Aug. 6, 1946. D. B. SHARPE ET AL 2,405,524

ABRASIVE ARTICLE AND METHOD OF MAKING

Filed June 27, 1944

Fig. 1.

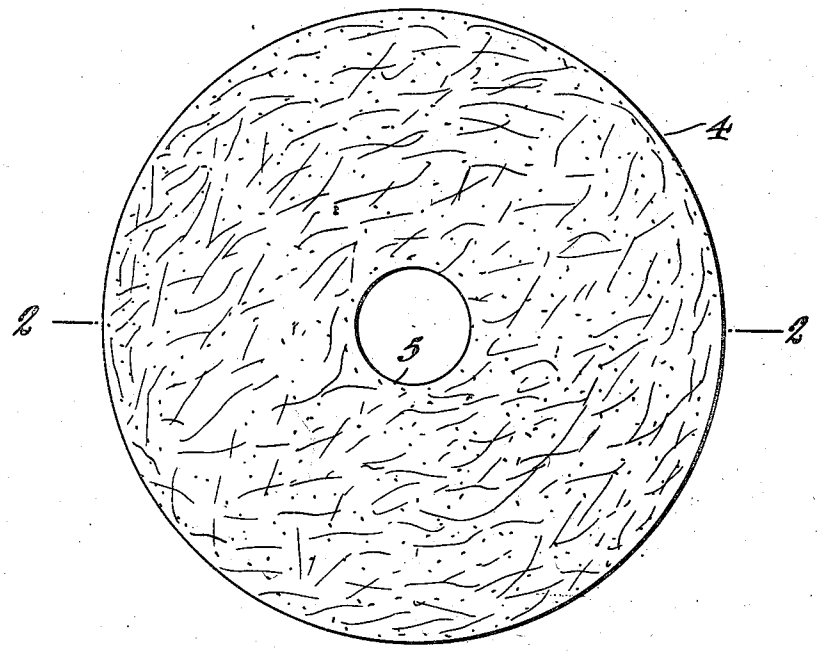


Fig. 2.

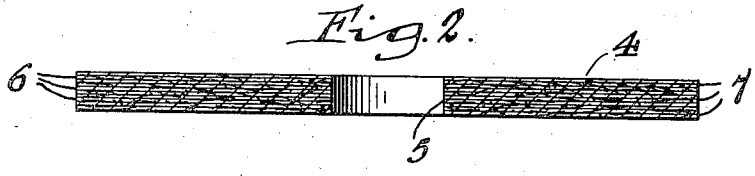
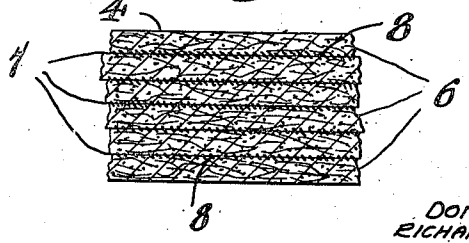


Fig. 3.



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ABRASIVE ARTICLE AND METHOD OF MAKING

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9 Claims. (Cl. 51—193)

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This invention relates to the manufacture of abrasive articles. More particularly, it relates to the manufacture of resilient abrasive articles of the bonded type such as grinding and polishing wheels, stones, discs, blocks, pads, sticks and the like formed of a composite of felted, fibrous sheets having abrasive grain, and usually an adhesive binder therefor, included internally of the fibrous sheets. The invention especially pertains to the making of such articles from a plurality of superimposed flexible, fibrous, abrasive-containing sheets of web material whereby the individual abrasive-included sheets are combined by means of an adhesive such that the finished article retains substantially all the "softness" of cutting or polishing behavior inherent in the abrasive-included fibrous sheet material constituting the abrasive body, and at the same time the abrasive article possesses an increased cutting rate over that normally expected or found in such products.

There has always been a need for abrasive articles of the bonded type which would combine an effective cutting action with satisfactory finishing or polishing whereby a reasonable amount of material would be removed from the work being abraded and at the same time the article would be left with a desirable surface finish or polish. Abrasive articles heretofore provided for such dual purposes have not been completely satisfactory in accomplishing both goals and have been found to be deficient in one respect or another. Among the reasons for their unsatisfactoriness have been the failure to combine an appreciable degree of cutting ability with a resilience or "softness" of cutting action, non-homogeneity of the abrasive article, lack of permanency of the abrasive content (i. e., failure of the abrasive wheel structure to retain the abrasive particles within the abrading body), non-uniformity of abrasive action, inflexibility, etc. Provision of satisfactory properties in one respect has usually been at a sacrifice of one or more of the other characteristics desirable in such products.

