THE WOOLMARK COMPANY

INTRODUCTION TO KNITWEAR

TRAINING MANUAL

CONTENTS

This short review aims to briefly cover some of the technical aspects which must be considered when producing quality Merino wool knitwear. It begins with wool production in Australia and follows the processing route from yarn through to fabric.

Particular attention is given to yarn selection, which is paramount to a quality knitwear product, along with the relationship between yarn and knitting machines.

Wool knitwear requires slightly different finishing procedures to other fibres and these will also be covered.

01 BENEFITS OF MERINO IN KNITWEAR

NATURAL
Merino wool is the natural fibre choice, made of a protein called keratin, the same protein as human hair.

BIODEGRADABLE
Under the right conditions Merino wool fibre takes only a few years to decompose.

RENEWABLE
Every year Australian Merino sheep produce a new fleece, which can be removed without harm to the animal.

FIBRE CRIMP
Merino wool is naturally crimped allowing for bulky yet light fabrics.

RESILIENCE
Merino wool fibres will return to their original state when bent or stretched, ensuring garments retain their shape during wear and laundering.

SOFTNESS
Australian Merino sheep are renowned for producing the finest wool. This fineness is the reason Merino wool garments have superior handle and superb drape.

COMFORT
Merino wool has the ability to respond to changes in temperature and humidity. The hygroscopic core of the wool fibre has the capacity to absorb up to 35% of its own weight in moisture (vapour) allowing humidity to move away from the body and evaporate.

02 AUSTRALIAN MERINO WOOL

The Australian Merino sheep derives its name and basic appearance from the famed Royal Merino flocks of Spain, having been introduced to Australia by European settlers over 200 years ago.

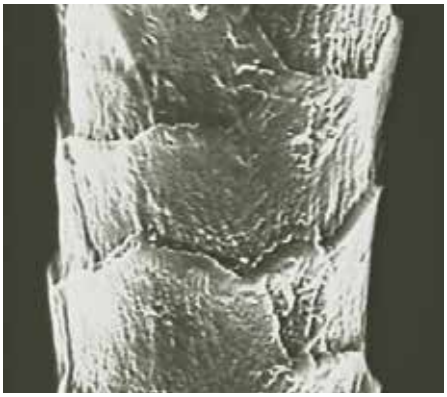
Australia is the world's largest producer of Merino wool. In 2010/11 Australia's 70 million sheep produced 345 mkgs of wool. The Australian wool clip is particularly suited to use in apparel, with 54% of annual production in 2010/11 being less than 20.6 micron. The finer the wool's diameter, the softer and more crimped it becomes. Crimp, the wave in the wool staple, contributes to the bulk and the lightness of wool knitting yarns.

Examination of a wool fibre under a microscope shows the scale structure which contributes to wool's performance qualities; for instance, these scales are the cause of felting.

Felting is the locking together of individual fibres during severe mechanical action (such as washing).

This fibre entanglement is irreversible; however if a machine-washable product is required there are a range of processes which change the surface of the fibre so that felting does not occur. Importantly these processes do not significantly affect the handle of wool.

NORMAL WOOL FIBRE



TREATED WOOL FIBRE

Micron (µm) is a measure of diameter equal to 1 millionth of a metre or 0.04 thousands of an inch; human hair is on average 45µm.

03 PROCESSING PIPELINE

The first step in creating yarn is to scour the greasy wool, this is essentially washing the wool in warm water to remove dirt and grease. The scoured and dried wool is then ready to process by one of two possible routes:

WOOLLEN ROUTE
Is shorter and used for heavier counts of yarn. In this case, fibres are randomly distributed in the yarn and are shorter than those used in a worsted yarn.

WORSTED ROUTE
Is typically used for finer counts of yarn. In this case the fibres are parallel to each other.

04 WOOLLEN PROCESSING

Scoured wool is disentangled in a card; the fibres are separated out by a series of pinned rollers moving at different relative speeds. The opened out wool fibres are stripped off the last of these rollers to make a thin web of fibre. This web is then split into strips by a series of tapes. The fine ribbon of fibres which sticks to each tape is rubbed in the condenser to make a delicate twistless strand called a slubbing. Strength is added to the slubbing by spinning.

Spinning draws out and twists the wool to make a yarn. This single strand may be suitable for weaving but not generally for knitwear as it must be two-fold. This means twisting together two yarns using opposite twist so that the yarn is balanced and doesn't snarl or twist, which leads to skewing of the knitted fabric.

