Sept. 6, 1966 H. F. ARLEDTER ET AL 3,270,846

FRICTION MEMBER WITH FRICTION MATERIAL

Original Filed March 15, 1957

4 Sheets-Sheet 1

Fig. 1

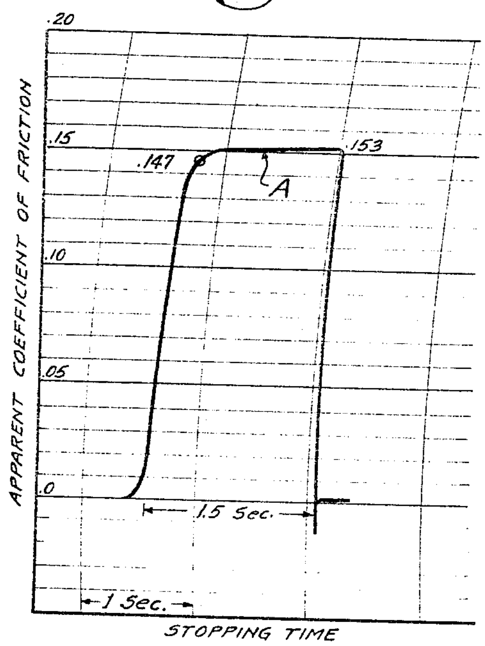


Fig. 2

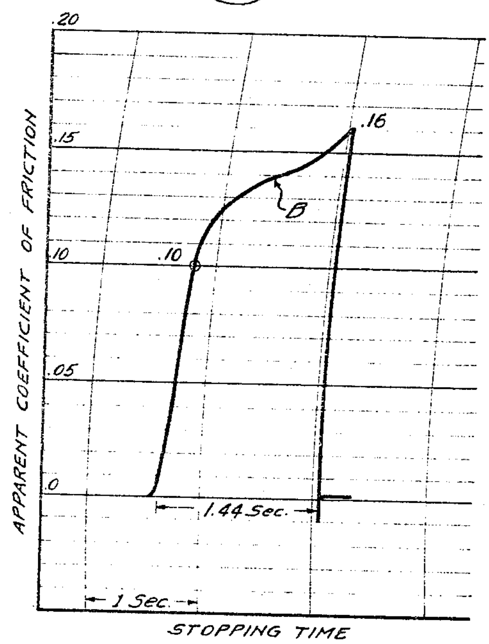


Fig. 3

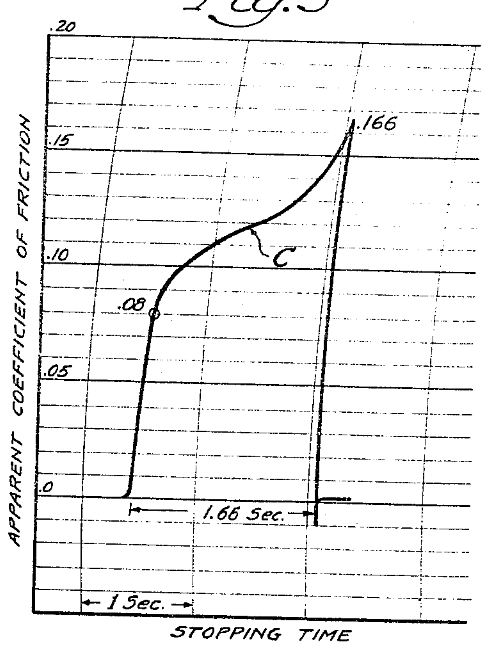
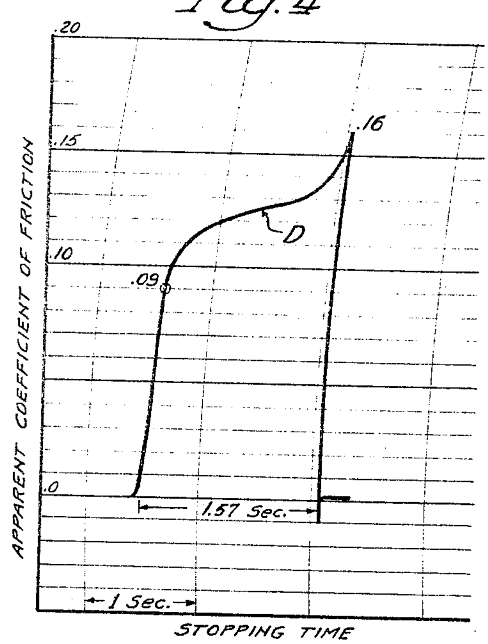


