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METHOD OF MAKING A PAPERMAKER'S FELT

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The present invention relates to papermakers' felts and a method for the manufacture thereof and more particularly to papermakers' felts made from synthetic fibers and a method by which such felts may be manufactured. The papermakers' felts to which this invention is directed are those which are used at any stage in the wet end or ahead of the driers of a papermaking machine. The term "papermaking machine" includes machines which are used for the manufacture of cement and asbestos-cement products, wall board, roofing felts, pulp laps and similar and related products. Such felts customarily have been made from natural wool or occasionally from a blend of natural wool and synthetic fibers. These felts are hereinafter referred to as papermakers' felts or as papermakers' wet felts.

Papermakers' wet felts are usually woven fabrics which have been fulled to cause the wool fibers therein to felt. In the manufacture thereof from wool or a blend of wool and synthetic material which contains sufficient wool to render the fabric fullable, it has been customary to weave a fabric of a given width and to "full" it to a width approximately one-half the woven width while maintaining the woven length approximately the same throughout the operation. In this manner the woven material assumes the desired firmness in texture and the felting of the wool fibers with one another gives the felt a high degree of dimensional stability under the conditions of use. The fulling operation also closes up the fabric giving it the ability to retain the fibers of the paper while being sufficiently porous to permit rapid removal of the water in the freshly laid paper. Beyond this, the natural wool papermaker's felt will remain resilient while wet and thus has the ability to pick up a freshly laid web of paper from the wire and conduct it through the presses. This highly exacting combination of requirements has heretofore been met only by a natural wool fabric or one in which natural wool has been blended with a limited amount of other fibers and in each instance it has been essential that the fabrics be capable of fulling.

According to the present invention, I provide a method for manufacturing entirely suitable papermakers' felts having great dimensional stability and having a life far in excess of that achieved by the best of woolen papermakers' felts, my new felts being made substantially wholly from synthetic materials or blends thereof which are not capable of felting and which heretofore have been used only in limited amounts in combination with large percentages of wool in the manufacture of papermakers' felts. According to my process, papermakers' felts may be made entirely or substantially entirely from fibers or blends of fibers which have dry tensile strengths substantially above 20,000 pounds per square inch, which is the average dry tensile strength of natural wool, and which do not lose tensile strength appreciably when wet and which fibers also have the property of taking a permanent set when subjected to heat treatment within the ranges of from 150° F. to 350° F. Among the fibers having such qualities are: nylon and fibers derived from polyvinylidene

chloride and acrylonitrile, copolymers of polyvinylacetate, polyvinylchloride and polyacrylonitrile and condensation products of terephthalic acid and ethylene glycol. The trade names "saran," "Orlon," "dynel" and "Dacron" are used to identify particular fibers within this group.

Many synthetic fibers such as those enumerated above are supplied by the manufacturers thereof in the form of a staple fiber which has been manipulated or treated by the manufacturer to resemble, as closely as possible, a natural wool fiber. Such fibers are generally identified as "crimped" although the particular conformations formed in the fibers thus identified may comprise crimps, crinkles, curls, spirals, indentations or serrations in one or more planes. Thus, for example, nylon is supplied as a staple fiber having a diameter and staple length falling within the range of diameters and staple lengths encountered in natural wool. While these nylon fibers do not have the characteristic of felting, they are supplied in a de-lustered form and with a large number of sharp crimps throughout their individual lengths which are permanent in the sense that the individual fibers will remain so crimped under conditions to which a woolen fabric is likely to be subjected. A yarn made from such staple fiber will exhibit substantially the bulk and springiness of wool and although it has a moderate initial shrinkage, it does not exhibit the tendency to felt. This makes such material highly desirable as a substitute for wool in many fields wherein progressive hardening and shrinkage characteristic of wool is undesirable. The lack of this characteristic, however, has rendered such fiber wholly unsuitable for the manufacture of papermakers' felts in accordance with known processes. I have found that by following particular steps in the weaving and in the handling of the fabric after weaving, an entirely satisfactory and unusually durable papermakers' felt can be produced in which the warp and filling yarns may be made wholly from such synthetic fibers.

The process and product of the present invention will be first described in general terms to enable those skilled in the art to manufacture papermakers' felts from a relatively large variety of synthetic resin fibers, and then will be described in the form of specific examples made from particular synthetic resin fibers.