05 WORSTED PROCESSING

Worsted processing shares common steps with woollen processing, however the transformation route is longer. Scoured wool is carded in a similar way to the woollen route, however it is removed from the card not as individual twistless slubbing but as a single thick sliver of parallel fibres. The next stage is a repeated sequence of gilling in which a number of different slivers are blended and then drawn out to increase the regularity. Combing, a similar process, is the next stage, in which the shorter fibres are removed to be processed as noil. The resulting combed sliver is known as top. The final stage before spinning is then drawing out of the top to make a small package of fine sliver known as a roving. This is the equivalent to the slubbing produced in the woollen route and has taken more steps to achieve.

During spinning, the roving is drawn out to about 20 times its original length and twist is inserted to produce a fine worsted yarn. Any large knots are then removed and replaced by fine splices before winding onto large packages. As with woollen yarns, worsted yarns destined for knitwear are generally two-fold.

YARN QUALITIES	
WOOLLEN	**WORSTED**
Shorter fibre length	Longer fibre length
Random fibre distribution	Parallel fibre distribution
Bulky yarns	Smooth yarns
Coarse to medium yarn counts	Medium to fine yarn counts
Wet finished knitwear	Wet or steam finished knitwear

06 YARN SELECTION

There are many factors which a knitter should take into account when selecting the right yarn for the end product.
YARN COUNT (Nm) Depending on the machine gauge and fabric structure.

MACHINE TYPE	GAUGE	YARN COUNT (Nm)
STRAIGHT BAR FULLY FASHIONED (gauge is needles per 1.5 inches)	9	9/2 - 12/2
	12	12/2 - 17/2
	15	13/2 - 20/2
	18	20/2 - 28/2
	21	22/2 - 32/2
	24	28/2 - 36/2
	27	32/2 - 40/2
V-BED FULLY FASHIONED (gauge is needles per 1 inch)	3	2/2 - 4/2
	5	4/2 - 9/2
	7	10/2 - 14/2
	8	12/2 - 17/2
	10	20/2 - 24/2
	12	24/2 - 32/2
	14	28/2 - 36/2
	16	36/2 - 48/2
	18	44/2 - 60/2
SINGLE JERSEY CUT & SEW (gauge is needles per 1 inch)	8	17/2 - 24/2
	10	22/2 - 36/2
	12	28/2 - 40/2
	14	32/2 - 48/2
	18	40/2 - 30/1
	20	48/2 - 32/1
	22	28/1 - 36/1
	24	32/1 - 40/1
	26	36/1 - 44/1
	28	48/1 - 55/1

WORSTED OR WOOLLEN
Which one of the two basic yarn types that is selected will depend on the end product required. Woollen yarns produce products that need wet finishing after knitting in order to remove the lubricants used in carding and create the characteristic bulk. Worsted yarns produce smooth compact fabrics. If the yarn and knitting conditions are clean it can be possible to finish worsted garments by steaming only, however it is generally better to give a light wet finish which has the advantage of improving fabric bulk and softness.

COLOURED OR UNCOLOURED
Depending on whether the end product is to be piece dyed.

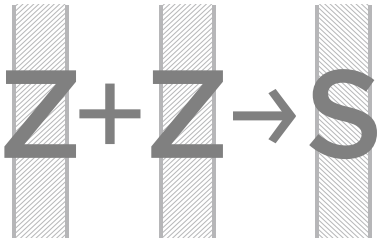
Once these decisions have been made it is essential that the yarn selected has the following attributes:

- Balance twist
- Count and twist regularity
- Correct mean fibre length
- Correct fibre diameter and distribution for the count
- Consistent and appropiate strength and extensibility
- Low yarn to metal surface friction
- Freedom from contamination
- Good dye fastness
- Free of knots

07 TWIST

A knitting yarn normally has lower twist than a weaving yarn so that it can produce a soft bulky product, however this twist must be balanced. If the yarn snarls or untwists it will cause spirality or skewing in the knitted fabric. In order to achieve balanced twist, knitwear yarns are nearly always two-folded.

By twisting together two single yarns in the reverse direction to the spinning twist and at about 60% of the spinning twist, the yarn should be balanced.



08 CONTAMINATION

Contamination can be a problem as the contaminant may dye differently from the yarn.

VEGETABLE MATTER (VM)
Plant matter picked up by the sheep whilst grazing. If the carbonising stage is not done properly VM will be seen as brown flecks in the yarn and garment.

DARK FIBRES
If present will show in pale coloured knitwear.

SYNTHETIC FIBRES
If present might not take the dye and are difficult to remove.

