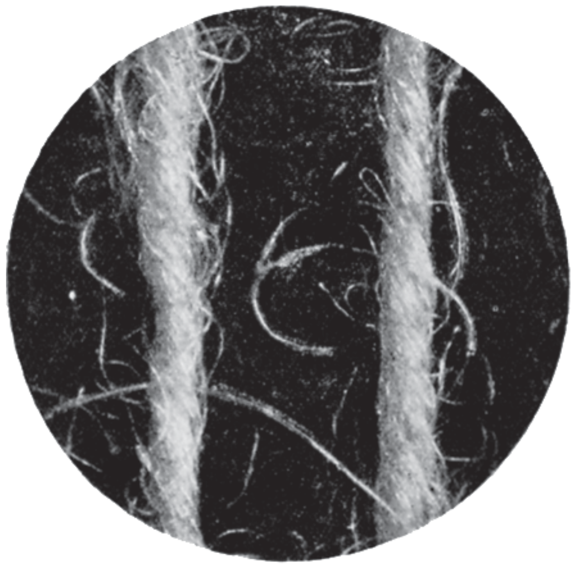

FIG. 35.—Welsh-wool yarns. 12 skeins (11·8 turns per inch).

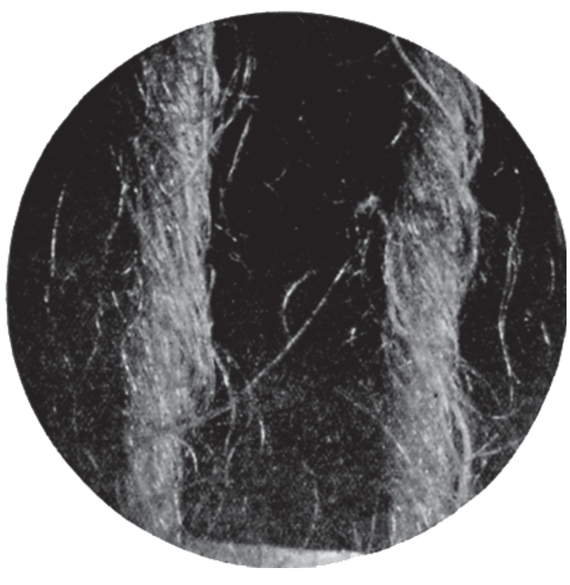

FIG. 35A.—Welsh-wool yarns. 12 skeins (6·5 turns per inch).

This will be better understood if yarns made of Border Cheviot and Welsh wools, and Yorkshire Crossbred and Saxony wools are compared, and also contrasted in felting property. Figs. 34 and 34A are threads spun from Cheviot, Figs. 35 and 35A, from Welsh wools to corresponding counts. The true qualities of a rough Cheviot yarn are peculiar to the threads in Figs. 34 and 34A. There is a fringe of straggling fibres, rolled into clusters, with the mass of the fibres twirled in one progressive movement. Variation in length and diameter of fibres causes, in spinning, the thicker and longer fibres to force the finer into the core of the yarn.

From the micro-photographs of the fibres of the Cheviot and Welsh wools (Figs. 23 and 25) it will be seen that the Welsh are smaller in diameter than the Cheviot. This is also traceable in the yarns (Figs. 34 and 35). There is a larger percentage of fibre in the Welsh than in the Cheviot yarns, though both are spun, as seen, to the same counts.

Experiments in fabrics of like setting with these two yarns proved the Welsh to be somewhat superior in felting to the Cheviot. The latter shrunk more unevenly, and developed a blanket-like handle and character. This was caused by the fine fibres felting more readily than those of a coarser nature, and forming a texture to which the latter were, by continued treatment in the milling machine, matted rather than felted. With the Welsh yarn the process was different. The fibres being of a higher average fineness, the milling was more equalised, so that a greater percentage of the wool felted at one period, with less of the blanket quality in the fabric. If a finer-fibred Cheviot wool had been used, its felling power would have been at least equivalent to that of the Welsh.

Fibrous density is a valuable felting quality. Yarns composed of coarse-fibred material are, comparatively, lacking in felting efficiency. In this consists one of the chief disagreements between Saxony and Crossbred, or Merino and Cheviot yarns. Saxony owes its higher shrinking power, in the first place, to a fuller serrated fibre, but there is also fineness in its favour in the yarn, and this fixes the number of fibres in a given diameter of thread by mechanical means which are amenable to no laws of variation. It is clear, therefore, that two yarns of the same counts, but one consisting of a higher percentage of fibres than the other, must differ in felting power. But when it is considered that the yarn with the higher percentage of fibre is also composed of wool of the more serrated structure, the superior felting power of a Merino as compared with a Crossbred yarn

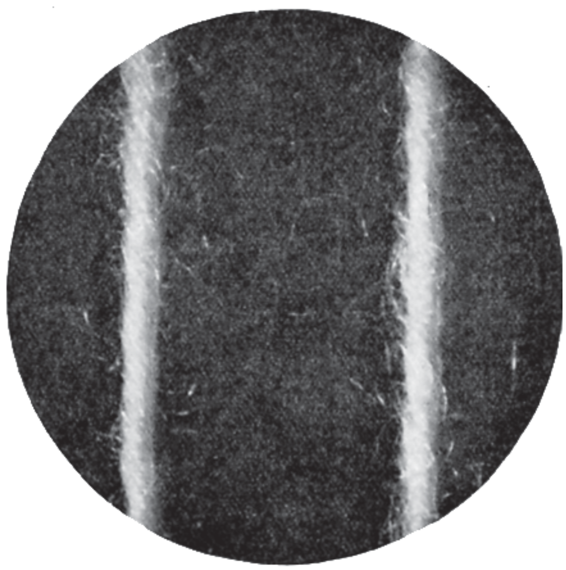

Fig. 36.—Saxony. 20 skeins (Hard Spun).

is increasingly apparent. Figs. 36 and 36A, and Figs. 37 and 37A show how such yarns differ from each other in these fibrous properties. They are of similar counts and twine, but Fig. 36 made from Tasmanian wool, and Fig. 37 from Yorkshire Crossbred. The difference between the structure of the two threads is greater than between the Border Cheviot and the Welsh, as might be expected from the use, respectively, of a fine (Tasmanian) and a comparatively coarse-fibred (Yorkshire) wool. Contrasting the two, it will be seen that the Tasmanian is almost a solid mass of fibre with a certain amount of extraneous filament, but lacking the comparatively "wild" character possessed by the yarn made of Yorkshire wool. The greater density of the thread in Fig. 36 is another factor that imparts felting power to the fabric in which it is used.

From these examples, it will be clearly understood how the nature of the yarn varies in felting strength with the difference in the fineness, length and evenness of the fibres in the wool,

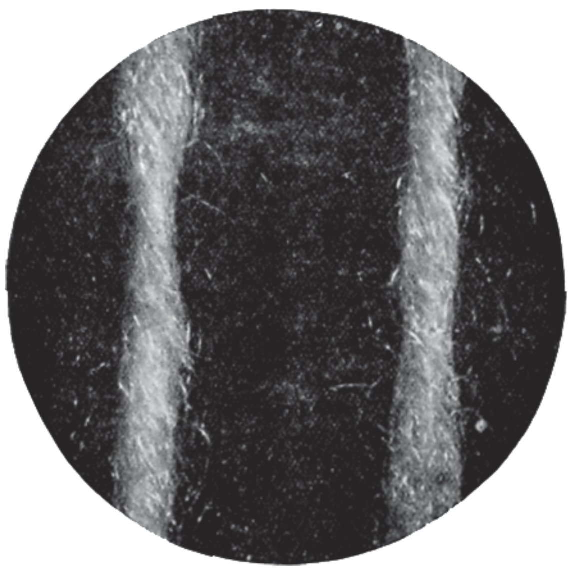

FIG. 36A.—Saxony. 20 skeins (Soft Spun).

in addition to its physical structure. Yarns may be made precisely in the same way, but when there is such a dissimilarity in these qualities of the materials as in the threads which have been compared, there naturally follows a difference in the shrinkage properties of the fabrics into which they are manufactured.

(44) *Methods of Yarn Construction and Felting.*

In the spun yarn, there are fibrous conditions which are conducive to, and others detrimental to, sound felting. A number of fibres laid in parallel form, straight and level in the thread, are not in the most suitable relation for felting. On the other hand a cluster of fibres, crossing and intertwining with each other, curly and wavy, are favourable to intermatting, and to becoming, under compression, increasingly meshed. The former condition is illustrative of the typical or true worsted, and the latter of the true woollen yarn. Several varieties of thread are spun between these two extremes. Experiment and research prove that the woollen has the higher felting property, so that the more closely the worsted structure is approached the less the felting quality of the fabric. Whatever method of yarn structure is adopted, the natural felting property of the fibre is not diminished; but, rather in the woollen or carded thread, the fibres are induced to felt, whereas this quality is not assisted, to the same degree, when the fibres are in the relation formed by the processes of combing and gilling.

There are, therefore, three essential features in which yarns made on these principles differ from each other. First, the woollen thread contains a much larger percentage of fibre, counts for counts, than the worsted; second, it possesses a more undulated surface; and third, it has more free ends of fibres, which afford the least resistance in felting.

These qualities of the two yarns may be contrasted in Figs. 38 and 38A, and 39 and 39A, the former being made on the woollen principle, and the latter on the worsted, but both spun to similar counts from the same kind of wool. The straightness of the fibres and evenness of the surface in the worsted, and the comparative irregularity of the woollen are clearly defined. In the twofold threads from the same wools, Figs. 40 and 41, these characteristics are still more accentuated. The worsted retains its straightness of structure, with the bulk of the fibres level or in a line, whilst the roughness of surface and the meshes of fibres obtain in the woollen in a more marked degree. Such strongly developed points of difference in yarn structure have an important bearing upon the felting property of fabrics. In a thread like Fig. 41, from which much of the short filament has been removed, and the curliness combed out of the fibres, there cannot be that disposition to mill as in the woollen, in which the fibres largely possess their natural qualities, and, as indicated, are carded and twisted in a manner that leaves them crossing each other in a more diversified way.

In experiments made with the yarns in Figs. 38 and 39, the yarn constructed on the woollen system made a fabric better adapted for milling than that on the worsted system. In instances where a fine Merino wool was spun to the same counts by carding, and spinning on the self-actor, to a similar yarn made on the worsted method, and also woven into a fabric of the same structure, the woollen had the higher felting property. As an example of this, reference may be made to experiments in which a 3's worsted, and a 7 skeins woollen (both of similar diameter), were used. In the milling of both fabrics together, the texture made of the woollen yarn shrank fully 8 per cent. more than the worsted. Here, the excess of shrinkage on the woollen was chiefly due to yarn structure.

(45) *Shrinkage of Fabrics made of Re-manufactured Fibres.*

Mungo, shoddy and other wool substitutes have not the same shrinking power as the raw materials from which they have been obtained. The process of grinding, or garnetting in the case of waste material, reduces the felting property of the fibre. Taking yarns made of Tasmanian wool, and of material reduced from waste from a similar quality of wool, and producing fabrics of the same setting in plain, twill and broken swansdown, the shrinkages were as follows :—

TABLE V.

Comparison in the Shrinkage of Fabrics made of Tasmanian Wool and Pulled Waste.

	Percentage of Contraction in Fabrics made of Tasmanian Wool.			Percentage of Contraction in Fabrics made of Pulled Waste.		
	Milling Periods.			Milling Periods.		
Weave.	30 Minutes.	60 Minutes.	90 Minutes.	30 Minutes.	60 Minutes.	90 Minutes.
Plain . .	23·50	31·75	41·75	12·50	22·25	33·25
$\frac{2}{2}$ twill . .	29·00	33·25	44·25	22·25	31·75	41·75
Swansdown .	30·55	39·00	47·25	20·75	33·25	40·25

The higher felting property is seen in each period in the yarn made of pure wool, but the ratio of shrinkage in each successive period is similar in both materials. This is an indication that the quality of the fibre of the pulled waste was, originally, of a similar fineness as that of the Tasmanian wool.

As the pulled waste is reduced in quality, according to the material from which it is obtained, the difference between the shrinkage of the cloth and that made from pure wool is proportionately increased.

Another feature which is exemplified by these results is the shrinkage life of pure wool as compared with mungo, or other re-manufactured fibre; that of the wool continues for a much longer period owing to the length and elasticity of the fibre. At a period when a fabric made from wool would be steadily shrinking, that made from waste would have lost its felting power, and instead of the cloth continuing to shrink in length and width the work in the milling machine would have the reverse effect.

(46) *Degree of Twine in the Yarn.*

The practice in manufacturing is to use a soft spun yarn for weft in fabrics which require to be well milled, and in which the warp yarn is twofold, or hard in twine. The primary object of this is to facilitate contraction of the cloth in the proces

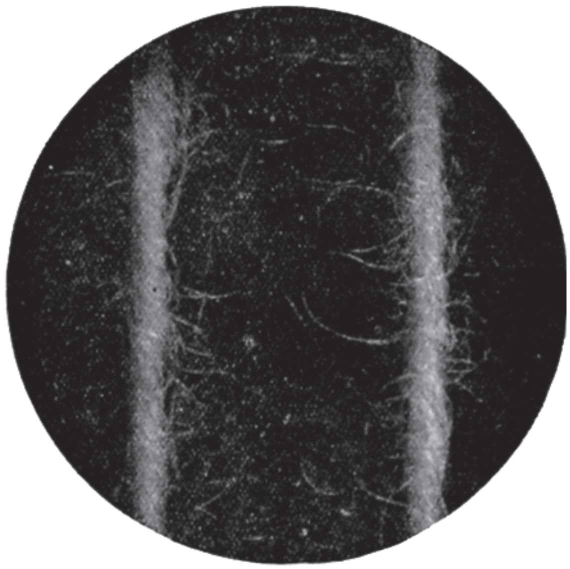

FIG. 37.—Crossbred. 20 skeins (Hard Spun).

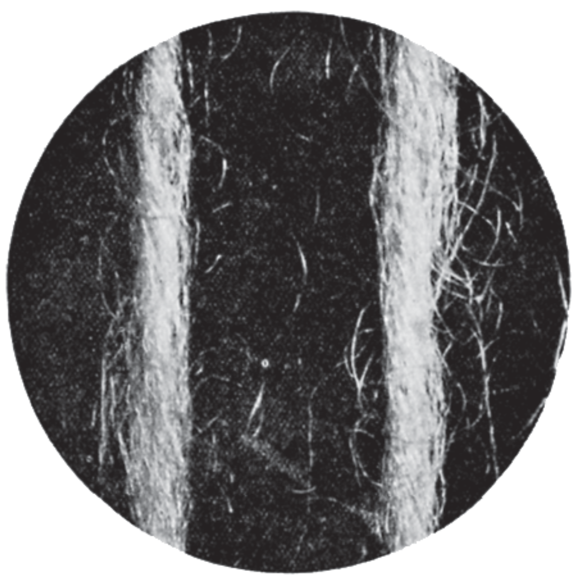

FIG. 37A.—Crossbred. 20 skeins (Soft Spun).

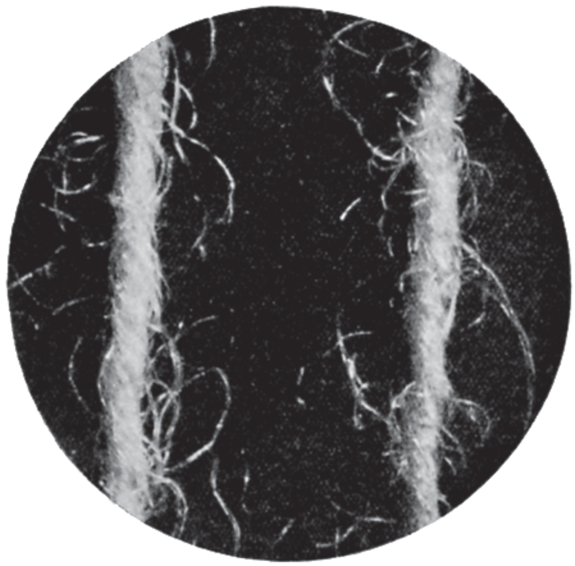

Fig. 38.—18 skeins Woollen Yarn (Southdown Wool), 16 turns per inch.

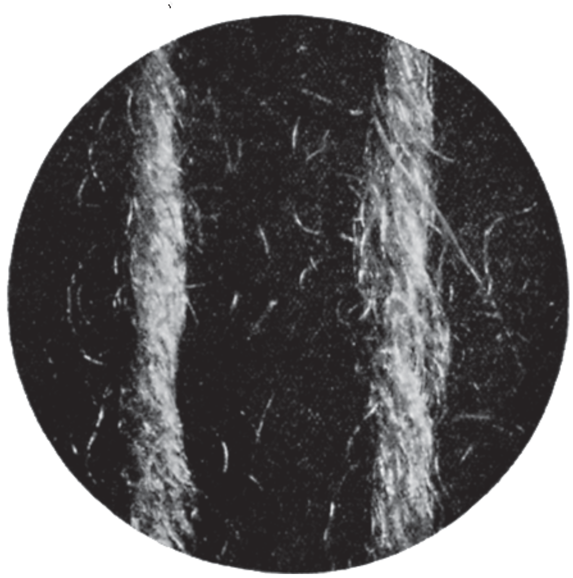

Fig. 38a.—18 skeins Woollen Yarn (Southdown Wool), 11·4 turns per inch.

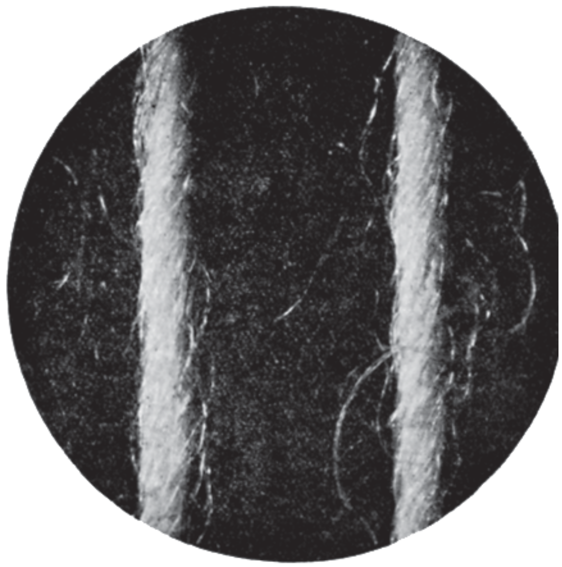

FIG. 39.—8's Worsted Yarn (Southdown Wool), 17·6 turns per inch.

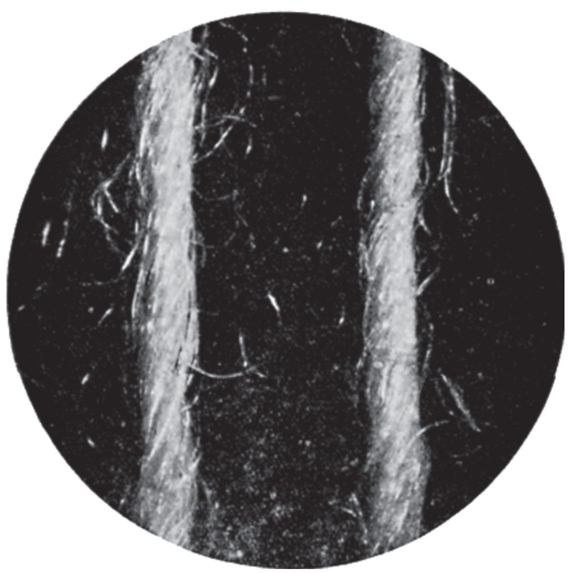

FIG. 39A.—8's Worsted Yarn (Southdown Wool), 12·9 turns per inch.

of milling. The firmer a thread, due to the degree of twist or twine, the less its felting property. Twine also apparently diminishes the diameter of the thread, as seen in Figs. 38 and 38A, both of which are yarns made of Southdown wool, from the same size of condensed sliver, and spun to 18 yards to the dram; so that any structural difference is a product of spinning alone. Twine, however, does not modify the average number of fibres in the yarn, nor yet the counts or the relation of the length to the weight, but it does affect (1) the actual diameter by compressing the fibres into closer contact with each other; (2) the solidity of the thread; and (3) its felting quality.

A number of experiments have been carried out in various fabric structures, materials and counts of yarn. These show the degree in which fabric contraction is controllable by the amount of twine in the yarn. One series in which Saxony, Cheviot and Pulled Waste were used may be analysed. The fabrics were made with a cotton warp, 2/20's, set $14\frac{1}{2}$'s reed 2's, and 36 inches in the reed. The counts of the weft yarn was 10 skeins, and the turns per inch, breaking strain and elasticity are stated below:—

TABLE VI.

BREAKING STRAIN AND ELASTICITY OF YARNS MADE OF TASMANIAN AND CHEVIOT WOOLS, AND PULLED WASTE.

Material.	Turns per inch.	Breaking Strain in Grammes.	Elasticity.
Tasmanian Wool .	11·33	1,105	3·76 ins.
" " . .	7·50	1,030	3·30 "
Cheviot " . .	9·00	924	3·00 "
" " . .	5·25	750	2·40 "
Pulled Waste . .	11·40	787	2·35 "
" " . .	6·20	607	1·65 "

Three weaves typical of fabric structure were used, and the relative shrinkages are given in the following table:—

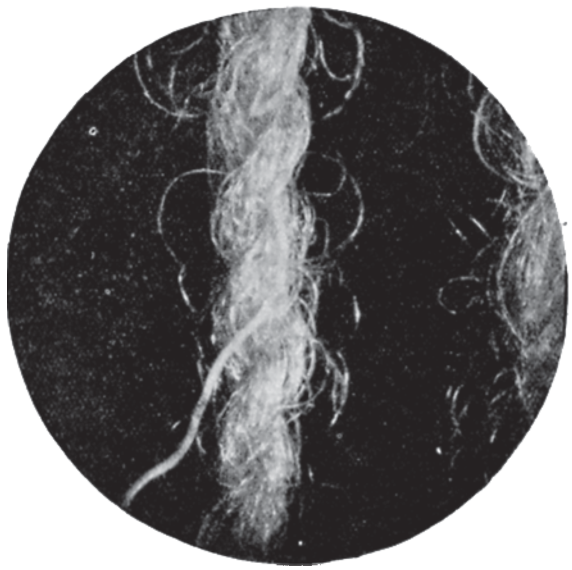

Fig. 40.—2/18 skeins Woollen Yarn (Southdown Wool), 9·7 turns per inch.