Experience has shown that best results are achieved by the use of synthetic resin fibers which have been so manufactured or processed as to resemble or exceed natural wool in such qualities as strength, springiness, etc., in the dry and wet states.

The selection of the synthetic resin fiber or mixture of such fibers may be guided very largely by the principles under which natural wool fibers heretofore have been selected for the manufacture of papermakers' felts having certain desired characteristics. Thus, synthetic resin staple fibers are available in various staple lengths and in various diameters including some which are in the ranges found in natural wool. In this regard, the lengths and diameters of the synthetic fibers are usually much more uniform than those encountered in natural wool and this leads to the decided advantage of uniformity of the ultimate product.

As of the date of filing of the present application, applicant is unaware of any synthetic fiber which resembles wool to the extent of having the tendency to felt but various processes which serve to roughen the surface or to form permanent crimps or bends or to coil or curl the fibers serves to increase the tendency of the fibers to engage one another in a relatively permanent relationship, thus contributing to dimensional stability of the final product. To the extent that felting properties may be imparted to synthetic fibers in the future, such fibers, provided they are otherwise appropriate for use in the present invention, should offer obvious advantage. However, it has been found that entirely satisfactory paper-

makers' felts may be made wholly from synthetic resin fibers available in the market as of the date of filing of this application and which fibers exhibit no definite tendency toward felting.

It is further essential that the selected synthetic fibers have a dry tensile strength in excess of 20,000 pounds per square inch which is the average dry tensile strength of natural wool and that the ratio of wet tensile strength to dry tensile strength exceeds or at least is approximately equal to the corresponding ratio in natural wool which averages about 77%, that the fiber retain a large degree of its original resilience when wet and that the selected synthetic fibers have an abrasion resistance at least equivalent to wool when wet. The selected fiber must also have the property of taking a permanent set when subjected to heat treatment within the ranges of from 150° F. to 350° F. Furthermore, any crimping or curling imparted to the fibers should be permanent in the sense that they will not straighten out under the tensions found in carding and spinning, weaving or finishing or heat treatment or under continued operation while wet at the temperatures encountered by papermakers' felts upon a papermaking machine or during such cleaning or reconditioning operations as are normally practiced. Otherwise the fabric will lose its bulk and resilience.

In the manufacture of paper the advantage to be gained by the decrease in viscosity of water through the application of heat is recognized and in many cases, temperature of the paper stock is raised for this purpose. Temperatures rarely exceed 140° F. for economic reasons although it is conceivable that temperatures ranging from 33° F. to 212° F. might be encountered in the normal manufacture of paper. In any event the felt is not at all likely to be subjected to temperature about 212° F. and for practical purposes a felt set at 212° F. or slightly higher, as for example from 212° F. to 240° F. will be quite adequate for use on machines used in the manufacture of paper, asbestos cement products, wall board, lap pulp and similar products.

Crimped nylon, "Dacron" or "Orlon" fibers will retain substantially their original crimped form throughout manufacture and use of a papermaker's felt made from such materials and they have a ratio of wet strength to dry strength considerably higher than natural wool. In the case of saran fibers there are two forms presently available which fall within the general classification of "crimped" fibers. One of these is identified by the manufacturer as "crimped" and the other is identified as "curled." Apparently due to differences in manufacture or processing, the saran fibers identified as "crimped" do not have sufficient stability under the conditions met in the manufacture and use of papermakers' wet felts while the saran fibers identified as "curled" have satisfactory stability. In the appended claims the word "crimped" is used in the general sense so as to include the curled saran fibers having the other characteristics set forth in the claims. Cellulosic fibers such as rayon or cellulose acetate are wholly unsuitable because of lack of strength, wet or dry, as well as their lack of characteristics leading to dimensional stability under the conditions herein involved.

It is desirable that the synthetic resin fibers exhibit at least a moderate amount of initial shrinkage when a woven fabric made therefrom is subjected to heat in the presence of moisture as by immersion in hot water or exposure to wet steam. When hot water is used any suitable additional swelling agents may be added if so desired as is customary in the shrinking of fabrics. This characteristic is exhibited by the nylon, "Orlon" and "Dacron" fibers identified hereinabove as otherwise suitable for use in the present invention.