In the past, attempts have been made to obtain the desired combination of cutting and polishing by incorporating fibrous fillers in molded abrasive articles such as articles made with a rubber bond. These products have not been satisfactory and none of them has ever been commercialized to any material extent.

In the recent past, an entirely new type of abrasive article has been developed which has gone into widespread commercial use. These articles and methods of making them are described in detail in copending application Serial No. 408,936, filed August 30, 1941, issued on August 15, 1944, as U. S. Patent No. 2,355,667. They are made by first preparing sheet material which contains a very substantial amount of abrasive grain included throughout the body of the material. The base of the sheet material is usually staple length cotton fibers and the sheets are made by any of several processes, as will be described in more detail hereinafter. In addition to a mechanical interlocking of the fibers and retention of the grain by such interlocking, the sheet material is usually provided with an adhesive which is incorporated during the manufacture of the webs from which the sheets are cut. Adhesives of various types may be employed, one common one being a mixture of rubber and casein. The sheets vary in thickness, being generally of the order of .010 inch.

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According to the invention of application Serial No. 408,936, abrasive articles such as wheels, stones, sticks, and the like are formed from the sheet material by assembling a number of such sheets to form articles of the desired thickness. In making such articles the adhesive which is present in the sheet material may be wholly relied on for bonding the sheets together or additional adhesive may be applied to one or both of the surfaces of the sheets.

Due to the different types of material that have to be abraded, it is necessary in the grinding wheel industry to provide abrasive wheels having different degrees of "grade," the more weakly bonded materials being commonly referred to as "soft" while the wheels in which the abrasive grains are more firmly bonded, as by the use of larger quantities of bonding material, are referred to as "hard." It has also been found that articles of different grade are required in the field in which the abrasive wheels made from the sheet material are used. By following the teachings of application Serial No. 408,936, it has been possible to make a variety of grades of the softer type wheels, but until the development of the present invention satisfactory wheels of this kind in the harder grades have never been made.

One method described in the earlier-filed application which has been tried unsuccessfully in an attempt to make the harder type of wheels has been through the use of the stronger and heat-resistant type of bonds such as phenol-aldehyde condensation products. According to the earlier-filed application, such bonds may be used but the

methods therein described for incorporating such resins have made articles which are not wholly satisfactory. For example, if the phenolic resin is employed in the form of either a liquid resin or a solution of solid resin in a suitable solvent the resins penetrate the sheet material and materially reduce the resilience found in articles using more flexible bonds. As a result the abrasive wheels thus made do not have the characteristic resilience and other combinations of unusual properties found in wheels of this type where other adhesives are used.

We have discovered that wheels which have both a higher cutting rate and a longer abrading life than articles of the prior application can be made by employing as an adhesive for joining the sheet material a phenol-aldehyde condensation product modified in such a way that the liquid is substantially non-penetrative, at least to the extent that it does not saturate and impregnate the sheet material as is the case with the resins of the earlier-filed application. As a consequence we have found that wheels made in accordance with our invention retain to a considerable extent the resilience and polishing action of the wheels of the earlier-filed application and at the same time have a much higher cutting rate and a longer life.

We have also discovered that the characteristics of the abrasive articles made in accordance with our invention can be modified to some extent by the employment of various fillers, the grade of the article being determined to some extent by the particular filler selected as well as by the nature of the adhesive.

The adhesives used in our invention are fundamentally mixtures of water-miscible liquid phenolic resins with water. Such mixtures may be used alone or powdered, normally solid resin may be suspended in such mixture and, as stated, inert filler may also be employed to modify the character of the finished wheel.

When such adhesive compositions are applied to the surface of fibrous material the resin and the filler are retained upon or adjacent the surface of the fibrous sheet and the loss of the water of the adhesive composition by absorption into the fibrous structure and by evaporation serves to raise the viscosity of the composition to the point where the resin does not soak into the fibrous material. At the same time the resin and filler on curing provides the abrasive article with a greater overall hardness which greatly enhances the cutting ability without detracting from the "softness" characteristic of the fibrous, abrasive-included structure. The combining phenolic adhesive composition is applied to one or both sides of the abrasive-included, fibrous sheet material and can be applied while the material is in roll form, after it has been cut in the form of large sheets, or after it has been cut to the ultimate size and shape to be used in fabricating the final abrasive article.

