipate heat rapidly enough to prevent the temperature of the drum from becoming excessive. The temperatures at which variation in the friction value occurs are those at which the binder in the friction material undergoes a physical change of state, and varies greatly with

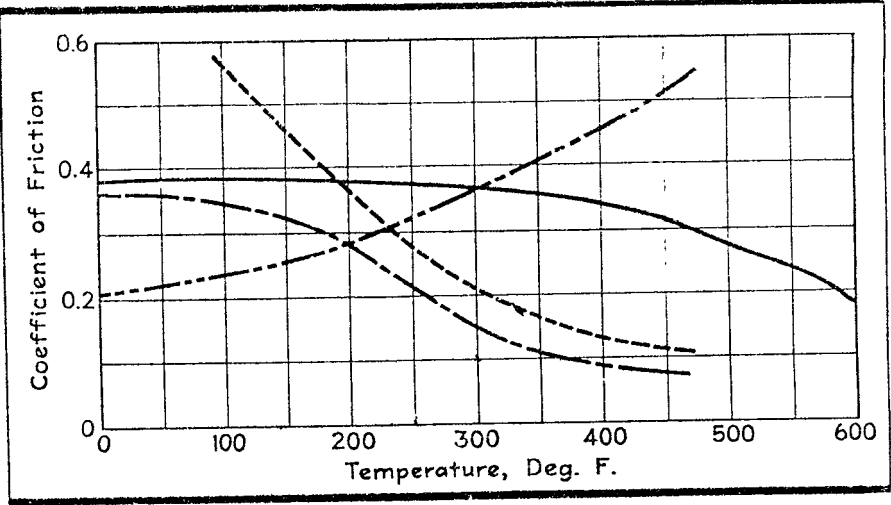


Fig. 1—Tests on various linings indicating how increasing temperature may affect frictional value under conditions of constant speed and pressure

different types of brake lining depending upon the heat resisting qualities of the binder or fillers after curing. The curves shown in Fig. 1 were established by dynamometer tests with various linings and indicate how with speed and pressure constant an increase of temperature may affect the coefficient of friction.

Although the binding materials are heat-treated in manufacture, the temperature on the surface of the friction material in service is often higher than that employed in manufacturing, with the result that the impregnant or binder may soften or even approach liquification thus reducing the coefficient of friction to low values and then to increase it as the binding materials are driven off developing a possibility of running on dry asbestos with a friction value of approximately 0.8. If a carbonaceous condition develops, the friction value may be higher or lower than normal, depending upon the character of the surface formed.

For satisfactory operation and long

life of lining, brake drum temperatures should never exceed 400 deg. F. for rubber bonded friction materials, nor 600 deg. F. for resinous materials. With the latter the higher temperature is permissible since the majority of the synthetic resins used in the manufacture of friction materials are thermosetting and are rendered infusible by the curing temperature.

High temperatures also break down the mechanical strength of asbestos fibers and destroy their structure. Asbestos occurs in nature in many different forms and chemical compositions. The form used in the manufacture of friction material is a magnesium silicate containing about 14 per cent water of crystallization. At temperatures at or above 700 deg. F. some of the water of crystallization is driven off, accompanied by a decided loss in strength of the fiber, in addition there may be a loss of organic impregnant through destructive distillation. At temperatures of about 1,000 deg. F. the magnesium silicate is rapidly dehy-

Table I—Performance Characteristics of Asbestos Linings and Blocks

These data cover only the best types of materials when used in dry service conditions.

STYLE	COEFFICIENT OF RUNNING FRICTION	RUBBING SPEED OF FT. PER MIN. MAX.	DRUM TEMP. MAX. DEG. F.		PRESSURE LB. PER SQ. IN.	RESISTANCE TO SHOCK	RATE OF WEAR
			SHORT PERIODS	CONSTANT			
Folded and compressed rubber compound	0.30—0.40	3,000	500	250	100	Excellent	Excellent
Flexible woven	0.35—0.45	5,000	500	250	50	Fair	Fair
Heavy-duty woven	0.35—0.50	7,500	750	500	100	Good	Good
Molded linings	0.30—0.40	5,000	750	500	100	Good	Good
Blocks	0.30—0.40	5,000	1,000	750	150	Excellent	Good

drated, resulting in a chalk-like substance without mechanical strength. Therefore, it can be readily understood why it is necessary to keep drum temperatures below 700 deg. F. in order to assure satisfactory operation.