The selected synthetic fiber or blend of such fibers may be carded and spun into yarn in accordance with the technique ordinarily employed in the carding and spinning of natural wool fibers. The yarns may be twisted and plied in any of the manners desired for particular

final results. The warp and weft yarns may be identical or may differ from one another in any of the respects already well known in connection with the weaving of papermakers' felts from natural wool.

The type of weave may be selected at will and excellent results have been had with plain weaving as well as with twills, etc., commonly used for producing papermakers' felts of various grades and for various intended uses. In view of the fact that only a moderate initial shrinkage can be expected and the fabric cannot be fully, the ordinary technique of weaving the fabric relatively loosely and shrinking and fulling it will not produce a fabric having the necessary final qualities. I have found that desired final construction may be achieved by supplying a proportionately greater number of warp ends on the one hand and so operating the loom on the other hand as to bring about a proportionately higher pick count to compensate for the lack of fulling quality. Thus the take up motion and the motion of the lay should be so adjusted that successive picks are beat up with relatively greater force than would be applied in the manufacture of a substantially identical final product from fiber including sufficient natural wool to render the same fullable.

Preferably the length of the synthetic papermaker's felt of the present invention is maintained and the effect of such shrinkage as the synthetic fibers may produce is chiefly confined to a reduction in width of the finished felt. Thus, in the case of a felt which is to be spliced, the woven length is the warp length and it is this dimension which is maintained so that shrinkage occurs only along the filling. When the felt is woven endless the filling length becomes the finished length and in that case shrinkage will be chiefly confined to the warp yarns while the filling threads are maintained substantially at their original length. With these considerations in mind, it will be apparent to those skilled in the art that in accordance with the present invention appropriate variations in the weight of yarn, count of warp ends and picks and in the degree of beating up may be resorted to to produce finished felts of widely varying specifications. Specific examples of endless and spliced felts will be set forth hereinbelow.

After the fabric has been woven from the selected synthetic resin fiber or blends thereof, it is shrunk by heating in the presence of moisture as by placing it in relaxed condition in water which is preferably heated to a temperature sufficiently to induce relatively rapid initial shrinkage. To the same end it may be exposed to an atmosphere of steam at or near normal atmospheric pressure. If it is desired to maintain the length of the felt substantially constant and to realize the major shrinkage in width, the felt is maintained under tension only in the direction of its length while permitting shrinkage in the cross-wise direction. A considerable amount of shrinkage can be achieved with any of the synthetic resin fibers set forth above as suitable for use in the present invention. While in some instances the fibers themselves will exhibit a very small amount of shrinkage, the woven fabric will shrink considerably more as a result of the tensioning of the yarns during spinning, twisting and weaving.

After the initial shrinking the fabric is dried and during the drying operation the fabric is subjected to an elevated temperature for a period of time sufficient to not only remove any moisture remaining from the immersion or steaming thereof but also to induce a permanent set of the synthetic resin fibers in the positions and configurations in which they find themselves when the felt is held at the desired final dimensions. The drying apparatus may be essentially the same as that heretofore employed in the drying of natural woolen felts and usually comprises a heated drum and an idler roll spaced therefrom for a distance sufficient to define a parth in which the full length of the felt may be maintained under tension

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while the drying proceeds. While in the manufacture of natural woolen felts it is customary to rotate the drying drum continuously, and thus to pass the felt continuously through an endless path, it has been found preferable in the drying and setting of the synthetic felts of the present invention to rotate the drying drum in steps. Each increment of advance imparted to the felt in successive steps is approximately equal to the length of felt which is exposed in direct contact with the heated drying drum. In this manner, each successive area of the felt may be maintained in contact with the surface of the heated drum for a period of time sufficient to dry the felt and soften the fibers somewhat so that they will relax into the shapes and positions assumed at that time. The felt is then moved by rotating the drying drum to bring a new increment thereof into contact with the drum. The increment leaving the drum is thus given an opportunity to cool and the fibers therein will assume a set which will be retained so long as the felt is not subjected to a temperature approaching the temperature at which the set was established.

The drying operation just described causes further shrinking of the fabric in the filling direction. The shrinkage thus effected plus the initial shrinkage described above will be greatly in excess of the shrinkage exhibited by the particular fibers from which the fabric is woven. For example, a nylon fiber which will shrink only about 2% when relaxed in hot water may be used for the manufacture of a papermaker's felt as described herein and the finished fabric will have shrunk by as much as from 25% to 40% in the direction of the filler yarns.