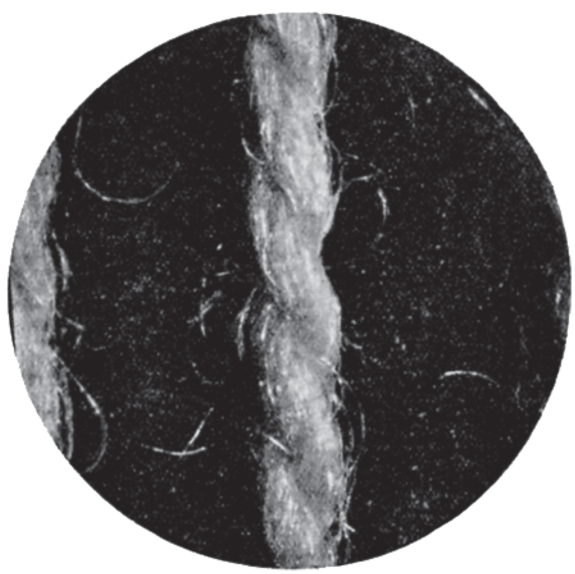

Fig. 41.—2/8's Worsted Yarn (Southdown Wool), 8·6 turns per inch.

TABLE VII.

CONTRACTIONS IN FABRICS MADE OF YARNS OF DIFFERENT DEGREES OF TWINE.

Weaves.	Tasmanian Wool.		Cheviot Wool.		Pulled Waste.	
	Twine.		Twine.		Twine.	
	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.
Plain . .	37·50	41·75	34·75	36·00	30·50	33·25
$\frac{2}{2}$ twill .	39·00	44·25	39·00	44·25	36·00	41·75
Swansdown .	41·50	47·25	41·50	44·25	37·50	40·25

Taking the Tasmanian, which is the highest felting material, the difference in contraction between hard and soft twine is 4·25 per cent. in the plain weave; 5·25 in the twill; and 5·75 in the swansdown.

The theory underlying these results is, that the felting quality of a yarn is affected by the degree of twine inserted. Worsted fabrics are subject to similar felting changes when made of yarns differing in this particular. The measure of contraction in these experiments is only slightly variable in the three materials, showing that with a corresponding unit of difference in twine, such as is necessary in the several qualities of fibres used, there is approximately the same ratio of difference in the felting of the fabrics.

The dissimilarity between the Cheviot and the Tasmanian is caused by the length and nature of the fibres in each yarn. As, however, the comparison is not between the felting of fabrics made of different materials, but between yarns varying in twine, this does not affect the results.

It should be noted that by prolonging the period of shrinkage, or the process of fulling, it is possible to gradually expand the felting power of hard-spun threads, but this does not destroy the hardness of handle which the cloth possesses. A fair degree of felting is produced in this way, but the textural quality is not satisfactory.

(47) *Folded Yarns and Shrinkage.*

Doubling or folding two or more yarns is another element which has an important bearing upon the fulling strength of the cloth. If doubling results in a firmer thread than the separate yarns used, the felting property of the fabric suffers. The process of folding may be done in three ways; (1) by twisting the several yarns in the same direction as the original twine, which produces a hard, unyielding yarn of reduced felting quality; (2) folding may eliminate a number of turns in the single yarn, giving as a result a yarn soft in structure; and (3) it may reduce the amount of twine in one or more threads and increase the same in others. Complex felting conditions are thus induced by folding or twisting several threads together. Certain of these factors may be auxiliary, and others deterrent in nature, during the felting of the cloth; but one law, operative in yarn structure, whether in single or compound threads, in relation to felting, is that the less the degree of twine the greater the degree of felting quality.

CHAPTER V.

THEORY OF FELTING: FABRIC STRUCTURE.

(48) Build of the Fabric. (49) Felting Quality of Standard Weaves. (50) Influence of Intersections. (51) Variation in Wefting. (52) Irregular Weaves and Felting. (53) Felting of two-ply Warp and Weft Fabrics. (54) Relative Shrinkage of Single and Backed Weaves.

(48) *Build of the Fabric.*

In addition to the measure of fabric contraction, in scouring and felting, being dependent upon the quality of the fibre and the structure of the yarn, it is also affected by the system of interlacing warp and weft in weaving; and it is the latter which has now to be considered.

Weave structure, as it influences fabric milling, forms a subject for experimental research. Experience in manufacturing has discovered and utilised the correct types of weaves for special milling work, *e.g.*, in beaver, melton, doeskin and other cloths; but fuller information is wanting on many aspects of the subject. For instance, it is well understood that one active controlling element in the process of fulling a woven fabric, is the frequency of the interlacings of the warp and weft. Moreover, it is also obvious that this is affected by such technical features as (1) the ratio of threads to picks, or relative compactness of warp and weft; (2) the relative diameters of the yarns; and (3) the fibrous materials of which the yarns are composed, and their several positions—face, centre or backing—in the woven structure; and also by the use of methods or practices in manufacturing differing from each other in nature and result.

In regard to fabric structure, it is as diversified as the possibilities of the process of weaving, and the range of materials and yarn construction.

Weaving possibilities afford unlimited structural diversity in (1) single cloths; (2) in fabrics multi-ply in the warp, weft or both; and (3) in special builds of fabrics. In each of these types of woven textures felting experiments have been carried out.

As to the range of materials and yarns, and their effects in the milling of the cloth, some data have been ascertained, as, for example, on the felting qualities of woollen and worsted yarns, and the effect of degrees of twine; but as the methods of mixing yarns in warp and weft, and of using them in weaves of different structure, are so diversified, they form another field for technical analysis and research.

(49) *Felting Quality of Standard Weaves.*

The effect of weave on the felting power of the fabric is distinct from the nature of the material or the yarn. This does not imply that a given structure of weave is not affected in felting degree by a change in quality of fibre, but rather that the contraction, in any material, is also determined by the method of intertexture. For example, comparisons in such standard weaves as the plain; angled prunelle; $\frac{2}{2}$ and $\frac{1}{3}$ twills; and broken swansdown, prove that the degree of shrinkage is governed (*a*) by the number, and (*b*) by the order of warp and weft intersections. Both the number of interlacings, and the system of grouping, operate on the contraction of the fabric. With the exception of the angled prunelle, the intersections are regular on each thread and pick of the weaves named. Assuming the setting in the warp to be the same for the five weaves, the unit of measurement would vary with the number of threads between the intersections. Thus, taking 30 threads per inch in the fabric from the loom, then the unit in the plain weave would be 1/30th; in the $\frac{2}{2}$ twill 1/15th; and in the $\frac{1}{3}$ twill two units, namely, 1/10th and 1/30th in succession. A fixed law in fabric structure is, the greater the unit the freer the process of fabric shrinkage. In Table VIII., the experimental

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TABLE VIII.

CONTRASTS OF MILLING PROPERTIES OF FABRICS MADE OF SAXONY AND CHEVIOT YARNS.

A. HARD SPUN YARN (OPENBAND).

Warp—2/20's cotton. Sett—15's reed 2's. 36 inches wide in loom.

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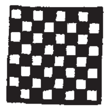
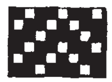
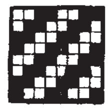
										
CLASS OF WOOL.	SAXONY.					CHEVIOT.				
Counts of Weft . .	10 skns.	10 skns.	10 skns	10 skns.	10 skns.	10 skns.	10 skns.	10 skns.	10 skns.	10 skns.
Turns per inch . .	$11\frac{1}{3}$	$11\frac{1}{3}$	$11\frac{1}{3}$	$11\frac{1}{3}$	$11\frac{1}{3}$	9	9	9	9	9
Picks per inch . .	24	28	33	33	33	24	28	33	33	33
Width in loom . .	36″	36″	36″	36″	36″	36″	36″	36″	36″	36″
Width out of loom .	33″	$32\frac{3}{4}$″	$31\frac{1}{2}$″	32″	32″	34″	34″	$33\frac{1}{2}$″	$33\frac{1}{2}$″	34″
Width after Scouring .	31″	31″	30″	30″	30″	33″	33″	$32\frac{1}{2}$″	33″	32″
Width after Milling, First Period . .	28″	26″	27″	27″	$26\frac{1}{2}$″	$31\frac{1}{2}$″	30″	30″	31″	29″
Do., Second Period .	$25\frac{1}{2}$″	$23\frac{1}{2}$″	24″	$23\frac{1}{2}$″	$23\frac{1}{2}$″	28″	25″	26″	26″	25″

B. SOFT SPUN YARN (OPENBAND).

Turns per inch . .	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{1}{4}$
Width out of loom .	32″	$32\frac{1}{2}$″	32″	32″	$32\frac{1}{4}$″	$34\frac{1}{2}$″	$34\frac{1}{4}$″	$33\frac{1}{2}$″	$33\frac{1}{2}$″	34″
Width after Scouring .	31″	31″	30″	30″	30″	34″	33″	33″	33″	33″
Width after Milling, First Period . .	$27\frac{1}{2}$″	26″	$25\frac{1}{2}$″	26″	25″	32″	$29\frac{1}{2}$″	$29\frac{1}{2}$″	$29\frac{1}{2}$″	$29\frac{1}{2}$″
Do., Second Period .	$24\frac{1}{2}$″	$22\frac{1}{2}$″	23″	22″	$21\frac{1}{2}$″	28″	$24\frac{1}{2}$″	25″	25″	$24\frac{1}{2}$″

results are given, in the several weaves produced in Saxony and Cheviot yarns, in two degrees of twine. They illustrate the effect of weave on shrinkage in these materials and yarn structures.

Abstracting the shrinkages on the five weaves, and converting them into percentages based on the reed or loom width, they are as follows:—

Weave.	Percentage of Shrinkage in Saxony Yarns.	Percentage of Shrinkage in Cheviot Yarns.
Plain . . .	29·00	22·25
Angled Prunelle .	34·75	30·50
$\frac{2}{2}$ twill . .	33·35	27·25
$\frac{1}{3}$ twill . .	34·75	27·25
Swansdown . .	34·75	30·50

(50) *Influence of Intersections.*

A primary cause of these differences in shrinkage is, as stated, the build of the fabric. A change in the grouping of the intersections effects a change in the amount of contraction. But this only partially explains the felting, for whereas in Table I., the angled prunelle has a slightly less shrinkage than the $\frac{2}{2}$ twill fabric, in Table VIII., where the setting, counts of yarn, and picks per inch are different, the felting results in these two weaves are changed. The ratio of picks has some influence. In this series of experiments there are 24 picks per inch in the plain weave, 28 in the angled prunelle and 33 picks per inch in the other weaves.

It has been shown that the number of intersections and the system of planning are both factors which determine the amount of shrinkage. The number is obtained thus: Intersections per inch multiplied by reed width in inches, multiplied by picks per inch: giving in the setting named in Table VIII., 25,920 intersections in the plain weave; 20,160 in the angled prunelle; and 17,820 in the $\frac{2}{2}$ and $\frac{1}{3}$ twills in one inch of fabric, 36 inches wide. Thus, there are approximately 45 per cent. more intersections in the plain than in the twill, and 28 per cent. more than in the angled prunelle. How these modify the felting of the fabric is instanced in the Shrinkage Table VIII. The plain weave has minus 5·75 per cent. of felting power as compared with the angled prunelle, and minus 4·35 per cent. as compared with the $\frac{2}{2}$ twill, though the latter has less intersections than the angled prunelle. The similarity of the shrinkage quality of these two weaves is due to the method of grouping the intersections. In addition, the warp is cotton, so that the shrinkage is only on the weft. If the warp had been woollen, then the felting power would have been more in favour of the $\frac{2}{2}$ twill. The point is, that while it follows in regular weaves, that the ratio of shrinkage corresponds with the ratio of intersections, yet in this example, it is clear that the system of arrangement is also a neutralising quantity. Each third pick in the angled prunelle twill draws the warp threads together in sets of three, acting in a like manner to a weave of the weft cord type; and any such condition assists and accelerates felting. There are no corresponding relations of warp and weft in the $\frac{2}{2}$ twill, the threads being crossed in pairs, and the movement progressive and not constant or in the same line.

Another example of a different character, of the influence of the order of grouping the intersections, is that of the $\frac{2}{2}$ twill and broken $\frac{1}{3}$ twill. The intersections are now identical in number, yet the shrinkages are excessive in the latter.

TABLE IX.

SHRINKAGE IN $\frac{2}{2}$ TWILL AND $\frac{1}{3}$ BROKEN-TWILL FABRICS.

	$\frac{2}{2}$ twill.	Broken $\frac{1}{3}$ twill.
Saxony: hard spun	33·25	34·75
Cheviot: „ „	27·75	30·50
Saxony: soft spun	36·00	39·00
Cheviot: „ „	30·50	31·75

The explanation here is that in the twill the movement, as stated, is progressive, pick 1 linking threads 1 and 2; pick 2, threads 2 and 3; whereas in the swansdown, picks 1 and 4 link threads 1 and 3, and picks 2 and 3 link threads 2 and 4.

Three of the principal elements in weave affecting felting are presented in these comparisons: (1) That when the intersections are in regular order, the less the number, the greater the felting property—all other conditions being the same—of the fabric; (2) it is possible to divert this law and reverse the result by the method of arranging the intersections; (3) in weaves of identical intersections the felting results vary according to the manner in which the same threads are grouped by successive picks.

(51) *Variation in Wefting.*

To illustrate in what way, and to what degree, the contraction in scouring and milling is affected by the density of the fabric, or, in this instance, by the variation in the number of the picks per inch, Table X. is given. It is based upon experiments in the plain weave, $\frac{2}{2}$ mat, and $\frac{4}{4}$ mat, each woven with 10 skeins weft, the warp being 2/20's cotton, 30 ends per inch.

Taking, for example, the plain weave, $\frac{2}{2}$ mat and $\frac{4}{4}$ mat, the percentages of shrinkage calculated from the reed width are as follows:—

TABLE X.

SHRINKAGE IN FABRICS MADE IN PLAIN WEAVE, $\frac{2}{2}$ AND $\frac{4}{4}$ MATS.

Picks per inch.	Percentage of Shrinkage from Reed Width to Milling 90 Mins.		
	Plain Weave.	$\frac{2}{2}$ Mat.	$\frac{4}{4}$ Mat.
18	55·4	—	—
24	47·3	55·4	—
32	39·2	50·0	56·7
42	30·0	43·2	55·4
58	—	—	52·7

It will be noticed that the percentages vary from 47·3 in the plain weave (24 picks per inch) to 50 in the $_{2}{-}^{2}$ mat (32 picks), and 55·4 in the $_{4}{-}^{4}$ mat (42 picks). The percentages in the plain decrease with each number of picks per inch from 8 to 9; in the $_{2}{-}^{2}$ mat from 5 to 7; and in the $_{4}{-}^{4}$ mat from 1 to 3.

(52) *Irregular Weaves and Felting.*

Research in several varieties of textile structures—both yarns and fabrics—has been carried out to determine the effect of weave on the felting quality of the cloth. In one series, two warps (2/16 skeins woollen and 2/7's worsted) were crossed with 12 skeins woollen and 5½'s worsted, forming separate pieces. As far as practicable, in spinning on the two systems, the yarns were made to the same counts and with similar turns per inch, as indicated below:—

TABLE XI.

WARP YARNS.

Woollen.			Worsted.		
Counts.	Turns per inch.	Yds. per lb.	Counts.	Turns per inch.	Yds. per lb.
2/16 skns.	5·1	2,048	2/7 's.	5·8	1,960

WEFT YARNS.

	Woollen.			Worsted.		
	Counts.	Turns per inch.	Yds. per lb.	Counts.	Turns per inch.	Yds. per lb.
A. Soft spun .	12 skns.	6·3	3,072	5½ 's.	6·1	3,080
B. Hard spun .	12 skns.	10·6	3,072	5½ 's.	10·6	3,080

Both warps were set 24 ends per inch in the reed and the following weaves were used:—

No. 1. $\frac{2}{2}$ twill.
,, 2. $\frac{2}{2}$ twill cutting two's.
,, 3. $\frac{3}{2}$ twill.

In this manner four fabric structures were obtained, woven respectively in (*a*) woollen warp and weft; (*b*) woollen warp and worsted weft; (*c*) worsted warp and weft; and (*d*) worsted warp and woollen weft. According to the theory deduced, *viz.*, that weave is an initial controlling factor in the milling process, the maximum shrinkage should be in Weave 3, and the minimum in Weave 2. This was actually so in each series of textures. There was, necessarily, an appreciable difference in the degree of felting in fabrics woven with hard and soft spun wefts, but the ratio of shrinkage was invariably highest in Weave 3 and lowest in Weave 2. Table XII. gives the results in the woollen weft fabrics.

TABLE XII.

SHRINKAGE RESULTS ON FABRICS WOVEN WITH HARD AND SOFT SPUN YARNS.

Plan No.	Picks per inch.	Wefts.	Percentage of Shrinkage.	
			Woollen Warp.	Worsted Warp.
1	26	12 skns.[1]	35·50	32·25
2	27	,,	32·25	30·50
3	33	,,	38·50	37·00
1	26	12 skns.[2]	32·25	30·50
2	27	,,	29·00	29·00
3	33	,,	35·50	35·50

[1] *Soft spun yarn.* [2] *Hard spun yarn.*

The weaves so far examined are elementary in structure. In a second series of experiments, weaves of a more irregular type were applied, namely, those in Fig. 42. As in the preceding examples, two warps and wefts—woollen and worsted—were used, namely:—

TABLE XIII.

	Counts.	Turns per inch.	Sett.
Warp I. .	2/20 skns. woollen	9·7	36 ends per in.
„ II. .	2/8's. worsted	8·6	„
Weft I. .	12 skns. woollen	13·8	
„ II. .	8's. worsted	12·2	

In Table XIV. the percentages of shrinkage in the several weaves and yarns are stated.

TABLE XIV.

PERCENTAGE OF SHRINKAGE OF FABRICS IN SEVERAL WEAVES.

Plans.	Wefts.	Picks.	Percentage of Shrinkage. Period 90 Minutes.	
			Warp I.	Warp II.
Fig. 42				
A	12 skns.	32	32·25	32·25
B	„	32	22·50	22·50
C	„	28	22·50	22·50
D	„	34	33·75	32·25
E	„	26	22·50	22·50
A	8 's.	32	32·25	29·00
B	„	32	22·50	19·25
C	„	30	22·50	22·50
D	„	36	33·50	32·25
E	„	29	22·50	19·25

Comparing, in the first place, the shrinkage in Plans A and B, that of the former in both woollen and worsted wefts exceeds that of the latter by 10 per cent. The picks per inch being the same in the two weaves, there is no textural condition accounting for this difference in shrinkage but that of weave structure. Examining the intersections, there are eight on each pick in twenty threads in Plan A, and in Plan B, ten on certain picks and eight on others, in twenty threads. The intersections are, therefore, not sufficient to cause this comparatively high shrinkage property of the fabric due to Weave A. The reversing or angling of Weave B is a feature which has diminished the shrinkage quality of the cloth. The movement to the right and to the left alternately of the twilled mat, on such a limited number of threads, lessens the felting character of the fabric.

The effect of this influence of weave structure on felting is further exemplified by Plan C. Here, there are the same intersections as in Plan A, but there is again a difference of approximately 10 per cent. in felting between the fabrics resulting from Weaves A and C respectively: from which it is apparent that in addition to the intersections, a further element in weave structure is determining the felting property of the cloth. Weave C is reversed in both warp and weft, forming a cut

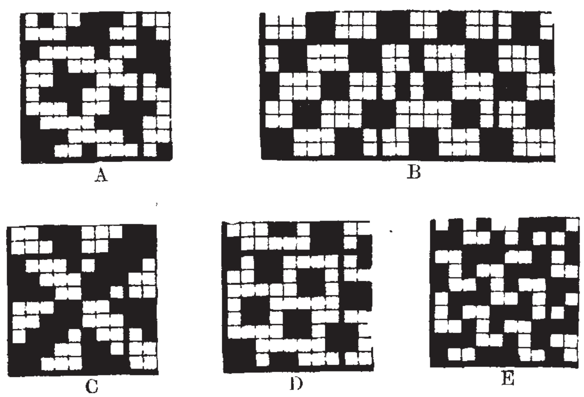


Fig. 42.

check, and this interchanging or reversing has so far reduced the shrinkage quality of the fabric, that with the intersections the same as in Weave A the felting is diminished, as stated in Table XIV. by 10 per cent.; or it is the same, practically, in Warp I as Weave E, which possesses one-third more intersections, but these arranged in regular twill order.

The highest shrinkage, it will be observed, is in Weave D, though the intersections are similar to those of Weave A. They are as follows in the two weaves :—

Weave A.	3 weft,	4 warp,	1 weft,	2 warp.
Weave D.	2 weft,	1 warp,	2 weft,	5 warp.

There are, thus, four types of intersections in A, and three types in D, with the maximum intersections in A, comprising four threads, and in D, five threads. It is these differences in the order and kind of intersections which produce in these weaves, cloths of different milling quality.