Increasing the normal braking pressure will, of course, increase the decelerating force applied to the drum, however, this is accompanied with slight tendencies either to build up or to decrease the coefficient of friction in most materials. Hence for any application the increase in decelerating force is generally in direct proportion to the increase in applied pressure. The curve in Fig. 2 was established from dynamometer tests on samples of linings at constant speed and temperature, and indicates how an increase in unit contact pressure may influence the coefficient of friction. Examples of the effect of increasing normal braking pressure on deceleration rate are shown in Fig. 3 for various coefficients of friction. Dry, unlubricated friction is independent of the area in contact for constant conditions of velocity, temperature and surfaces. Increased area, however, is obviously highly beneficial in reducing wear.

At low speeds of a few feet per hr. most friction materials have a coefficient of friction which is less than their values at high operating speeds. When the rate of sliding approaches zero just before stopping, it is thought that the coefficient of friction rises sharply possibly because of a fade at higher speed and an antifade on cooling of the contact surfaces. A drop in frictional resistance as the velocity approaches zero is desirable. If the low speed frictional resistance is considerably below the normal friction value, however, the holding ability of the brake may become uncertain. Since if for any reason a slight movement or vibration of the drum were induced in a standing or suspended load, the frictional grip of the brake would immediately drop and the load might start and continue to creep indefinitely.

Some tests have shown that with increases of rubbing speeds up to about 500 ft. per min. there is a gradual increase in the coefficient of friction, and that at rubbing speeds between 500 to 5,000 ft. per min. there is a small dropping off in the friction value as the velocity increases, however, this reduction is small.

The rate of wear of asbestos friction materials varies considerably in different types. In order to maintain a friction level within dependable limits some wear is desirable to remove the smooth glazed surface which forms on the lining because of accumulations which take place. Oil or grease may

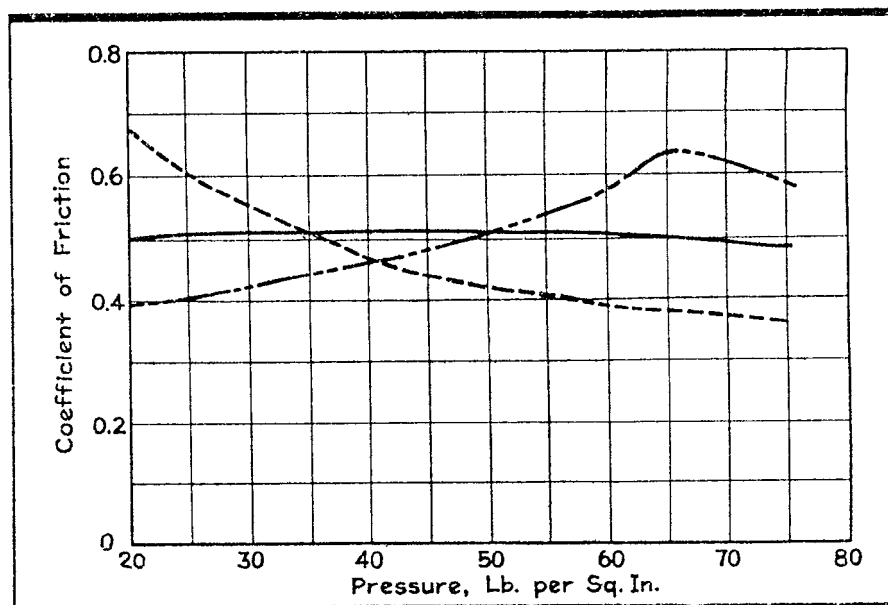


Fig. 2—Increase in unit contact pressure is accompanied with slight tendency either to build up or to decrease the coefficient of friction in most materials