After the abrasive-included, fibrous sheet material has been properly sized, as above described, it is cut to the desired size and shape and a suitable number of the sheets are assembled in superimposed relation and consolidated as by heat and pressure to form the desired article. The formed article is then usually given a further oven cure to complete the curing of the phenolic binder whereupon the abrasive article is edged and dressed according to standard practice and the article is ready for use.

In order to better understand the nature of the invention, reference is made to the accompanying drawing, in which:

Figure 1 is a top plan view of an abrasive grinding wheel made in accordance with the present invention;

Figure 2 is a vertical diagrammatic cross-section through the line II—II of Figure 1; and

Figure 3 is a highly enlarged, fragmentary section of Figure 2.

The abrasive-included, fibrous web material used in making the products of the present invention can be manufactured in several ways. A very satisfactory method of making included-abrasive sheet material of the herein required type is that set forth and fully described in U. S. Patents Nos. 2,284,715 and 2,284,716. Briefly, the felted fibrous web is formed by feeding a plurality of thin carded fibrous membranes from a number of carding assemblies onto a moving endless support so that each membrane is deposited or superimposed upon the preceding membranes until a web of loosely felted fibrous material of the desired thickness is built up on the traveling support. A number of abrasive grain hoppers are also disposed between the carding assemblies and above the traveling conveyor. Abrasive grain is fed from the hoppers onto the fibrous membranes at various stages in the building up of the final web, so that, as a result, the abrasive material is applied between the individual membranes making up the web and so is internally distributed throughout the fibrous web or sheet. A suitable adhesive binder is then incorporated within the fibrous-abrasive web and the web is consolidated to a desired density and passed to a curing zone, where the adhesive is matured or set. The included-abrasive web is then wound into rolls for use as a source material for the manufacture of the products herein described.

In practicing the invention, any of the abrasive materials in common use may be employed, such as silicon carbide, diamonds, boron carbide, fused aluminum oxide, flint, corundum, emery, rouge and similar substances. The size of the abrasive particles may vary from the finest polishing or buffing powders to the coarser grit sizes used in grinding.

Other methods of incorporating abrasive material internally of the fibrous sheet material during its manufacture may be employed. For example, the abrasive particles can be thoroughly admixed with the adhesive binder and the mixture applied to the uncompacted web by the usual adhesive-applying rolls. This method has been found to be particularly satisfactory for the inclusion of the finer abrasive materials of the size employed in buffing and polishing operations.

Another method is to project the abrasive material into the web or sheet after it has been built up to the desired thickness and immediately prior to consolidating the web. The projection of grain is suitably carried out by means of a blast of air or gas against one or both surfaces of the fibrous web, the air stream being laden with the abrasive material to be included internally of the web. The other steps in the formation and consolidation of the web are carried out in a manner similar to that used in the previous procedures.

Felted fibrous webs having abrasive material included within the web and which are suitable for use in the fabrication of the herein described products can also be made by a modification of the above processes in which the individual fibers are interwoven and interlocked by a gentle air or gaseous agitation of the thin carded membranes

during their deposition. This process is termed "aerodynamic weaving" and is used to promote the strength and eliminate any laminations from the web. For a more complete description of such a process and product, reference is made to U. S. Patents Nos. 2,284,738 and 2,284,739 in which further details are also given of the above procedures for including abrasive materials within the fibrous structures.

Abrasive sheet material of the herein required type can also be made by wet felting procedures employing the various types of paper-stock fibers and including abrasive therein at the time of making the sheet material. One satisfactory method of making the abrasive-included sheet material by wet felting procedure is that set forth and fully described in copending application Serial No. 461,139, filed October 7, 1942.

Briefly, the felted fibrous paper stock material having abrasive grain incorporated internally thereof is made by first forming a liquid, usually aqueous, suspension of fibrous material, the fiber content of the suspension being very low and in the neighborhood of 0.5 to 5% of the suspension, collecting the fibrous suspension on a suitable support, introducing abrasive grains with or without an adhesive binder into the fibrous web while it is in a highly aqueous, or fluid, condition, extracting the water or other liquid medium from the web, and further drying and compacting the web to the desired density. Optionally, the abrasive grains can be given a preliminary coating of a suitable adhesive, which is preferably soluble or softenable in the liquid suspending medium or a component thereof, to assist in holding the fibrous abrasive-containing web in compacted form after it has been compressed. The process can be carried out in a number of ways.