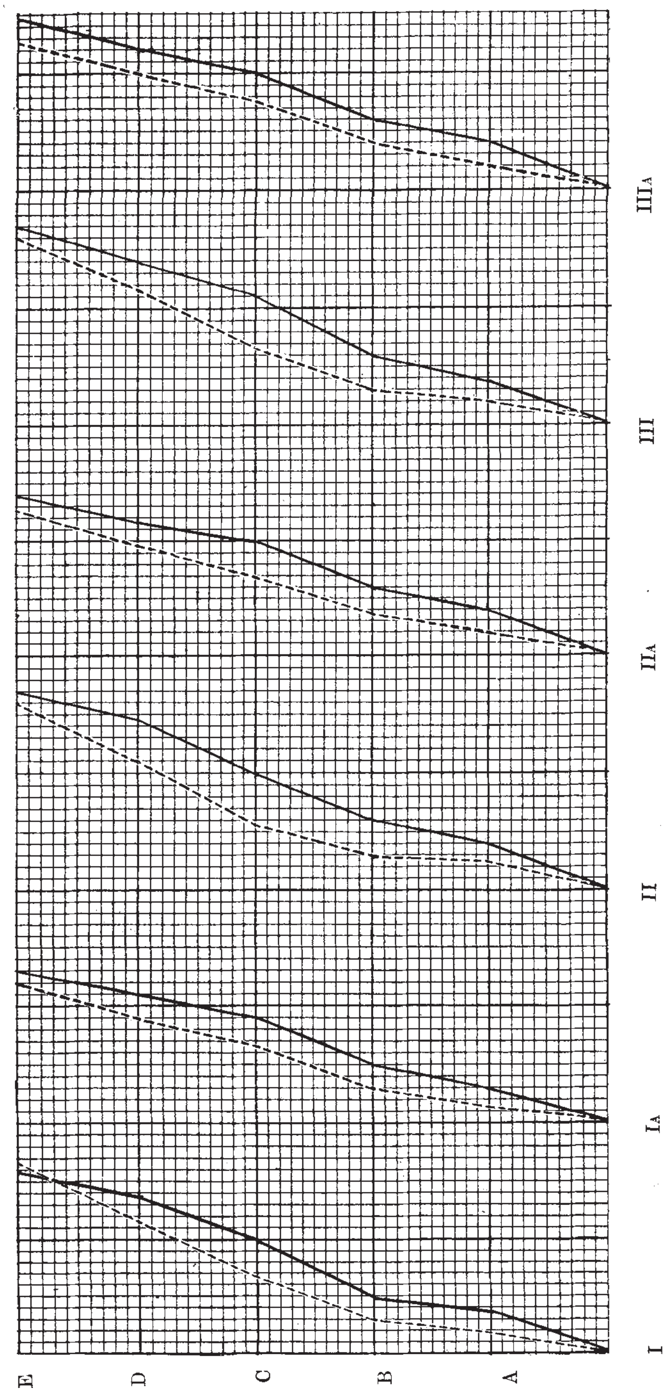
(53) *Felting of Two-ply Warp and Two-ply Weft Fabrics.*

Several of the principles of intertexture affecting the shrinkage of fabrics single in structure, are common to fabrics two-ply in either warp or weft. The supplementary set of yarns is, however, a complicating factor. It follows, the more intricate the fabric structure, the more numerous the technicalities controlling the felting process.

Backed cloths are intermediate between single and double cloths. In regard to felting, they offer a structure more difficult of analysis than the former, and less difficult than multiply fabrics. In one direction of the texture, there are two series of yarns lying one over the other, bound together by a third series, appearing alternately on the under and upper surface. Of these two series, one is limited to each side of the fabric. The scheme of weaving may be the same or dissimilar in the respective yarns. In the case of the weaves being the same, the shrinkage quantity is affected by similar principles to those applicable to single weaves, with one additional influencing factor, namely, the binding or stitching of the face and backing yarns into the same fabric. Should, however, the backing weave be of a different structure to the face weave, it may increase the felting quality of the fabric. If, for example, the ${}_{2}{-}^{3}$ twill should be backed with a 10-end sateen—a comparatively loose but regular back—the sateen would increase the shrinkage quality of the cloth. In fabrics in which the face weave is regular, and the backing weave irregular, or both irregular in structure, the possible contraction can only be fixed by experiment.

(54) *Relative Shrinkage of Single and Backed Weaves.*

For a comparison of this nature, backed textures with the same weave on both surfaces are the most suitable. In such cloths, the underside is a duplication of the face with certain changes in setting. In Fig. 43 the shrinkage curves are



.... Cheviot. ——— Saxony.

Fig. 43.—Comparison in Shrinkage Curves, Single and Backed Weaves.

A = Line of contraction from loom.
B = ,, ,, ,, after scouring.
C = ,, ,, ,, ,, milling 30 minutes.
D = ,, ,, ,, ,, ,, 60 ,,
E = ,, ,, ,, ,, ,, 90 ,,

I = Prunelle twill.
IA = Backed prunelle.
II = $\frac{1}{3}$ twill.
IIA = ,, backed.
III = Broken $\frac{1}{3}$ twill.
IIIA = ,, ,, backed.

drawn of the prunelle, $\frac{}{3}\!\!\frac{1}{}$ twill, and broken swansdown, in both single and backed fabrics. The contraction on lines A, B and C corresponds in the types of texture in each of the weaves; showing that in these examples, the difference between single and backed cloths does not result in any disparity in shrinkage, in the processes of scouring and preliminary milling; but in the periods of felting indicated on lines D, E and F the behaviour of each kind of structure is distinct.

The following are the units of shrinkage as represented by the diagram (Fig. 43):—

TABLE XV.

COMPARATIVE SHRINKAGES OF SINGLE AND WEFT-BACKED FABRICS IN SAXONY (S.) AND CHEVIOT (C.) YARNS.

Periods of Contraction.	Units of Shrinkage in Inches:											
	Prunelle.				Swansdown.				Broken Swansdown.			
	Single.		Backed.		Single.		Backed.		Single.		Backed.	
	C.	S.	C.	S.	C.	S.	C.	S.	C.	S.	C.	S.
A	2	3½	1¼	3	2¼	4	2	4	2	3¾	2	4
B	3	5	3	5	3	6	3½	6	3	6	4	6
C	6½	10	6½	9	5½	10	7	10	6½	11	7½	10
D	11	13½	9	11	11	14½	9½	11½	11½	14	10	12
E	16½	16	12	13	16	17	12½	14	16	17	12½	14

In each of these standard examples there is an excessive shrinkage in favour of the single weaves of from 3 to 4 units. The two structural elements at the base of this are (1) the simpler grouping of the intersections in the single weaves; and (2) the binding of the two weft surfaces together, strictly two textures, in the backed weaves: which, whilst not adding to the number of intersections on the picks, inserts a textural condition which detracts from the felting quality of the cloth. The results in Table XV. show that the ratio of shrinkage between the two types of weave is the same in both Cheviot and Saxony yarns, and also that in cloths of the weft reversible character, the difference in the degree of felting is approximately the same though the weave structure may be varied. Thus (Period E), in the prunelle (Saxony yarns), in the single weave, there are sixteen units of shrinkage, and thirteen units when backed; in the broken swansdown (Saxony yarns) single weave, seventeen units, and fourteen in the backed weave; that is to say, a difference of one unit of shrinkage between the two types of weave, but in both a difference of three units of shrinkage between single and backed.

A deduction which follows is, that the changing of a single weave into a reversible—1 face, 1 backing—diminishes the felting property of the cloth. This takes place even if the number of picks per inch in either of the two surfaces of the backed fabric, is less than in the single structure. The picks per inch were in the single swansdown 33, and in the backed weave 58, with the same yarns and setting. Removing one of the wefts—face or backing—would leave a single texture with 29 picks per inch, and of similar felting quality to the single swansdown cloth, but the binding of the two layers of yarn together in the backed weave reduces the felting result.

CHAPTER VI.

THEORY OF FELTING: COMPOUND FABRICS.

(55) Structure of Backed Fabrics and the Felting Quality of the Cloth. (56) Three-ply weft Fabrics. (57) Yarn Characteristics in Compound Weft Fabrics. (58) Fabrics Compound in the Warp. (59) Felting of Compound Weaves. (60) Double Cloths and Varied Felting. (61) Stitching or Tying of Double and Compound Weaves and the effects on Milling.

(55) *Structure of Backed Fabrics and the Felting Quality of the Cloth.*

THE method of constructing backed and compound weaves, as to the order of the face and backing yarns, may have an appreci-

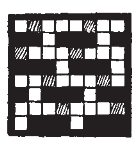


FIG. 44.

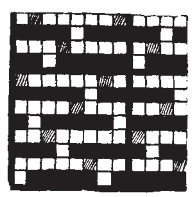


FIG. 45.

able effect on the felting of the fabric. This is the case if the order of face and backing yarns alters the number of intersections in the backed weave. When, for example, the swansdown and eight-shaft sateen are arranged 1 pick face and 1 pick backing or 2 picks face and 2 picks backing, the order of wefting does not, in certain counts of warp and weft yarns, setting, and picks per inch, modify the felted result.

The same features affecting felting in single weaves apply, with some variation, to weaves of the backed type. The interlacings of the warp and weft are a controlling element. For instance, in the backed swansdown (Fig. 44) and the backed six-end sateen (Fig. 45), there is a difference of two intersections in ten threads, yet in the same fabric setting (reed, picks per inch and yarns) the milling in the latter (woollen yarn) was 35·6 per cent, and in the Crossbred worsted yarn 31·5; whereas in the former (woollen yarn) it was 28·7 and in the Crossbred worsted 23·2 per cent.

The weave applied to the back also varies the felting quality of the face cloth. As suggested, the looser and more open the backing weave the greater the measure of contraction in a definite period of milling. The four-shaft twill, backed with a three-and-one weave, gives a fabric of different felting property to the same weave backed with an eight-end sateen. The following are shrinkage results in the two weaves, the counts of warp and weft yarns and setting being alike, with an increase of eight picks per inch in the twill backed with sateen.

TABLE XVI.

Weft.	$\frac{2}{2}$ Twill. Backed with $\frac{1}{3}$ Twill.	$\frac{2}{2}$ Twill. Backed with 8-end Sateen.
Cheviot yarn .	35·0 per cent.	40 per cent.
Saxony ,, .	38·8 ,, ,,	43 ,, ,,

The sateen-backed weave has here an increase shrinkage value of 5 per cent. in both kinds of yarn.

(56) *Three-ply Weft Fabrics.*

In three-ply weft fabrics, several conditions obtain distinct from ordinary backed fabrics. Weaves differing in fineness and fastness may be used for the three textures. The face cloth may be fast, the centre medium, and the back loose woven; or the face medium, and the centre fast woven.

Figs. 46 to 50 are examples in three-ply weft weaves, and Figs. 46A, 48A and 50A, sections showing the interlacings of warp and weft yarns in such fabrics.

An eight-end twill forms the face, and a two-and-two twill the centre in Fig. 46; and an eight-end sateen and back, with two-and-two twill centre, the face and back in Fig. 47. Figs. 48 and 49 are similar to Figs. 46 and 47 with the centre weave plain. Fig. 50 has a four-and-four twill centre.

Theoretically, the weave Fig. 50 should have the highest, and the weave Fig. 48 the lowest shrinkage property. Milling experiments gave 51·4 per cent. shrinkage in Fig. 46; 52·72 in Fig. 47; and 41·66 in Fig. 48, on a period of ninety minutes.

The effect of the weave structure will be better understood from the sectional drawings. The relation of the picks to the threads in Figs. 46A and 48A, produces fabrics distinct in structure. The face and backing weaves are the same, but the plain weave in the centre of Fig. 48A, makes a faster build of fabric than the two-and-two twill in Fig. 46A. On the other hand, the $\frac{4}{4}$ twill centre in Fig. 50A gives a looser or more open fabric structure. The relative firmness of texture, due to the frequency of the warp and weft interlacings, is plainly seen in Figs. 46A, 48A and 50A.

Milling quality in three-ply weft cloths is determined by the structure of each of the three weaves; that is to say, the face and backing weaves in the two cloths may be the same, but if in one the centre be plain and in the other twill, the latter being the looser structure has the greater felting quality.

(57) *Yarn Characteristics in Compound Weft Fabrics.*

The diversity of felting produced by the different types of weave indicated, is of practical utility in the manufacture of certain varieties of fabrics. This is rendered more valuable by the application to each weave, in two or three-ply cloths, of yarns of dissimilar felting qualities. Worsted yarn may be used for the face and woollen for the backing fabric; or fine woollen twist yarn for face and soft spun woollen yarn for back. There are also makes of backed cloths in which the same yarn is used for both sides, but if different, as indicated, the higher quality of yarn will, more or less, according to the structure of the weave, control the felting.

Take, for example, a worsted face and woollen back fabric. The woollen being usually softer spun than the worsted

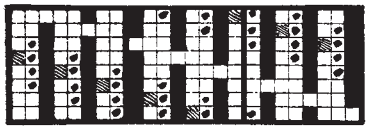


Fig. 50.

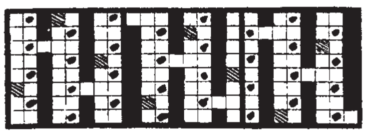


Fig. 49.

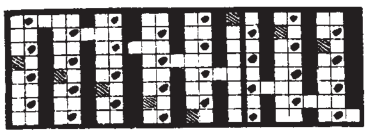


Fig. 48.

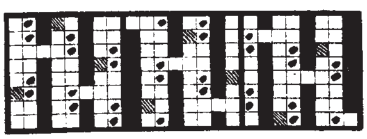


Fig. 47.

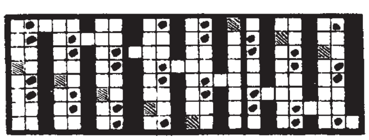


Fig. 46.

Fig. 46a.

Fig. 48a.

Fig. 50a.

Figs. 46 to 50.—Three-ply Weft Weaves.
Figs. 46a, 48a, 50a.—Sections of Three-ply Weft Fabrics.

should increase the shrinkage of the face cloth made of the worsted yarn. On the other hand, if worsted were used for the face and a coarse quality of shoddy for the back, the shrinkage on the worsted would scarcely be affected by the backing yarn. But in cotton warp and worsted weft-face unions, with a medium quality of mungo for back, the looser interlacing of the backing weave should add to the degree of felting due to the worsted face yarn.

Fig. 33, referred to in Paragraph 41, is a fabric consisting of the three-ply weave (Fig. 51) which has an eight-end sateen face, a plain weave centre and a sixteen-end sateen back; three weaves of distinct shrinkage values. By using a worsted or lustre yarn for face, cotton for the centre and fine woollen for the back, the weave structures and qualities of the yarns increase the disparity of felting between the face and backing textures. In the milling process, the Saxony yarn—loose weave structure—rapidly forms a clothy felted surface, but the faster weave on the face and a material of less felting property, cause the lustre yarn to loop or buckle. The greater the difference in the weave structures and also in the quality of the materials for face and backing. the more definite the curly characteristic. If, on the other hand, the face yarn were Cheviot, and the backing fine wool, there would possibly be no greater difference between the two weaves, or the Cheviot and Saxony textures, due to felting, than that the former would have the characteristics of a milled serge and the latter of an ordinary Saxony.

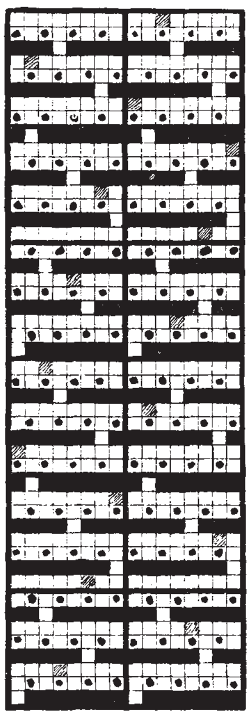


Fig. 51.

Another application of this type of weave in relation to milling is in heavy cloths for overcoatings and mantles, with a serge yarn for the face, and a yarn of finer material but not pure wool, for the back. The distinct felting property of the materials is to give character to the compound fabric, namely, the bright yarn a clear serge effect, and the mungo yarn a surface which may be raised and covered with fibre after milling.

(58) *Fabrics Compound in the Warp.*

Fabrics, compound in the warp, correspond in structure to fabrics compound in the weft, threads of warp taking the place of picks of weft, and the cloths being two or more fold in the warp and single in the weft. Warp-backed cloths, in which a wadding weft is used, afford additional points for consideration in felting, because the wadding may be woollen and soft spun, for imparting thickness and milling property to the cloth; or, it may be a thick cotton yarn, in which instance it would reduce the milling property due to the woollen or worsted yarns making the face and backing fabrics. But the ordinary types of these cloths are single in the weft and unwadded, hence if the structure and order of the yarns are the same as in the weft-backed cloths described, the milling results should be similar, but changing the shrinkage from weft to warp of the piece. For example, in weft-backed fabrics, with a *cotton warp*, the shrinkage in length is almost *nil*; whereas in warp-backed fabrics, with a *cotton weft*, the shrinkage would be chiefly in the length, and only to a small degree in width.

Three of the principal types of warp-backed fabrics in relation to milling are:—

I. Reversibles, fabrics with the same weave for face and back; *e.g.* (*a*) face and backing warps worsted, and woollen weft; (*b*) face and backing warps and weft woollen (Fig. 52).

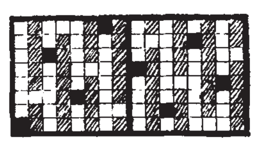


Fig. 52.

II. Fabrics with faster weaves for the face than the back; *e.g.*, two-and-two twill face and sateen weave for back, and made in similar or different qualities and counts of yarn for warp and weft (Fig. 53).

III. Fabrics threefold in the warp and single in the weft;

e.g., sateen face and back, and a finer weave, such as two-and-two twill for centre (Fig. 54).

I. In warp-backed fabrics, in which worsted warp and woollen weft are used, shrinkage may be in both length and width, but if the smartness and character of the worsted face are to be distinctive of the finished cloth, then the felting should be more in the direction of the weft than the warp. When woollen warp and weft are used for a face-finished cloth, the felting may be equally on the length and width, though both sides of the fabric (Fig. 52) consist of warp yarn, and the weft passes between the face and backing threads.

II. In the second class (Fig. 53), with finer weaves on the face than on the back, should the felting be chiefly on the warp, the backing weave would be an influencing factor. For

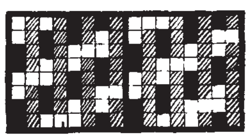


Fig. 53.

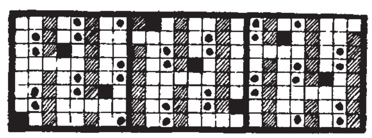


Fig. 54.

instance, a $\frac{2}{2}$ twill fabric, single weave, would shrink in the same period, less in length than the backed weave, the comparative looseness of the backing weave, and also the quality of the backing yarn, making the difference in the felting of single and compound fabrics.

III. Three-ply warp cloths may be arranged in a similar way to three-ply weft fabrics as to weaves for face, centre and back. Taking the example (Fig. 54), the milling on the length of the piece would be similar to that of a single cloth, but for the stitching of the three layers of warp together, and the centre weave; the centre weave being $\frac{2}{2}$ twill would be a deterrent, in the process of shrinkage, on the sateen face and backing textures. As in three-ply weft fabrics, by altering the face to a finer weave: the shrinkage on the length would be further reduced. The weft shrinkage in such fabrics is chiefly affected by (1) the relation of the weft to the face, backing and centre warps;

(2) the quality of the material used in each, warp,—woollen, worsted or cotton; and (3) the character of the centre weave.

(59) *Felting of Compound Weaves.*

Double and single cloths do not shrink alike in milling. They are distinct from each other in construction, and are also distinct in felting qualities. A double fabric, as the term indicates, is one consisting of two textures of the same or dissimilar yarns and structure. These are bound together by the threads and picks of one fabric, at regular intervals in weaving, interlacing with those of the other fabric. As to which cloth felts the better, under corresponding conditions, namely, a single or a double texture of precisely double the threads and picks per inch and of similar yarns, is influenced (1) by the method of stitching; (2) the arrangement of the weaves—face and backing—to each other; and (3) the measure of felting property developed in a cloth of double the density of threads to a single texture, but in all other data the same. These points can only be satisfactorily explained by the analysis of definite examples.

(60) *Types of Double Cloths and Varied Felting.*

The principal types of double cloths in which the degree of shrinkage is varied by the method of construction are as follows:—

I. Reversible cloths, with the same weave and counts of yarn and setting on both sides.

II. Cloths arranged one face, one backing, in both warp and weft, with different weaves, counts and quality of yarns for face and backing.

III. Cloths arranged two face, one backing, in both warp and weft, with the same weave on both sides, but of different counts of yarn.

IV. Cloths arranged two face, one backing, in both warp and weft, of distinct weaves, counts and qualities of yarns on each side.

I. *Reversible Double Cloths.*—These have the same weave, counts and qualities of yarn on both sides, so that the chief modifying element in felting is the method of stitching the two fabrics together. There are two layers of warp and weft exactly alike, each forming a separate fabric, and these, in weaving, are stitched or bound into one. There is, first, the felting of the warp and weft in each fabric, and second, of one fabric to the other. The process is compound. In reversibles,—the face and back exactly the same,—felting is regular or uniform in each texture: and not as in some double-make fabrics, where the backing texture may have a higher shrinkage property than the face, and *vice versa*.

Types II. and III., Double Cloths with Face and Back dissimilar.—These, as defined, are of two principal types, *viz.*: (1) Fabrics arranged one face and one backing in both warp and weft, with counts and qualities of the yarns different; and (2) fabrics arranged two face and one back, and irregularly, with the same or different counts of yarns and weaves for each side.

The first of these, constructed one face and one backing in both warp and weft, are made (*a*) with worsted yarn for face and woollen yarn for back; (*b*) solid worsted; and (*c*) face warp and weft worsted, backing warp cotton, and backing weft woollen; and also in other classes of yarns.

Each quality of yarn in a two-ply fabric exercises a specific effect in milling, but there is one rule applicable to the principal classes of these fabrics, namely, the yarn of the highest shrinkage property, as in other compound cloths, controls the degree of felting. Assuming, for example, the face warp and weft to be worsted and the backing woollen, should the latter yarn be of a fine quality of wool, it will increase the degree of shrinkage, in a given period, of the worsted fabric: this is done for a distinct purpose in manufacturing, as, for instance, in the construction of a fine cloth, the face being made of worsted yarns, and possessing, on the underside, the qualities of a milled woollen.

