CENTROCOT
Innovation experience

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To

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To kind attention of

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INVESTIGATION
IN PHYSICAL DURABILITY
OF KNITTED FABRIC AND FINISHED GARMENTS

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1. INTRODUCTION

Apparel and footwear production currently accounts for 8.1% of global greenhouse gas emissions[1], as much as the total climate impact of the entire European Union. This is mainly due to the enormous exploitation of planetary resources and to the uncontrolled growth of *fast fashion* phenomenon, producing cheap, disposable clothing, made indiscriminately, imprudently, and often without consideration for environmental and labour conditions.

Fast-changing fashion trends and a decrease in product quality have reduced the life span of clothes. Thus, the first pathway to circularity is to ensure the longevity of textile products through circular design by increasing the durability and repairability of textiles[2]. In fact, increasing durability allows longer use and reuse of products, contributing to extending the life cycle of textiles.

Physical durability is defined as the ability of a material to exist for a long time without significant corruption and, especially for fabrics, to resist continuous wear, use and care.

Several underlying design principles increase the durability and quality of garments, including technical requirements for colour fastness and fabric resistance, and practical requirements like clothes that are multifunctional and fit for purpose and that repair kits and/or spare parts are available.

Product longevity and durability is fundamental in circularity of textiles because 40% of all reasons for consumers discarding clothes are linked to (physical) changes of garments[3] including, for example:

- a hole or tear
- worn-out appearance
- loss of elasticity or shape
- stains
- colour changing or fading.

For all these reasons, durability has recently become a hot topic in discussion about what determines the circularity of textile products.

In fact, in March 2022 the European Commission published its proposal for the *Ecodesign for Sustainable Products Regulation*[4]. Its objective is to set binding requirements on how products are designed, through a specific act for textile products, covering aspects such as "**durability**, repairability, fibre-to-fibre recyclability, and mandatory recycled content, minimise and track presence of substances of concern, reduce adverse impacts on climate and environment, microplastic shedding". At the same time, the European Commission launched the *EU strategy for sustainable and circular textiles*[5], which highlights the same characteristics and adds that "failures in quality such as colour fastness, tear strength or the quality of zippers and seams are among the main reasons for consumers to discard textiles".

It is evident how ESPR framework will drive towards setting a range of requirements for textile products, including product durability, considered a fundamental requirement to more circular and sustainable products.

[1] https://quantis.com/report/measuring-fashion-report/
[2] https://www.eea.europa.eu/publications/textiles-and-the-environment-the
[3] Laitala, K., et al., 2015, 'Making clothing last: a design approach for reducing the environmental impacts', International Journal of Design 9(2), pp. 93-107.
[4] https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en
[5] https://environment.ec.europa.eu/strategy/textiles-strategy_en

Durability can be measured in laboratory by testing fabrics' resistance to abrasion and pilling, tear resistance, strength and elasticity, felting and shrinkage.

For example, natural wear can be simulated through different methods, nowadays it is mostly done by testing both the fabric's pilling, abrasion, fuzzing and matting resistance.

In order to determine dimensional stability properties, fabrics are washed in the standardized washing machine called Wascator, simulating home laundry for testing after-care modification: changes of fabrics or garments, colour fastness to detergents or bleach, appearance changes and retention of creases.

Specific testing protocol was defined in order to assess the durability of fabrics and clothes and compare with limit values.

Thus, the present document describes and elaborates the results obtained from the assessment of the durability of 4 samples of fabric (**Sensitive Classic**, **Sensitive Plus**, **Sensitive Power Evo**, **Sensitive Plus Bonded**) and 2 samples of garments (**blazer** made with Sensitive Plus Bonded and **trousers** made of Sensitive Power Evo).

All tests and their results are also reported in the Test Report No. 24RA10311 (Sensitive Plus Bonded), 24RA10314 (Sensitive Power Evo), 24RA10328 (Sensitive Classic), 24RA10329 (Sensitive Plus), issued by Centrocot SpA on October 15, 2024.

2. CHARACTERIZED MATERIAL

The samples under investigation are knitted fabric produced by Eurojersey S.p.A. and garments tailored from same fabric (Sensitive fabric). The material constituting all Sensitive fabric is Polyamide and Lycra® in different compositions.

In order to investigate the physical durability of textile materials, samples were treated and analysed according to the analytical protocols reported in Chapter 3.

The tested samples and respective names are reported in Table 1.

Table 1. Samples and respective names, reference numbers and features.

Fabric	Type	Ref. Centrocot	Composition	Weight
Sensitive Classic	Fabric	**24LA16564/01 – 15 cycles** **24LA16564/02 – 50 cycles** **24LA16564/03 – 100 cycles**	75% microfibre PA / 25% Lycra®	164 g/m^2
Sensitive Plus	Fabric	**24LA16565/01 – 15 cycles** **24LA16565/02 – 50 cycles** **24LA16565/03 – 100 cycles**	73% microfibre PA / 27% Lycra®	117 g/m^2
Sensitive Power Evo	Fabric	**24LA16528/01 – 15 cycles** **24LA16528/02 – 50 cycles** **24LA16528/03 – 100 cycles**	74% microfibre PA / 26% Lycra®	250 g/m^2
Sensitive Plus Bonded	Fabric	**24LA16555/01 – 15 cycles** **24LA16555/02 – 50 cycles** **24LA16555/03 – 100 cycles**	73% microfibre PA / 27% Lycra®	250 g/m^2
Sensitive power Evo	Garment - Trousers	**24LA16553/01 – 15 cycles** **24LA16553/02 – 50 cycles** **24LA16553/03 – 100 cycles**	74% microfibre PA / 26% Lycra®	250 g/m^2
Sensitive Plus Bonded	Garment - Blazer	**24LA16556/01 – 15 cycles** **24LA16556/02 – 50 cycles** **24LA16556/03 – 100 cycles**	73% microfibre PA / 27% Lycra®	250 g/m^2

3. TEST METHODS

Specific testing protocol was defined in accordance with reference protocols developed by Technical Working Groups and with the customer's requirements, in relation to the assumed applications for the fabric and apparel.