The temperatures at which drying and setting occur may be varied at will in accordance with the particular fiber or blend of fiber used and in accordance with any particular conditions to which a felt may be subjected in further processing or in ultimate use. For example, many natural wool felts are impregnated with a thermosetting resin and heated to set such resin during the manufacturing operations. In some instances the thermosetting resin requires heat treatment at about 300° F. to 350° F. When such materials are incorporated into a felt made in accordance with the present invention and such higher temperatures are applied the synthetic resin fibers will take the permanent set, herein described, at the higher temperature.

Also, whether or not the felt is impregnated, it may be desired to have the felt withstand some particular temperature to which it will be subjected in use. In such event the felt is set at a temperature somewhat above that particular temperature. Ordinarily a papermaker's wet felt may be set at or slightly above the boiling temperature of water and it will maintain its desirable characteristics throughout its life in the usual papermaking operation.

Thus the step of drying the felt of the present invention may be availed of to set the fibers as described. The drying drum described above is normally heated by steam. While the fibers may be dried and set at a temperature as low as about 150° F., for practical purposes in the manufacture of a nylon felt which will be subjected to ordinary papermaking conditions, the drum preferably will be maintained at about 220° F. and each increment may be left in contact therewith long enough for evaporation of all of the water and for the dried felt to assume approximately the temperature of the drum. The fibers will thus be set at about 220° F. and the finished felt will be entirely suitable for normal papermaking uses wherein it will not be subjected to temperatures in excess of about 212° F.

If the felt is to be impregnated with a thermosetting resin or if it is desired that it withstand higher temperatures it may be passed through further heating devices maintained at suitable temperatures. In the case of nylon the maximum temperature should not greatly ex-

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ceed about 350° F. if all of the original characteristics of the fiber are to be preserved.

The selection of the drying and setting temperature for synthetic resin fibers other than nylon may be governed by the same considerations. The temperature must be at least high enough to set the particular fiber or blend of fiber and it should be sufficiently high to condition the felt for the use which it will encounter. The maximum temperature should not exceed that at which the original desired characteristics of the fiber or blend might be lost.

Felts made wholly from synthetic resin fibers in accordance with the present invention have successfully demonstrated their utility on paper machines of various types in connection with the production of widely differing grades of paper as well as in the production of other related products such as those made from asbestos cement and wallboards and the like made from different types of furnish. In some of these instances the furnish contains materials of highly abrasive nature and the life of natural wool felts has been exceedingly short. The felts of the present invention not only have adequately demonstrated the greatly increased tensile strength and life which might be expected as a result of the substitution of synthetic resin fibers having greater tensile strength and abrasion resistance than natural wool, but also exhibit desirable greater porosity and have been completely satisfactory in dimensional stability and ease of cleaning and maintenance.

Throughout the specification, emphasis has been laid upon the fact that in accordance with the teachings hereof, it is possible to make papermakers' wet felts by weaving a fabric from yarns consisting wholly of a particular synthetic resin fiber or a blend of two or more such fibers. Obviously minor amounts of other fibers, including natural wool, might be blended therewith without departing from the essentially novel features of this invention. The felts heretofore made from blends of natural and synthetic fibers have always contained sufficient natural wool fibers to render the fabric capable of being fullled whereas the felts of the present invention contain no natural wool fibers or, at most, insufficient quantity thereof to make the fabric fullable. The process of the present invention provides for the production of papermakers' felts from fibers which are essentially incapable of felting and the product of the present invention is a papermaker's felt made in the form of a woven fabric which is essentially incapable of fulling.

Specific examples of papermakers' felts and of the process for producing the same will now be given and, for purposes of illustration, there also will be given a description of the process and product resulting from the manufacture of a natural wool felt having substantially the same final specifications.