Fig. 4



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4 Sheets-Sheet 2

Fig. 5

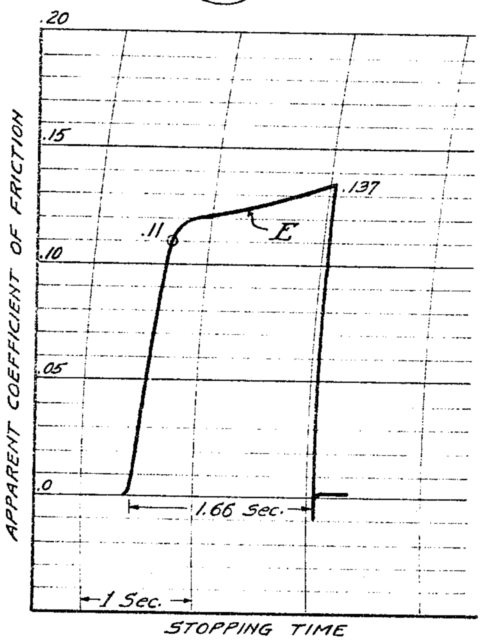


Fig. 6

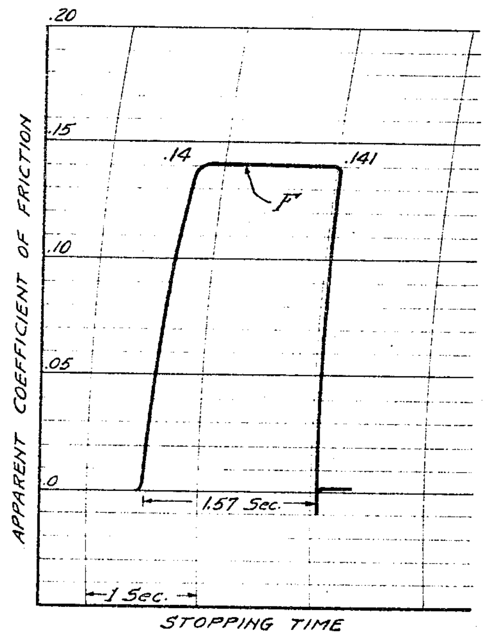


Fig. 7

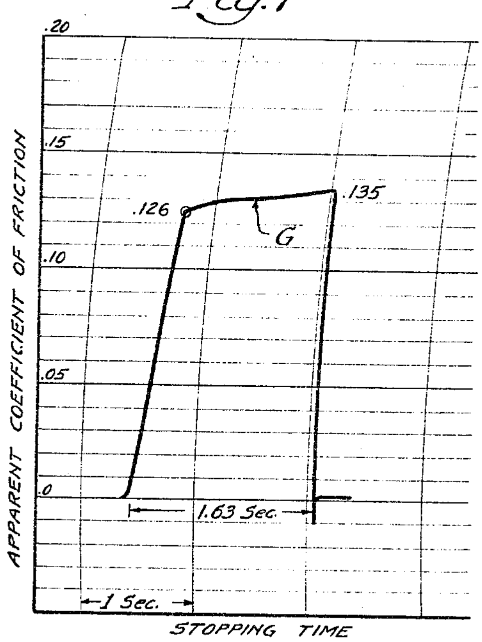
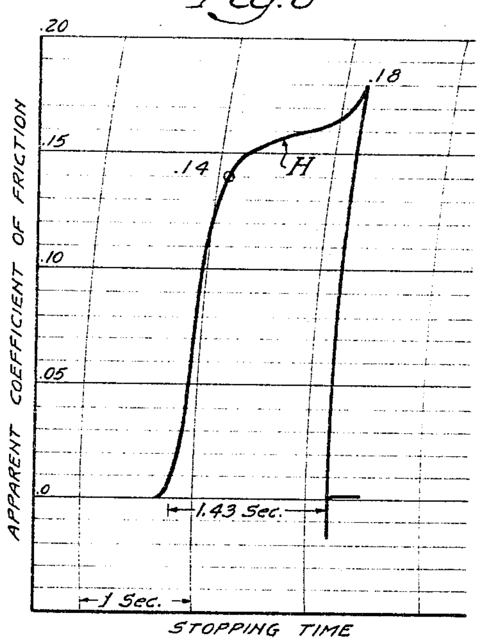


Fig. 8



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FRICTION MEMBER WITH FRICTION MATERIAL

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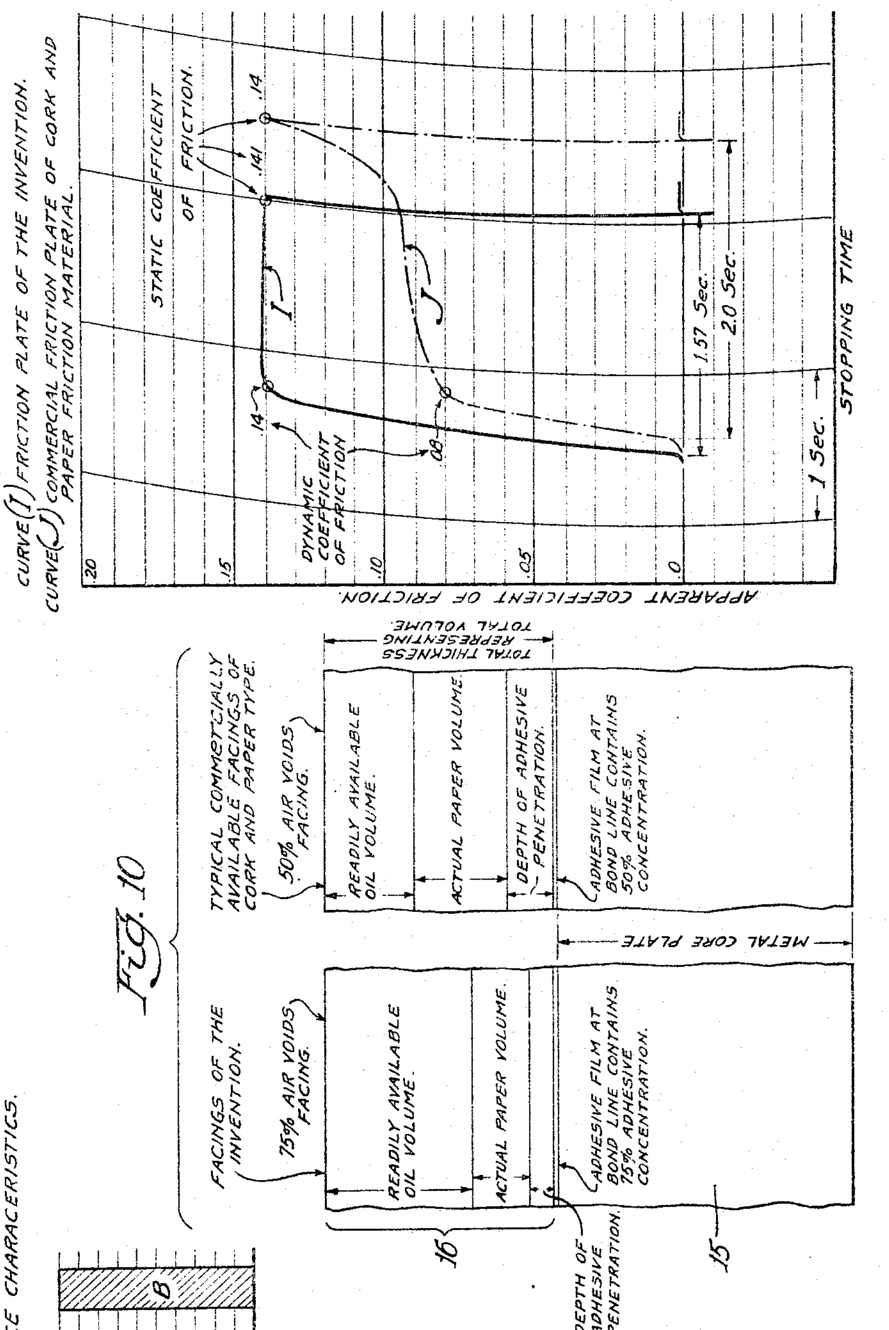