In producing suiting, coating and mantle cloths of this order, special regard has to be had to the setting. The worsted face fabric should be set a degree looser than if a woollen back were not to be applied. This allows of the shrinkage necessary without detriment to the smart clear finish of the worsted. Should the cloth be woollen, and twist warp for the face, and single yarn for the back, similar relative results might be obtained in felting.

Type IV., arranged two face and one back, or irregularly in both warp and weft.—The following are some of the principal of these fabrics: (*a*) worsted warp and weft for face, and woollen warp and weft for back; (*b*) worsted face warp, woollen face weft and woollen back; (*c*) worsted face warp and weft, cotton backing warp and woollen weft; and (*d*) single woollen yarn for face and twofold woollen yarn for back.

(*a*) *Worsted face and Woollen back.*—As the backing yarn is made on the carded principle, and is also softer in twine and thicker than the face, if the weaves should be the same for both face and backing cloths, felting would be improved. If a twill formed the face and a sateen weave the back, giving a faster structure on one side than on the other, the shrinkage of the cloth would be determined chiefly by the woollen yarns, which would also be the case in fabrics arranged three face and one backing, and irregularly such as two face, one back, one face, one back.

(*b*) *Worsted face warp, Woollen face weft, and Woollen backing.*—This is a standard method of making milled Vicuna cloths with a soft quality of finish. Three parts of the fabric being woollen, the shrinkage is chiefly affected by this yarn: but the face and the backing weaves have to be taken into account. Assuming an example, twill face and plain back, the face texture with worsted warp crossed with woollen weft would have approximately—if the quality of the material were the same—similar shrinkage property to the backing cloth made entirely of woollen. The relative results are determined by the setting of the face and backing yarns. It would follow that if the backing yarn were making a loose texture, and the face yarn a fast texture, the backing would have a tendency to give uneven shrinkage.

(*c*) *Worsted face warp and weft, Cotton backing warp, and Woollen weft.*—Here, as in other examples, the action of felting is determined by the quality of the wool used for the worsted and woollen yarns. On the other hand, the cotton warp detracts from the felting quality of the fabric, being bound to the worsted texture, and stitching, regularly, under the woollen weft. This diminishes the shrinkage, first, of the worsted in length, and second, of the woollen weft, so that the cotton warp operates in the milling process to the reduction of the degree of felting in both length and width of the fabric.

(*d*) *Single woollen yarn for face and Twofold woollen yarn for back.*—In the manufacture of golf cloakings, it is a practice to have a finer yarn for the back or lining than for the face, arranging the fabric one thread face to two threads backing or lining. If the weaves should be the same for both face and backing fabrics, the yarn for the former must be about double the thickness of that used for the latter. As such cloths are well milled—the specimen (Fig. 55) has been set 78 inches in the reed for 56 inches finished—they should be constructed of yarns, for each surface, of similar felting property. One method of doing this is to use a twist yarn for the back consisting of two threads of the single yarn forming the face. In this example, there is no special effect developed in milling due to the fabric structure; but in the selection of the yarns for the face and lining, if the folded yarn should be hard in twine, or not of the same material as the single yarn, irregular shrinkage of the two sides would result.

The points are (1) that when using yarns of different counts for each side of the fabric, to obtain evenness in milling, each counts or thickness of yarn must be of corresponding felting property; (2) that if one yarn is single and the other folded or twisted, it is desirable that the latter should consist of two or more threads of the single yarn, and the degree of twist must not produce a folded thread of such hardness as to reduce milling quality; (3) that in fabrics in which there is a necessary difference in the counts and quality of the yarn for face and lining, only moderate milling should be practised, and this regulated according to the difference in the character of the yarns used.

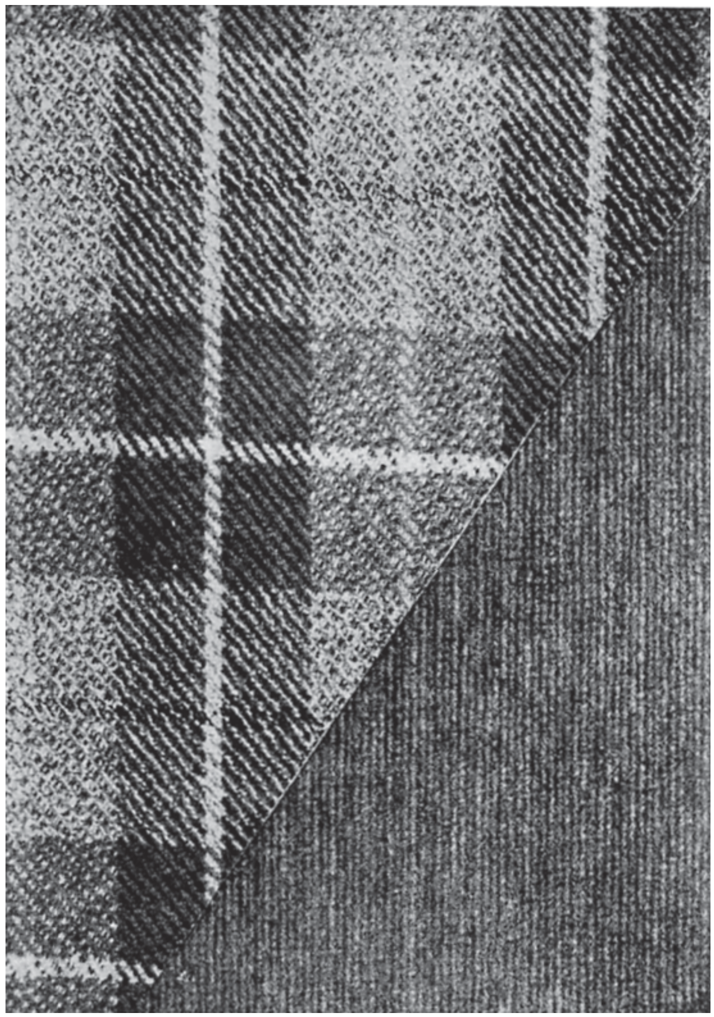


Fig. 55.

Golf Cloaking, with different pattern, yarns, and finish on each side.

(61) *Stitching and Tying of Double and Compound Weaves.*

In the various classes of compound weaves, stitching, or the system of binding two or more cloths together, operates on felting. It is a subject in which experimental research is needed. Some deductions may, however, be made from the series of examples given in Figs. 56 to 61. They are woven in 30 skeins yarn with 75 threads and 94 picks per inch, and treated alike in the milling process.

A comparison may first be made between Figs. 56, 57 and 58,

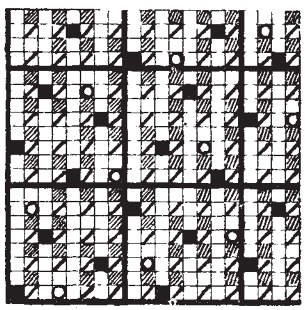


Fig. 56.—▣ = Warp stitches.

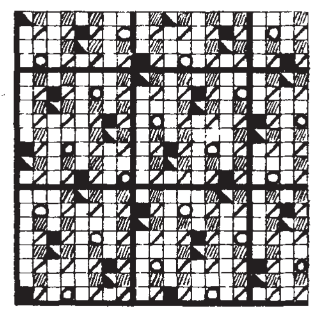


Fig. 57. —▣ = Warp stitches.
◣ = Weft ,,

the intersections on the face and backing threads and picks being as follows :—

TABLE XVII.

Intersections of Double Weaves.

	Intersections.			
	Threads.		Picks.	
	Face.	Back.	Face.	Back.
Plan 56. Sateen face and back (warp stitched)	4	4	14	16
Plan 57. Sateen face and back (double stitched)	4	4	12	12
Plan 58. Sateen face and twill back (warp stitched) . . .	4	8	14	12

The relative shrinkages in scouring and milling were :—

TABLE XVIII.

SHRINKAGES OF DOUBLE WEAVES.

	Scouring.		Milling.	
	Length.	Width.	Length.	Width.
Plan 56 . .	4·42	4·61	24·00	26·15
Plan 57 . .	4·71	4·68	18·86	17·18
Plan 58 . .	5·55	6·15	19·40	27·69

The shrinkage in scouring is given, but it is the milling shrinkage which is suggestive.

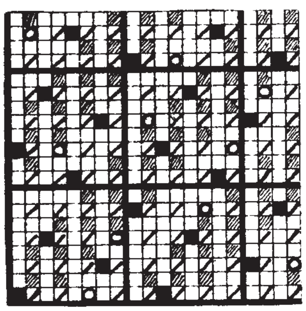


FIG. 58.—◻ = Warp stitches.

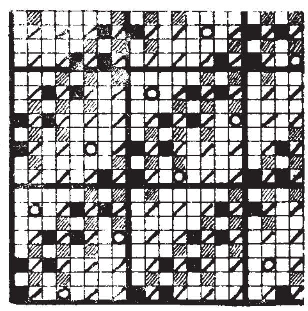


FIG. 59.—◻ = Warp stitches.

Dealing, in the first place, with the fabric from Plan 57, there is a less shrinkage in width and length than in the fabrics from Plans 56 and 58. Still, it is the weave structure with the smallest number of intersections, and therefore, by the law of intersections, should give a cloth of the highest milling property. Stitching is, obviously, an additional influencing factor. The cloth is double stitched, that is, the face bound to the back with both threads and picks. The result is a firmer compound cloth than in single stitching, and one in which there is not the same facility of contraction in milling.

A further comparison of the effect of single and double stitching is supplied in Plans 59, 60 and 61, the intersections being :—

TABLE XIX.

INTERSECTIONS IN COMPOUND WEAVES, SINGLE AND DOUBLE STITCHED.

	Intersections.			
	Threads.		Picks.	
	Face.	Back.	Face.	Back.
Plan 59. Twill face and back (warp stitched)	8	6	10	12
Plan 60. Twill face and back (double stitched)	4	4	8	8
Plan 61. 10-shaft twilled mat (warp stitched)	8	6	10	12

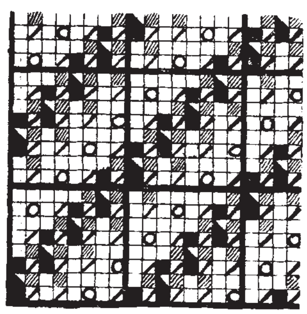


FIG. 60.—[O] = Warp stitches. [◣] = Weft „

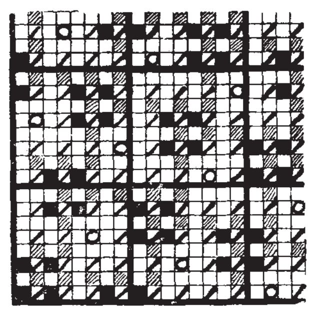


FIG. 61.—[O] = Warp stitches.

The weaves are again the same on face and back with more intersections in the single stitched cloth, producing the following milling results:—

	Shrinkage in Length	and Width.
Plan 59	21·15	27·69
Plan 60	16·88	18·46
Plan 61	7·68	35·43

The value of stitching in modifying the effect of the interlacings is indicated by these examples.

Analyse, in the second place, Plans 56 and 58, and 56 and 61. The weft shrinkage in both Figs. 56 and 58 is about the same or only one degree less in Fig. 56 than Fig. 58. The intersections on the face and backing picks are given in Table XVII. Comparing the shrinkage in length, it is 24 per cent. in Plan 56 and 19·4 in Plan 58, the backing threads in the latter weave having eight intersections as compared with four intersections in Plan 56.

Plan 61 may be contrasted with Plan 56. It is a double 10-shaft weave, but the arrangement of the stitching is the same as in Plan 56. There is only 7·68 per cent. shrinkage on the length, but 35·43 on the width. There are eight intersections on the face threads and six on the backing threads, against four on each in Plan 56, making a difference of 16·32 per cent. more felting in the length in Plan 56 than in 61, but in width there is an increase in favour of the latter of 9·28 per cent. the intersections on the face and backing picks in Plan 56 being thirty, and in Plan 61, twenty-two.

In these comparisons, the ratio of shrinkage in length and width of the cloths from each weave is not considered, on account of the difficulty of securing the same pressure in the warp and weft directions in felting.

Double cloths may also be stitched with centre warp, or centre weft, when the principles explained in relation to ordinary stitching are applicable. If centre yarns are used for wadding purposes, the weave structure is not modified, these yarns lying between the face and backing fabrics, but they necessarily have an effect upon shrinkage according to the quality of material of which they are made. A woollen centre warp, for example, will increase the shrinkage property of a double fabric, whilst a cotton yarn will decrease this property in the cloth.

CHAPTER VII.

FULLING AND MILLING MACHINERY.

(62) "Fulling" and "Milling". (63) Routine in the Fulling Stocks and Milling Machine. (64) Construction and Working of the Faller Stocks. (65) Milling Machines. (66) Routine of Milling. (67) Corrugated Guide Rollers. (68) Machines with Two or More Upper Rollers. (69) Duplex Machines. (70) Machines without Flanged Roller. (71) Mechanical Devices applied to the Spout. (72) Roller Milling Machine with Stampers in the Spout. (73) Principle of Combined Milling Machine and Stocks. (74) Combined Scouring and Milling. (75) Milling without Artificial Compression.

(62) "*Fulling*" *and* "*Milling*".

THESE terms applied to fulling machinery have distinct meanings. Fulling relates mainly to the older form of machine or stocks, the design and construction of which were, no doubt, suggested by the method of tramping the cloth practised in ancient times. The term "Walker" was also used, and still obtains in the German "Walkmaschine". "Milling" is descriptive of all kinds of machinery in which the felting routine consists of a series of compressions on the piece or cloth. To full and to mill are technically synonymous, both denoting the working on the fabric to increase compactness, solidity and wearing strength. Still, "fulling" literally signifies, as the French "fouler," to tread, to press, as by the action of the stocks, and thus improve the density of the woven fabric by felting, whereas "milling" is more indicative of the treatment the cloth undergoes in the successive operations in the milling machine.

(63) *Routine in the Fulling Stocks and Milling Machine.*

By both methods pressure is applied to the cloth, but in distinct ways. When fulling in the stocks, the piece or pieces, having been prepared by soaping, are placed in the trough T (Fig. 62) in a roll or ball form. The movement of the cloth in this condition in fulling is one of turning under the hammering, pounding or tramping of the stock fallers. The process is simple in character. The same amount of force is directed on

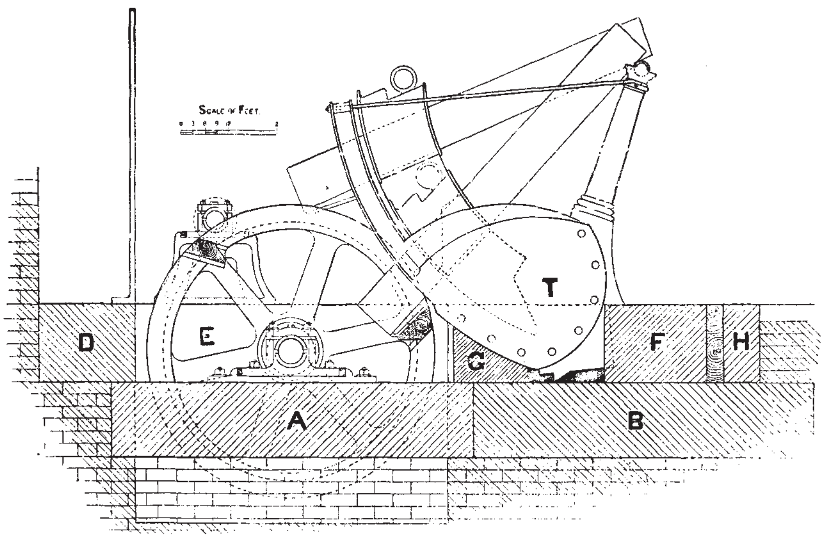


FIG. 62.

the length and width of the piece. Shrinkage decreases the superficial space occupied by the piece, and has the effect of increasing the distance traversed by the fallers, and the force of impact with the cloth. In other words, when the pieces are first put in the stocks they have the greatest bulk, the movement of the fallers being the minimum, but this increases with the felting. The bursting pressure (*i.e.* the fulling condition) is thus maintained.

This routine may be contrasted with that characteristic of the milling machine. The felting on the length and width of the pieces is performed in separate parts of the machine, the process being a compound one. Firstly, as the piece, in a rope form, passes through a neck or guide and between a pair of squeezing rollers, the pressure is on the weft line of the fabric; secondly, the piece is cuttled and held momentarily in lengths in the spout, the lid of which is weighted according to the amount of felting required. There is, thus, compression on the weft, followed by compression on the warp direction of the cloth, under which there is, first, shrinkage mainly on the former, and second, mainly on the latter. In each process there is also some felting in both length and width.

Greater equality of felting, in warp and weft of the cloth, results in the stocks than in the milling machine. Another advantage of the stocks is less liability to produce marks and defects, particularly creases or mill rigs. Running the pieces in length, and necessarily in folds, in the ordinary machine, is sometimes the cause of rig marks, especially in Crossbred-yarn fabrics. If such faults commence at an early stage in milling, they may result in creases irregularly distributed throughout the piece. The chief advantage of the milling machine over the stocks is in economy, one machine doing the work of several stocks. Still, in felting pieces of a Crossbred quality, or any class of fabrics which have a disposition to rig, by running in the same set of folds during the process, it is an advantage to treat them in the stocks before felting in the milling machine. This preparatory fulling imparts a condition to the pieces which prevents rig marks, and, at the same time, equalises felting.

(64) *Construction and Working of the Faller Stocks*

Fig. 62 is a section of the ordinary type of fulling stocks, which occupies a floor space of 12 ft. by $4\frac{1}{2}$ ft. Each pair of fallers varies in width from 18 ins. to 28 ins. at the bottom, and are driven by one tappet shaft, suitable foundations A, B, D, F, and H being made and the tappet wheel let partially into the floor as shown.

The tappets, three on each side of the tappet wheel E, raise the fallers which drop by gravity. The approximate speed of the tappet wheel is 13 revolutions per minute imparting 78 strokes of the fallers on the piece at each revolution. The fallers operate on the pieces in the trough T, in two ways. First, they pound the cloth, and second, keep it in constant movement, forcing it against the curved rear portion of the trough.

There are some modifications of this simple mechanism. such as driving the fallers automatically, and the use of three fallers instead of two. In the Grosselin stocks, the two outside fallers alternate in action with the centre faller. The object is to obtain more frequent compression of the pieces and greater felting result. For this purpose, the Russell fulling stocks is also constructed. It may be loaded with pieces at both ends. In the centre is the main driving shaft on which are eccentrics actuating the stock feet alternately from either side, forward and backward. At each end of the stocks there is a trough or box with curved hinged door, against which the pieces are pounded in the felting operation. The capacity of the boxes may be reduced by bringing them nearer to the central shaft.

In the original form of stocks, as pointed out, the fallers are lifted a certain distance, released, and allowed to drop by their own weight. When the action of the fallers is governed by crank or eccentric gearing, the growing force of the impact with the gradually decreasing bulk of the pieces is not a natural sequence as in the faller stocks. By devising means of adjusting the position of the parts operating the fallers, this drawback has been partially obviated. In the stocks sketched in Figs. 63 and 64, there is a contrivance by which the fallers, during shrinkage of the cloth placed in part C, may be automatically brought into closer contact with their work. The position of the shaft B, on which the eccentrics carrying the fallers are fixed, can be advanced a distance of 13 inches. The turning of the wheel A (Fig. 63) by connective gearing alters the shaft from G to F (Fig. 64) and, necessarily, the stock feet E and D, D indicating the position of the fallers when the shaft is at F, and E when the shaft is fixed at G. By this arrangement, the felting of the cloth can be uniformly maintained, and pieces of varying length and weights can be treated.

A second method of automatically controlling the action of the fallers, consists in crank driving, and connecting arms or levers which may be varied in length. In each system, in order to have increasing compression on the pieces throughout the

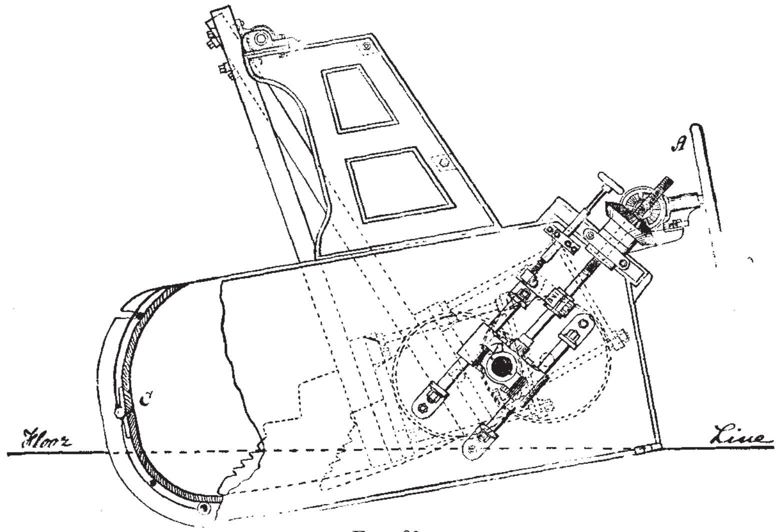


Fig. 63.

operation of fulling, the fallers are, at intervals, mechanically adjusted, but in the original faller stocks no such adjustment is required.

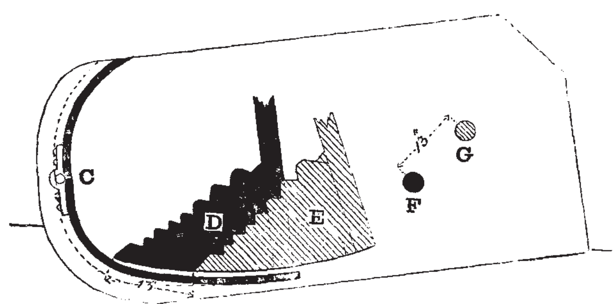


Fig. 64.

(65) *Milling Machines.*

Fig. 65 is an illustration, Fig. 66 a side elevation, and Fig. 67 a front elevation of the ordinary type of milling machine. Fig. 68 is a view of a milling plant.