09 STRENGTH AND ELASTICITY

Wool fibres are strong and elastic due to the fibre structure. Yarn strength and elasticity are related to the fibre length and yarn twist. Woollen spun yarns, where the fibre length is shorter, and the twist lower, can result in garments which are more prone to weakness and more likely to wear through.

10 DYE FASTNESS

One of the most important points to consider when buying a dyed wool yarn is the colour fastness, in other words its resistance to dry rubbing and domestic washing.

The detailed process of dyeing wool is an extensive topic which cannot be covered here. However, it is worth considering the different stages in the processing pipeline at which dyeing can be carried out. Woollen yarn dyeing nearly always occurs at the loose scoured stage – just before carding. This is called stock dyeing.

Worsted yarns can be dyed at the following three stages: before spinning (as top) or after spinning in the form of open hanks or wound packages.

Stock, top and hank dyeing usually produce a bulky yarn whereas packaged dyed yarns tend to set flat and are less bulky. Package dyeing is therefore not recommended for knitwear yarns.

11 FIBRE DIAMETER

The wool fibres which make up the yarn are of fundamental importance. The following table shows the typical ranges of average fibre diameters for knitwear yarns.

The finer the wool fibre, the finer a yarn can be spun. In general both the softness and the bulk increase as the fibre diameter becomes finer. This applies to both worsted and woollen yarns.

Trying to spin fine yarns from wools with too high a fibre diameter leads to various challenges. Not only does the fabric lose its softness, but yarns also become irregular. Lower quality yarns can result in an irregular fabric surface (stitch distortion). Stitch distortion occurs when the knitted stitches, of irregular yarn, twist in different directions. Distortion is most likely seen in worsted rather than woollen fabrics and typically in yarns containing wool fibres with a diameter greater than 22 microns.

<table>
<tr><th colspan="16">TYPICAL FIBRE QUALITIES OF MERINO WOOL KNITWEAR YARNS</th></tr>
<tr><td rowspan="12">WORSTED
SPUN YARNS</td><td>17</td><td>18</td><td>19</td><td>19.50</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr>
<tr><td colspan="5" rowspan="2">Merino Extrafine
2/24 to 2/48Nm</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="8">Pure Merino wool</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3" rowspan="2">Other
2/14 - 2/32Nm</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="11">58 - 70mm length</td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td colspan="6" rowspan="2">Lambswool blend
2/24 to 2/48Nm</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="6">55 - 65mm length</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>WOOLLEN
SPUN YARNS</td><td colspan="5">Pure Lambswool
2/15 to 1/27Nm
35 - 55mm length</td><td colspan="5">Lambswool blends
2/12 to 1/14Nm
40 - 50mm length</td><td colspan="3">Soft Shetland
2/12 to 1/14Nm
48 - 60mm length</td><td colspan="3">Shetland
2/8 to 2/12Nm
48 - 60mm length</td></tr>
</table>

12 SURFACE FRICTION

For efficient knitting the yarn-to-metal friction should be low. If the yarn has a high friction it tends to stick on the knitting needles, reducing knitting efficiency and possibly causing defective products. It is always recommended that knitting yarns are waxed by the spinner to ensure optimum knitting performance.

13 KNOTS

Most Merino wool yarns produced by spinners are knot free. Any yarn breakage which occurs in knitting will result in the need for knotting. Any necessary knots should be tied at the edges of the knitted panels where they are less noticeable and can be tied more securely.

14 KNITTING

In the industry the two main types of knitting machines are flat bed machines (with two knitting beds forming the shape of an inverted "V") and the straight bar or fully fashioned frame with a single knitting bed. V-bed machines can be used for almost any knitted structure including cables and jacquards, whereas the straight bar machines are generally limited to classic, plain-knit styles.

The typical hand powered V-bed machine is simple in design, but can be used to produce a wide range of fabric structures. The garment panels can be shaped by transferring selvedge stitches to widen or narrow the piece or they can be cut out of a simple rectangular piece.

A V-bed machine with a knitting bed about two metres wide is typical of machines of this type, built for cut and sew products. A single knitted panel could, for instance, produce three bodies or four sleeves with perhaps 25% of cutting waste. The newer type of electronic V-bed is narrower, about 1.2 metres, and designed to produce shaped knitwear panels with minimal cutting waste. However, the speed of knitting is reduced because of the time taken in transferring stitches to narrow or widen the panel.

The older type of straight bar machine is highly mechanical. There are still many of these machines across the world producing classic plain knitwear styles in wool at a high rate of production. The more modern version produces a similar type of product although it may also knit Intarsia in a plain knit structure, that is a patchwork type of fabric using a number of different coloured yarns.