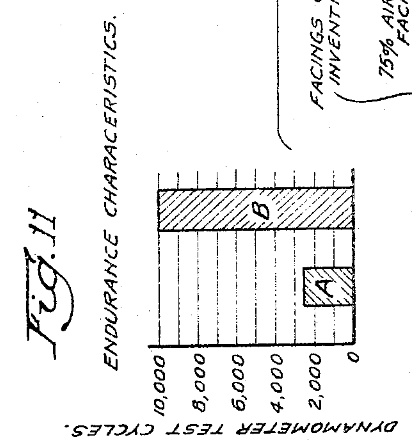

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Fig. 15

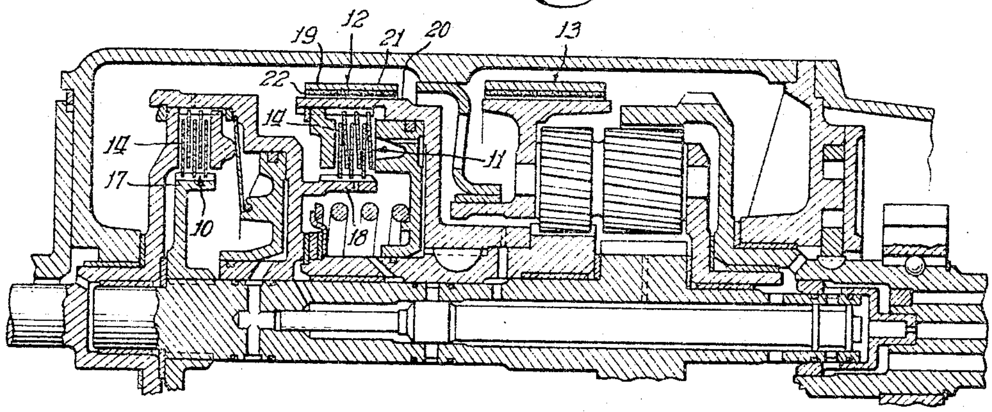


Fig. 12

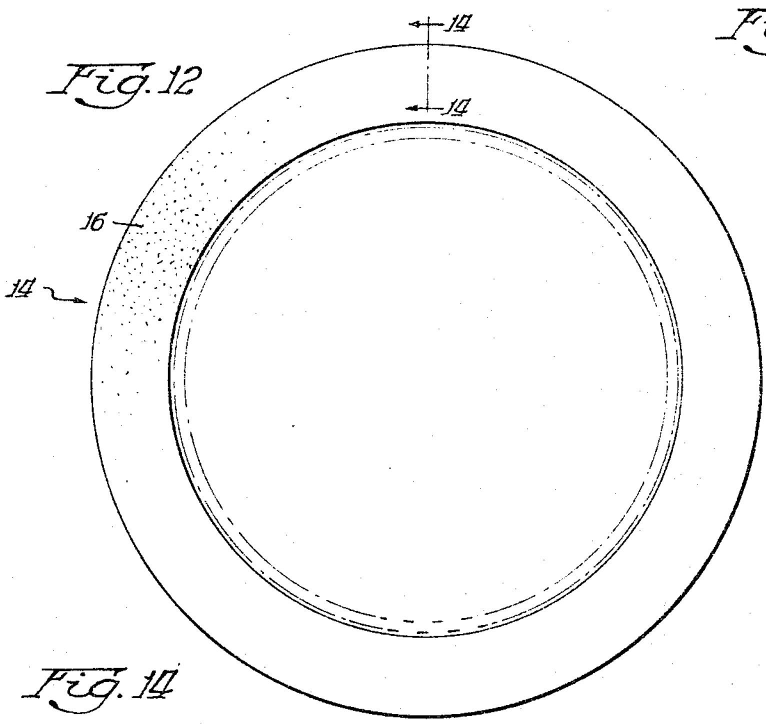


Fig. 13

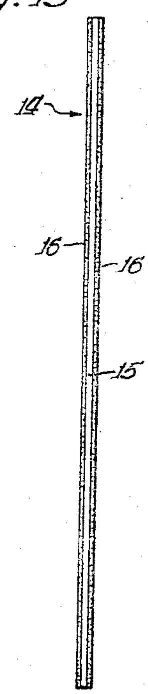
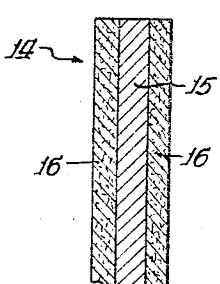


Fig. 14



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FRICTION MEMBER WITH FRICTION MATERIAL

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Continuation of abandoned application Ser. No. 646,349, Mar. 15, 1957. This application Apr. 10, 1961, Ser. No. 104,499
15 Claims. (Cl. 192—107)

This is a continuation of application Serial No. 646,349 filed March 15, 1957, now abandoned.

The present invention relates to improvements in friction members for clutches and brakes and more particularly to friction plates having friction facings thereon especially adapted for use in wet clutches of torque transmitting assemblies which run in oil or other fluids.

Wet friction materials as used in present applications generally fall into 3 main groups, namely, (I) metallic, (II) semi-metallic, and (III) cork or cork and paper types. These groups generally have the following characteristics:

(I) Metallic:
- (a) High heat resistance.
- (b) High cost.
- (c) Low coefficient of friction, i.e., dynamic coefficient of about .04 and static coefficient of about .11.
- (d) May be used with high unit loads.

(II) Semi-metallic:
- (a) Medium heat resistance.
- (b) Medium cost.
- (c) Medium coefficient of friction, i.e., dynamic coefficient of about .08 and static coefficient of about .12.
- (d) Can withstand medium unit loads.

(III) Cork or cork and paper:
- (a) Low heat resistance.
- (b) Low cost.
- (c) High coefficient of friction, i.e., dynamic coefficient of about .08 and static coefficient of about .14.
- (d) May be used with low to medium unit loads.

Usually, the design engineer thinks of the aforementioned materials as belonging to the three distinct groups described, and he must design with one group particularly in mind. He may not allow himself the freedom to design a mechanism, eliminating from his considerations the friction material to be used on the assumption that a friction material may be later tailored to fit his requirements. Using such an approach in the past has led to serious limitations in the engineer's final product.

In general, once a particular design has been matched to the use of one of the above-mentioned groups it is not usually feasible to change to another group without re-adapting or rematching the design. For example, to use materials from another group may require changing apply loads, rate of application of the apply loads, and in the case of multiple disc friction devices, changing the number of discs. In the case of friction band applications, contact area or band width may require changes to keep within usable unit loads.

All of the friction materials in groups I, II, and III are of such a nature that at least one or two means must be incorporated to control their release and engagement characteristics. These means include, for example, the use of various grooving patterns in the friction material to permit a controlled oil flow and/or the use of waves or coning on the metal separator plates as used

in multiple disc clutch applications. In the particular case of waves, the waving may be applied to either the friction drive plates or to the metal separator plates. With materials of the invention, in most cases, the release and engagement characteristics are of such a nature that neither grooving, waving, or coning is required. This permits the low cost of using the friction material of the invention to be further lowered by eliminating the need for the costly grooving, waving or coning operations.

Furthermore, if materials having a substantially higher coefficient of friction than those of groups I and II were available, and if these materials could withstand the normal environmental temperatures encountered by materials of those groups, the following design improvements could be made possible.

(1) Fewer friction elements, or elements having a smaller friction area could be used in multiple element applications.

(2) If the same number and size elements were used, a substantially higher coefficient of friction would permit the use of a lower clutch application load. In the case of fluid transmissions this could make possible the lowering of operational line pressures and the resulting savings in over-all hydraulic efficiency.

In the case of removing one friction element from a multiple disc clutch in use in a high volume production product, the resulting savings are substantial.

With friction materials of the invention we have established a new group of materials for use by the design engineer. This new group offers the designer the following unique advantages. Through the use of one basic paper used in conjunction with several resins or combinations of resins we are able to provide the design engineer with heretofore unobtainable friction materials which may have their coefficients of friction tailored to the specific application. By way of example, a friction material, characteristics of which are hereinafter described in FIG. 6, has the unique characteristic of having a dynamic coefficient of friction substantially equal to its static coefficient of friction. This single characteristic when present in the friction material used in multiple disc friction assemblies as used in automotive automatic transmissions results in a highly desirable, shock-free, smooth power shift from one gear to another.