The machine is $4\frac{1}{2}$ ft. wide, $8\frac{3}{4}$ ft. long and 7 ft. high, the speed of the shaft being about 80 revolutions per minute. The main parts of the machine, Fig. 67, are the knocking-off motion K,

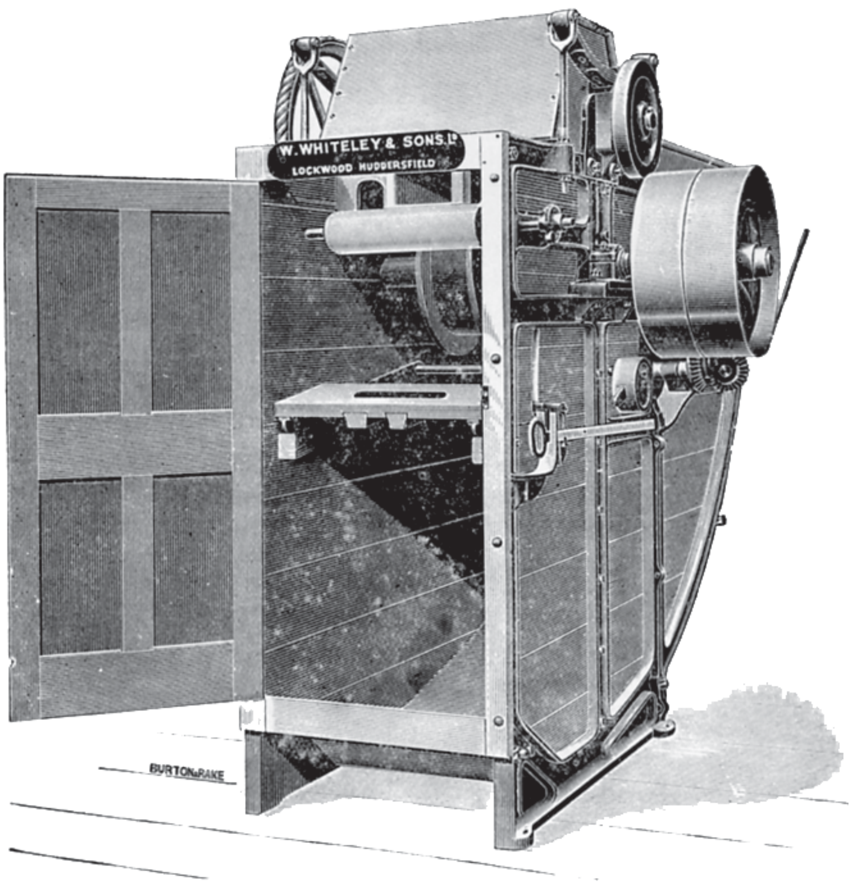


FIG. 65.

R and C, flanged roller, B, pressure roller B^1, the neck or throat N, and the parts for milling in length, shown in Fig. 69. The pieces pass through the divisions in the board K, over the guide roller G, between the rollers B and B^1, through the spout S, Fig. 69, and into the bottom of the machine. Should the pieces for any cause get fast in the machine, the board K rises, and by the connections C, removes the strap from the fast pulley P, on to the loose pulley P^1. As shown, the two rollers B and B^1 are driven by spur wheels, A being on the main or central

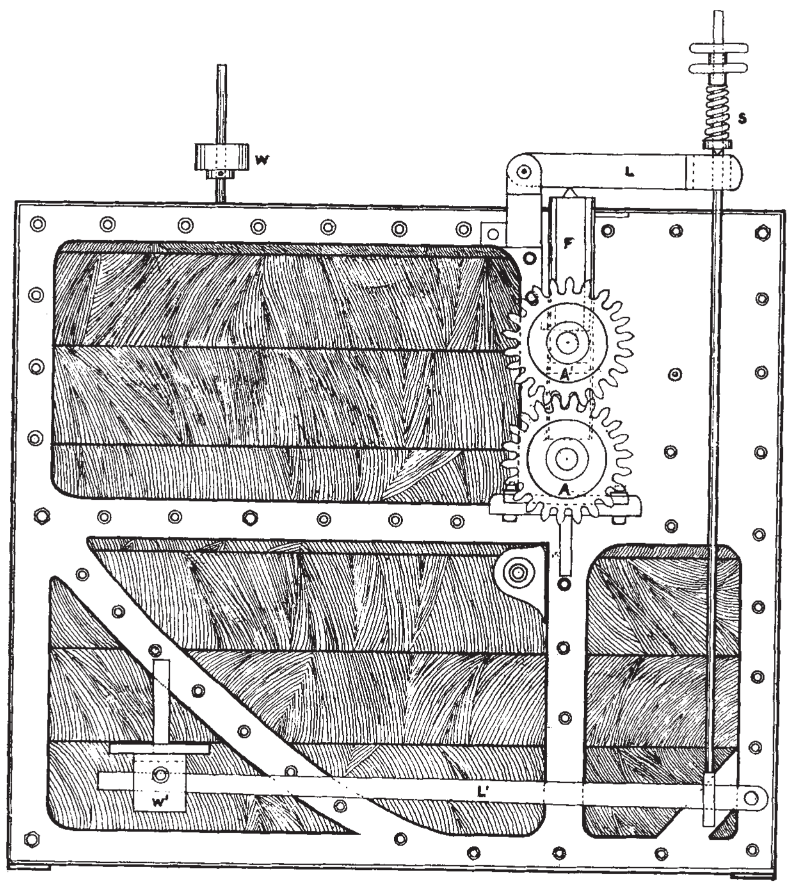


Fig. 66.

driving shaft and gearing with A^1 (Fig. 66). The upper roller B^1 fits within the flanges of B (Fig. 67), and receives pressure from the levers L, L^1 (Fig. 66). This is not the common device for weighting. It has been designed in the Textile Department of the Leeds University for experimental work, and for the

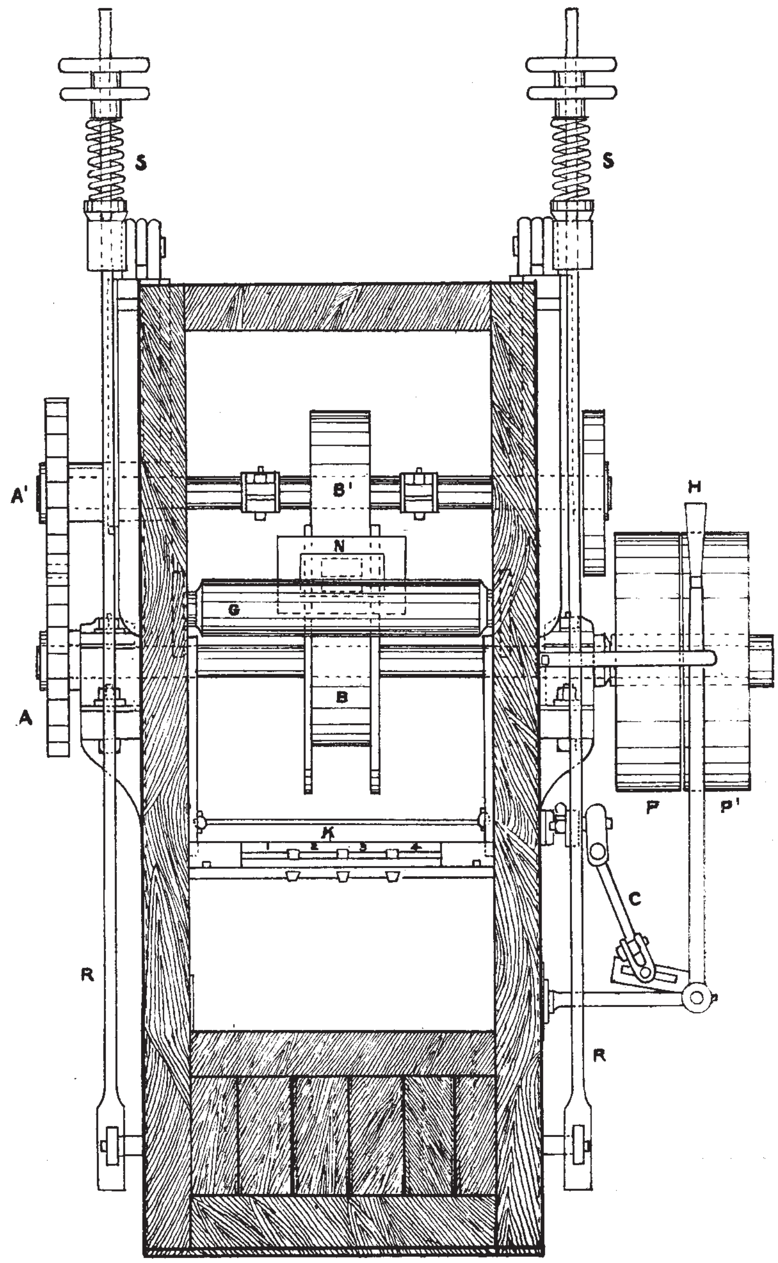


Fig. 67.

Fig. 68.—Plant of Milling machines.

regulation and registering of the weight transmitted by means of the upper roller on the pieces. Usually, the part F—duplicated at the other side of the machine—fixed on the shaft of wheel A^1, by spring arrangement is made to increase or diminish the pressure on the flanged roller.

In Fig. 69, the arrangement for weighting the lid and retaining the pieces in successive lengths in a cuttled state, is shown. The lever C, secured to D, is on the end of the shaft of roller B^1.

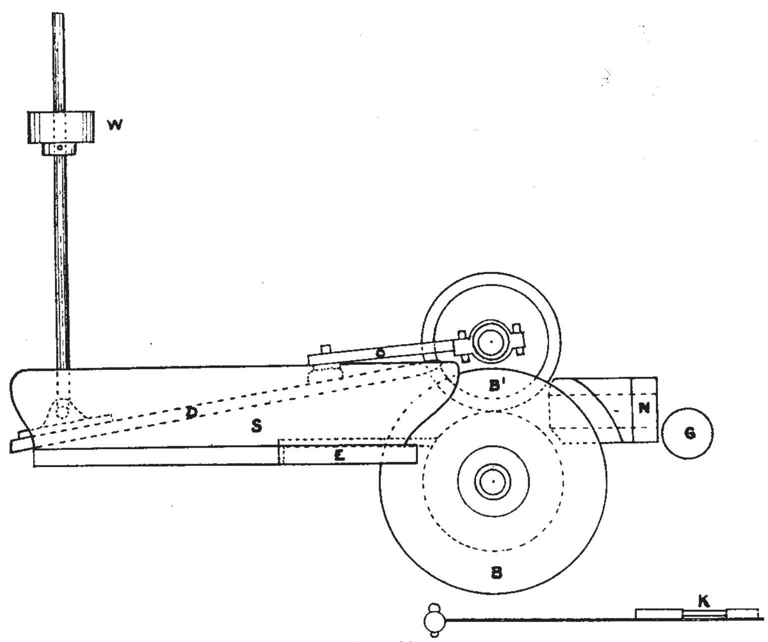


FIG. 69.

Having applied the necessary quantity of soapy solution to the pieces, they are passed through the apertures 1 to 4 in the board K (Fig. 67) over the guide G and into the neck N. Here they run through a diminishing space to the nip of the squeezing rollers, pressure being chiefly on the weft direction of the fabric. They are, in this manner, guided and kept within the flanges of the roller B, the degree of shrinkage depending mechanically upon the resistance of the upper roller B^1.

The weight W (Fig. 69) is increased to give additional

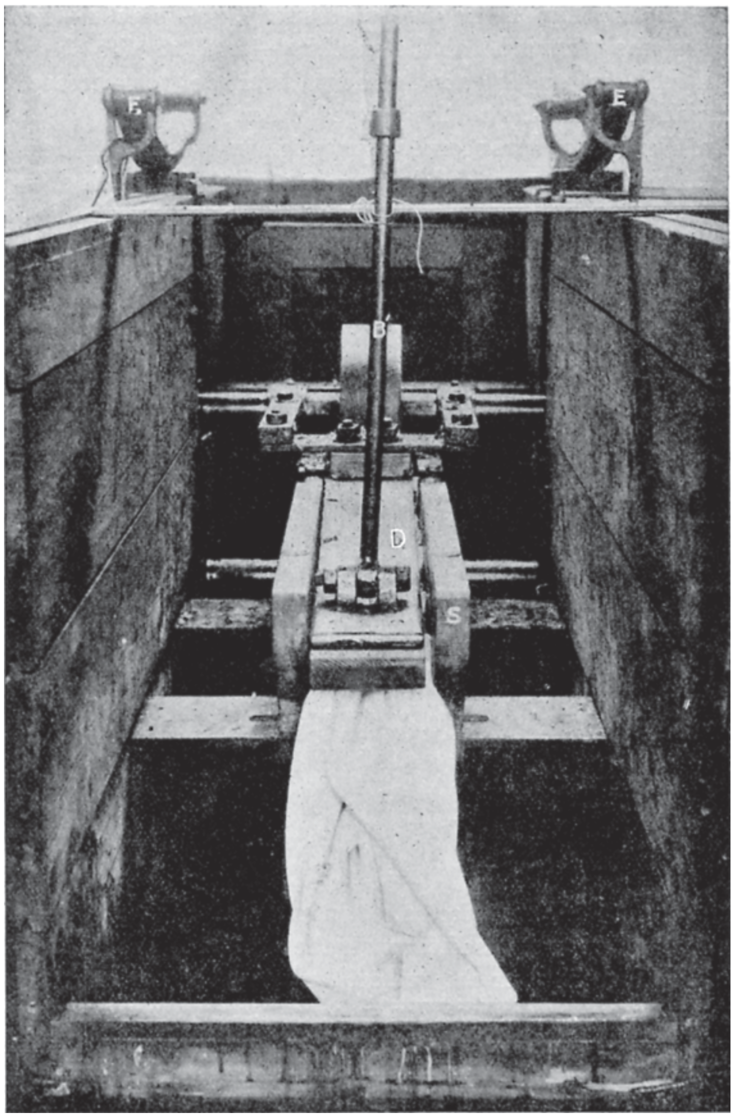


FIG. 70.—Interior of milling machine.
E = springs, B^1 = upper roller, D = lid, S = side of spout.

shrinkage in the length of the pieces, which cuttle in folds when held by the lid D of the spout S, remaining thus until the ac-

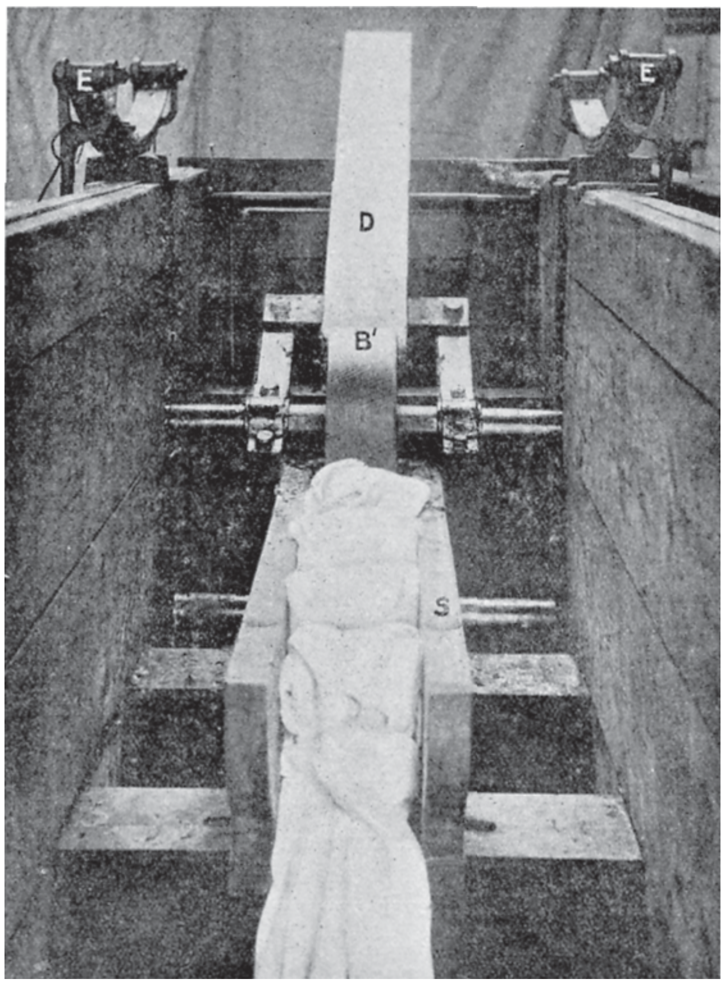


FIG. 71.
E = springs, B^1 = upper roller, D = lid, S = spout side.

cumulated length lifts the lid and travels forward to the lower part of the machine. This action is illustrated in the two views of the interior of the machine given in Figs 70 and 71, the back part, and also the upper portion of the framework having been removed. The former shows the cloth as it passes from the spout under pressure of the lid, and the latter, the cuttling of the cloth in the spout, the lid being turned back for this purpose. It will be seen how on the pieces immediately being released from the squeezing rollers, they fill the spout, cuttling or accumulating in folds. This is conducive to felting on the length, especially when the lid is heavily weighted. In Fig. 70, a length of the cloth has just been forced from the spout, with the lid in normal working position, to repeat the retaining and pressing action on the cloth in process of cuttling in the spout.

(66) *Routine of Milling.*

The passage of the cloth through the machine may be briefly described. The pieces, as seen in Fig. 72, pass through the knocking-off board K, over the guide roller and through the neck into the spout (Figs. 69, 70 and 71). From here they move in a cuttled form down the sloping end of the machine, in which condition a certain amount of shrinkage transpires. This varies with the length and weight of the pieces, these being factors which affect the pressure on the folded condition of the cloth.

It will be observed, that by this routine the pieces are compressed at several stages, and in different ways. First, in running through the spaces in the knocking-off board, next between the horizontal guide rollers, if two are used, and in some machines between vertical guide rollers to be compressed in the neck or throat, followed by similar action between the squeezing rollers, then the shrinkage in length in the spout, and, finally, as the pieces travel into the lower part of the machine. Felting takes place wherever pressure or cuttling is applied, so that there are only the lengths of cloth between the spout and the rear end of the machine, the front of the machine from the bottom to the knocking-off board, and from the latter to the guide rollers, where felting is not actually forced by mechanical action. The frequent repetition of these operations, continued during periods varying with the amount of felting necessary, produce and maintain felting conditions.

(67) *Corrugated Guide Rollers.*

When the pieces are run in drafts, say four together, each piece enters a separate aperture in board K, Fig. 67. The two

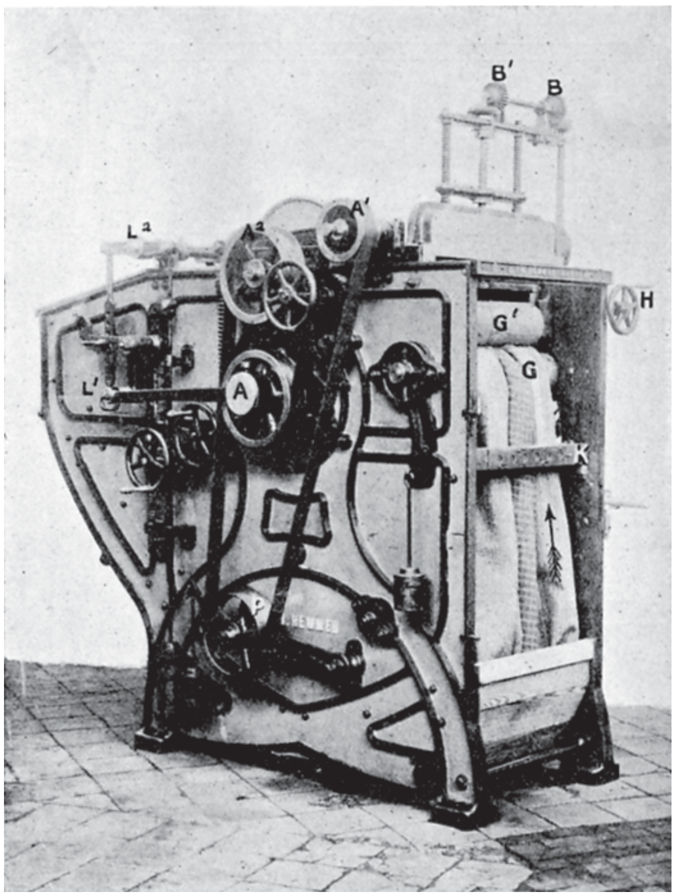


Fig. 72.—Hemmer's milling machine.

outside pieces, when they run direct to the neck over a simple guide roller, travel at a different angle from the pieces in spaces 2 and 3. This may produce ballooning and knotting of the pieces. In Whiteley's machine, a pair of corrugated guide rollers G and G^1 (Fig. 73) are useful in removing this defect, and also in acquiring some additional shrinkage on the cloth for each round through the machine. The construction of the machine, and the relation of the parts to each other, are seen in the side elevation (Fig. 74). Passing through the knocking-off

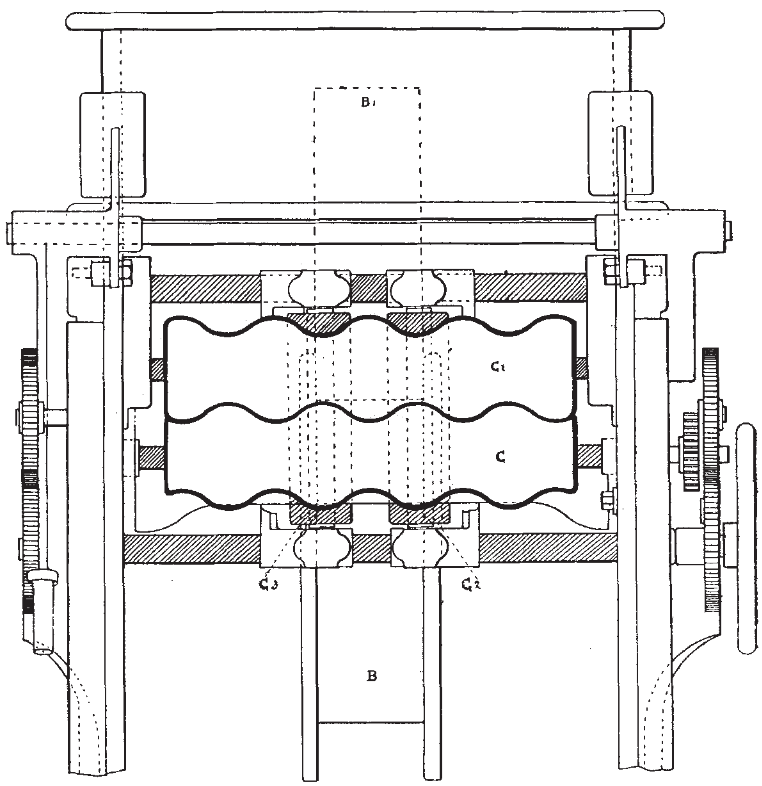


FIG. 73.

board, the pieces are taken between rollers G and G^1 to a pair of vertical rollers, and then follow the usual routine. There are, thus, two methods of crushing and also of changing the folds of the pieces before they reach the flanged roller, namely, horizontal crush between G and G^1, and crush by the vertical rollers G^2 and G^3. The rollers G, G^1, and G^2, G^3, are adjustable to take pieces of various weights and to modify the felting pressure. This compound roller crushing on the pieces is effective both as a factor in milling and in preventing rig marks.