WOOL KNITWEAR MACHINES	
V-bed (flat bed)	Straight bar (fully fashioned)
For shaped or cut and sew products	For classic shaped products

More recent straight bar machines tend to be highly automated and, like the electronic V-beds, computer controlled. Perhaps one of the basic decisions when developing a new range is whether to make a "cut and sew" product or a shaped product. There is little doubt that a shaped product is usually better than "cut and sew" in terms of overall quality. The seams are neater and less bulky and the whole garment is usually more attractive. In addition there is very little cutting waste which is an advantage when buying a premium yarn such as wool. The cost of the extra quality is in time, whether manual or electronic machines are used, although shaped garments will take longer to knit than "cut and sew" and probably longer to make up. We strongly recommend that trials in the development of a wool knitwear range are based upon shaped products.

Straight bar machines and most V-bed machines are suitable for shaped knitwear. The only type not ideal is the single–carriage wider bed electronic V-bed. Manual machines for instance can produce excellent products at a low price provided care is taken in setting up stitch lengths, yarn tensions and ensuring machines are clean and well maintained.

Straight bar products are mainly classic plain knitted styles with worsted yarns being used on 21 gauge (14 needles/inch) or finer and woollens on the heaviest gauges. The standard for woollen lambswool yarn is 15 gauge (10 needles/inch) moving to the coarser woollens as the gauge becomes heavier.

WHICH MACHINE TYPE?	
V-BED	**STRAIGHT BAR**
Structured versatility	High productivity
Shaping possibility	Good stitch quality
Handflats: low capital expense and lower production rate	Shaped products: limited structure range
Electronic: high capital expense	High capital expense
Handflats: quality control difficult	

The V-beds give a lot more scope for structure variety. Fine gauge (14) is ideal for "Merino Cool™" products in smooth worsted yarns. This higher-value type of knitwear may often feature interesting shaping or structure detail. Medium gauge V-bed (seven or eight gauge) products can be of all types. Jacquards and structures are usually included in the gauge which is important for men's knitwear.

Moving down to the heavier five gauge, this is ideal for Aran type knitwear with traditional cable structure features. Although knitted in coarse gauge, these garments may be very soft and bulky, especially if knitted from a number of ends of finer worsted yarns together.

A relatively new approach to knitting is the use of whole garment knitting machines from companies like Shima Seiki and Stoll.

The garments resulting from these machines use one end of yarn and have no seams thus reducing labour content of the garment. Currently the finest gauge is 18npi though finer gauges are being developed by both companies.

	V-BED	STRAIGHT BAR	WHOLE GARMENT
FINE	14-18 gauge	21-27 gauge (14-18npi)	12-18 gauge
	"Cool Wool" Ladies Knit	Classic worsted Merino	Classic and Jacquard knits
MEDIUM	7-10 gauge	15-18 gauge (10-12npi)	7-10 gauge
	Men's Jacquard sweater	Classic woollen Lambswool	Men's Jacquard sweater
COARSE	3-5 gauge	9-12 gauge (6-8npi)	3.5-5 gauge
	Chunky Aran sweater	Classic woollen soft Shetland	Chunky Aran sweater and cardigans

15 MAKING UP

The making up of shaped wool knitwear is normally done by means of specialised equipment, primarily a linker for attaching the collar and shoulder seams and a cup seamer for side seams and completing the sleeves. Both machines use a simple chain stitch to attach the parts without cutting. In a linker, each stitch of the chain passes through a knitted stitch. This is known as stitch-for-stitch linking, and creates a very neat compact seam. Cup-seaming is carried out by running the two selvedges between two knurled wheels. Although not a stitch-for-stitch seam, this process is faster, and when carried out by a skilful operative, can be very neat. An overlocking machine is used extensively in cut-and-sew work. This machine simultaneously cuts and then binds the raw edge with a thread. The result is rarely as neat as linked or cup seamed panels.

16 FINISHING

FINISHING HAS THREE PURPOSES

1. To relax the fabric structure so that no further shrinkage occurs during domestic washing

2. To clean the product, removing oil and dirt accumulated during the manufacturing process

3. To provide the desired surface finish, whether soft, smooth or milled

As mentioned earlier, unless conditions are extremely clean, it is normally best to finish in water. This has the advantages of also helping the fabric to relax to its natural shape and of increasing bulk and softness by allowing fibres in the yarns to expand.

A side paddle is a simple machine for wet finishing or scouring knitwear. Garments are allowed to circulate gently in warm water and detergent for about 20 minutes before tumble-drying and steam pressing.