The friction material of the invention may be described as group IV having the following characteristics:

(IV) New group (friction materials of the invention):
- (a) Medium to high heat resistance.
- (b) Adaptable to various applications by varying the coefficients of friction.
- (c) Ability to withstand medium unit loads.
- (d) Low cost.
- (e) Dynamic coefficient of friction may be made substantially equal to the static coefficient.
- (f) Does not require the use of grooving, waves or coning, which, of course, might be used, should other circumstances dictate such use.
- (g) Very high resistance to fade.
- (h) Generally long endurance.

It is contemplated that a variety of friction members such as clutch devices of various configurations and braking devices of various configurations may be made utilizing the friction materials of this invention. It is to be understood that the design of these devices need not necessarily be confined to a friction plate but may include, for example, conical-shaped devices such as are used in cone clutches, wavy plates such as are utilized in some clutch devices, brake bands engageable on a cylindrical surface, etc. However, for purposes of simplicity of description, the invention will be described only with reference to the construction of a friction plate, and such description is not to limit the scope of the claims to only that type of a friction member.

The friction plate described herein consists of a core plate, generally made of metal, and a friction facing which is an interfelted fibrous paper sheet secured to one or both sides of the core plate. The core plate may variously be referred to as a backing member or a supporting member.

Conventional wet and dry friction facings have been manufactured heretofore by several methods, for example, either by using a molding technique employing powdered materials which are mixed in the proper proportions and molded under heat and/or pressure, or by employing a felting technique such as is employed in the production of a kraft felt or paper product. The materials previously utilized in forming these friction facings include asbestos, cotton, kraft fibers, leather, rubber, cork, cashew nut shell powder, metal powder, resins, binders, colloidal clay, mica, iron oxide, carbon and sulfur. The heretofore known friction facings however, have suffered from many defects in that they possess some of the desirable properties necessary in such a product, but do not possess all of the necessary properties. For example, they may be deficient in regard to one or more of the following: the relation between the dynamic and static coefficient of friction, "feel," ease of engagement, abrasive resistance and abrasiveness, heat resistance, life expectancy under severe conditions of heat and moisture, and other engagement characteristics that a clutch fabricator might reasonably require. In the past no one type of friction facing has been adaptable to a variety of applications for which friction plates may be required in one or a number of transmission assemblies. Consequently, for each different type of application, transmission manufacturers have had to resort to a number of individual friction plates which are made of completely different materials. In view of the many deficiencies of the known friction facings, particularly when used in the present day high-powered fluid transmission cars, the automobile industry has been greatly interested in obtaining a wet friction facing which would possess more nearly all of the desirable properties rather than only a few.

Accordingly, it is the object of the present invention to provide an improved friction plate consisting of a core plate, preferably of metal, and a resin-containing interfelted fibrous paper sheet friction facing secured thereto, preferably adhesively, for use in wet clutches which will provide in the clutch assembly an improved coefficient of friction; improved resistance to heat and moisture; very good "feel" in shifting between the various speed ratios; high abrasion resistance; low abrasiveness; and longer life expectancy under severe conditions of heat, moisture and abuse encountered in the operation of an automobile.

Another object of this invention is to provide a friction material which will yield a variety of desired coefficients of friction as required by various applications and desired relationships between the dynamic and static coefficients of friction when different resins are added to the material.

Still another object of the invention is to provide a final friction plate wherein the friction facing will have a high oil or fluid holding capacity. Where the term oil is used herein, it is meant to also comprehend other commercially available liquids having the requisite properties for any particular installation.

FIGURES 1 through 9 are curves illustrating operational characteristics of a friction facing containing different types of resins.

FIG. 10 is an enlarged cross-sectional view of a friction material bonded to a backing member.

FIG. 11 is a bar graph comparison of endurance characteristics of a friction plate of the invention with a commercial cork and paper-type plate.

FIG. 12 is a plan view of a typical friction plate.

FIG. 13 is an edge view of the friction plate shown in FIG. 12.

FIG. 14 is a sectional view through lines 14—14 of FIG. 12.

FIG. 15 is a half-sectional view in elevation of a typical automotive automatic transmission showing multiple disc clutch packs and brake bands.

While the present invention is being described herein as having particular application to friction plates for use in wet clutches adapted to operate in connection with bringing two rotating parts into synchronism, it will be appreciated that this same type of friction plate may be used in a braking or retarding device wherein one or more elements are stationary and other rotating elements are brought to a stopped condition when brought into pressure contact with the stationary elements.

A particular use of friction plates and braking devices is shown in FIG. 15. FIG. 15 shows multiple disc clutch packs **10** and **11** and braking devices **12** and **13**. Friction plates **14** comprising a core plate **15** and friction facings **16** (FIG. 13) are attached by splining, for example, to hubs **17** and **18**. Braking device **12** comprises a brake band **19** engageable on brake drum **20**. Brake band **19** comprises a backing member **21** and a friction facing **22**.

For purposes of clarification of terminology used herein, the following words and phrases are defined:

(1) "Paper" or "paper sheet"—a friction material from which a friction facing is made and which contains basically, at least, three components as hereinafter described, namely, cellulosic fibers (or synthetic fibers substituted in whole or in part), asbestos fibers and a filler material. The expression "based on the weight of the paper" as used herein, shall mean the total weight of these three components. Other components, as hereinafter described, may be added for further enhancing the qualities of a friction facing made therefrom.

(2) "Friction facing" or "facing"—as used herein shall mean, paper material as described above with a resin added thereto either originally while making the paper or at a later stage by impregnation of the paper with a resin solution.

A suitable paper which will impart the above properties to a wet friction facing must contain a high ash content, but the paper must show good uniformity throughout and have no marked two-sidedness, i.e, there should be a uniform dispersion of all the elements throughout the paper. The paper must possess a good uniform absorbency for resin solutions if the paper is to be impregnated with a resin rather than have the resin in powdered form therein. The paper must show good over-all strength, including good edge strength in the final product. The density of the paper must be low in order to have a resultant high oil absorbency capacity after the paper is made into a friction facing and applied to the core plate. In addition, the paper must be of such a nature that the friction facing made therefrom will be a flexible, porous, compressible layer, which will release oil under compression and absorb the oil after the pressure is released in the final torque transmitting assembly. It is this property of "give" under pressure and return to the original shape and thickness after the clutch pressure is released which is partly responsible for the excellent results obtained with the paper.

In the broader aspects it is contemplated that the friction facing shall contain the below-named ingredients within the stated percentage ranges.

The friction facing made of this paper contains the following principal components: cellulosic fibers, asbestos fibers, specific filler material and a resin. Synthetic fibers may be substituted in whole or in part for the cellulosic fibers. In addition to these components the friction facing may also contain various other components as set forth below in order to improve further the properties thereof.