Example 1.—A papermaker's felt was made from fiber comprising 100% crimped nylon staple fiber having a staple length of 3 inches and a fiber diameter lying within the range of fiber diameters encountered in natural wool. Such fibers have a dry tensile strength of about 58,000 pounds per square inch and a wet tensile strength of about 56,000 pounds per square inch. Each fiber had been sharply and permanently crimped throughout its length to the extent that when straightened out under tension each fiber is approximately four inches in length. The fiber was carded, spun and twisted into yarn in accordance with ordinary technique applicable to natural wool fiber. Yarn thus made weighing 700 grains per 100 yards, in the grease, was used for both warp and fill. A reed having 7 dents per inch was used with two warp ends per dent. The takeup mechanism and lay were adjusted to supply 16 picks per inch in a conventional 4-harness satin weave. Under these conditions wherein there are 14 warp ends per inch and 16 picks per inch of relatively heavy yarn, it was essential that each pick be beaten up with sufficient force to pack the 16 picks into a lineal inch.

This felt was woven as a piece and after the requisite length was woven it was spliced to form an endless loop. The fabric was then placed under longitudinal tension but without crosswise tension in a bath of water maintained at a temperature of 180° F. for about 20 minutes in order to permit the fabric to take an initial shrinkage in the filler direction. The felt was then dried by passing it around a rotary drier drum and an appropriately spaced idler roll. The distance between the idler roll and the drier drum was established so as to place the felt under tension and bring it back to its original woven length. The drier drum was heated to a temperature of 220° F. and was held against rotation for approximately 5 minutes during which the water was evaporated from that portion of the felt in direct contact with the surface of the drier drum. After the water was evaporated the felt achieved a maximum temperature of about 220° F., the temperature of the drum. At the latter temperature the crimped nylon fibers were relaxed into the shape and position which they assumed in the woven fabric and they become set in such relationship upon cooling of the fabric to room temperature. During the drying and setting operation the fabric shrunk in width and the ratio of woven width to the finished width was 140%.

The drier drum was rotated stepwise to move successive lengths of felt into and out of direct contact with the surface thereof for drying and setting as aforesaid until the entire length of felt has been dried and set.

The felt may be then napped and singed or otherwise processed in accordance with known procedures which will vary with regard to the particular use for which the felt is intended.

In its finished form the felt of this example has a weft count of 16 per inch and a warp count of 19.6 per inch. The increase in warp count is the result of the shrinkage in the filler direction, the ratio of woven width to finished width being, as stated above, 140%.

For purposes of comparison, a papermaker's felt was woven from 100% natural wool fiber wherein the warp yarns weigh 700 grains per 100 yards in the grease and the filling yarns weigh 500 grains per 100 yards. The reed was provided with 5 dents per inch with two warp ends per dent. The take-up mechanism and the lay were so adjusted as to supply 16 picks per inch but it should be noted that since the filling yarns have less weight than those used in the manufacture of the nylon felt of the present example, the successive picks need not be so firmly beaten up. The weave was the same conventional 4-harness satin. The fabric was then spliced after which it was fulling in accordance with known procedure and placed upon the drier with the tension roll so positioned as to tension the felt at its original woven length. The drier drum was heated to 220° F. and rotated continuously to progressively dry the felt as is usual with the manufacture of felts from natural wool. The ratio of the woven width to the finished width was 200% and the finished felt had a warp count of 20 and a pick count of 16. The warp yarns, of course, retained their original 700 grain weight and thus were completely comparable in weight with the warp yarns in the finished nylon felt of the present example. The filling yarns of the wool felt weighed 500 grains when woven but after the reduction in width due to shrinkage and fulling, the filler yarns are equivalent to 1000 grain yarn and thus comparable with the final 960 grain weight of the nylon yarn used as fillers for the nylon felt. It is apparent, therefore, that the two finished felts are very closely comparable in finished construction.

The two felts of the present example were then subjected to identical abrasive tests on a special testing machine having driven press, tension and elongation rolls, showers, drag bars, speed indicators and other instruments to simulate a press section of the common paper machine. This testing machine is particularly con-

structed to provide a means of duplicating, with reasonable accuracy, the widely varying pressures, tensions, temperatures, chemical conditions and abrasive conditions which exist in paper machines of various types. The tests applied to the wool and nylon felts of the present example are known to be identical within an accuracy of plus or minus 2% as the result of many years of experience with this particular testing machine.