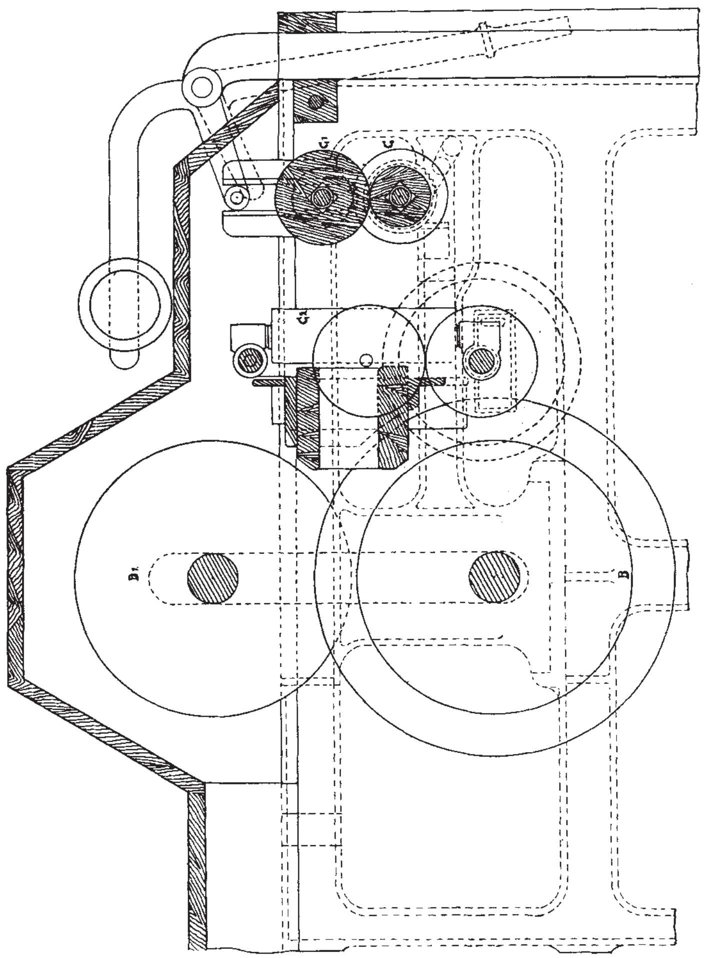


Fig. 74.

(68) *Machines with Two or More Upper Rollers.*

Several English and Continental makers of milling machines have adopted the plan of placing two or three rollers over the main squeezing roller, with the object of more frequently crushing the pieces than if only one roller were used. A common and simple method of driving such rollers is by spur-wheel gearing, but in the Hemmer and Kemmerich machines

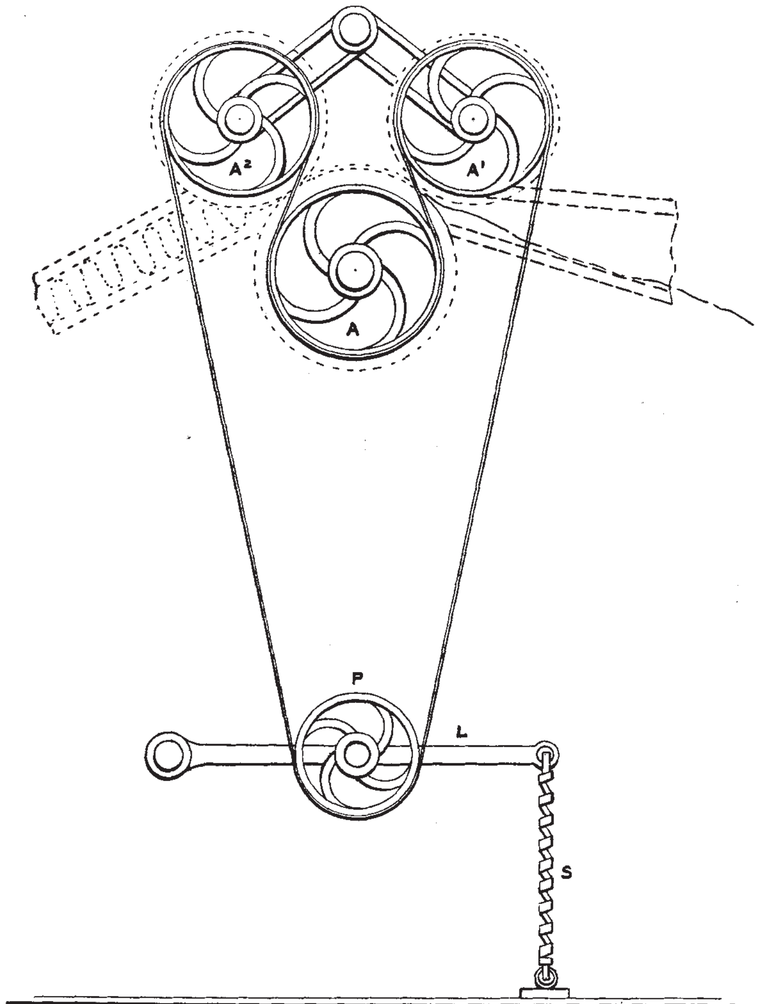


FIG. 75.

other devices are applied, namely, those sketched in Figs. 75 and 76. In both, the idea is to obtain a positive uniform drive, and yet one of some give or elasticity in the relation of the upper rollers to the surface of the lower roller. With the use of spur wheels, such rollers may only be lifted by the cloth to the extent of keeping the wheels in gear with each other. Both rollers are

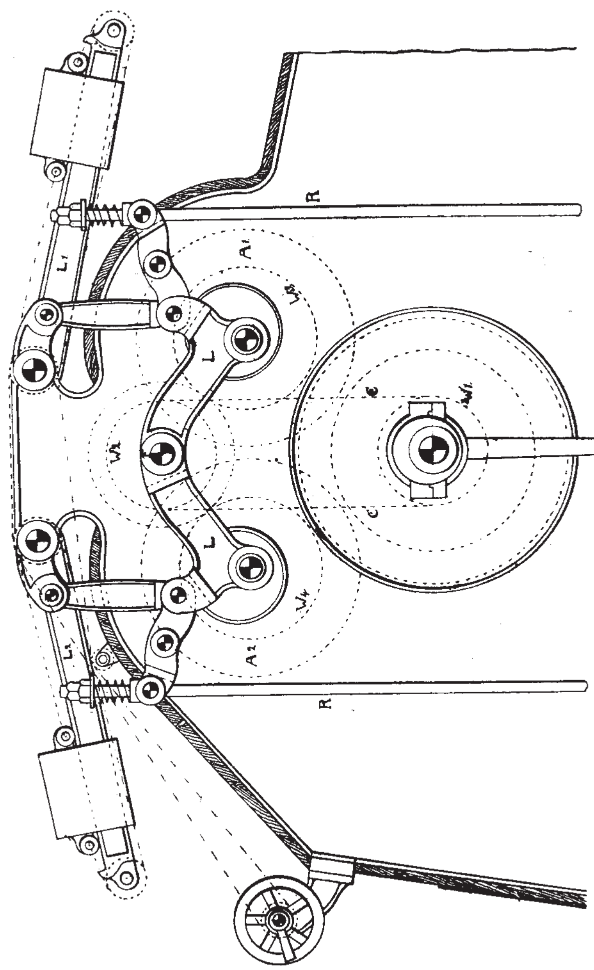


Fig. 76.

under pressure due to weights or springs. In the two drives (Figs. 75 and 76) there is, possibly, more elasticity of vertical displacement of rollers B and B¹ (Fig. 69) with a constant and uniform speed. As seen in Fig. 75, the pressure is applied to rollers A^1 and A^2 by the driving strap passing first round the pulley A on the central shaft, over the two upper pulleys, and under the pulley P on lever L weighted or tensioned by spring. This method of driving is also shown in the view of the Hemmer machine (Fig. 72).

In Fig. 76, the pressure rollers are carried on levers L fulcrumed at F. This lever is connected by links to weight levers L^1 and L^2. (The connecting rods R, R^1 communicate with the mechanism for putting the machine out of action.)

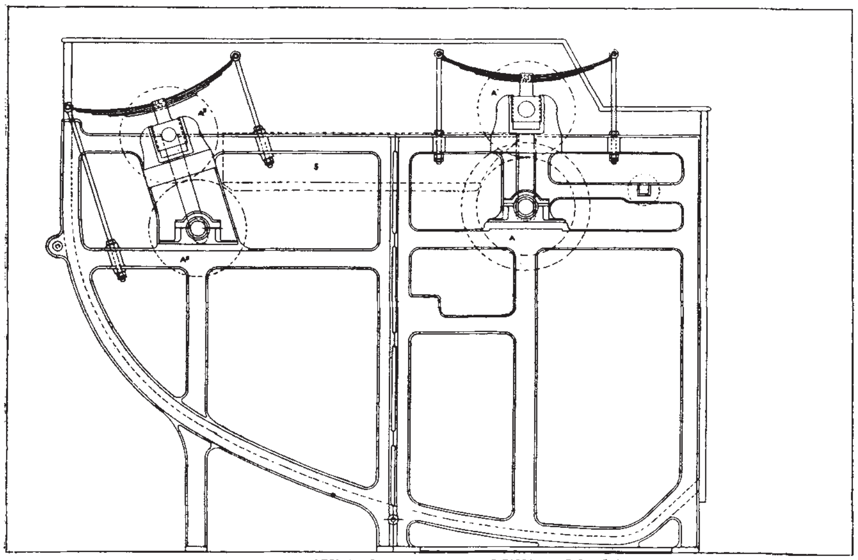


FIG. 77.—Whiteley's Duplex Milling Machine.

The positive drive is obtained by chain gearing. The chain C passes round W^1 on the main shaft, and W^2 on the shaft of the carrying lever L. Connection wheel drive is direct from this shaft, with wheels W^3 and W^4 on the shafts of rollers A^1 and A^2. The distance of the pressure rollers from the bottom roller can be mechanically adjusted, and the former may, also, change angularly in relation to the fulcrum F of lever L.

(69) *Duplex Machines.*

Two types of duplex machines, very different in construction, are sketched in Fig. 77 and Fig. 78. In Whiteley's machine (Fig. 77) there are two pairs of rollers, the first pair A, A^1, bearing the same relation to the guide rollers, neck and spout, as in the ordinary milling machine. The supplementary rollers A^2, A^3 are placed at the rear of the spout. Both pairs of rollers are under spring control. Milling is the same as in the ordinary machine until rollers A^2, A^3 are reached. These rollers are eighteen or more inches from end to end, to allow lateral spreading or opening out of the pieces. On leaving the spout, the pieces, before passing into the lower part of the machine, are subjected to horizontal crush or pressure, varied by the degree of felting required on the weft.

This additional feature of the machine has two effects: roller action after cuttling warp ways in the spout, and supplementary felting weft ways. There is, first, shrinkage due to passing through the neck, and over the flanged roller, both of which are on the weft, as explained; second, felting on the warp; and third, felting on the weft.

The milling action is also varied in character and amount, in the class of machine sketched in Fig. 78. By following the routine of the cloth, the nature of the compound felting which is produced will be understood. There are two pairs of main squeezing rollers, with supplementary horizontal and vertical rollers, as well as the usual felting in the spout. From roller G, the pieces are compressed by vertical rollers B, and enter the neck N of the machine, pass forward to the squeezing rollers A, A^1, and A^2, A^3, which are ordinary rollers without flanges, and some eighteen inches wide. From the first pair, A, A^1, the pieces run between the vertical rollers B^1 (only the rear one shown) to the second pair of horizontal rollers A^2, A^3, and into the spout S.

There are several mechanical compressions at various stages in the milling routine. First, between vertical rollers, the cloth being made to spread within certain limits vertically, under transverse pressure; second, in the neck, where the pressure is on both warp and weft of the pieces; third, between the first pair of squeezing rollers; fourth, between the second pair of vertical rollers; fifth, repetition of the third process between rollers A^2 and A^3; sixth, chief shrinkage in the spout on the warp way of the cloth.

In the Hemmer machine, the pairs of squeezing rollers may be run at the same or different speeds. This allows, first, of the pieces being tensioned in length during milling; and second, of an auxiliary felting by the accumulation of the cloth on a board fixed between the two pairs of rollers. Over the board there is a tongue, so that a certain amount of pressure may be applied as the cloth passes to the second pair of rollers.

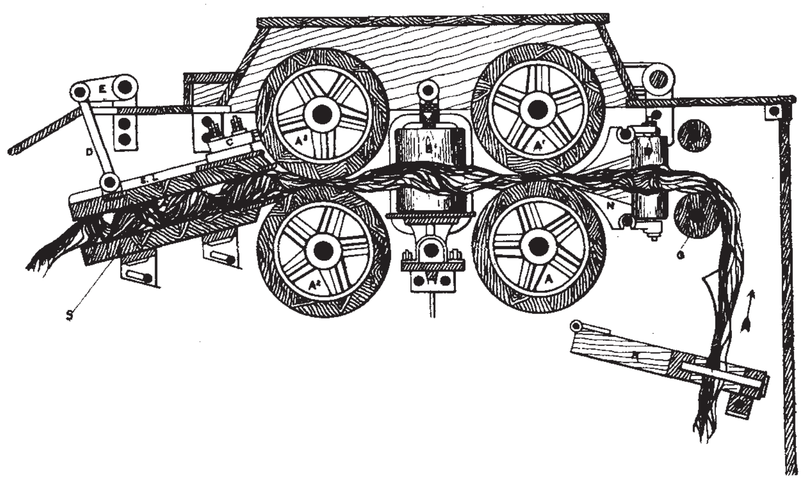


FIG. 78.—Duplex milling machine.

Tensioning of the pieces between the rollers may be satisfactorily done when little milling is required on the warp, as, for example, in treating pieces made with worsted warp and woollen weft, and in which the object is to retain, as near as possible, the scoured length, effecting the shrinkage in the width.

In these duplex machines, diversity of felting action is provided. This must increase the amount of felting possible in a given time, and be more economical in results than the single type of machine. But there are other advantages, namely, more even milling, and less liability to produce rig marks and faults. With the diversity of roller action, there must be frequent changing in the relative positions of the layers of fabric. The pieces may, in this way, be run and milled continuously in length, with little possibility of defects arising in the cloth.

(70) *Machines without Flanged Roller.*

The use of a flanged roller with one or more upper rollers fitting between the flanges, is a sound principle of construction in milling machines. One advantage is that the pieces are forcibly held within the width of the flanges when under heavy vertical pressure. This secures rapid felting, but may also be the cause of faulty work. If there is not sufficient weight on roller B^1 (Fig. 67) the pieces are liable to get over the edges of the flanges, or should the lid, in consequence of the weight applied, be too operative, the spout becomes overloaded. Such defects can, as a rule, be obviated by proper regulation of the weight and length of cloth put in the machine, and of the pressure on the squeezing rollers and the lid of the spout.

Several other forms of rollers are also used in milling machines, such as corrugated, concave and convex, and plain surfaced. In the machine described (Fig. 78) the squeezing rollers are plain, but wide enough to prevent the pieces spreading over the ends, when passing between the rollers. The vertical guide rollers in front of the squeezing rollers in this type of machine, have the effect of maintaining the pieces in a compressed and central position.

In the Hemmer tandem machine, rollers of different construction are used for the front and back pair. The first pair may be corrugated circumferentially, and the second pair transversely to the circumference, the recesses of the lower roller in each pair being opposite the raised portions in the upper roller. Neither of these systems of milling gives that lateral or side pressure which is such an important feature when the pieces are held within a pair of flanges and subjected to vertical pressure.

(71) *Mechanical Devices applied to the Spout.*

The spout is an essential part of all milling machines for acquiring felting in length. Ordinarily, the spout lid is weighted.

In some machines, *e.g.* Kilburn's, the sides may also be made to oscillate, and a hinged portion of the lid may operate upon the cloth vertically. In neither of these modifications is there any change in the form of, or additions to, the spout.

Increased felting is made possible by two devices; first, the introduction of a series of rollers into the spout; and second, of pounding or hammering mechanism. The object of both is to

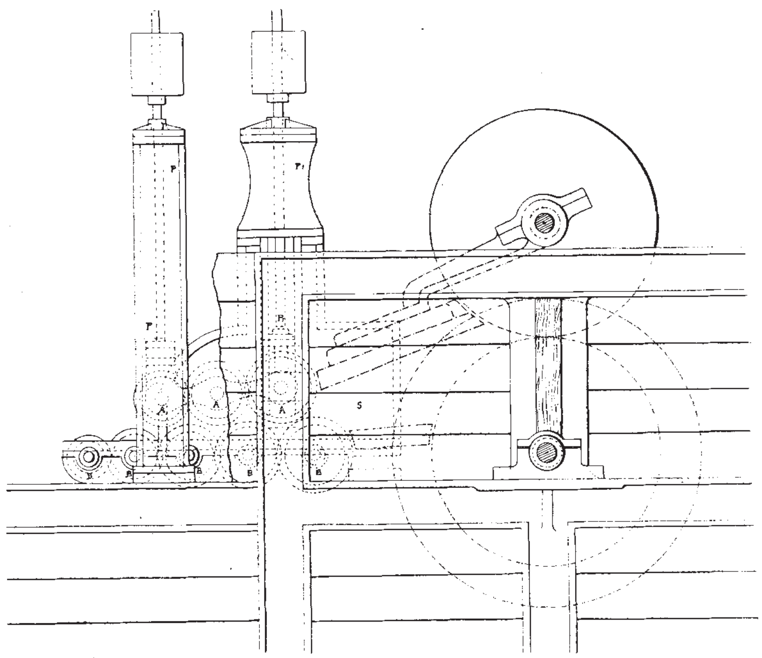


FIG. 79.

add to the felting capacity of the machine, and also to change the condition of the layers of cloth formed between the squeezing rollers.

Kilburn's improvement (Fig. 79) consists of two series of rollers, the lower five, and the upper series three in number. These are placed at the rear end of the spout, and form a supplementary part of it. The three upper rollers are linked together and mounted on the uprights P, P^1, which are weighted, so that the felting action imparted to the cloth is adjustable.

In the milling of heavy cloths this arrangement has been found satisfactory. In Preston's machine, a large corrugated roller is fixed below the end of the spout, and three smaller rollers, also corrugated, arranged triangularly over this roller. These retard the progress of the cloth, holding it, for a period, cuttled in the spout. The pressure of the rollers on the pieces, and

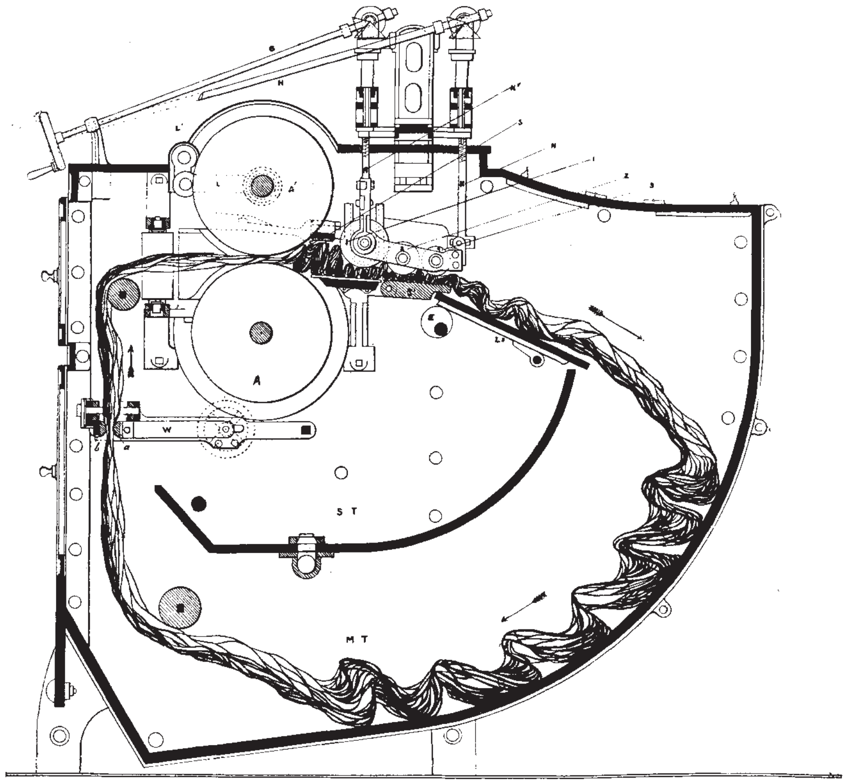


FIG. 80.—Crosset and Debatisse milling machine.

their retarding and milling action, can be modified by lever and crank gearing.

Another machine (Figs. 80 and 81) in which rollers are fixed in a frame and operated in the spout, is constructed by Crosset and Debatisse. Such rollers, with the method of regulation of the pressure on the fabric, form two of the principal features of the machine, but there are other important mechanical details.