In one such modification the fibrous suspension of paper-stock is deposited upon a foraminous support in one step and the abrasive grain is deposited in several increments while the web is still in a highly aqueous or fluid condition. That portion of abrasive applied first penetrates deepest into the web structure, and the abrasive of each succeeding deposition penetrates the web to a lesser degree by reason of the continually decreasing amount of water present and the consequent thickening of the fibrous body. The distribution of abrasive within the web can thus be controlled by variation of the amounts and places of deposition during the dewatering of the web so as to obtain any desired effect.

In a modified form of the process a fluid fibrous suspension is collected upon a plurality of revolving foraminous supports, such as cylinders, which are partially immersed in the fibrous suspension. The thin fibrous membranes collected upon the foraminous supports are then successively transferred to a common carrier, usually a moving endless felt blanket or belt, in superimposed relationship to form a fibrous web structure. Abrasive grain is incorporated into the fibrous web structure by deposition or projection between and into the various individual membranes as they are deposited on the carrier support. This method has the advantage that, since the fibrous suspensions can be varied, the composition or structure of various portions of the web can be varied if desired. Adhesive binders can be incorporated in the fibrous web, regardless of the procedure used, at various stages in the process, such as by inclusion in the fibrous suspension, introduction during dewatering of the web, with the abrasive grains as a coating thereon, or after the web has been substantially dewatered and prior to the final compacting and drying of the web.

A still further modification which can be used to make fibrous abrasive materials is the process of forming a wet fibrous abrasive lap by a cylinder wet-press process, in which a fibrous suspension similar to that used in the cylinder method above is fed, usually from a single cylinder mold, onto a traveling wet felt carrier belt. The thin fibrous membrane is conveyed over one or more suction boxes to remove a portion of the water and passed between a pair of pressure rolls. As the fibrous material passes between the pressure rolls it is transferred to the upper pressure roll upon which it is wound in a series of successive layers until the desired thickness of fibrous material is obtained, whereupon the material is removed by hand or by a suitable knife or doctor blade. Abrasive grain is fed onto the fibrous sheet previous to its passage between the pressure rolls and is thereby incorporated within the fibrous structure.

Another satisfactory method of making included-abrasive, paper-stock web material is that set forth and fully described in copending application Serial No. 461,140, filed October 7, 1942. In accordance with the process therein set forth, fibrous paper-stock abrasive sheet material is made from an aqueous suspension of around 3% fiber content in which the fibers are distributed in the suspension as substantially individually separated fibers. This fibrous suspension is agitated, beaten, or otherwise mechanically treated, with sufficient vigor to render the fibers partially gelatinous, abrasive grain being incorporated in the suspension to the desired extent. A sufficient amount of abrasive grain is added to provide an abrasive grain content of over 40%, and preferably 60–70% or more by weight of the final product after the water has been extracted. The agitation of the fibrous suspension previous to and/or during the addition of abrasive grain is very important in preparing a liquid in which the abrasive particles will remain uniformly in suspension. This stability of suspension is believed to be due, at least in part, to the adherence of the abrasive particles to the partially gelatinized fibers. The amount of agitation or beating of the fibrous suspension necessary to provide a suitable stable mixture of abrasive and fiber of the proper consistency depends upon the size of the abrasive particles. For example, a very slight agitation serves the purpose when the finest abrasive polishing powders are used whereas with the use of 60 or 80 grit abrasive grains, it is desirable to subject the suspension to a much longer and/or vigorous agitation. Suspension of the abrasive particles may be assisted by incorporating an adhesive in the fluid mass, either in the form of a preliminary coating of the abrasive particles or by the addition of the adhesive to the liquid. In either case, the adhesive should preferably be soluble in the liquid medium of the suspension or at least softenable or soluble in a component thereof.