The following laboratory tests are included in this set of tests, in accordance with relevant standards.

- **Domestic washing and drying for textile testing UNI EN ISO 6330:2022**

Domestic washing has been reproduced following the procedure in UNI EN ISO 6330:2022, using the Wascator with ECE - DETERGENT 98 and sodium percarbonate as additive for increasing the abrasion during the washing to simulate the worst case. The same flat drying is then applied to all the samples.

These steps are carried out for simulating the use and care of the samples and are performed at three different levels

- Minimum use → 15 cycles of washing and drying
- Medium use → 50 cycles of washing and drying
- Maximum use → 100 cycles of washing and drying

- **Durability analyses**

The test conducted on the six samples are reported and described in Table 2.

Table 2. Durability tests and respective description, reference standards and tested samples.

Test name	Description/target	Standard	Tested samples
Dimensional change in domestic wet washing and drying	Dimensional change is calculated by measuring marked distances before and after the treatment to see if the article is able to maintain the original size.	UNI EN ISO 5077:2008 + UNI EN ISO 6330:2022 + UNI EN ISO 3759:2011	All samples after 15, 50, 100 cycles of washing
Method for assessing appearance of apparel and other textile end products after domestic washing and drying	Samples are visually analysed by evaluating the change in colour and pilling with respect to the original one, to assess if treatment created a damage in the sample.	UNI EN ISO 15487:2018	All samples after 15, 50, 100 cycles of washing
Spirality	Spirality is calculated by measuring the change in position of two marked area of the sample, to see if there is distortion	ISO 16322-2:2021	All fabric samples after 15, 50, 100 cycles of washing

	of the article and changes in shape.		
Slippage resistance of yarns at a seam. Fixed load method	The resistance of the seams in finished garments is tested by applying a constant load and measuring the slippage resistance (of the already present seam).	UNI EN ISO 13936-2:2004	All garments before washing and after 15, 50, 100 cycles of washing
Abrasion (Martindale)	The sample is rubbed with wool fabric (abrading sample) at 9 kPa of pressure. The end test is considered when 1 yarn is broken (hole formation). If no hole is detected, the test is interrupted after 105000 rubbings (upon customer's request).	UNI EN ISO 12947-1:2000 + EC 1-2010 + UNI EN ISO 12947-2:2017	All fabric samples before washing and after 15, 50, 100 cycles of washing
Formation to surface pilling, fuzzing or matting. Pilling box method	The sample is evaluated after 14400 rotations of the pilling box. Pilling, fuzzing and matting are evaluated by three valuers on a 5-to-1 scale.	UNI EN ISO 12945-1:2021 + UNI EN ISO 12945-4:2021	All fabric samples before washing and after 15, 50, 100 cycles of washing
Stretch	The dimensional stability after 5 cycles of load application is evaluated along two directions of the knit.	UNI EN ISO 20932-1:2022	All fabric samples before washing and after 15, 50, 100 cycles of washing
Bursting strength. Pneumatic method	The bursting strength and bursting distension are measured with membrane apparatus to evaluate mechanical resistance of the material.	UNI EN ISO 13938-2:2020	All fabric samples before washing and after 15, 50, 100 cycles of washing
Measurement of surface colour	The colour of the fabric is measured using the spectrophotometer Datacolor 600V and colour coordinates are compared to see colour difference.	UNI EN ISO 105-J01:200	All fabric samples before washing

Calculation of colour differences	Colour coordinates of treated samples are compared to see colour difference with respect to the original.	UNI EN ISO 105-J03:2009	All fabric after 15, 50, 100 cycles of washing

The purpose of these analyses is to characterize the material from physico-mechanical point of view after washing treatment, in order to understand the physical performance after simulated use.

To perform the test, the sample is used as is, by cutting out the suitable specimens for each individual analysis method.

All tests are carried out after conditioning at standard atmosphere of 20±2°C and 65±4% humidity or 23±1°C and 50±5% humidity, according to the imposed conditions.

4. RESULTS

The presented Technical Report describes the set of tests carried out on the fabric samples and garments in order to predict the impact of a product's physical durability on its potential Duration of Service lifetime. The tests have been defined according to EN or ISO standard test methods.

The results of the tests are here expressed as absolute values and put in comparison with most recent proposed protocols from Technical Working Groups.

These protocols are usually developed by following different methodologic approaches, for example by assessing the physical durability according to subcategories of products based on their intended use and technical *performance* and defining for each one a specific testing protocol. On the other hand, a methodology for evaluating the lifespan of products could be based on the study of the physical solidity and resistance of products over time according to predefined usage and maintenance cycles, starting from the *defects* that cause the end of life of the products.

It is worth noting that, at the moment of this report, the considered reference values are from ongoing studies, thus they are still under discussion and further variations could be considered in the future. For this reason, these values are not unquestionable and should be carefully considered, even though they are a very useful tool to assess durability of products.