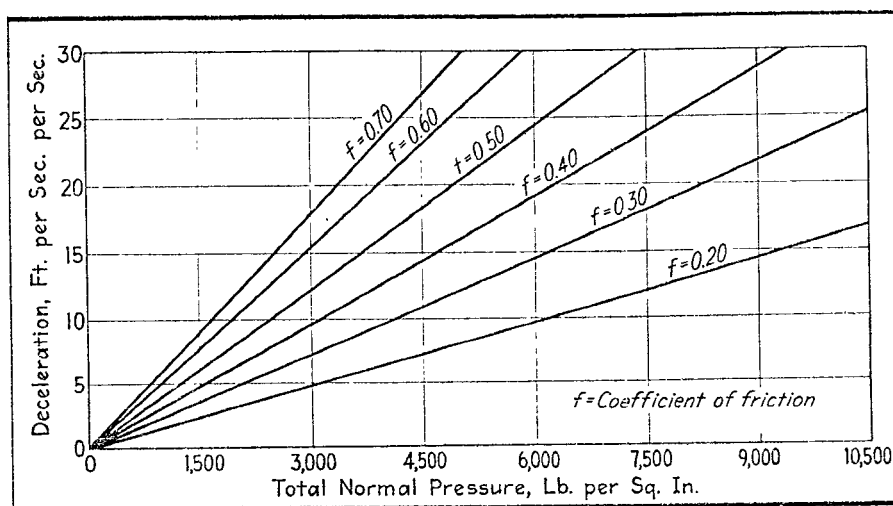


Fig. 3—Examples of the effect of increasing total normal braking pressure on the coefficient of friction

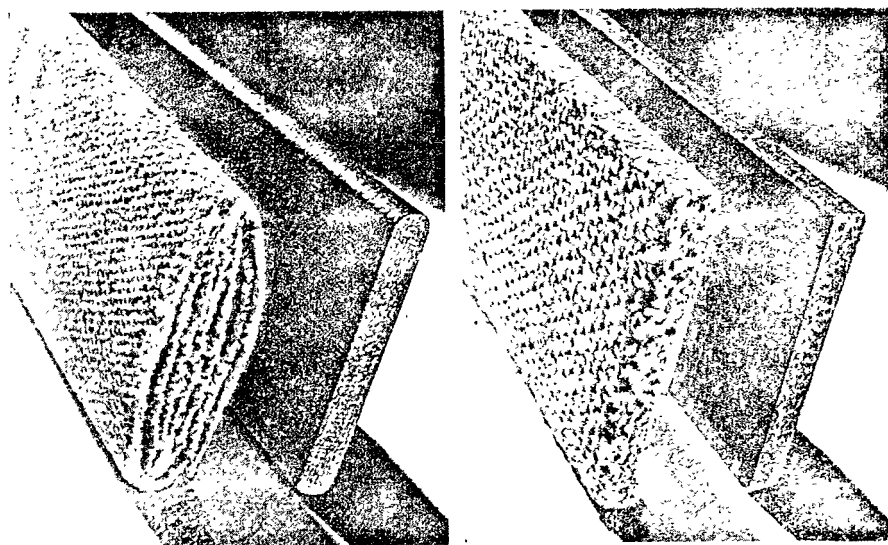


Fig. 4—Asbestos linings. Left, folded type. Right, flexible woven type

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cause the lining to glaze. As glazing develops the coefficient of friction fades. Rough drum surfaces naturally increase wear and develop an apparent high friction value.

The effect of water on asbestos friction materials is to form a lubricating film, hence with some linings dangerous slipping occurs when the material is wet. This film during braking operations, however, is quickly squeezed out if not renewed. The rate of recovery in friction value depends upon the amount of water absorbed by the asbestos fibers. Asbestos is a hygroscopic material, it will absorb from two to four per cent moisture from the atmosphere. During manufacture the asbestos fibers are sometimes waterproofed as well as covered with the impregnating material. But as the friction lining or block wears in service, the fibers at the surface become uncovered and absorb water in addition to that held in the interstices of the lining structure and in the brake dust, which may when the lining has not worn uniformly account for the grabbing effects of asbestos friction materials when damp. The curves in Fig. 5, taken from Prony brake tests, indicate the effect of water on the frictional value of linings and their ability to recover from the lubricating effect of the water film. The ideal lining, of course, would be unaffected by water. Some linings, in recovering from the lubricating effect of the water film, become very sensitive and remain so for a considerable time. Others recover their prior effectiveness and remain at this level.