There are present in the paper from about 30% to about 70% by weight of cellulosic fibers or synthetic organic fibers or mixtures thereof. Typical cellulosic fibers which may be employed include alpha cellulose, sulfite cellulose, sulfate cellulose, cotton, linen, rag and the like. Suitable synthetic organic fibers must be capable of withstanding ambient temperatures in excess of 200° F. and are formed by extrusion or spinning. Such for example, are: viscose rayon, synthetic fibers made by the condensation of dimethyl terephthalate with ethylene glycol (Dacron), dinitrile fibers (Darlan), synthetic fibers made from polyacrylonitrile (Orlon), synthetic organic fibers formed from polyamide resins made by the polymerization of a hexamethylene diamine salt of adipic acid (nylon), saponified and stabilized cellulose acetate (Fortisan), polytetrafluoroethylene fibers (Teflon), copolymers of vinyl chloride and acrylonitrile (Dynel) and the like. It is also preferred that the synthetic organic fibers have a length in excess of about 4 millimeters, i.e., from about 4 millimeters to about 15 millimeters, since fibers of such length possess high physical strength under stress, impact and high temperature and the ability to yield under pressure without deforming. Felted mats of such fibers also show high oil absorbency.

The paper also contains from about 5% to about 35% by weight, and preferably from about 5% to about 25% of asbestos fibers. The asbestos fibers may be either long fibered material or short fibered material, the long fibered asbestos being the preferred form.

From about 10% to about 50% by weight of filler material, which may exist in the form of particles or in the form of fibers, is in the paper. The filler materials which may be employed, for example, are particles of diatomaceous earth, alumina, or fibers of aluminum silicate, glass, or quartz, or mixtures thereof. Many types of glass fibers may be used. The diatomaceous earth and alumina filler materials in the form of particles can have a size of from about 1 micron to about 30 microns, and preferably from about 1 micron to about 8 microns, in order that the absorbent paper will have a sufficiently high resin penetration rate, good absorbency, and good bonding of the filler particles in the paper, and further that a friction facing formed from the paper will have the desired coefficient of friction. Particles of smaller size produce paper having only a fair resin penetration rate, while particles of larger size impart excessive abrasiveness to the paper and a friction facing formed therefrom. Filler materials in the form of fibers preferably have a diameter less than about 5.5 microns, in order that the fibers will not be abrasive. Very good results have been obtained with fibers of the range of 0.75 micron to 3 microns.

It should also be pointed out that the coefficient of friction will be increased by increasing the hardness of the filler material. It has been found that filler materials of a hardness of less than about 3.5 mohs would not enhance the friction qualities of a friction facing over and above what could be obtained in a facing composed only of cellulosic fibers and asbestos fibers. Therefore, filler materials such as the above-mentioned of a hardness of more than 3.5 mohs should be used.

The preferred filler materials are particles of diatomaceous earth and glass fibers. Glass fibers are seat resistant and inert, and help to impart the desired coefficient of friction to friction facings formed from the paper. Felted glass fibers will enhance the oil absorbency qualities of the paper. Diatomaceous earth possesses many properties not possessed by conventional filler particles used in forming filled paper which make it highly desirable for use in a friction facing. Thus, with most fillers, paper shows a decreasing resin penetration rate with increasing filler content. With diatomaceous earth, however, the reverse is true in that as the amount of diatomaceous earth in a paper is increased, the resin penetration rate of the paper also increases. Also, with most fillers, as the filler content of the paper increases, the density of the paper also increases while the percent resin pickup decreases. As the diatomaceous earth content of a paper is increased, however, the density is decreased, the resin pickup is increased, and the uniformity of resin distribution is improved. Diatomaceous earth also reduces the moisture absorbency of the paper in an amount proportional to the amount of diatomaceous earth filler present therein. In addition, paper filled with diatomaceous earth does not shrink excessively on drying, and hence, the original density of the paper is substantially retained after wetting and redrying.

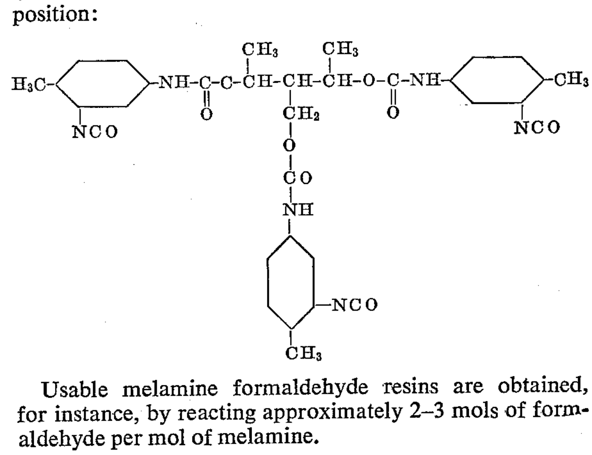
A high strength resin is also added to the paper. This resin may be added to the paper stock in the form of a powder. However, the preferred manner of adding the resin is to incorporate the resin in the friction facing by impregnating the paper with a resin solution or emulsion after the formation of the paper. From about 10% to about 50%, and preferably about 20% to about 40% of the resin powder may be added, this percentage being based on the weight of the other principal components, namely, cellulosic fibers or synthetic fibers or mixtures thereof, asbestos fibers and filler materials. If, however, an impregnating resin solution is used, the paper is saturated so as to pick up a comparable amount of resin from the solution.

Resins, as the term is used herein, which are suitable for use in this friction facing must impart to the facing the following characteristics under conditions encountered in actual operation of a friction device. An acceptable friction paper faced plate must be heat resistant to temperatures of at least 200° F., must be relatively hard, must impart to the facing resiliency, good impact and overall strength, plastic recovery, resistance to oil or other fluid and resistance to abrasion. The resin used must be of such a nature that it will be compatible with and cure in the presence of the paper material. The resin may be cured in any well-known manner including using heat and/or a catalyst, and/or radiation sources. Typical resins having the above qualities are polyurethane resins, melamine formaldehyde resins, melamine aldehyde resins, silicone resins, phenolic resins and modified phenolic resins.

The polyurethane resins usable for products of the invention are a combination of condensation products of polyesters and isocyanate compounds containing two or three —NCO— groups. The condensation products of polyesters are made, for instance, of adipic acid and triols like glycerin, hexane triols, trimethylol propane and diols like butylene glycol of phthalic acid and xylene formaldehyde. The isocyanate compounds used contain two or three —NCO— groups. Such isocyanates are phenyl diisocyanate, p,p'-diphenylmethane diisocyanate, tolylene diisocyanate, and triphenyl methane triisocyanate.

The polyesters chosen shall be of such a nature that the final combination product with the isocyanate shall be medium to hard.

The preferred embodiment of polyurethase resins is, for example, a 1:1 condensation mixture of Multron R4 which is a polyester made from 2½ mols adipic acid, 0.5 mol phthalic acid and 4 mols triol; and Mondur C (Desmodur TH) which has the following chemical composition:



Usable melamine formaldehyde resins are obtained, for instance, by reacting approximately 2–3 mols of formaldehyde per mol of melamine.

A spray dried melamine formaldehyde resin is prepared by spray drying a syrup obtained by reacting 2 mols of formaldehyde with each mol of melamine.

The melamine formaldehyde resin is dissolved and used in solvent mixture of, for instance, 50% ethyl alcohol and 50% water.