In the first place, the adjustment of the upper squeezing roller, and that of the rollers in the spout, may be done from the front of the machine by wheel and handle. The method of driving the top roller A^1 is also different from that of other

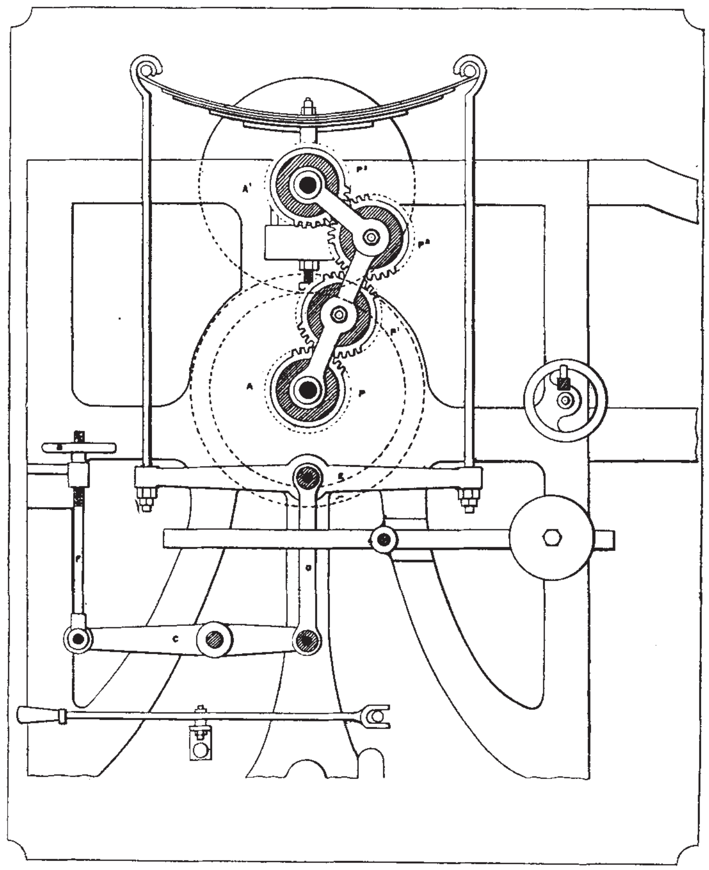


FIG. 81.

machines. On the shaft of roller A (Fig. 81) there is a toothed wheel P, which, through two intermediate pinions P^1, P^2, drives the toothed wheel P^3 on the end of the upper roller A^1. The point of gear of this wheel with the upper pinion may be varied.

The shaft of the upper roller A^1 is carried by levers L and L^1 (Fig. 80). The raising or lowering of the roller is done by turning the handle B (Fig. 81) fixed on the shaft F, which through levers and connections C, D and E, may increase or lessen the pressure on the upper roller, by the action of the springs at either side of the machine.

A second feature is the upper trough, ST (Fig. 80) which may be used for soaping or scouring. Assuming that it is used for soaping prior to milling, that is, to get the pieces evenly saturated, by turning the shaft on which the eccentric E is fixed, the board L^3 is lowered, and the hinged portion of the spout S^1 falls below the eccentric, so that the pieces instead of running, as seen, over the slide L^3, may pass direct into the upper trough ST.

But the chief characteristics of the machine are the rollers 1, 2, 3, and their action in the spout. These are fastened together by cross-bars, and suspended on the uprights N, N^1, at the top of which are carried bevel wheels gearing with the wheels on shafts H and G. The distance of the rollers from the base of the spout S, can be adjusted by the handle, through the thread portion of the uprights N, N^1. As the regulators for N, N^1 are independent, roller 3 may be brought nearer to the bottom of the spout than roller 1, and the resistance offered to the piece increased. The roller action has a certain changing effect on the piece, which is not present in the use of an ordinary spout lid, and also adds to the fulling process.

The routine of the cloth is indicated by the arrows. The pieces pass through the wringer or knocking-off board W, of which parts *a* and *b* are adjustable, so that the space may be altered with the thickness of the cloth to be milled. There are several sections in the wringer. The pieces then pass over the guide roller, and through the throat and squeezing rollers to the spout S, where they are subjected to the roller fulling, with the hinged part of the spout S^1 fixed as shown, over the guide board L^3 and into the lower trough MT.

(72) *Roller Milling Machine with Stampers in the Spout.*

The improvements which have been described as additional to the action of the spout have, for a primary object, the turning

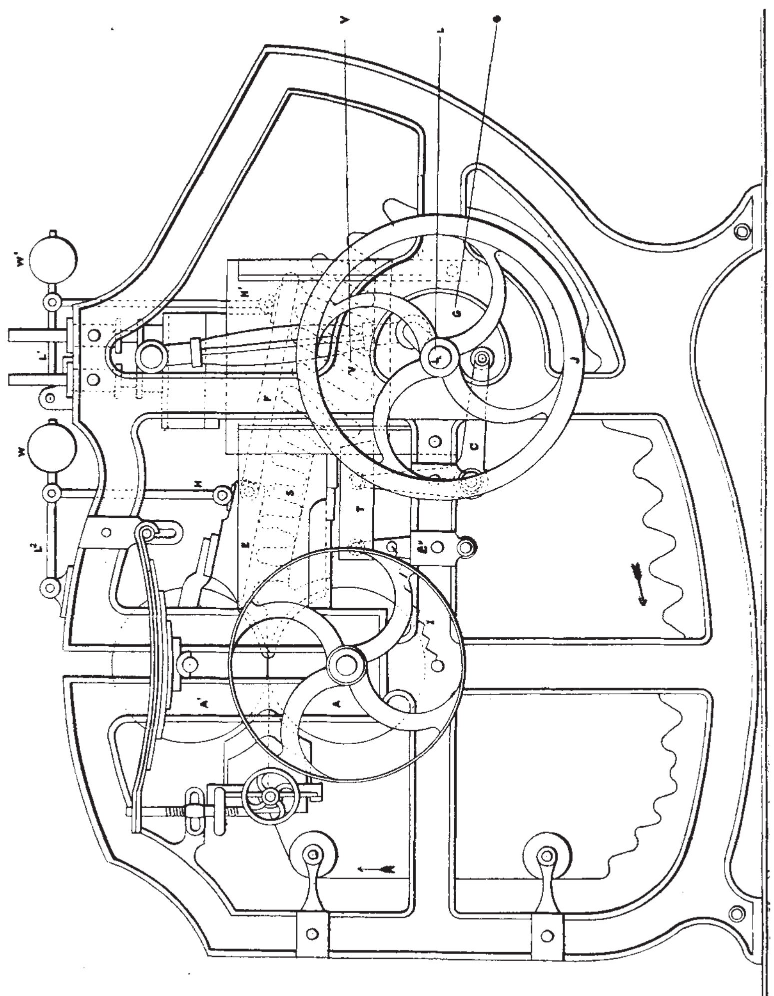


FIG. 82.—Grosselin's Compound Milling Machine.

over of the pieces for the prevention of defects, as well as to produce increased felting. The two systems in Figs. 82, 83 and 84 show methods approaching, in principle, the action of the faller stocks. There is, in addition to the milling, which is

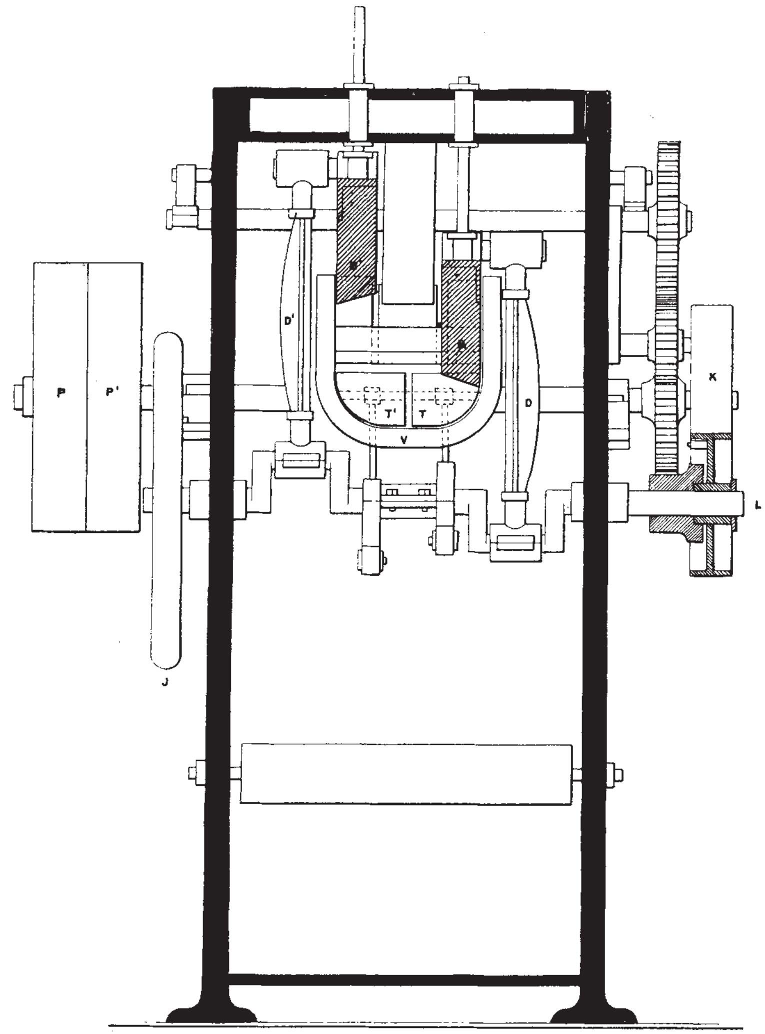


FIG. 83.—Grosselin's Compound Milling Machine.

performed in the centre parts of the machine, a pounding or beating of the cloth, whilst in cuttled form, in a portion of the spout. There can be no doubt as to the increased fulling result effected by this form of mechanism. It will be seen later, how, as a further development of this idea, milling machines are also made, in which automatic fallers operate on the cloth after it leaves the spout, during accumulation in a receiver.

Taking the Grosselin machine (Figs. 82 and 83) the primary improvement is the use of vertical beaters, which are actuated by crank shaft L and arm connections D, D^1. Fig. 82 is an end elevation of the machine, and Fig. 83 a front elevation. The machine is driven in the usual way. The pulleys P and P^1 are on the main shaft of the flanged roller, on the opposite end of which is the pulley K, which by belt drives the pulley on the crank shaft L. This, by clutch gearing, imparts motion to the crank shaft and the beaters. This method of driving makes it feasible to stop the feed rollers, as in the ordinary machine, when the pieces being milled become knotted, and for the crank shaft and beaters to continue for a short time in motion, owing to the impetus of the fly wheel J.

In one construction the piece is pushed forward, on being liberated by the delivery rollers, by propellers T, T^1, into the receiver V. These propellers are actuated by cam G on the crank shaft L, by levers C, C^1, the retarding movement being effected by springs I. The lid, F, of the spout (Fig. 82), is a retaining lever or plate, resisting the forward progress of the cloth. This part F is connected by rod R^1 to weighted lever W^1. Section E, which retains the fabric in the spout S, is fulcrumed on the upper shaft in the same way as the spout lid, and is weighted through connecting rod H and the levers L^1 and L^2.

The operation of the beaters B, B^1 (Fig. 83) is direct from the crank shaft L, beater B being shown in the bottom position, and beater B^1 in the top position, and the propellers T^1 in the forward, and T in the backward position. Necessarily, the propellers must be timed with the beaters, that is to say, moved forward when the beaters come into the position B. The beaters are shaped at the bottom as shown, which has the effect of pressing the cloth inwards, or from one beater to the other, as it is operated upon in the receiver V.

The process of milling is the same here as far as section S, or the miniature spout. It is in the portion V where the compound action of the beaters and propellers takes place. The beaters rise and fall alternately, pressing the cloth laterally from the sides of V to the centre. At the same time, the propellers force the cloth against the pressure lid F, which retains it in the receiver V, by the weights on levers L^1 and L^2.

The machine is well designed and automatic in action; the beaters and propellers coming in contact with the cloth alternately, the beaters hammering or beating the cloth, and the propellers pushing it, by cam movement, forward. In this way the felting action of the milling machine is done between the flanged and upper rollers, and also in the cuttling in the spout, with the supplementary felting or fulling performed by the beaters and propellers, whilst the cloth is retained in the receiver V.

The chief features in the McLardie machine (Fig. 84) are, the method of operating the beaters or plungers, and their position in the spout. In the Grosselin apparatus they are placed at the end of the spout, but here immediately behind the squeezing rollers, and act upon the pieces as they are liberated by the latter. The cloth during cuttling is pounded vertically. This has not only a fulling effect, but also causes the pieces to be constantly changing positions as they pass through the spout.

Fig. 84 is an end elevation of a two-faller machine, but three or more sections may be used, increasing the fulling output, The beaters B, B^1, are driven positively by the crank shaft A, A^1, to which they are connected by arms D, D^1. These are regulated as to the pressure they apply to the cloth, by springs. Each plunger B is corrugated underneath, and also the spout base, in the part where they operate on the fabric. Attached to each beater is a hinged lid, which is weighted, and retains the cloth in the spout. The cloth having been under the roller pressure, collects on section C, and is fulled by the plungers B, B^1, rising and falling alternately, and running in slides S, S^1 fixed to the sides of the machine. It is then felted by the pressure of the spout lid whilst still in a cuttled form.

The method of driving B and B[1] is direct and positive. The driving of the rollers by speed pulleys P^2 and P^3 provides a means

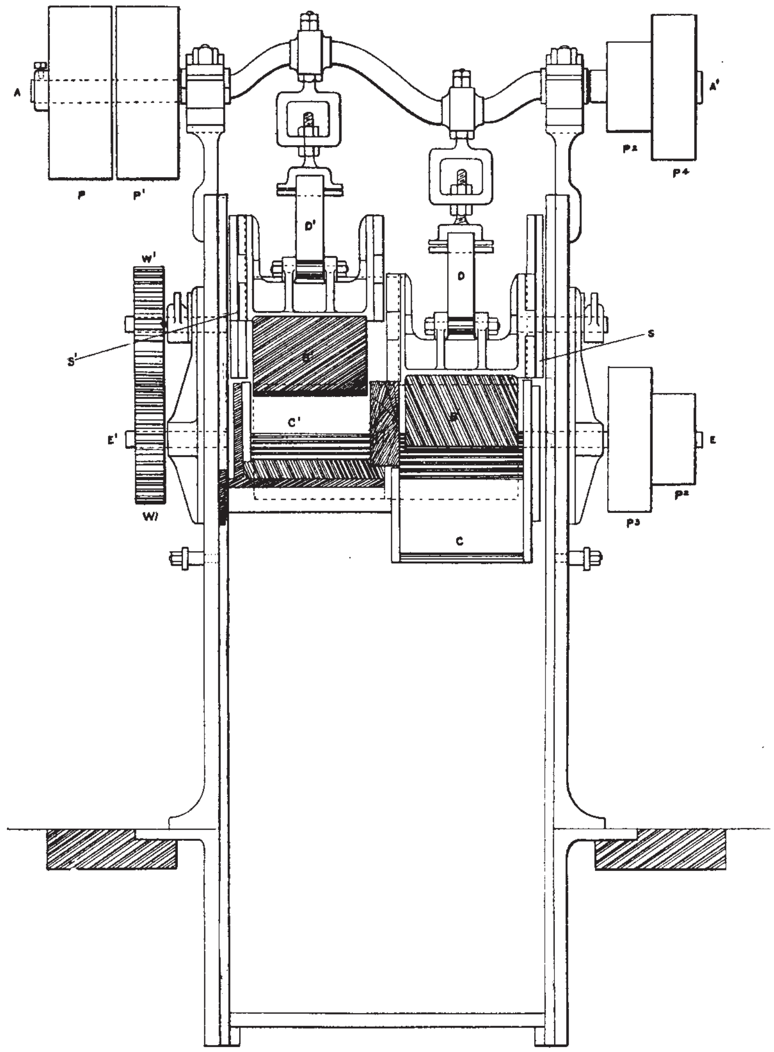


FIG. 84.—McLardie's Compound Milling Machine.

of running the squeezing rollers at different speeds to suit the qualities of fabrics being treated. P, P[1] are the loose and fast belt pulleys. At A^1 are fixed pulleys P^2 and P^4, which drive P^3 and P^5 on the end of the flanged roller shaft; spur wheels W, W^1 turn the upper squeezing roller of the machine.

(73) *Principle of Combined Milling Machine and Stocks.*

The practice is well understood of using the stocks and milling machine in combination, milling partially in the former and completing in the latter. The utility of this has been shown, but the acquirement of both principles of felting in one machine is comparatively new. In a sense, milling machinery in which vertical stampers or hammers are used is a step towards this construction, for the common form of milling machine is adopted with the additional pounding mechanism. The advantage of combining the roller or cylinder machine and stocks is obvious from the distinctive character of each system of felting. The older system is slow, but even in result; the newer system economical, and rendered more accurate and effective by the improvements referred to.

In the duplex milling machines, though transverse and vertical roller pressure is applied with subsequent cuttling of the pieces, yet there is no substitute for the pounding action characteristic of the stocks. The "cover" of the fulled cloth, due to treatment in the stocks, is of a different quality to that obtained by compression in the milling machine.

There is a difficulty in combining the two systems in the same machine, because the pieces in the milling machine and in the stocks are treated in different conditions; in one they are running continuously, and in the other they are rolled in the ball form. To acquire a similar action in the milling machine as in the stocks, necessitates that in some part of the machine there should be a confined space, in which a sufficient length of cloth may be compacted and worked upon by fallers. At the same time, the continuous passage of the cloth between the rollers is an essential: in other words, there must be intermittent felting, or rather fulling of successive and corresponding lengths of the piece by the stocks, and continuous action on the pieces between the squeezing rollers. Several lengths of cloth must collect in the space in which the fallers operate, be subjected to their action for a short time, and then released, other lengths of cloth following successively. To do this a new type

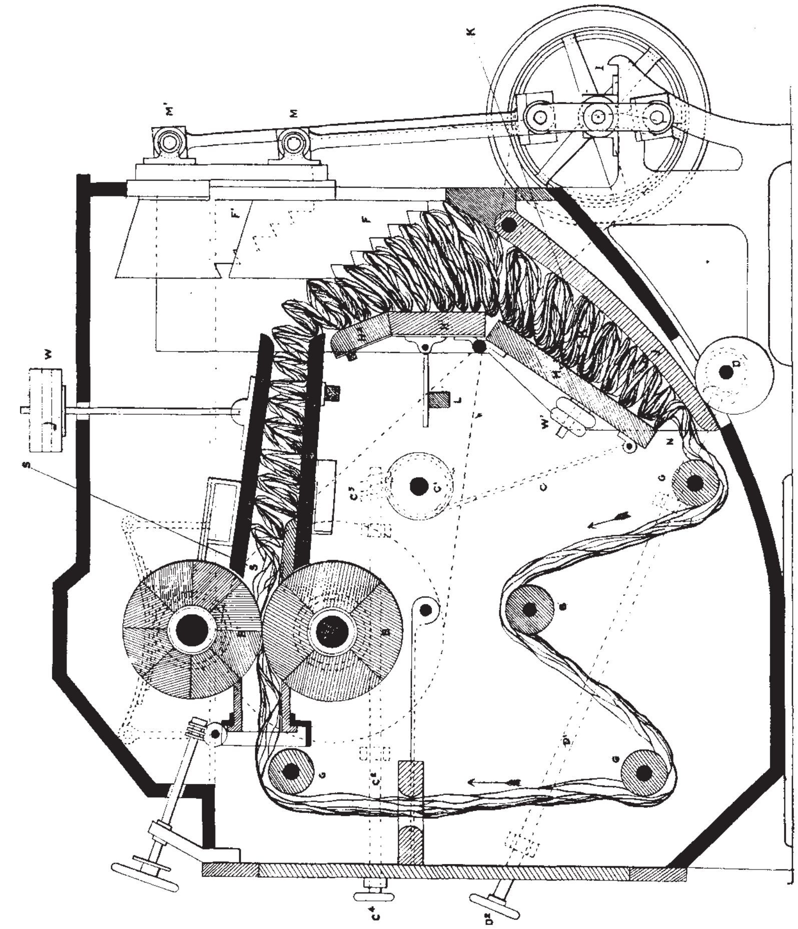


FIG. 85.—Preston's Combined Milling Machine and Stocks.

of machine, with the essentials of an ordinary milling machine, is necessary.

Preston's machine, sketched in Fig. 85, comprises the ordinary milling parts with vertical fallers. One of the principal features is the receiver K, with adjustable lower portion J, and upper or side portions H, H^1, H^2. In the stocks, the pieces are constantly being turned over, which secures even felting, but this is not possible when the pieces are subjected to roller and faller action alternately. In this case, though it is necessary that the pieces should be held in the space K under faller action, F, F^1, still the mechanical parts limiting this space should not be absolutely rigid. During the running of the machine, this section K must be filled by intermittent feeding from the spout S, maintaining a constant supply of cloth. The fallers, operating upon the cuttled pieces, press them closer and closer together as they pass towards point N. When the layers of fabric are so compactly forced together that the faller action has no further compressing effect, part H rises, lifting the weights W^1, and a length of cloth escapes. This fulling intermittently, in the receiver K, cuttling and forcing the layers of fabrics into more compact relation, continues throughout the milling operation.

The regulation of these parts is done mechanically. The hinged section H is adjusted by chain C, chain wheel C^1 and the shaft C^2, the worm wheel C^3 which gears into the wheel C^1. The less the weight and thickness of the cloth, the less the distance of H from J at point N. J is adjusted by shaft D^1, carrying a worm wheel gearing into the tappet wheel D, so that by turning this at D^2, the movable part J may be highered or lowered. H is similarly altered by turning C^4, closing or opening the space through which the pieces pass into the bottom of the machine. H^2 is also adjustable, having a cross shaft, through the divisions of which locking pins may pass into part L.