Some linings have a tendency to swell with the absorption of water so that they drag on the drum surface if the clearance is small. Oil may also cause linings, particularly rubber-bonded linings, to swell and soften. Some synthetic resin-bonded linings are not physically affected by a thorough soaking in oil; their frictional value, however, drops considerably. Oil on a rubber lining, on the other hand, usually increases the frictional value after the consequent softening and disintegrating of the rubber.

For satisfactory braking operations lining materials should be fitted tightly to bands with full bearing on the backing surface to prevent wrinkling and consequent crowding. All rivets or bolts used for fastening the lining should be body tight in the band in order to prevent any "play" that might cause a rivet failure by shear if subjected to shock or impact.

There should be no clearance on the bolts in line with the force on the blocks, as the blocks may slip and

shear the bolts. All bolts and screws should have heavy steel lock washers to prevent loosening under vibration.

For flexible industrial linings larger than 1/2 in. thick brass bolts are generally employed because the shearing effect increases with the difference in radius of the outer and inner lining surface. Flexible linings less than 1/2 in. thick are usually secured to the bands by rivets. In Fig. 6 are shown various methods for fastening.

Fastenings should never be permitted to come in contact with the brake drum. The heads should be countersunk below the friction material surface as far as can conveniently be done without weakening the holding power of the fastening. In flexible materials, it is customary to

counterbore at least half the thickness; in rigid materials about two-thirds the thickness.

Because of wear of the friction material, it is sometimes impossible to prevent occasional contact of the fastenings with the drums. Every effort should be made, therefore, to prevent the possible cutting, scoring, or wearing away of the drum by the proper selection of the fastening material. Rivets and bolts for fastening friction material to bands are usually made of brass, copper, or aluminum.

Brass rivets are superior to copper because they abrade rather than drag or plate the drum surface and show a minimum tendency to score under normal operating conditions.