Phenolic and modified phenolic resins found to be useful in our investigation were of the following nature:

One step phenol-formaldehyde alkaline catalyzed resoles; one or two step phenol-formaldehyde resins, ammonia or hexamethylene tetramine catalyzed of the novolac and resole type; oil soluble heat reactive resin of the resole type; phenol, cresol, alkylphenol, formaldehyde resins; phenol-aniline formaldehyde resins; and phenol-formaldehyde cashew nut shell liquid resins.

The friction facing in paper form may be produced by conventional water-laid paper-making machines and processes, such as by the use of a Fourdrinier paper-making machine.

As noted above, the paper may also contain other components in order to further improve the desirable properties of the paper. Thus, the paper may contain from about 1% to about 10%, and preferably from about 3% to about 6%, based on the weight of the paper of a binder in order to increase the strength of the paper. The binder may be elastomeric compounds or resinous compounds. Typical elastomeric compounds include chlorinated rubber, and synthetic rubbers, such as neoprene (polychloroprene) and butadiene-acrylonitrile copolymers sold under the trade name of Hycar. Suitable resinous binders include nylon; polyacrylic resins, such as polymethacrylate and polymethylmethacrylate; and polyvinyl acetate. The preferred binders are neoprene latex and polyacrylic resins. The binders can be incorporated into the paper either by sizing the stock, i.e., adding the binder solutions or emulsions to the stock and flocculating the same, or by spray methods or the use of a size press.

The paper may also contain a synergistic mixture of guar gum and polyethylene imine or melamineformaldehyde resin. This synergistic mixture makes possible the obtention of a paper having high ash content and high filler retention with only very small losses of filler particles in the white paper. The paper may thus contain from about 0.1% to about 2% based on the weight of the paper of polyethylene imine or melamine-formaldehyde resin and from about 0.1% to about 2% based on the weight of the paper of guar gum.

In order to further increase the wet strength of the paper, reduce the moisture absorbency and increase the life expectancy of a friction facing formed from the paper, there may be incorporated in the paper a fiber and filler surface size. The fiber and filler surface size attaches itself to the fibers and fillers and bonds chemically with the resin. The surface size may be, for example, methacrylate-chromic chloride, methyl silicone, vinyl silane, or the alkyl silicone resin known as Y–1100 sold by the Linde Air Products Company. From about 0.2% to 1% of the fiber and filler surface size based on the weight of the paper is normally employed.

After the material in paper form has been sheeted out in the conventional manner on a paper-making machine, it is incorporated into a friction member. If the paper friction material has had the desired amount of resin incorporated therein during the paper-making process, it will only be necessary to apply adhesive to the backing member, attach the friction facing thereto and cure the friction member. If, on the other hand, the desired amount of resin has not been added during the paper-making process, the paper material is impregnated with a desired resin solution, the solvent removed, the resin cure advanced, and the friction facing adhesively secured to the core plate. In either case, after the adhesive is applied to the core plate and the friction facing applied thereto, the composite friction plate is placed in a

mold, pressure is applied to the composite friction plate, and cure of the resin and the adhesive is effected to complete fabrication of the friction member. The applied pressure brings the thickness of the composite friction plate down to a predetermined size so that the resultant air voids in the friction facing will fall within a predetermined range.

In the preferred manner of carrying out this phase of the invention, the paper material is cut into suitable blanks. The blanks are saturated with an alcoholic phenolic resin solution such as 30% CR–136 in methanol of a concentration necessary to achieve the desired resin pickup in the paper material. The saturated facings are baked for a period of time, such as 15 minutes at 300° F., to drive off the solvent and advance the cure of the resin. Backing members are cleaned, and a suitable adhesive applied thereto, such as Armstrong J–1104 or Palmer 6035. The friction facing and backing member are positioned and held in pressure contact by a fixture which also limits the compression of the friction facing to achieve the air voids desired. The assembly is heated for a period of time, such as 30 minutes at 325° F. measured at the bond line, to completely cure the resin and the adhesive. The completed friction member is then removed from the fixture.

It should be pointed out that this friction facing in its final form has an extremely high porosity. Our investigations have shown that it is necessary to have at least 60% air voids readily available for oil absorption and preferably above 70% to obtain the required high oil holding capacity in the finished friction facing in the final plate assembly. This high liquid or oil holding capacity of the finished friction facing contributes in a critically important degree to the ability of this friction facing to withstand a high rate of energy absorption per unit area of the facing. It will be appreciated that in order to achieve this air volume in the friction facing, the friction material must have an air volume of at least 70% and preferably of at least 75%.

While the invention has thus far been described with reference to broad ranges of materials which may be used in the composition of the friction material, we have had particularly successful results with friction plates having friction facings of the following nature: an interfelted fibrous paper sheet containing a mixture of about 55% cellulosic fibers (e.g. cotton linters), about 33% diatomaceous earth, about 12% asbestos fibers, and about 36% of a resin based on the weight of the mixture. This amount of resin is equivalent to saying that the content of resin is about 26.5% of the whole.

Our friction plate has an extremely good uniform bond between the core plate and the friction facing. The superiority of this bond, however, lies not in the adhesive itself, but rather in the friction material. To explain further, this friction material has a high volume of air voids, i.e., open spaces, uniformly distributed throughout the material. This high volume of air voids uniformly distributed permits a greater concentration of the adhesive material at the surface of and partially into the friction facing as shown in FIG. 10. This higher concentration of the adhesive leaves a larger amount of the original air voids of the friction facing (i.e., before penetration of the adhesive) than would be possible with a less porous friction material. Since only a shallow depth penetration of the adhesive is required because of the strength and uniformity of the paper, a consequently higher percentage of air volume (see FIG. 10) is left to serve as an oil holding reservoir.

In FIGS. 1 through 8, there is illustrated a series of curves. These curves dramatically demonstrate the results that are achieved with respect to stopping time, coefficients of friction, and the relationship between the dynamic and static coefficients of friction by saturation of a particular paper composition with a variety of different resins. Time in seconds is represented on the X-axis and the apparent coefficient of friction is represented on the Y-axis. These curves are the results of tests run on a laboratory friction machine on the type used in the automotive industry and where made on friction facings composed of the materials described in the embodiment above with the exception that different resins were used in each case. The curves are labeled with letter symbols to indicate the respective resins used. There is set forth below a table indicating the types of resins used to yield the respective curves.