The tensile strength of the warp and filling yarns was tested at the beginning of the test and at frequent intervals during the progress thereof and the decrease in tensile strength was plotted against time. As might be expected, the nylon yarns exhibited tensile strength much higher than that of wool at the beginning of the test. As the test proceeded, the nylon warp yarns showed a rate of wear about the same as that for the wool warp yarns but in view of their greater original strength the nylon warp yarns exhibited after 48 hours more than twice the tensile strength of the wool warp yarns after about 36 hours. Warp yarns are relatively straight and protected by the filler yarns so that a felt seldom fails as a result of wear on the warp yarns. The closely packed filler yarns present knuckles on the surfaces of the felt and are most subject to wear from abrasion. The nylon filling yarns had considerably greater tensile strength than the wool filling yarns at the beginning of the test, as might be expected, but the rate of wear upon the nylon was somewhat less than that upon the wool so that at the end of 48 hours the nylon filling yarns exhibited greater tensile strength than that exhibited by the wool filling yarns after only 14 hours. This test indicated that the nylon felt could be expected to last almost four times as long as the wool felt insofar as abrasive wear is concerned. However, the life of a felt is not solely dependent upon its resistance to abrasion and the very much greater tensile strength of the nylon felt makes it less vulnerable to damage from mishaps of various sorts. Therefore, the superiority of the nylon felt over the woolen one under actual conditions of use has been found to be even greater than that indicated in the abrasion tests.

Example 2.—A papermaker's felt was woven in endless form from yarns having a weight of 700 grains per 100 yards, in the grease, for both warp and fill, the yarns being made from 100% crimped nylon fibers identical with those described above in Example 1. The reed was provided with 8 dents per inch with 4 warp ends per dent and one warp end per eye on 8 harnesses. Since the felt was being woven endless the warp count in top and bottom was therefore 16 per inch. The take-up mechanism and lay were adjusted to supply 11 picks per inch top and bottom and the weave was a plain endless weave.

In this felt the woven length, i. e., the length warp-wise, becomes the finished width and the woven width becomes the finished length. The woven fabric was shrunk in water at 180° F. for about 20 minutes, with the filler yarns maintained under tension so as to retain the original woven width which was destined to become the finished length. After shrinking the felt was dried and set in stepwise manner as described in Example 1. The ratio of the woven length to the finished width was 116%. The amount of shrinkage was considerably less than that encountered in Example 1 since, in the present example, the relatively straight warp yarns were permitted to shrink while in Example 1 the filler yarns were permitted to shrink. The finished warp count remains at 16 per inch while the finished filler count is increased as a result of shrinkage to 12.75 per inch.

For purposes of comparison, a similar endless felt was woven from yarns comprising 100% natural wool fiber, the yarn weight being 640 grains per 100 yards, in the grease, for the filler yarns supplied to the loom and 350 grains per 100 yards, in the grease, for the warp yarns supplied to the loom. The reed was provided with 7 dents per inch with 4 warp ends per dent and one warp

end per eye in 8 harnesses. The warp count, as woven,

was therefore 14 per inch. The take-up motion and the lay were so adjusted as to supply 6 picks per inch top and bottom. After weaving, this woolen felt was shrunk and fullled and thereafter dried in accordance with known technique and the ratio of woven width to finished length was 110% and the ratio of woven length to finished width was 200%. The finished warp count was 15.5 per inch and the finished filler count was 12 per inch. Since the warp yarns were reduced to half their woven length by shrinkage and fulling the finished warp yarn weight was increased to 700 grains; thus being comparable to the finished nylon warp yarn weight of the present example. The filler yarns remained at 640 grains and thus are comparable to the 700 grain nylon filler yarns of the present example.

Tests similar to those described in Example 1 indicated that the nylon felt of the present example should last at least four times as long as the wool felt of this example.

Example 3.—Papermakers' felts identical in construction with those of Examples 1 and 2 were made with blends of crimped nylon fibers and fibers sold under the tradename "saran," the latter having a fiber diameter lying within the range of diameters encountered in natural wool. The proportion of saran fibers to nylon fibers may be varied considerably without noticeable effect upon the durability of the finished felt. Specifically, a blend containing 90% nylon staple fibers and 10% saran staple fibers produces papermakers' felts having all of the desirable attributes of those of Examples 1 and 2 which in addition exhibit a desirable great tendency to pick up a freshly laid web of paper.