Results from testing protocol are reported and discussed below separately for each sample and garment.

SENSITIVE CLASSIC FABRIC (REF. NO. 24RA10328)

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The sample has been evaluated after washing and drying and the following observations have been reported in Table 3.

Table 3. Evaluation of appearance of apparel and textiles after domestic washing.

Specimen	Permanent creasing (smoothness)	Surface change (pilling, matting…)	Change of colour
After 15 cycles	5	5	4-5
After 50 cycles	5	5	4-5
After 100 cycles	5	5	4-5
Reference	≥4	≥4,5	≥4,5

Values reported in Table 3 are referred to a grade scale in which 5 means no change (very smooth appearance) and 1 is referred to a severe change with respect to the initial material (creased and severely wrinkled appearance). Reference values can be reported quantitatively as in the results table or qualitatively as the "Absence of defect: non hole and no broken yarn" after laundry.

The detailed visual assessment scale is reported in Table 4.

Table 4. Evaluation of smoothness, surface change and colour change according to the visual assessment.

Specimen	Smoothness	Surface (pilling)	Change in colour
Grade 5	Very smooth, pressed, finished appearance	No change	No change in colour
Grade 4	Smooth, pressed, finished appearance	Partially formed pills	n.d.
Grade 3.5	Fairly smooth, but nonpressed appearance	n.d.	n.d.
Grade 3	Mussed, nonpressed appearance	Moderate pilling	n.d.
Grade 2	Rumpled, obviously wrinkled	Distinct pilling	n.d.
Grade 1	Crumpled, creased and severe wrinkled	Severe pilling	Strong change in colour

No holes were detected in knitted fabric after laundering cycles. No significant change was observed after 100 laundering cycles in Sensitive Classic fabric.

Figure 1. Appearance of Sensitive Classic fabric samples before and after 15, 50, 100 cycles of washing and drying.

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the fabric before treatment. The (-) sign indicates a shrinkage and the (+) sign indicates an elongation.

Table 5. Dimensional change for the Sensitive Classic fabric.

Specimen	Dimensional change in length	Dimensional change in width
After 15 cycles	-2.5%	+1.0%
After 50 cycles	-3.0%	+1.0%
After 100 cycles	-3.0%	+1.0%
Reference	≤3% or <5%	

Spirality

The spirality of the knitted fabric is tested after washing and flat drying, by measuring the distance between two marked points, to calculate the twisting in fabric after washing.

Table 6. Percentage of spirality for the Sensitive Classic fabric.

Specimen	Percentage of spirality
After 15 cycles	0.1%
After 50 cycles	0.2%
After 100 cycles	0.3%
Reference	0-4%

Abrasion

The abrasion test is carried out using the Martindale method for evaluation of the presence of abrasion before and after the different number of cycles of washing and drying.

Table 7. Abrasion test results for sample of Sensitive Classic fabric.

Specimen	Number of rubbings	Formation of pills	Elimination of pills
Before washing	>100000	No	No
After 15 cycles	>100000	No	No
After 50 cycles	>100000	No	No
After 100 cycles	>100000	No	No
Reference	>25000 or >20000		

As reported in Table 7 none of the parameters indicate surface abrasion for Sensitive Plus fabric with the Martindale test, thus they are highly above the threshold of >25000 cycles for pants and >20000 cycles for shirts.

Formation to surface pilling, fuzzing or matting. Pilling box method

The pilling box test is carried out for evaluating the presence of surface pilling, fuzzing or matting before and after the different number of cycles of washing and drying.

Table 8. Pilling test results for sample of Sensitive Classic fabric.

Specimen	Pilling	Fuzzing	Matting
Before washing	5	5	5
After 15 cycles	5	5	5
After 50 cycles	5	5	5
After 100 cycles	5	5	5
Reference	≥4,5		

Reference values for all considered products and testing protocols are ≥4,5, as reported in the results table, because no fabric aspect change should be present after care. Results are expressed with the following visual assessment (Table 9), correlating a discrete numeric value to the respective sample aspect.

Table 9. Evaluation of pilling, fuzzing and matting according to the visual assessment.

Specimen	Pilling	Fuzzing	Matting
Grade 5	No change	No change	No change
Grade 4	Partially formed pills	Slight surface fuzzing	Slight surface matting
Grade 3	Moderate pilling	Moderate surface fuzzing	Moderate surface matting
Grade 2	Distinct pilling	Distinct surface fuzzing	Distinct surface matting
Grade 1	Severe pilling	Dense surface fuzzing	Dense surface matting

Stretch

The stretch test is carried out with the dynamometer to verify the ability of the fabric to return to the original size after 5 cycles of stretch (35 N load and 30 min of relaxation after release of tension).

Table 10. Evaluation of stretch for Sensitive Classic fabric.

Specimen	Stretch whale	Growth whale	Recovery whale	Stretch course	Growth course	Recovery course
Before washing	109%	11.4%	88.6%	169%	20.2%	79.8%
After 15 cycles	112%	12.4%	87.6%	168%	20.0%	80%
After 50 cycles	113%	13.8%	86.2%	171%	22.2%	77.8%
After 100 cycles	114%	14.6%	85.4%	166%	19.6%	80.4%

The determination of elasticity of fabrics is important for assessing product deformation during use. The threshold is specified as minimum recovery after 30 minutes of relaxation and it is fixed at 90% for maximum level. In this case, the growth is reported in the table above for whale and course.