The driving of the fallers is done by crank shaft on wheel I, turned by strap from the pulley on the shaft of roller B. Through the upright arms M, M^1, alternate movement is given to the fallers F, F^1. The routine of the pieces in the running of the machine is seen from the arrows, G being guide rollers.

For the felting of heavy cloths, such as Irish friezes, and where the process is required to be rapid, this duplex milling is effective. The combination of the roller milling with that of the stocks, also frequently changes the relation of the lengths of fabric, and in this way proves a preventative to rig marks, producing, at the same time, good fulling quality in the cloth.

(74) *Milling Apparatus Applied to the Scourer.*

In scouring machines, certain modifications are applied which induce some felting. For fabrics in which only light milling is necessary, such as costumes and tweeds, various forms of combined machines are used.

Kilburn's machine has already been referred to, but it is more of the character of a milling machine than of a scourer to which special apparatus of a simple construction has been applied, to obtain a degree of milling.

The invention of Bailey (Fig. 86) consists in removing the draft board from the scourer, and substituting in its place a number of guides or necks N, similar to the throat in the milling machine. This results in squeezing the pieces in the folded condition each time they pass through the machine, in addition to the pressure applied between the main scouring rollers. Cross-drafting of the pieces may be practised as in the "scourer".

There is an advantage in this method, in dealing with fabrics of the light Cheviot type where bright colours are used, as in one and the same operation the pieces are scoured and felted to a sufficient degree. One process is thereby saved, and this should leave the fabrics with a cleaner tone, than if they were, in the first place, scoured and washed-off, and subsequently milled and rewashed-off.

(75) *Milling without Artificial Compression.*

In the several methods of felting described, mechanical pressure on the cloth has been an essential feature. If it is feasible to mill without such compression, pounding or hammering and friction, the fabric would suffer to a minimum degree in the waste of fibre or flock. A measure of fulling is, no doubt, possible, in woollen and worsted fabrics, when saturated with soapy solution, by simply running between squeezing rollers, and retaining, behind such rollers, lengths of the cloth in cuttles or folds. But this is not the milling characteristic obtained in heavy cloths in faller stocks or the milling machine. There are

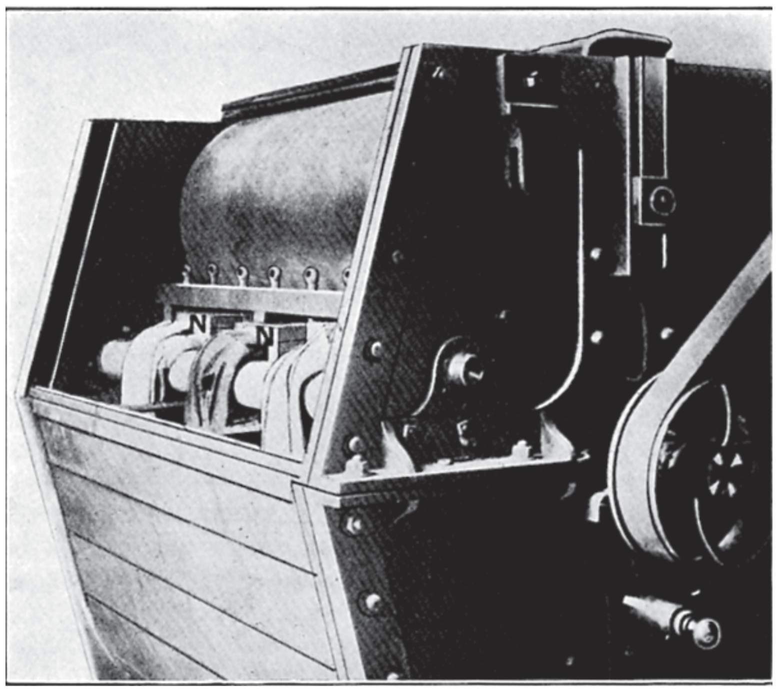


FIG. 86.

some varieties of fabrics manufactured in which light milling or shrinkage is only necessary, and which, during milling, it is an advantage to run full width. Worsted serges, and worsted warp and woollen weft Vicunas, and other classes of worsted fabrics in which some milling improves the finished result, should be treated by this method.

The machine (Fig. 87) of Tinker and Arran, is for the combined purpose of scouring, milling and crabbing. It consists of the main trough T, shaped as in a milling machine, of the upper trough T^1 used as in scouring, and washing-off, of the squeezing

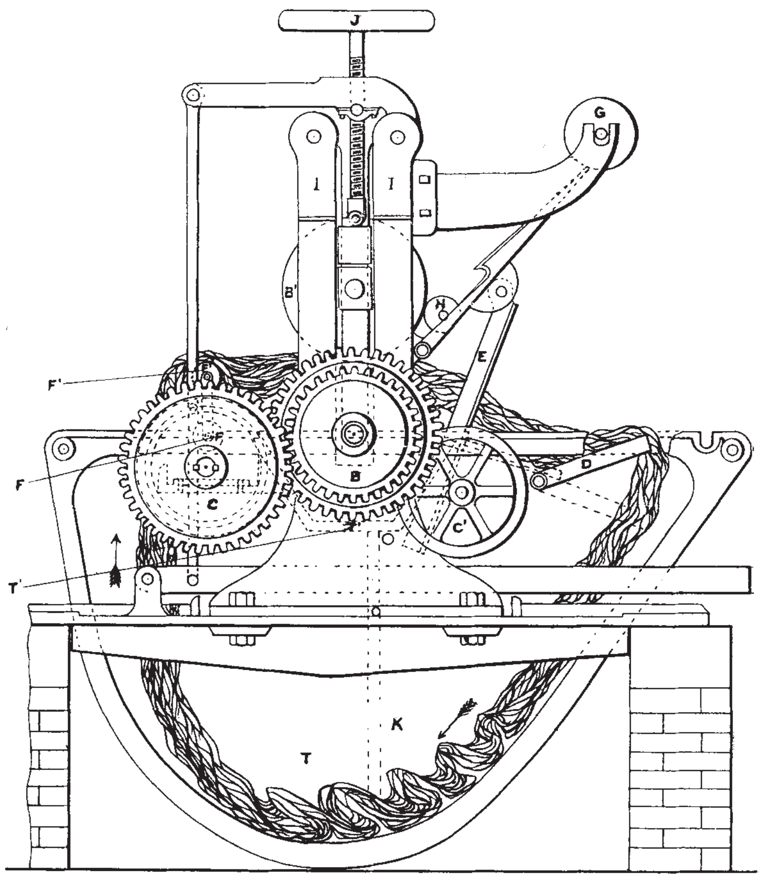


FIG. 87.

rollers B, B^1, and of perforated rollers for blowing the piece with steam. The fabrics may be run full width, or in the rope condition, in which case they are treated as in scouring, with the usual draft board. Perhaps the chief utility of the machine is in the felting of pieces full width, when they pass over guide roller F^1 from the bottom of the trough T, between rollers B, B^1, and cuttle on the board D. The shrinkage is regulated by the angle at which this board is fixed, and the amount of cloth which is retained in a folded state from the nip of the rollers B, B^1, to the end of the board D. (In the drawing, a part of the frame-work has been removed to show the effect of raising D, and the cuttling of the pieces). A supplementary fulling board K, may be further made to retain the pieces passing from D down the sloping frame-work to the bottom of T. When scouring, the hinged board D is lowered, and the pieces pass from B, B^1, into the lower part of the machine, thence to guide rollers F^1, the pressure on B being adjusted by wheel J. After scouring, one method consists in running the pieces on to the perforated roller and blowing with steam, rewinding on to a second roller from the opposite end, and reblowing, which has the effect of fixing, setting and levelling the fabric prior to milling. Milling, however, may be the only process in some classes of finish after scouring; but in worsteds and Crossbred-yarn fabrics, it is desirable to crab or blow before milling.

CHAPTER VIII.

THE THEORY OF RAISING.

(76) Treatment of the Cloth. (77) Condition of the Cloth. (78) Dry Raising. (79) Damp and Wet Raising. (80) Raising Determined by the Degree of Felting. (81) Quality of the Material and the Raised Result. (82) Raising and Weave Structure. (83) Quality of the Fibre and Yarn Structure. (84) Raising of Fabrics in which Special or Fancy Yarns are used.

(76) *Treatment of the Cloth.*

RAISING has already been defined, and its action on the cloth explained. It is understood how, in this process, an otherwise thready surface is, by degrees, covered with fibre, termed the pile of the cloth. In some raised fabrics, this pile resembles that obtained in weaving: but, whereas in weaving, the pile is the result of cutting floats of either warp or weft yarns, causing the ends of the threads thus produced to project vertically from the foundation of the texture; in raising, the pile is the result of combing the extraneous fibre on to the surface of the cloth. In the manufacture of certain classes of rugs, the pile developed by raising is similar in character to that due to the operation of weaving, but it has not the same permanent effect.

The method of treating the cloth varies in routine, and also according to its condition of moisture. Raising as shown (Pars. 25 and 26) may be on the warp, weft, or both warp and weft, and the piece may be dry, damp, or wet.

The objects of raising are, by the action of the points of the teazles or card-wire, to disturb, raise up, and straighten the fibres on the surface of the fabric; and second, to produce a definite character of pile, such as the rough pile in the melton, the velvet pile in rugs, and the smooth dress-face pile in doeskins and beavers. The action of the raising points in relation to the surface of the cloth may be :—

(1) The raising points may move in the opposite direction and have a higher superficial speed than the cloth, as in the Raising Gig (Fig. 118).

(2) In card-raising machines, the card-covered rollers and the points of the clothing may be in the same direction as the cloth, with the rollers having a higher superficial speed than the latter.

(3) The cloth may be acted upon in two ways alternately; *e.g.*, both series of rollers may travel against the cloth, but the points of the card-clothing act upon the piece in one series, and the back of the card-wire in the other series of rollers.

In the first of these methods (Gig machine), the raising points resist the forward movement of the piece, combing and straightening the fibres; in the second, they draft through the fibres; and in the third, there is compound action, both methods of raising taking place in succession.

(77) *Condition of the Cloth.*

In the process of raising, the condition of the cloth as to moisture has an important effect upon the fulness and quality of the pile of fibres. This is the case in different classes of material, *e.g.*, short, medium, and long-stapled wools, mohair, alpaca, and camel's hair. In a fabric raised dry, the pile of fibres is comparatively rough, and may be readily removed in cutting; if damp, the fibres are laid in one direction, and do not form what is termed a "velvet" or vertical pile. Certain makes of fabrics, as that illustrated in Fig. 89, in the manufacture of which a more or less lustrous material is used, raising *wet* gives a wavy, undulated appearance; should the same fabric be raised *dry*, no waviness would result, but a loose, rough shag of fibres. Each condition—*dry*, *moist* or *damp*, and *wet*—has a specific effect and requires to be considered separately.

(78) *Dry Raising.*

Dry raising lifts or gets up the fibre on to the surface of the texture, so that in the cutting operation the weave and pattern due to colour may be clearly brought out. Several classes of

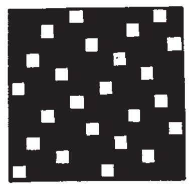


FIG. 88.—Weave for Pattern 89.

costume and suiting cloths in Cheviot, Saxony and Crossbred yarns are treated in this way. Fig. 90 is a fabric which has, in Section A, been raised dry and cut, but raised and not cut in

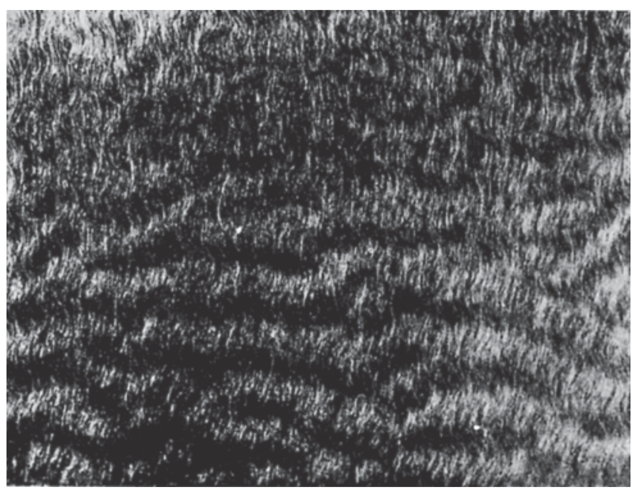


FIG. 89.

Section B. The difference in the distinctness of the textural effect is quite marked. In A, both warp and weft threads may be seen, and the details of the style, colour and texture are pronounced. These are features which dry raising should give in fabrics, in consequence of the cutting process. When the fabrics are taken direct from tentering after milling, to the cutting, which is done to obtain a comparatively rough, fibrous finish, cutting mainly clears the face of the cloth of straggling and loose fibre, and even if the operation is repeated, fails to produce the character of surface seen in Section A. In fabrics milled to a small degree, a certain amount of balk or loose fibre develops on the surface, and this can only be effectively removed by first raising dry, and then treating on the cutting machine.

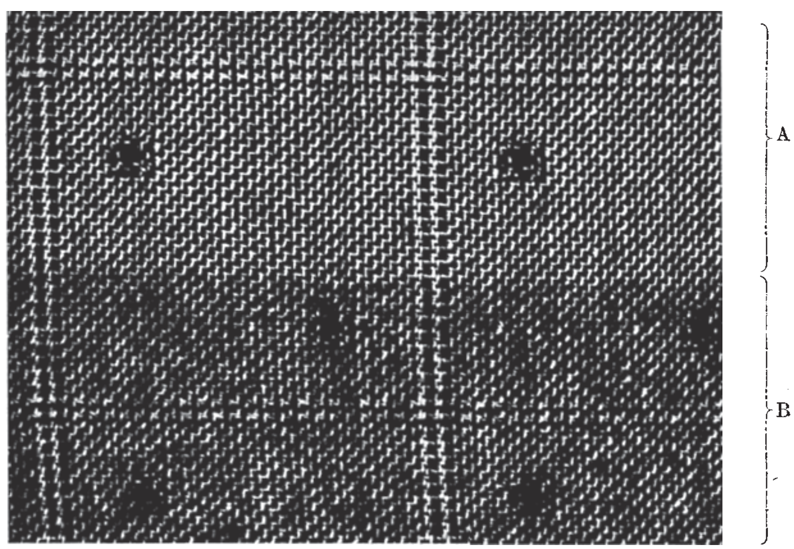


Fig. 90.

The nature of the cloth, woollen or worsted, may modify the distinctness of result, but not the comparative effect of cutting *prior* to, and *after* raising. The explanation of dry raising having such a different effect from raising damp, is, that the wool fibres, when subjected to friction in a dry condition, develop a degree of electricity that renders the wool less pliable to the combing action of the teazles. The fibres resist the raising points so far as laying, straightening, and fixing them in a uniform direction, but are, possibly, as much drawn from the surface of the threads, providing the point of contact with the teazles is equal to that in raising the cloth in a damp state.

(79) *Damp and Wet Raising.*

As seen, dry raising operates on the tangled mass of fibre, the result of milling, but if it is essential that the fibre should not only be raised, but combed and straightened, then the cloth must be, more or less, in a damp condition. The term, *damp*, is used here as distinct from the term, *wet*, which condition imparts another quality to the fibrous surface obtained. The dampness of the fabric does not lessen the effectiveness of the raising points when brought in contact with the cloth, but the fibres are drawn in a line, and in consequence of being straightened and worked in one direction, a face or lustre is acquired on the texture. It follows, that all dress-face cloths are, in the raising process, treated in this condition. By raising the piece from the beginning to the finishing end, reversing and repeating the operation several times in succession, a full pile of fibres is obtained, and brightness of finish.

Wet raising is the process which involves the greatest diversity of treatment in finishing. This will be understood if the raising routine of a woollen doeskin, or a beaver, is described. Finishing here, as regards raising, consists of treating the cloth several times at different stages of work. Prior to dyeing, the piece is practically finished, or possesses a fibrous face. Raising commences after milling, comprising at least five operations from the "tail" and "head" end alternately. After tentering and drying, what is termed "dry beating," that is, steaming and raising to lay and level the fibres, is done. Then follow the processes of cutting, brushing, recutting, rebrushing, steaming and pressing. In this way, a face or pile of fibres is developed which, by a process of boiling repeated several times, is made permanent. Subsequent to dyeing the piece is again raised, tentered, and, after blowing with steam, raised to finally straighten the fibre. The processes of cutting, blowing with steam after cutting, brushing and steaming, and pressing, further fix the lustrous finish. An interesting feature here is the nature and variety of raising. The first raising following milling is the most important for getting up and laying the fibre, but the slighter raising, termed "dry beating," following drying, the severer raising after dyeing, and a second dry beating which takes place after tentering and dyeing, are useful in developing the "face" finish.

The doeskin finish, so typical of wet raising, may be applied to cloths with a warp or a weft face. The real doeskin is the former, the weave being five or eight-end warp sateen. In the production of union pilots and beavers, in which cotton warp and low woollen weft are used, a like finish may be produced though the cloths have a weft surface. The difference in the raising routine of the doeskin and the union imitations, both as to the quality of pile and the effect on the yarns, should be explained. Examining and testing the warp threads in the doeskin after raising, show that they have suffered somewhat in strength, but have only a slight fray of fibres; but the yarns removed from the union fabric, similarly raised, have quite a shag of fibre, and have suffered in strength. It has been shown (Chapter II.) that raising across the thread has a different effect from raising on the length of the thread, and these two fabrics, doeskin and union beaver, are examples. To develop a full pile in the union fabric, raising across the yarn is necessary for the simple reason that it is only the weft yarn which has raising quality, yet the finish of the cloth must give a fibrous face in which the pile is raised on the length of the fabric.

(80) *Raising Determined by the Degree of Felting.*

All cloths, unless unduly loose in structure, may be raised to a degree. Thus, fine, thin fabrics, such as costumes and dress materials made of woollen yarn, or of worsted warp and woollen weft, are raised, though only having a moderate amount of felting. Raising may be done on the piece when in the grease, but this is chiefly for the purpose of felting the raised fibre into the foundation of the cloth in scouring and milling. Raising is definitely affected by the quality of the fibre, the structure of the yarn, and the firmness of the fabric as produced in the loom, and especially by felting. There are instances, as for example, in low-class blankets and rugs, where a soft and full pile of fibre is wanted, but not laid in a particular direction, where the operation of raising is done after preparatory milling: but to raise to the extent as in a beaver or billiard cloth, so that the surface is actually covered with a dense pile, requires excessive felting before the fabric is subjected to the action of the raising machine, as shown in the doeskin.

Felting, as explained, gives a hard, close texture, with the fibres of the yarns intermatted or milled together, and even the yarns themselves, in some cloths, formed apparently into a piece of felt. Raising, in such instances, does not so much draw and comb the fibres from separate threads of warp and weft, as from a compact texture, where the surface is covered with a quantity of milled fibre. This is exactly the nature of fabric adapted to repeated raising, especially when the cloth is in a damp or wet state. The fibres may be raised, straightened, drawn into a line with each other, and yet adhere to, and compose a permanent part of the face of the fabric.

(81) *Quality of the Material and the Raised Result.*

Textile fibres have different raising qualities. Vegetable, animal and silk fibres may be used separately, or in combination, in fabrics in which raising is practised, but hard threads, such as linen, do not raise satisfactorily. For example, if a texture with a linen warp and silk weft were raised, in a short time a shag of fibres would be formed on the silk weft, but there would be no such effect on the linen warp. A soft spun linen weft would raise, but not in the same way as woollen or silk. On the other hand, jute is a vegetable fibre that raises well on the teazle gig, the operation softening the character of the pattern in the fabric: it is mainly adapted to jute textures for tapestries, curtains and hangings.

Fibres of wool, mohair, alpaca, and camel's hair, are more suitable for raising than those alluded to, and hence it is in fabrics made of such materials that raising is more frequently and successfully done. In the use of wool, the densest pile is producible, the coarser the wool the less dense being the pile.

Two very different effects are seen in the patterns (Figs. 91 and 92) one a Cheviot, and the other a Saxony cloth, both made of the same counts of yarn and submitted to the same amount of milling and raising, with two very different effects. In the Saxony, there is a much fuller or denser pile of fibres than in the Cheviot, which will be well understood by those acquainted with the yarns which result from the use of fine and coarse wools. The Saxony yarn, equal to a 60's quality worsted, may contain about 50 per cent. more fibre than a Cheviot yarn equal to a 20's quality worsted. It must follow that, in the fabrics made of these two yarns, when felted and raised, the Saxony possesses a much closer and denser pile than the Cheviot. An examination of the fabrics shows that the Saxony

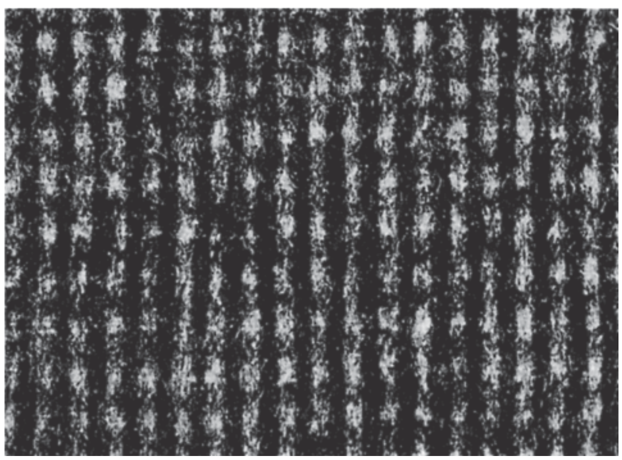


Fig. 91.

has a soft, full pile of fibres, but shorter in the staple than that of the Cheviot, and this latter characteristic is noticeable in the two illustrations. In Fig. 92 the checks of black and white are quite defined, and there is little indication of the trail of white fibres over the black checks, or the black fibres over the white checks. How different in the Cheviot pattern (Fig. 91) in which the mingling of black and white fibres from the respective checks destroys that clear definition of black and white spaces noticeable in the Saxony, and results in an intermediate grey shade. The marked dissimilarity between the two textures suggests the variety of pattern or cloth obtainable, by combining these two yarns in stripes, check and other forms; but it is the