FIG. 1, Curve A, Catalin CR–136—ammonia catalyzed straight one-step phenol-formaldehyde resole
FIG. 2, Curve B, Palmer 6211—an oil modified phenolic resin
FIG. 3, Curve C, Palmer BJ136—an oil modified phenolic resin
FIG. 4, Curve D, Durez 11230—a phenolic resin
FIG. 5, Curve E, Bakelite CLS 3509—an alkali catalyzed cresol-phenol-formaldehyde resole
FIG. 6, Curve F, Catavar 157—an alkali catalyzed straight one-step phenol-formaldehyde resole
FIG. 7, Curve G, Cymel 405—a melamine formaldehyde resin
FIG. 8, Curve H, Mixture of Multron R4 and Mondur C—a polyurethane resin

The numerical values shown on curve A of FIG. 1 will now be explained. The number .147 represents the dynamic coefficient of friction, and the number .153 represents the static coefficient of friction. The number 1.5 shown at the bottom of the curve represents the stopping time which term is hereinafter explained. Corresponding numbers on the remaining curves have the same meaning. Uniform test results shown by the curves are obtained by engaging the test clutch to stop a moving flywheel of known kinetic energy level. The stopping time in seconds is one measure of performance. Suitable instrumentation is used to record the coefficients of friction directly and continuously during the engagement allowing the measurement of the coefficients of friction under both dynamic and static conditions. It will be appreciated that while some of these curves may be individually substantially reproduced by a particular type of friction facing, there is no single friction material presently known by the inventors which will yield the variety of illustrated relationships by the mere change of the resin and control of the amount of resin dispersed throughout the facing. This is, of course, a unique quality in this type of friction material in that it permits a manufacturer of friction plates to employ a selected basic friction material and satisfy his varied requirements merely by changing the resin and the amount thereof in the material. It is evident that a friction facing which may show a series of different but desirable characteristics merely by the change of the resin therein provides a utility which has heretofore been unobtaintable by the use of heretofore available commercial friction facings. This very important advantage is obtainable without sacrificing other vital requirements of a good friction facing, namely, good endurance, good resistance to heat, lack of abrasiveness, etc.

The automotive industry has required for some time for certain applications, but has not had available to it, a friction plate which would provide at the first moment of engagement a dynamic coefficient of friction which was as high or substantially as high as the static coefficient of friction. It is, of course, not alone sufficient that this relationship exists but the friction plate must also have high endurance.

Referring now more specifically to FIGS. 1, 6 and 7, it will be seen that one of the results of this invention has been to achieve such a relationship between the dynamic and static coefficients of friction by adding the particular resin noted for each of the respective curves to a paper material containing the ingredients described above.

Stopping time indicates the time that transpires from the time that an adjacent friction plate and a plain metal plate rotating relative to each other become engaged until they rotate as a unit without slippage. It will be observed that the stopping time in each of the curves is a relatively short time. In FIG. 1, for example, it is 1.52 seconds and in FIG. 2 it is 1.44 seconds as compared to 2.0 seconds for one of the best heretofore known friction materials illustrated by Curve J in FIG. 9. This is also a highly desirable characteristic because for certain applications it permits the reduction of the number of friction plates required. It is easily understood that in a multiple disc clutch pack, for example, which contains plates wherein the stopping time is considerably greater, i.e., having less work capacity per plate that more plates would be required with a longer stopping time than plates of the invention having a shorter stopping time.

The two curves shown in FIG. 9 are a comparison of engagement characteristics of a typical cork and paper type friction plate (Curve J) with the engagement characteristics of a friction plate of the present invention (Curve I). These curves are made on a laboratory-type friction testing machine commonly used in the automotive industry. Curve I shows substantially equal dynamic (.14) and static (.141) coefficients of friction and is indicative of a smooth, shock-free shift attained in a multiple disc type clutch using therein the friction plate of the invention. This shock-free shift is refererd to as having good "feel" in the automotive industry. Curve J illustrates a much less smooth shift in the same multiple disc type clutch using a typical friction plate of cork and paper. The shorter stopping time shown by Curve I (1.57 seconds) as against the stopping time shown by Curve J (2.0 seconds) is another advantageous characteristic of the friction plate of the invention and is indicative of the higher rate of energy absorption per unit area of the facing of the friction plate of the invention under the same operating conditions.

Endurance test results of a multiple-disc clutch in an automotive automatic transmission are shown on the bar graph of FIG. 11. In one case the clutch plates in the multiple-disc clutch were commercial cork and paper friction plates. In the other case, friction plates of the invention were used. This multiple-disc clutch was endurance tested in an automotive automatic transmission on an engine-driven dynamometer. In the case of the multiple-disc clutch using commercial friction plates (A) having cork and paper facings, FIG. 11 shows that A failed after 2500 shift engagement endurance cycles. The bar graph shows that the friction plates of the invention, designated as B, remained in good operating condition after 10,000 shift engagement endurance cycles.

In addition, this friction facing with proper choice of resin, can be made to produce a coefficient of friction substantially higher than that in other commercially available friction facings adaptable for use in fluid transmissions.

Therefore, it will be observed from the curves that the inventors have conceived and developed a superior friction plate in that they have been able to achieve with one basic material the highly desirable characteristics of a wide range of stopping times and coeffcients of friction, and a controllable relationship between the dynamic and static coefficients of friction by the mere change of the resin in the friction facing. At the same time we have been able to preserve those necessary qualities of long endurance, resistance to abrasion, lack of abrasiveness, etc., which are also necessary in a good friction plate.

The following are other examples of specific embodiments which further illustrates the friction facing in paper form of the invention.

Example 1

Fifty-four parts of cotton linters beaten to a beating degree of 16°–19° S.R. were well mixed and brushed together with 12 parts of long fibered asbestos and 34 parts of diatomaceous earth of a particle size ranging from 2 microns to 8 microns at 2% stock consistency to insure a homogeneous mixture. 0.5 part zinc oxide in fine powder form as an acid acceptor, 0.1 part of Neozone A (phenyl-alpha-naphthylamine) and 0.2 part of nickel dibutyl dithiocarbomate as latex stabilizers were added thereto with 100 parts of neoprene latex 736 (polychloroprene) of 3.5% solids content. Alum was then added to give a pH of 5.0. The fiber slurry was diluted to a stock consistency of 6 grams per liter and 0.4 part of guar gum and 1 part of melamine-formaldehyde resin solution added thereto in the head-box to obtain good fiber-filler flocs. A paper was then formed in the conventional manner on a Fourdrinier paper-making machine followed by drying and calendering of the sheet.

The paper so formed contained 54% cotton linters, 34% diatomaceous earth, 12% asbestos fibers, 3.5% neoprene latex based on the weight of the paper, 0.4% guar gum based on the weight of the paper and 1% melamine-formaldehyde resin based on the weight of the paper.

Friction facing blanks cut from this paper were then impregnated with an alcoholic solution of Catalin CR 136 to incorporate therein 36% of resin by weight of the paper. This friction facing was then cured and bonded to a core plate in the manner previously herein described. Such a friction facing in its final cured state had an air volume of 75%.

Example 2

Forty-five parts of cotton linters of 17° S.R., 10 parts of blue asbestos and 45 parts of diatomaceous earth particles having a mean size of 6 microns treated with a 0.5% solution of the alkyl silicone resin surface size known as Y–1100 and dried at 100° C. were mixed in a paper-maker beater at a stock consistency of 3%. The stock was diluted to 10 grams per liter with white water and a synergistic mixture of 0.5% guar gum and 1% melamine-formaldehyde resin was added thereto in the headbox. The paper furnish was then processed in the conventional manner on a Fourdrinier paper-making machine and the paper product so obtained treated in a size press with a 3% solution of melamine-formaldehyde resin. The paper so formed contained 45% cotton linters, 45% diatomaceous earth, 10% asbestos fibers, and 8% melamine formaldehyde resin binder based on the weight of the paper, and a synergistic mixture of 0.5% guar gum and 1% melamine-formaldehyde resin based on the weight of the paper. The paper product was then impregnated with an oil soluble heat reactive phenolic resin resole type solution to give a friction facing containing about 28% of resin based on the weight of the paper. The friction facing was precured and then secured to a core plate in the manner described herein. The resulting friction facing had an air volume of 70% and showed low moisture absorbency, and good life and strength under severe test conditions of moisture and heat.