The target values can be also defined for an intermediate level with 85%≤recovery≤90% or for a basic level with 80%≤recovery≤85%.

For Sensitive Classic fabric, the average stretch values are within the *basic level* after 100 cycles of washing.

Measurement of surface colour and calculation of colour difference

The colour difference of the fabric is measured with the Spectrophotometer Datacolor 600V and results are reported in Table 11.

Table 11. Colour coordinates for sample od Sensitive Classic fabric.

Specimen	Before washing	After 15 cycles	After 50 cycles	After 100 cycles
Colour difference	ΔE = 0.00	ΔE = 0.25	ΔE = 0.28	ΔE = 0.59

The difference of colour between the reference sample (24LA16564, fabric as is) is calculated after mapping of colour coordinates of the fabric before any laundering and by measuring the difference with the spectrophotometer. The color distance between colors ΔE includes deviations along three main directions, namely the L* axis representing lightness, the a* axis representing red-green deviation and the b* axis representing the yellow-blue deviation[6].

Note that the human eye does not perceive color distances (green, red, yellow, blue) to the same extent as differences in colorfulness (chroma) and lightness. Generally, a person will first perceive distances in color shade, then in colorfulness, and finally in lightness. This method allows to mathematically calculate the color differences which are not always visible at naked eye.

Usually, a color distance of ΔE = 1 is an acceptable color difference for brilliant yellow or green shades, but for achromatic grey colors, in contrast, ΔE = 1 represents a different color that is not acceptable.

Bursting strength. Pneumatic method

In order to set the experimental conditions and establish the test area, a first test has been carried out using two areas: 7.3 and 10 cm^2. See Appendix 1 for further information about the choice of the test area.

The results of the burst resistance of Sensitive Classic fabric are reported in Table 12.

Table 12. Burst resistance with pneumatic method for Sensitive Classic (test area 7.3 cm^2).

Specimen	Burst resistance (average)	Burst resistance (without membrane correction*)	Average height at burst
Before washing	313 kPa	456 kPa	28 mm
After 15 cycles		>440 kPa	>28 mm
After 50 cycles		>440 kPa	>28 mm

[6] https://www.datacolor.com/wp-content/uploads/2022/06/color-management-ebook-4-en.pdf

After 100 cycles		>440 kPa	>28 mm
Reference	≥400 for class I 300<&>400 for class II		

*Membrane deformation value is 143 kPa used to correct the values for obtaining the average burst value according to the ISO 13938-2.

Differently to the *as is* fabric, due to the high elasticity and burst resistance of the fabric, the samples after all cycles of washing do not bust. This means that probably the knitted fabric “relaxes” and becomes more elastic. This behaviour should not be considered a *fail* because denotes a higher fabric strength, thus respecting the technical requirements from testing protocols.

SENSITIVE PLUS FABRIC (REF. NO. 24RA10329)

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The sample has been evaluated after washing and drying and the following observations have been reported in Table 13.

Table 13. Evaluation of appearance of apparel and textiles after domestic washing.

Specimen	Permanent creasing (smoothness)	Surface change (pilling, matting…)	Change of colour
After 15 cycles	5	5	4-5
After 50 cycles	5	5	4-5
After 100 cycles	5	5	4-5
Reference	≥4	≥4,5	≥4,5

The detailed visual assessment scale is previously reported in Table 4.

Reference values can be reported quantitatively as in the results table or qualitatively as the “Absence of defect: non hole and no broken yarn” after laundry.

No holes were detected in knitted fabric after laundering cycles. No significant change was observed after laundering cycles in Sensitive Plus Fabric, as reported in Figure 2.