After a fiber-abrasive suspension of suitable consistency has been prepared as above outlined, it is flowed or otherwise deposited on a suitable foraminous support in the form of a continuous, highly aqueous layer from which the water or other liquid suspending medium is extracted, and the resulting film is further dried and compacted to the desired density. These operations can be performed by flowing the suspension onto a mov-

ing endless wire screen or by collecting a plurality of thin membranes onto cylinder molds and transferring them to a suitable felt blanket in superimposed relation to form a web of the desired thickness. While it is usually desirable to proceed in the described manner of forming continuous fibrous webs by this particular method, the process can be practiced in modified form by using the same thin suspension of fibers and abrasive to form individual abrasive-included sheets by a series of discontinuous steps. Adhesive binders can be incorporated in the fibrous web, regardless of the procedure used, at various stages in the process, such as by inclusion in the fibrous suspension, introduction during dewatering of the web, as a coating on the abrasive grains, or after the web has been substantially dewatered and prior to the final compacting and drying of the web.

Modifying agents such as waterproofing compounds, anti-friction agents, flexibilizers, plasticizers and other fillers may be incorporated in the web at the time of making irrespective of the particular procedure followed, in order to render the web resistant to water or impart other specific desirable properties to all or certain controlled portions of the web.

Abrasive-included, fleted fibrous web material such as that made by any one of the aforementioned methods is used as a source of raw material for the making of abrasive articles in accordance with the present invention. As a specific example of the manner in which the present process has been carried out and an abrasive article made in accordance with the present invention, the following procedure is given.

A flexible, felted fibrous web material made in accordance with the teachings of U. S. Patents Nos. 2,284,738 and 2,284,739 and containing approximately 75% of fused alumina particles of 30 mesh grit size, 15% cotton fibers and 10% rubber material derived from latex, is sized with an aqueous solution of a water miscible phenolic resin containing finely divided inorganic cryolite fillers to provide about 20% wet weight of coating material based on the weight of the fibrous sheet material. A composition which has been found highly satisfactory for the purpose of applying as an adhesive sizing coating to one or both sides of the fibrous sheet material is the following:

Sizing composition No. 1

	Parts by weight
Water-miscible, liquid phenolic resin (such as that known and sold under the trade name "Bakelite" BR 10190)	45.0
Powdered cryolite	31.5
Water	23.5

The phenolic resin hereinabove specified is only given as a specific example of one type of non-penetrative phenolic resin which has been found highly adaptable for use in carrying out the present invention. It is a liquid phenolic resin which is miscible with water, at least to a limited degree, to form a clear solution, and by reason of the aqueous nature of the resin solution as herein used, does not penetrate the fibrous backing to an undesirable degree. Other non-penetrating phenolic resins can be provided by forming a dispersion or an emulsion of a solid and/or liquid phenolic resin in water in which case on application of the sizing adhesive to the fibrous web material the water constituent of the composition tends to penetrate the fibrous structure, whereupon the resinous component remaining becomes so viscous that it does not penetrate the fibrous web but remains substantially on the surface. Retention of the resin on or adjacent the surface during curing of the resin is further accomplished by employing a water-miscible resin containing a minor amount of a solid resin. During the initial curing stage when the liquid resin would normally fall to a lower viscosity whereby it might penetrate the fibers, the solid resin simultaneously dissolves in the liquid resin so as to raise the viscosity of the latter or at least maintain its original viscosity so as to retard or prevent penetration. A resin composition of this latter type found suitable for the herein proposed use and containing a filler is as follows:

Sizing composition No. 2

	Parts by weight
Liquid phenolic resin (such as that known and sold under the trade name "Bakelite" BR 10190)	40.9
Solid powder resin (such as that known and sold under the trade name "Bakelite" BR-2417)	9.1
Cryolite filler	28.6
Water	21.4

Although cryolite has been specified as the filler in both of the adhesive sizing compositions given above, other inorganic filler materials can be used. For example, satisfactory results are obtained by the use as fillers of such substances as whiting, various clays and other finely divided mineral fillers.

After applying an adhesive size or coating composition such as sizing composition No. 1 above, the adhesively sized fibrous material is dried at about 160° F. for approximately 30 minutes, whereupon it is ready for immediate further processing, although the sized and dried material retains sufficient tack that it can be set aside and further processed after storage for several weeks.