Example 4.—Papermakers' felts having the same desirable attributes of those in the preceding examples may be made in accordance with said examples except that the initial shrinkage is effected by exposure of the fabric to an atmosphere of wet steam instead of by immersion in hot water. Thus any of said felts may be steamed in any of the several ways which are customarily employed for shrinkage of fabrics. A suitable procedure is to conduct the fabric through a path wherein jets of steam are released into the atmosphere and directed onto the fabric whereby the fabric is moistened and heated to induce shrinkage comparable to that achieved by immersion in hot water.

Felts manufactured from synthetic resin staple fibers in accordance with the present invention exhibit considerably greater porosity than felts made from natural wool and of identical construction. For this reason and because the synthetic resin fibers herein availed of are usually much stronger than natural wool, it is not necessary that a particular natural wool felt be replaced by a synthetic fiber felt which is identical, pick for pick, end for end and weight for weight. Thus in some instances it may be possible to replace a particular natural wool felt with a synthetic fiber felt of heavier construction because of the relatively greater porosity of the synthetic fiber felt. Furthermore, the greater tensile strength of felts made from synthetic materials will make it possible to substitute a considerably lighter construction where maximum porosity is particularly desired. The synthetic felts of the present invention greatly expand the area within which felts may be designed and the value of this will be apparent when it is considered that in many instances the design of a natural wool felt must constitute a compromise between desired porosity and requisite tensile strength.

The present application is a continuation-in-part of my application Serial No. 313,367, filed October 6, 1952, now abandoned.

What is claimed is:

1. The method of making papermakers' wet felts from yarn composed substantially entirely of thermoplastic synthetic resin fibers having crimps which are stable below a predetermined temperature and are capable of taking and retaining a set in addition to said crimps at

a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt, comprising the steps of weaving a fabric tightly from said yarn, immersing said tightly woven fabric in hot water to shrink the same transversely of the felt, applying tension to said tightly woven fabric during said shrinking step to prevent shrinkage of the same longitudinally of the felt, and drying and heating the shrunken fabric under longitudinal tension and at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt to set the fibers in said shrunken fabric in the positions and conformations existing during said drying and heating step while retaining substantially all of the original crimps therein.

2. The method of making papermakers' wet felts from yarn composed substantially entirely of thermoplastic synthetic resin fibers having crimps which are stable below a predetermined temperature and are capable of taking and retaining a set in addition to said crimps at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt, comprising the steps of weaving a fabric tightly from said yarn, immersing said tightly woven fabric in hot water to shrink the same transversely of the felt, applying tension to said tightly woven fabric during said shrinking step to prevent shrinkage of the same longitudinally of the felt, drying and heating a relatively small portion of the shrunken fabric under longitudinal tension and at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt to set the fibers in said portion of the shrunken fabric in the positions and conformations existing during said drying and heating step while retaining substantially all of the original crimps therein, and periodically advancing said shrunken fabric under longitudinal tension to dry and heat the entire length thereof by increments.

3. The method of making papermakers' wet felts from yarn composed substantially entirely of thermoplastic synthetic resin fibers having crimps which are stable below a predetermined temperature and are capable of taking and retaining a set in addition to said crimps at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt, comprising the steps of weaving a fabric tightly from said yarn, heating said tightly woven fabric in the presence of moisture to shrink the same transversely of the felt, applying tension to said tightly woven fabric during said shrinking step to prevent shrinkage of the same longitudinally of the felt, and drying and heating the shrunken fabric under longitudinal tension and at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt to set the fibers in said shrunken fabric in the positions and conformations existing during said drying and heating step while retaining substantially all of the original crimps therein.

4. The method of making papermakers' wet felts from yarn composed substantially entirely of thermoplastic synthetic resin fibers having crimps which are stable below a predetermined temperature and are capable of taking and retaining a set in addition to said crimps at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet felt, comprising the steps of weaving a fabric tightly from said yarn, heating said tightly woven fabric in the presence of moisture to shrink the same transversely of the felt, applying tension to said tightly woven fabric during said shrinking step to prevent shrinkage of the same longitudinally of the felt, drying and heating a relatively small portion of the shrunken fabric under longitudinal tension and at a temperature below said predetermined temperature and above the temperatures ordinarily encountered in using papermaker's wet

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felt to set the fibers in said portion of the shrunken fabric in the positions and conformations existing during said drying and heating step while retaining substantially all of the original crimps therein, and periodically advancing said shrunken fabric under longitudinal tension to dry and heat the entire length thereof by increments.

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