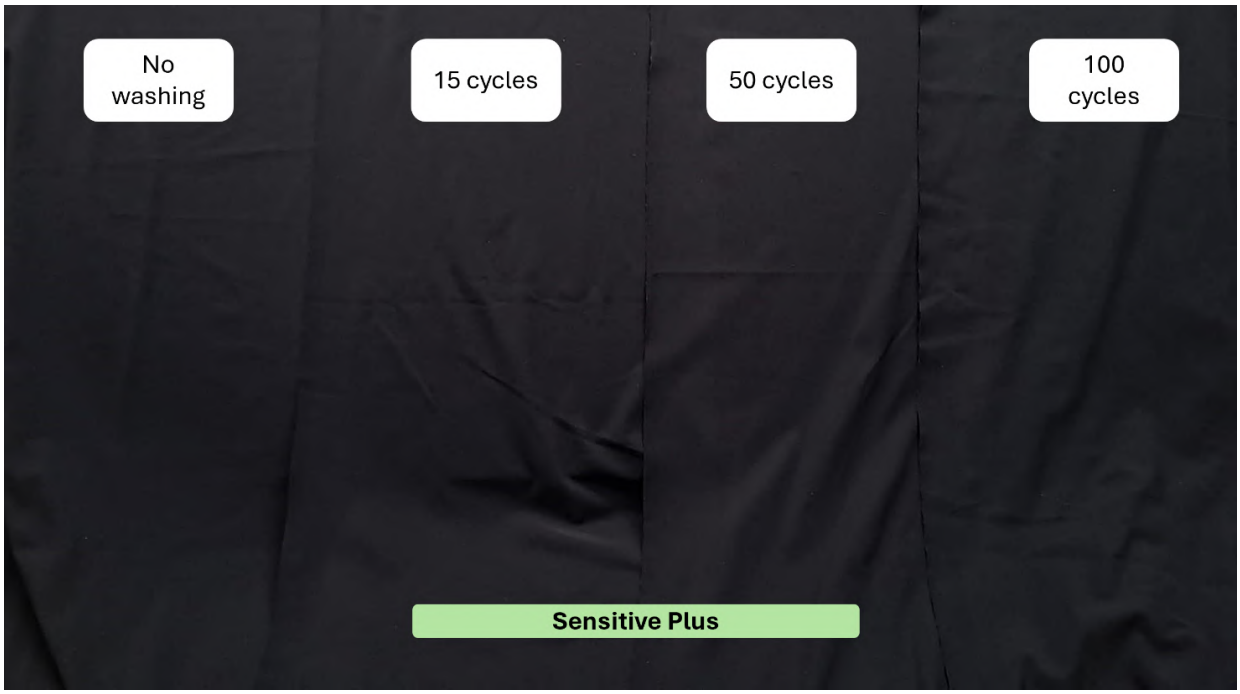

Figure 2. Appearance of Sensitive Plus fabric samples before and after 15, 50, 100 cycles of washing and drying.

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the fabric before treatment.

Table 14. Dimensional change for the Sensitive Plus fabric.

Specimen	Dimensional change in length	Dimensional change in width
After 15 cycles	-4.5%	+1.5%
After 50 cycles	-5.5%	+1.5%
After 100 cycles	-5.5%	+2.0%
Reference	≤3% or <5% for class I (aspirational) ≤5%-7% for class II (basic)	

Spirality

The spirality of the knitted fabric is tested after washing and flat drying, by measuring the distance between two marked points, to calculate the twisting in fabric after washing.

Table 15. Percentage of spirality for the Sensitive Plus fabric.

Specimen	Dimensional change in length
After 15 cycles	1.0%
After 50 cycles	0.8%
After 100 cycles	0.9%
Reference	0-4%

Abrasion

The abrasion test is carried out using the Martindale method for evaluation of the presence of abrasion before and after the different number of cycles of washing and drying.

Table 16. Abrasion test results for sample of Sensitive Plus fabric.

Specimen	Number of rubbings	Formation of pills	Elimination of pills
Before washing	>100000	No	No
After 15 cycles	>100000	No	No
After 50 cycles	>100000	No	No
After 100 cycles	>100000	No	No
Reference	>25000 or >20000		

As reported in Table 16 none of the parameters indicate surface abrasion for Sensitive Plus fabric with the Martindale test, being highly above the threshold of >25000 cycles or >20000 cycles.

Formation to surface pilling, fuzzing or matting. Pilling box method

The pilling box test is carried out for evaluating the presence of surface pilling, fuzzing or matting before and after the different number of cycles of washing and drying.

Table 17. Pilling test results for sample of Sensitive Plus fabric.

Specimen	Pilling	Fuzzing	Matting
Before washing	5	5	5
After 15 cycles	5	5	5
After 50 cycles	5	5	5
After 100 cycles	5	5	5
Reference	≥4,5		

Reference values for all considered products and testing protocols are ≥4,5, as reported in the results table, because no fabric aspect change should be present after care. Results are expressed with the visual assessment reported in Table 9, correlating a discrete numeric value to the respective sample aspect.

Stretch

The stretch test is carried out with the dynamometer to verify the ability of the fabric to return to the original size after 5 cycles of stretch (35 N and 30 min of relaxation after release of tension).

Table 18. Evaluation of stretch for Sensitive Plus fabric.

Specimen	Stretch whale	Growth whale	Recovery whale	Stretch course	Growth course	Recovery course
Before washing	104%	7.0%	93%	182%	25.4%	74.6%
After 15 cycles	113%	10.2%	89.8%	177%	25.4%	74.6%
After 50 cycles	114%	11.6%	88.9%	179%	25.4%	74.6%
After 100 cycles	113%	13.6%	86.4%	186%	29.4%	70.6%

As previously described, the threshold is specified as minimum recovery after 30 minutes of relaxation and it is fixed at 90% for maximum level.

The target values are 80%≤recovery≤85% for basic level and 85%≤recovery≤90% for intermediate level.

For Sensitive Plus fabric, the average stretch values are slightly below the basic level after 100 cycles of washing, mainly due to the high stretch in course direction.

Measurement of surface colour and calculation of colour difference

The colour of the fabric is measured at the standard conditions with the Spectrophotometer Datacolor 600V and results are reported in Table 19.

Table 19. Colour coordinates for sample of Sensitive Plus fabric.

Specimen	Before washing	After 15 cycles	After 50 cycles	After 100 cycles
Colour difference	ΔE = 0.00	ΔE = 0.25	ΔE = 0.27	ΔE = 0.41

The difference of colour between the reference sample (24LA16565, fabric as is) is calculated after mapping of colour coordinates and is considered non-significant (ΔE<1).

Bursting strength. Pneumatic method

The results of the burst resistance of Sensitive Plus fabric are reported in Table 20.

Table 20. Burst resistance with pneumatic method for Sensitive Plus.

Specimen	Burst resistance (average)	Burst resistance (without membrane correction*)	Average height at burst
Before washing	265 kPa	411 kPa	28 mm
After 15 cycles		>430 kPa	>27 mm
After 50 cycles		>430 kPa	>27 mm
After 100 cycles		>430 kPa	27 mm
Reference	≥400 for class I 300<&>400 for class II		

*Membrane deformation value is 146 kPa used to correct the values for obtaining the average burst value according to the ISO 13938-2.