The dried, resin-coated material is then cut to the desired size and shape for use in making the abrasive article. For example, in making the grinding wheel illustrated in the drawings a number of disc-shaped pieces of sheet material having the diameter of the wheel shown in Figure 1 are cut from the web material and assembled in superimposed relation to form the abrasive wheel. Instead of sizing the abrasive web material in roll form prior to cutting to size, the web can be sized with the desired adhesive after it has been cut to size, although the former method is preferred because of the greater facility of sizing and drying the material in roll form. Also, in forming abrasive wheels having a central mounting arbor, the arbor hole can be cut from the individual disc-shaped pieces at the time of cutting the web material or cut from the formed article after the disc-shaped sheets have been compressed, depending upon the thickness of the wheel being made.

More recently, improved methods of reducing the web material in sized condition to the ultimate size for use in forming the final abrasive bodies of the desired shape have been devised. These improved methods have been more fully set forth and described in the copending application Serial No. 542,324 filed June 27, 1944, issued on May 8, 1945, as U. S. Patent No. 2,375,263; they are applicable to carrying out the present invention and in fact constitute the preferred method of performing the adhesive-applying and cutting of the web material. Briefly, the abra-

sive-included, fibrous web material is first sized with a suitable water-miscible, phenolic resin composition such as that given in Example 1 above, either in roll form or in the shape of relatively large sheets of the material, after which a sufficient number of large sheets of the adhesively-coated material are assembled in superimposed relation to provide a slab of specified thickness, as for example, ¼" thick when compressed as by cold-pressing at approximately 4000 pounds per square inch. The number of individual sheets to be used in forming one of the compacted slabs is determined by weighing. In the case of the herein illustrated example, these preformed slabs of sheet material are then dried out on a punch press, or by similar mechanism, or cut or punched out by hand, to provide a number of discs having the diameter of the abrasive grinding wheel 4 shown in Figure 1. The arbor hole 5 is usually punched out at the same time. The punched out pieces of slab material are ready for use in forming the desired abrasive article.

Reference is made to the drawings which depict an abrasive wheel 4, formed from a single disc-shaped segment of the slab material and having a centrally positioned mounting arbor 5. As Figures 2 and 3 show, this single disc of initially compressed slab material consists of a number of layers of abrasive-included, felted fibrous sheet material 6 which have been adhesively coated with a thin layer of water-miscible phenolic resin composition 7. The single piece of slab material is placed on a hot press and subjected to a pressure of about 2000 pounds per square inch at 260° F. for fifteen minutes to form the abrasive grinding wheel. The hot pressed wheel is removed from the press, placed in an oven and baked at about 260° F. for approximately ten hours to complete the curing of the adhesive. The article is then pressed and edged according to standard practices whereupon it is ready for use. When only a single disc-shaped piece of slab material is used the resulting abrasive wheel is usually approximately ¼" thick.

Thicker wheels are formed by superimposing one or more additional pieces of slab material one on the other and hot pressing the several pieces of slab material to combine them and compress the material to the desired shape and density. In hot pressing wheels having a thickness of more than ¼", the same temperature and pressure are used as for the thinner wheels, the period of the hot-press cure being determined by allowing 15 minutes for the first ¼" thickness plus 5 more minutes for each additional ¼" thickness.

Improved methods of performing the hot pressing operation have been devised for the making of abrasive articles of the herein described type; these improved methods are more fully set forth and described in copending application Serial No. 542,567 filed June 28, 1944, issued on June 19, 1945, as U. S. Patent No. 2,378,386. These improved hot pressing operations are not only applicable to carrying out the present invention, in fact they constitute the preferred method of obtaining the final consolidation and formation of the abrasive article. Briefly, the pieces of slab material from which the grinding wheel or other abrasive shape is to be formed are placed between two layers of heavy cloth which have been previously saturated with water and the excess water removed as by squeezing. A suitable fabric is heavy coarsely woven canvas or duck, although other woven or felted materials suitably dampened can be used. By the use of these cloth layers between the hot-press platens and the piece or pieces of slab material constituting the abrasive article being formed, a more uniform abrasive body is obtained as is more fully explained in the aforementioned pending application. Abrasive articles made by this latter method, following the hot-pressing operation, are likewise subjected to an oven cure similar to that set forth above.