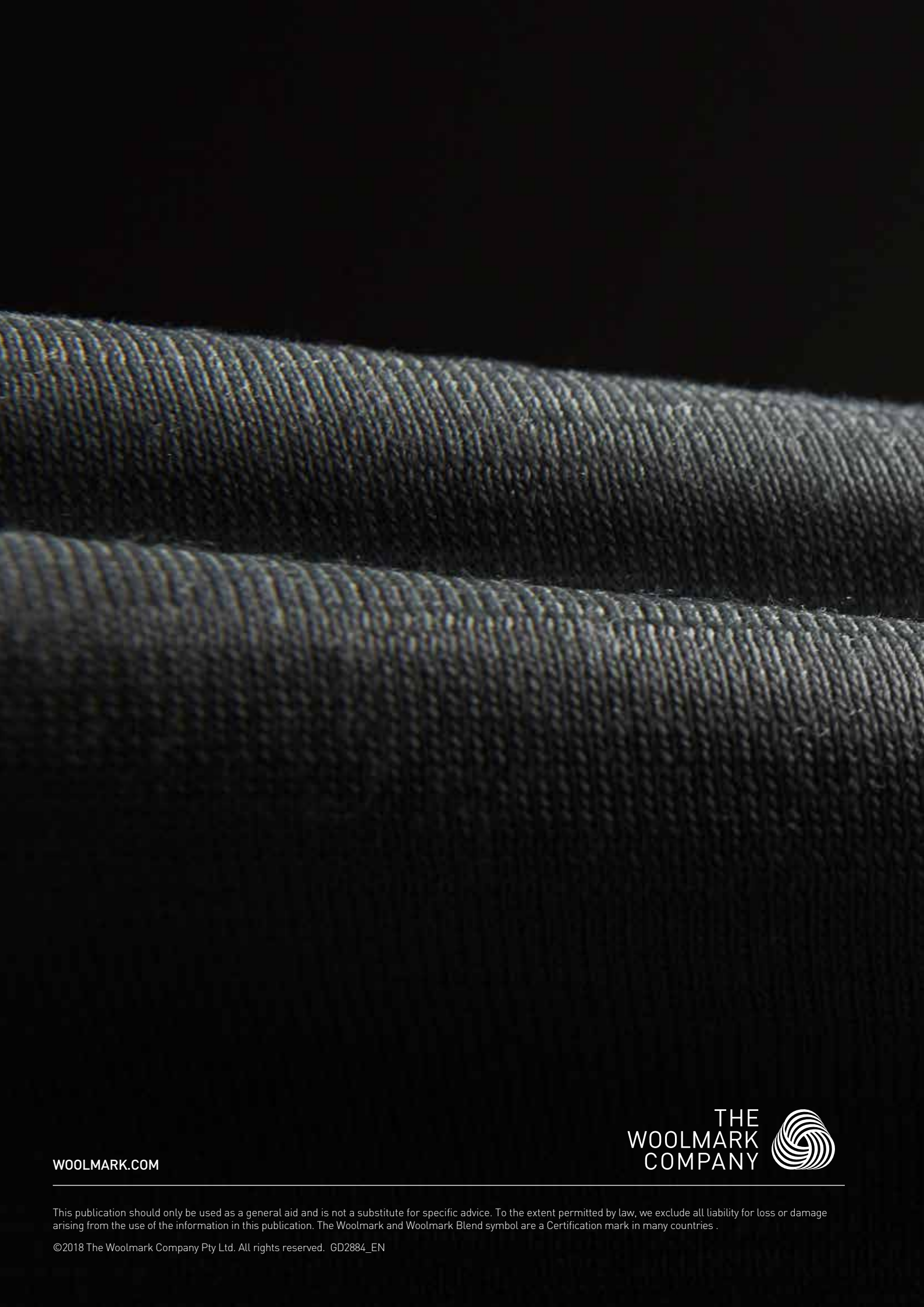
Sometimes a fuzzy "woollen" surface is required, particularly for knitwear produced from woollen spun yarns. In this case a more severe treatment is required.

The rotary milling machine is rather like a large domestic washing machine. Again warm water and detergent are used, the action is more severe than a side paddle. Whichever machine is used, a good rinse is essential afterwards to remove all traces of detergent and oils.

After the attachment of a label and a final press the garment is ready for delivery to the retailer.

17 SUMMARY

In this review, the different stages of manufacture have been examined very briefly. The Woolmark Company technical staff, located across the globe, are available to provide detailed guidance on all aspects of knitwear production.



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