Differently to the *as is* fabric, due to the high elasticity and burst resistance of the fabric, the samples after all cycles of washing do not bust. This means that probably the knitted fabric “relaxes” and becomes more elastic. This behaviour should not be considered a *fail* because denotes a higher fabric strength, thus respecting the technical requirements from testing protocols.

SENSITIVE POWER EVO FABRIC (REF. NO. 24RA10314)

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The sample has been evaluated after washing and drying and the following observations have been reported in Table 21.

Table 21. Evaluation of appearance of apparel and textiles after domestic washing.

Specimen	Permanent creasing (smoothness)	Surface change (pilling, matting…)	Change of colour
After 15 cycles	5	5	4-5
After 50 cycles	5	5	4-5
After 100 cycles	5	5	4-5
Reference	≥4	≥4,5	≥4,5

Reference values can be reported quantitatively as in the results table or qualitatively as the "Absence of defect: non hole and no broken yarn" after laundry.

No holes were detected in knitted fabric after laundering cycles. No significant change was observed after laundering cycles in Sensitive Power Evo sample, as visible in Figure 3.

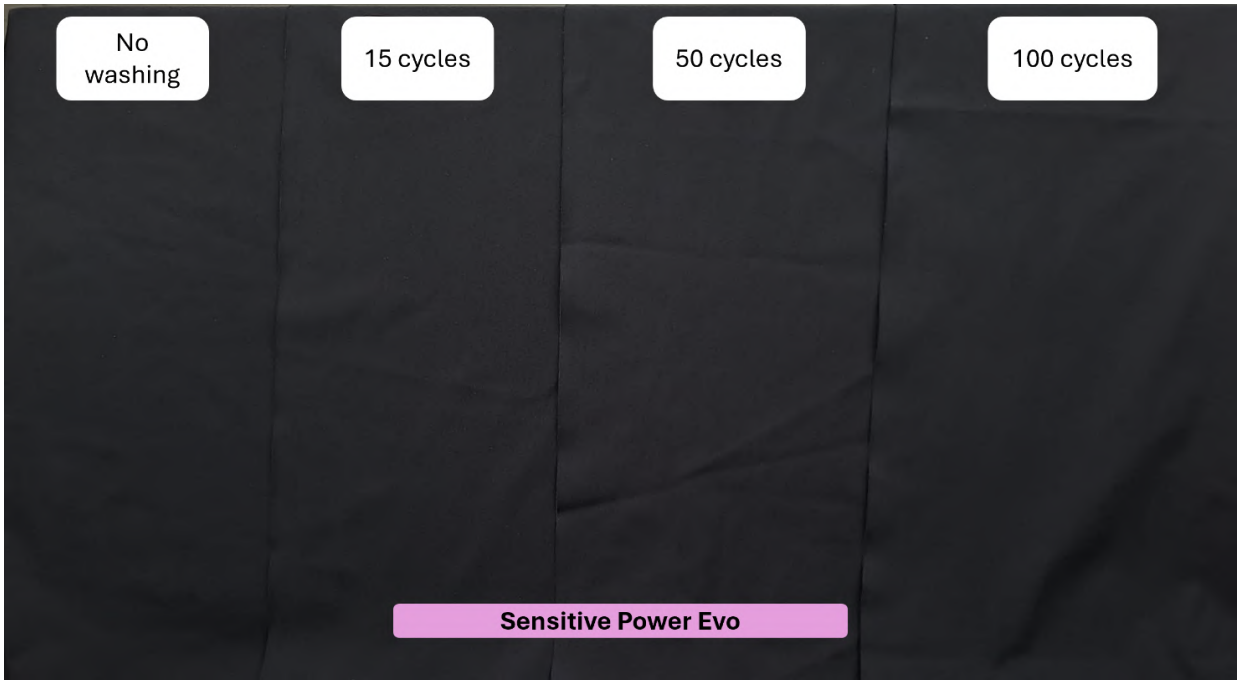

Figure 3. Appearance of Sensitive Power Evo fabric samples before and after 15, 50, 100 cycles of washing and drying.

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the fabric before treatment.

Table 22. Dimensional change for the Sensitive Power Evo fabric.

Specimen	Dimensional change in length	Dimensional change in width
After 15 cycles	-3.0%	+2.0%
After 50 cycles	-3.0%	+2.5%
After 100 cycles	-4.0%	+3.0%
Reference	≤3% or <5% for class I	

Spirality

The spirality of the knitted fabric is tested after washing and flat drying, by measuring the distance between two marked points, to calculate the twisting in fabric after washing.

Table 23. Percentage of spirality for the Sensitive Plus fabric.

Specimen	Dimensional change in length
After 15 cycles	0.7%
After 50 cycles	0.7%
After 100 cycles	0.9%
Reference	0-4% for class I

Abrasion

The abrasion test is carried out using the Martindale method for evaluation of the presence of abrasion before and after the different number of cycles of washing and drying.

Table 24. Abrasion test results for sample of Sensitive Power Evo fabric.

Specimen	Number of rubbings	Formation of pills	Elimination of pills
Before washing	>100000	No	No
After 15 cycles	>100000	No	No
After 50 cycles	>100000	No	No
After 100 cycles	>100000	No	No
Reference	>25000 or >20000		

As reported in Table 24 none of the parameters indicate surface abrasion for Sensitive Power Evo fabric with the Martindale test, after treatment highly above the threshold of >25000 cycles and >20000 cycles.