Figure 3 which is highly enlarged, shows in detail the nature of the structure of an abrasive grinding wheel as made above, using a single previously cold pressed piece of slab material. It particularly shows the manner in which the abrasive-included, felted fibrous sheets 6 making up the wheel are substantially free from the laminating adhesive 7 which by reason of its non-penetrative properties has not penetrated the fibrous structure to any appreciable degree. The small amount of penetration 8 shown adjacent the surfaces of the fibrous sheets serves to hold the sheet material strongly together without separation in use and furthermore produces in the wheel a somewhat harder and more rigid condition which promotes a much faster cutting action and less wheel wear in use so as to increase the efficiency of the wheel cutting rate beyond that obtained using more resilient types of combining adhesives. At the same time the restriction of that penetration from the greater part of the fibrous structure serves to retain in the abrasive body the property of "soft" cutting and polishing action so desirable in such type wheels.

It has been found that the character of the abrasive articles produced by the herein-described process, as for example the grade of hardness, can be altered by variations in the quantity and character of the adhesive binder employed in making the abrasive-containing, fibrous sheet material, and particularly by the herein-described choice of auxiliary or supplemental adhesive substance which is admixed with the sheet material as a size thereto. It is desirable that the adhesives selected for making the aforesaid articles do not smear during grinding operations. This is especially true in polishing wheels and devices where smearing of the bond tends to produce a "hot cutting" or burning action which is ruinous to the finish being produced.

The herein-described invention offers numerous improvements or advantages over the prior art. It provides an abrasive article of the bonded type which combines an unusually high amount of material removal in grinding operations without a correspondingly high amount of wheel removal together with a highly satisfactory polishing action. As a demonstration of the manner in which the present use of water-miscible phenolic combining compositions of the herein-described type functions in the abrasive product made in accordance herewith, grinding tests were carried out on the grinding of steel using wheels employing water-miscible phenolic resin compositions as the combining adhesive and similar tests made using wheels in which the combining adhesive was an ordinary solution of a phenolic resin in an organic solvent. The comparative figures showed that wheels made with the herein-described type of combining adhesive removed more than 20% material than a similar type abrasive wheel using a phenolic resin dissolved in an organic solvent as the combining adhesive and furthermore showed almost 50% less wheel loss than in the case of the latter type wheel.

The articles of the present invention not only

are capable of grinding with a relatively high rate of stock removal from the material being ground but at the same time produce a surface finish equal to that obtained by an ordinary bonded abrasive article employing abrasive particles several grits smaller. Abrasive products made as herein-described cut both efficiently and effectively with accompanying polishing action and are capable of high operating speeds without chattering, operating smoothly to remove burrs and produce very high finish on metal castings. It is theorized that the "soft" cutting action of such abrasive articles is the result of the abrasive grains being cushioned by the surrounding felted fibers and binder so as to prevent gouging and scratching and to provide the abrasive grains with a yielding background by which they are caused to maintain individually more effective contact with the work and at the same time absorb and take up inequalities of the surface so as not to mar or scratch the surface being finished.

Although certain specific conditions have been set forth for the example given it will be understood that the invention is not limited to the conditions therein described. Generally speaking, it has been found desirable to compress the articles under pressures of the order of 2,000 to 4,000 pounds per square inch. The length of time that the article is subjected to heat and pressure is determined to some extent by the size of the article being formed but is usually in the range of 15 to 30 minutes. Likewise articles in different grades can be made by varying the type of fibrous sheet material employed and the type and amount of adhesive applied thereto as a size.

In the specification and claims, where reference is made to a non-penetrative phenolic resin, the term is meant to include a phenolic resin which when applied as a sizing coating to the flat face of a sheet of abrasive-included felted fibrous web material of the herein-described type, and that sheet is compacted with other sheets of similarly sized felted fibrous, abrasive-containing material, and the assembly subjected to the heat and/or pressure required to mature the resin, the resin size coating on the felted sheet material will not penetrate the fibrous layers and impregnate the individual fibers of the fibrous sheet material to such an extent that the fibers of the fibrous structure are rendered brittle and lacking in resilience; an abrasive article so fabricated, as a result of the lack of absorption of the resin into the fibers thereof, will be resilient and flexible and will cut with a softness of action, that is, with an auxiliary polishing action, of the herein-described type.