As a general rule, solid flat head

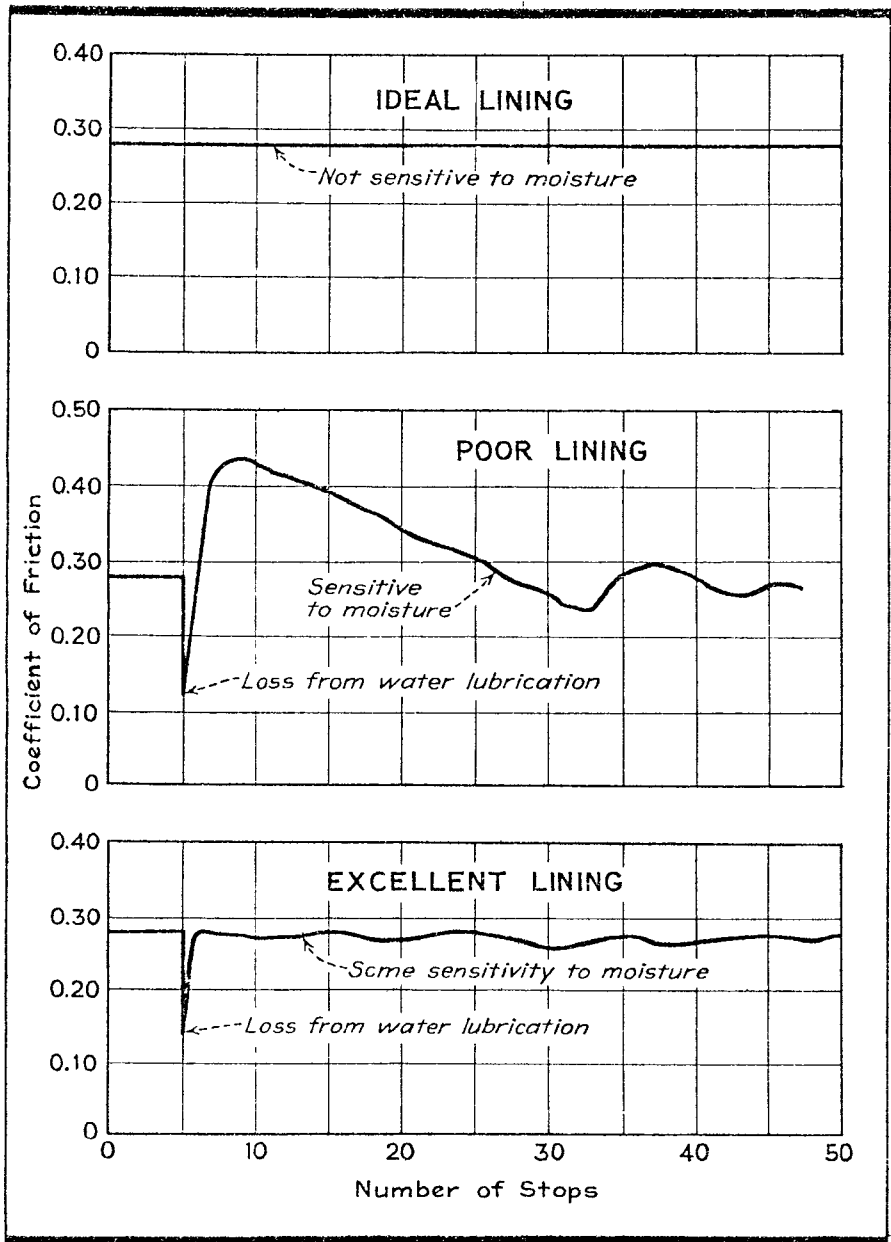


Fig. 5—Curves from Prony brake tests indicating the effect of water on the frictional value of linings and their ability to recover

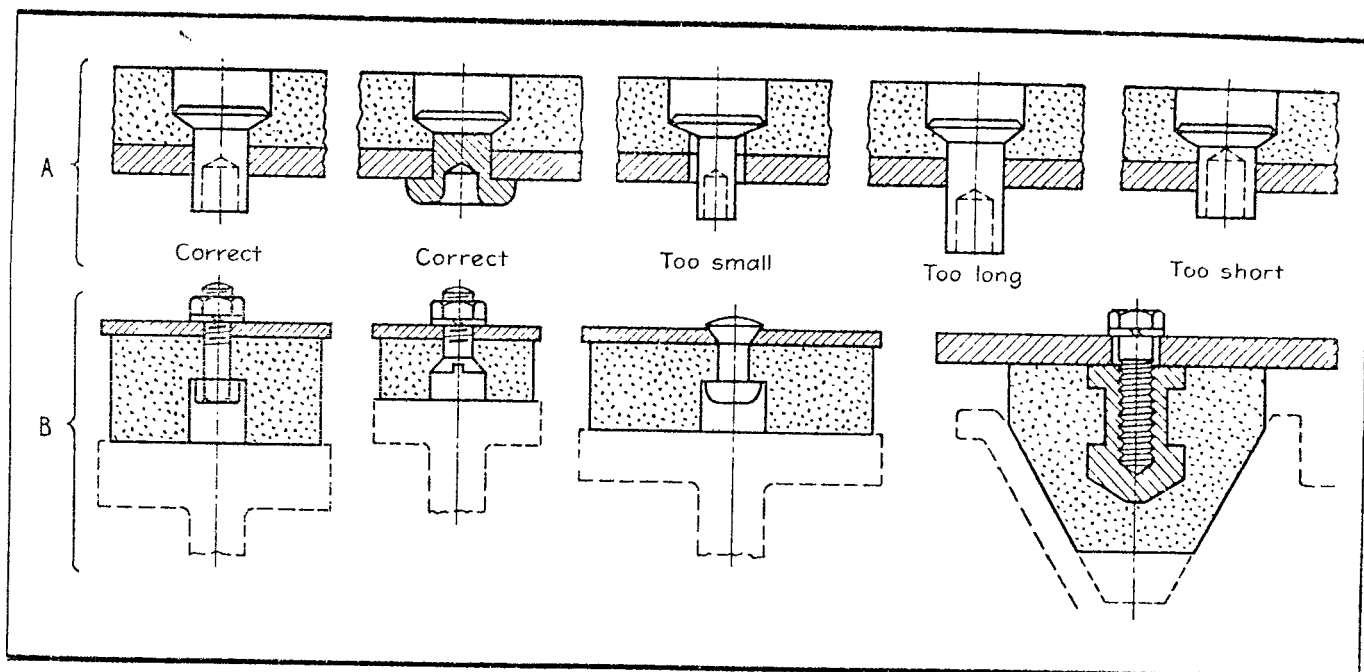


Fig. 6—Methods of fastening friction materials to brake bands. (A) Correct and incorrect methods for riveting linings to brake bands. (B) Methods of fastening blocks to bands