Formation to surface pilling, fuzzing or matting. Pilling box method

The pilling box test is carried out for evaluating the presence of surface pilling, fuzzing or matting before and after the different number of cycles of washing and drying.

Table 25. Pilling test results for sample of Sensitive Power Evo fabric.

Specimen	Pilling	Fuzzing	Matting
Before washing	5	5	5
After 15 cycles	5	5	5
After 50 cycles	5	5	5
After 100 cycles	5	5	5
Reference	≥4,5		

Reference values for all considered products and testing protocols are ≥4,5, as reported in the results table, because no fabric aspect change should be present after care. Results are expressed with the visual assessment reported in Table 9, correlating a discrete numeric value to the respective sample aspect.

Stretch

The stretch test is carried out with the dynamometer to verify the ability of the fabric to return to the original size after 5 cycles of stretch (35 N and 30 min of relaxation after release of tension).

Table 26. Evaluation of stretch for Sensitive Power Evo fabric.

Specimen	Stretch whale	Growth whale	Recovery whale	Stretch course	Growth course	Recovery course
Before washing	44%	2.0%	98%	109%	12.6%	87.4%
After 15 cycles	49.1%	2.8%	97.2%	102%	10.2%	89.8%
After 50 cycles	49.8%	4.4%	95.6%	107%	12.0%	88%
After 100 cycles	49.7%	5.2%	94.8%	99.9%	13.2%	86.8%

The stretch and the growth (both course and whale) are well maintained also after 100 cycles of washing, with negligible difference with respect to the fabric before care simulation.

For Sensitive Power Evo fabric, the average stretch values are within the aspirational level after 100 cycles of washing (recovery >90% after 30 minutes).

Measurement of surface colour and calculation of colour difference

The colour of the fabric is measured at the standard conditions with the Spectrophotometer Datacolor 600V and results are reported in Table 27.

Table 27. Colour change for sample of Sensitive Power Evo fabric.

Specimen	Before washing	After 15 cycles	After 50 cycles	After 100 cycles
Colour difference	ΔE = 0.00	ΔE = 0.22	ΔE = 0.38	ΔE = 0.42

The difference of colour between the reference sample (24LA16528, fabric as is) is calculated after mapping of colour coordinates and is considered non-significant (ΔE<1).

Bursting strength. Pneumatic method

The results of the burst resistance of Sensitive Power Evo fabric are reported in Table 28.

Table 28. Burst resistance with pneumatic method for Sensitive Power Evo.

Specimen	Burst resistance (average)	Burst resistance (without membrane correction*)	Average height at burst
Before washing	611 kPa	754 kPa	28 mm
After 15 cycles	610 kPa	748 kPa	28 mm
After 50 cycles	593 kPa	789 kPa	28 mm
After 100 cycles	602 kPa	800 kPa	28 mm
Reference	≥400 for class I 300<&>400 for class II		

*Membrane deformation value used to correct the values is 143 before washing, 138 kPa after 15 cycles, 196 kPa after 50 cycles, 198 kPa after 100 cycles.

Due to the higher strengthen and “rigidity” of the fabric, the burst resistance of the Sensitive Power Evo is remarkably higher with respect to reference value, also after 100 cycles of washing.

SENSITIVE PLUS BONDED FABRIC (REF. NO. 24RA10311)

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The sample has been evaluated after washing and drying and the following observations have been reported in Table 29.

Table 29. Evaluation of appearance of apparel and textiles after domestic washing.

Specimen	Permanent creasing (smoothness)	Surface change (pilling, matting…)	Change of colour
After 15 cycles	5	5	4-5
After 50 cycles	5	5	
After 100 cycles	5	5	
Reference	≥4	≥4,5	≥4,5

Reference values can be reported quantitatively as in the results table or qualitatively as the "Absence of defect: non hole and no broken yarn" after laundry.

No holes were detected in knitted fabric after laundering cycles. No significant change was observed after laundering cycles in Sensitive Plus Bonded, as visible in Figure 4. Appearance of Sensitive Plus Bonded fabric samples before and after 15, 50, 100 cycles of washing and drying.