One means of determining the efficacy of any particular resin for use as the combining adhesive in practice of the present invention is to apply a small amount of the proposed resin adhesive composition having a viscosity of 320 poises at 81° F. as measured on the MacMichael viscosimeter (which viscosity has been found to be satisfactory for use herein as the combining adhesive) to the surface of a piece of highly bibulous paper as, for example, ordinary unsized blotting paper, of .045" in thickness. If the resinous material of the aforesaid viscosity soaks into and penetrates the paper to the extent that it stains the opposite side of the paper in less than one hour, it is not considered to be a non-penetrative resin within the intended meaning of the term. A satisfactory non-penetrative resin of the type herein employed, when reduced to the aforementioned viscosity and applied to bibulous paper of the described type, will not penetrate the paper to the extent of staining the opposite side of the paper after a period of one hour and I prefer to employ resins which will not penetrate the paper, under the conditions specified, after a period of several hours.

Having described and set forth the invention in detail the scope of the invention is not to be confined other than by the appended claims.

We claim:

1. An abrasive article of manufacture comprising a plurality of layers of abrasive-included felted, fibrous sheet material, the major portion of the abrasive content being distributed internally of the fibrous sheet material, said layers of fibrous sheet material being adhesively combined in superimposed relation by means of an adhesive binder comprising a phenolic resin which is substantially non-penetrative of said fibrous sheet material.

2. An abrasive article of manufacture comprising a plurality of layers of abrasive-included felted, fibrous sheet material, the major portion of the abrasive content being distributed internally of the fibrous sheet material, said layers of fibrous sheet material being adhesively combined in superimposed relation by means of an adhesive binder comprising a phenolic resin and an inorganic filler, said phenolic resin being substantially non-penetrative of said fibrous sheet material.

3. An abrasive article of manufacture comprising a plurality of layers of abrasive-included felted, fibrous sheet material, the major portion of the abrasive content being distributed internally of the fibrous sheet material, said layers of fibrous sheet material being adhesively combined in superimposed relation by means of an adhesive binder comprising a phenolic resin and a cryolite filler, said phenolic resin being substantially non-penetrative of said fibrous sheet material.

4. A method of making bonded abrasive articles which comprises applying a coating of a non-penetrative phenolic resin adhesive composition to the surface of an abrasive-included felted fibrous web material having a major portion of the abrasive content distributed internally throughout said fibrous sheet material, said adhesive composition being substantially non-penetrative of said fibrous sheet material, assembling a plurality of sheets of said adhesively-coated web material in superimposed relation and compressing the same, and heating to cure the resin.

5. A method of making bonded abrasive articles which comprises applying a coating of a water dispersion of a phenolic resin to the surface of an abrasive-included felted, fibrous web material having a major portion of the abrasive content distributed internally throughout said fibrous sheet material, said phenolic resin dispersion being substantially non-penetrative of said fibrous sheet material, assembling a plurality of sheets of said adhesively-coated web material in superimposed relation and compressing the same, and heating to cure the resin.

6. A method of making bonded abrasive articles which comprises applying a coating of an adhesive comprising a water dispersed, phenolic resin and an inorganic filler to the surface of an abrasive-included felted, fibrous web material having a major portion of the abrasive content distributed internally thereof, assembling a plurality of sheets of said adhesively-coated web

material in superimposed relation and compressing the same, and heating to cure the resin.

7. A method of making bonded abrasive articles which comprises applying a coating of an adhesive comprising a water dispersed, phenolic resin and a cryolite filler to the surface of an abrasive-included felted, fibrous web material having a major portion of the abrasive content distributed internally thereof, assembling a plurality of sheets of said adhesively coated web material in superimposed relation and compressing the same, and heating to cure the resin.

8. A method of making bonded abrasive articles which comprises applying a coating of a non-penetrative adhesive composition comprising a water-miscible phenolic resin to the surface of an abrasive-included felted, fibrous web material having a major portion of the abrasive content distributed internally throughout said fibrous sheet material, said adhesive composition being substantially non-penetrative of said fibrous

sheet material, assembling a plurality of sheets of said adhesively-coated web material in superimposed relation and compressing the same, and heating to cure the resin.

9. A method of making bonded abrasive articles which comprises applying a coating of a non-penetrative adhesive composition comprising a water-miscible phenolic resin and an inorganic filler to the surface of an abrasive-included felted, fibrous web material having a major portion of the abrasive content distributed internally throughout said fibrous sheet material, said adhesive composition being substantially nonpenetrative of said fibrous sheet material, assembling a plurality of sheets of said adhesively-coated web material in superimposed relation and compressing the same, and heating to cure the resin.

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