rivets are the most satisfactory type for industrial purposes. Semi-tubular rivets are better for this work than the full tubular kind as they can be spread more easily when upsetting to make a tighter grip. Split rivets should not be used on industrial equipment under any considerations.

The minimum length of rivet should be the thickness of lining under the rivet head, plus the thickness of the brake band or shoe, plus the diameter of the rivet body. The maximum length should be not more than one and a quarter times the minimum length.

For fabric linings it is suggested that rivet heads be made twice the diameter of the body or shank. Molded linings are dense and mechanically strong and do not require rivets with as large heads to hold the lining in position.

The number of rivets to use in a lining will depend upon the maximum pressure of engagement, the maximum coefficient of friction, and the safe shear strength of the rivets. The area A of brake lining in sq. in. per rivet, may be expressed in terms of maximum pressure of engagement p in lb. per sq. in., maximum coefficient of friction f , and safe shear strength S in lb. per rivet, as

$$A = S/pf$$

Safe shear strength of brass rivets based on a unit strength in shear of 12,000 lb. per sq. in. can be listed as

5/16 in. dia. rivet.....	920 lb.
1/4 in. dia. rivet.....	600 lb.
3/16 in. dia. rivet.....	300 lb.
1/8 in. dia. rivet.....	150 lb.

Rigid friction materials 3/8 in. thick and smaller are termed molded linings; and thicker pieces are known as friction blocks. Because of their high mechanical strength, rigid molded friction materials are often used where high stresses would break down the softer and more flexible types of materials. Rigid molded materials being formed under pressure and the binder set to a rigid and infusible condition usually are more resistant to heat and more constant in frictional values over a relatively wide range of temperature than are the flexible types. Rigid molded linings are also less compressible and so require less frequent adjustment when high pressures are employed.

Molded linings in roll form are usually made with an integral backing material to increase their mechanical strength, and are suitable for either internal expanding or external contracting wrap band or shoe type brakes. These linings have the friction facing on one side only and have to be curved to suit design with the backing on the proper surface, that is, internally for expanding and externally for contracting brakes. Coefficients of friction range from 0.20 to 0.50. The linings are highly resistant to wear and are suitable for rubbing speeds up to 5,000 ft. per min., drum temperatures up to 500 deg. F. constant service, and up to 100 lb. per sq. in. brake pressure. Flexibility depends on incompletely curing the organic binder and this type is more inclined to fade at high temperatures.

In recent years manufacturers are

trying to design brake linings that have definite friction values and to include a graded range of these values in their line. It has been found, however, that some brakes require an overall frictional value, where there are two or more shoes, and this value is not satisfied by any one lining. Some brake designers use different types or styles of lining for different brakes in order to select the friction and wear characteristics that are most satisfactory.

To provide in-between friction values, two different linings may be used on a given brake. One type of lining may be used on an energizing shoe and another kind on an auxiliary shoe. In the two-shoe type of brake, the energizing shoe does more of the braking than the non-energizing shoe and wears faster. To compensate for this increased wear, one automobile manufacturer furnished a thicker piece of lining on the energizing shoe. Another type of two-shoe brake has a longer piece of lining on the energizing shoe than on the non-energizing shoe. Some lining segments are so tapered that they are thicker at the areas of more rapid wear yet fit the drum.

EDITOR'S NOTE: For contributing data and helpful criticism during the preparation of this article, the editors acknowledge their appreciation of the valuable cooperation of J. W. Hemphill, Jr., Johns-Manville Sales Corporation; T. R. Stenberg, Marshall-Felipe Div., Bendix Aviation Corporation; and Dr. F. C. Stanley, Raybestos Div., Raybestos-Manhattan, Incorporated.