Example 3

A friction facing was formed as described above and consisted of 53% cotton liners, 20% asbestos fibers, 27% glass fibers having a diameter of 1 micron, and 33% of a two step phenol-formaldehyde novolac resin containing hexamethylene tetramine as a curing agent based on the weight of the paper, and 0.5% guar gum based on the weight of the paper, and 1% melamine-formaldehyde resin based on the weight of the paper. This friction facing had an air volume of 76%.

Thus, it will be observed that the friction member described herein combines the following advantages: good heat resistance; high endurance; very high resistance to fade; a friction plate adaptable to various applications by varying the coefficient of friction by the change and control of the resin content and type in the friction facing; permits shock-free engagements when shifting from one drive speed to another; ability to achieve a dynamic coefficient equal to the static coefficient by proper choice of resins; additional manufacturing operations such as grooving, waving or coning are not required; generally a lower cost to manufacture than anything now commercially available for similar applications; and a high air volume and uniform dispersion of the air voids in the friction facing to give a high oil-holding capacity permitting a continuously lubricated engagement.

It will be appreciated that various modifications and variations in addition to those suggested above may be made in the products of the invention, and accordingly it will be understood that the invention is to be limited only within the scope of the appended claims.

We claim:

1. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of from about 30% to about 70% by weight of at least one fibrous material selected from the group consisting of natural cellulosic fibers and synthetic organic fibers capable of withstanding 200° F., from about 5% to about 35% by weight of asbestos fibers, from about 10% to about 50% by weight of at least one inorganic filler material of a hardness of more than 3.5 mohs, and said facing further containing from about 10% to about 50% based on the weight of the paper of at least one cured thermosetting resin, said facing having a readily available air volume of at least 60%.

2. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of from about 30% to about 70% by weight of at least one fibrous material selected from the group consisting of natural cellulosic fibers and synthetic organic fibers capable of withstanding 200° F., from about 5% to about 35% by weight of asbestos fibers, from about 10% to about 50% by weight of at least one filler material of particulate and fibrous fillers selected from the group consisting of diatomaceous earth, glass, alumina, aluminum silicate, and quartz, and said facing further containing from about 10% to about 50% based on the weight of the paper of at least one cured thermosetting resin, said facing having a readily available air volume of at least 60%.

3. A friction member for a torque control device adapted to operate in oil of the type having a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of from about 30% to about 70% by weight of at least one fibrous material selected from the group consisting of natural cellulosic fibers and synthetic organic fibers capable of withstanding 200° F., from about 5% to about 25% by weight of asbestos fibers, from about 10% to about 50% by weight of at least one filler material of particulate and fibrous fillers selected from the group consisting of diatomaceous earth, glass, alumina, aluminum silicate, and quartz, and said facing further containing from about 20% to about 40% based on the weight of the paper of at least one cured thermosetting resin, said facing having therein means defining readily available air voids of at least 70%.

4. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of from about 30% to about 70% by weight of at least one fibrous material selected from the group consisting of natural cellulosic fibers and synthetic organic fibers capable of withstanding 200° F., from about 5%

to about 35% by weight of asbestos fibers, from about 10% to about 50% by weight of at least one inorganic filler material of a hardness greater than 3.5 mohs, and said facing further containing from about 10% to about 50% based on the weight of the paper of at least one cured thermosetting resin, from about 0.1% to about 2% guar gum based on the weight of the paper and from about 0.1% to about 2% of a material selected from the group consisting of polyethylene imine and melamine-formaldehyde resins based on the weight of the paper, said facing having a readily available air volume of at least 60%.

5. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of a mixture of about 55% by weight of natural cellulosic fibers, about 33% by weight of diatomaceous earth, about 12% by weight of asbestos fibers, and said facing further containing from about 10% to about 50% of at least one cured thermosetting resin based on the weight of the paper, said facing having a readily available air volume of at least 60%.

6. A friction member for a torque control device adapted to operate in oil and characterized by having a dynamic coefficient of friction which is substantially equal to the static coefficient of friction comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of a mixture of about 55% by weight of natural cellulosic fibers, about 33% by weight of diatomaceous earth, about 12% by weight of asbestos fibers, and said facing further containing about 36% by weight of the paper of a cured thermosetting resin selected from the group consisting of an alkali catalyzed straight one-step phenol-formaldehyde resole and melamine-formaldehyde resin, said facing having a readily available air volume of about 75%.

7. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of about 53% by weight of natural cellulosic fibers, about 20% by weight of asbestos fibers, about 27% by weight of glass fibers, and about 33% of a cured thermosetting resin based on the weight of the paper, said facing having a readily available air volume of about 76%.

8. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet consisting essentially of a mixture of about 45% by weight of natural cellulosic fibers, about 10% by weight of asbestos fibers and about 45% by weight of diatomaceous earth, and about 28% of a cured thermosetting resin based on

the weight of the paper, said facing having a readily available air volume of about 70%.

9. A friction member as defined in claim **1** wherein the cured thermosetting resin is a polyurethane resin.

10. A friction member as defined in claim **1** wherein the cured thermosetting resin is a melamine-formaldehyde resin.

11. A friction member as defined in claim **1** wherein the cured thermosetting resin is a silicone resin.

12. A friction member as defined in claim **1** wherein the cured thermosetting resin is a phenolic resin.

13. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing comprising an interfelted fibrous paper sheet comprising from about 30% to about 70% by weight of at least one fibrous material selected from the group consisting of natural cellulosic fibers and synthetic organic fibers capable of withstanding 200° F., from about 5% to about 35% by weight of asbestos fibers, from about 10% to about 50% by weight of diatomaceous earth and glass fibers and said facing further containing from about 10% to about 50% based on the weight of the paper of at least one cured thermosetting resin, said facing having a readily available air volume of at least 60%.

14. A friction member for a torque control device adapted to operate in oil comprising a metallic backing member and a resilient porous friction facing adhesively secured to the backing member, said friction facing having an interfelted fibrous paper sheet comprising a mixture of about 47% by weight of cellulosic fibers, about 30% by weight of diatomaceous earth, about 11% by weight of long fibered asbestos fibers, about 9% by weight of glass fibers, about 3% by weight of neoprene latex, and said facing further containing from about 10% to about 50% of at least one cured thermosetting resin based on the weight of the paper, said facing having a readily available air volume of at least 60%.

15. A resilient porous friction facing especially adapted for use in wet friction devices comprising an interfelted fibrous paper sheet comprising about 52% by weight of natural cellulosic fibers, about 12% by weight of long fibered asbestos fibers, about 23% by weight of diatomaceous earth, about 10% by weight of glass fibers, about 3% neoprene latex, and about 36% of at least one cured thermosetting resin based on the weight of said paper, said facing having a readily available air volume of at least 60%.

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