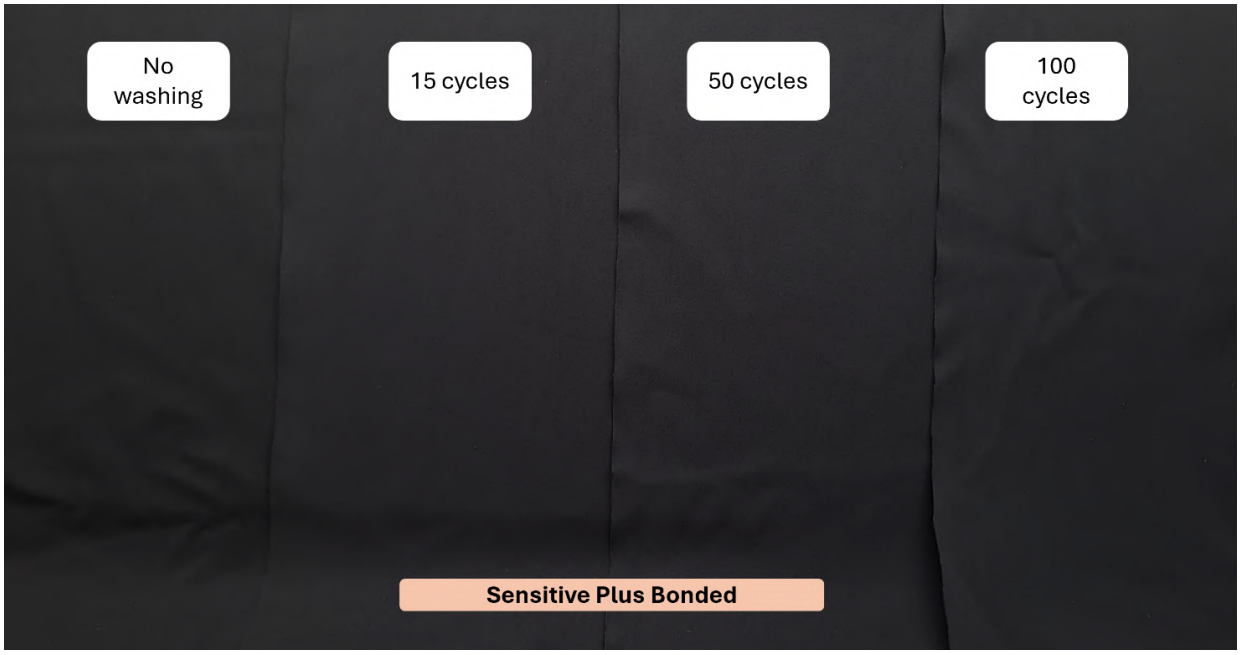

Figure 4. Appearance of Sensitive Plus Bonded fabric samples before and after 15, 50, 100 cycles of washing and drying.

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the fabric before treatment.

Table 30. Dimensional change for the Sensitive Plus Bonded fabric.

Specimen	Dimensional change in length	Dimensional change in width
After 15 cycles	-1.5%	0.0%
After 50 cycles	-2.0%	0.0%
After 100 cycles	-2.0%	0.0%
Reference	≤3% or <5% for class I	

Spirality

The spirality of the knitted fabric is tested after washing and flat drying, by measuring the distance between two marked points, to calculate the twisting in fabric after washing.

Table 31. Percentage of spirality for the Sensitive Plus Bonded fabric.

Specimen	Dimensional change in length
After 15 cycles	0.6%
After 50 cycles	0.2%
After 100 cycles	0.5%
Reference	0-4% for class I

Abrasion

The abrasion test is carried out using the Martindale method for evaluation of the presence of abrasion before and after the different number of cycles of washing and drying.

Table 32. Abrasion test results for sample of Sensitive Plus Bonded fabric.

Specimen	Number of rubbings	Formation of pills	Elimination of pills
Before washing	>100000	No	No
After 15 cycles	>100000	No	No
After 50 cycles*	>100000	No	No
After 100 cycles	>100000	No	No
Reference	>25000 or >20000		

As reported in Table 32 none of the parameters indicate surface abrasion for Sensitive Plus Bonded fabric with the Martindale test. Nonetheless, after 50 cycles, the yarn was broken, showing a hole in the knit. After 100 cycles of laundering, the fabric shows abrasion resistance highly above the threshold of >25000 cycles and >20000 cycles.

Formation to surface pilling, fuzzing or matting. Pilling box method

The pilling box test is carried out for evaluating the presence of surface pilling, fuzzing or matting before and after the different number of cycles of washing and drying.

Table 33. Pilling test results for sample of Sensitive Plus Bonded fabric.

Specimen	Pilling	Fuzzing	Matting
Before washing	5	5	5
After 15 cycles	5	5	5
After 50 cycles	5	5	5
After 100 cycles	5	5	5
Reference	≥4,5		

Reference values for all considered products and testing protocols are ≥4,5, as reported in the results table, because no fabric aspect change should be present after care. Results are expressed with the visual assessment reported in Table 9, correlating a discrete numeric value to the respective sample aspect.

Stretch

The stretch test is carried out with the dynamometer to verify the ability of the fabric to return to the original size after 5 cycles of stretch (35 N and 30 min of relaxation after release of tension).

Table 34. Evaluation of stretch for Sensitive Plus Bonded fabric.

Specimen	Stretch whale	Growth whale	Recovery whale	Stretch course	Growth course	Recovery course
Before washing	80.4%	4.4%	95.6%	94.8%	6.8%	93.2%
After 15 cycles	78.8%	4.4%	95.6%	93.3%	6.8%	93.2%
After 50 cycles	79.4%	5.4%	94.6%	88.2%	4.8%	95.2%
After 100 cycles	79.6%	5.2%	94.8%	91.7%	6.8%	93.2%

Reference value is specified as minimum recovery after 30 minutes of relaxation and it is fixed at 90% for maximum level.

For Sensitive Power Evo fabric, the average stretch values are within the aspirational level of >90% recovery after 100 cycles of washing.

Measurement of surface colour and calculation of colour difference

The colour of the fabric is measured at the standard conditions with the Spectrophotometer Datacolor 600V and results are reported in Table 35.

Table 35. Colour change for sample of Sensitive Plus Bonded fabric.

Specimen	Before washing	After 15 cycles	After 50 cycles	After 100 cycles
Colour difference	ΔE = 0.00	ΔE = 0.04	ΔE = 0.31	ΔE = 0.40

The difference of colour between the reference sample (24LA16556, fabric as is) is calculated after mapping of colour coordinates and considered non-significant (ΔE<1).

Bursting strength. Pneumatic method

The results of the burst resistance of Sensitive Plus Bonded fabric are reported in Table 36.

Table 36. Burst resistance with pneumatic method for Sensitive Plus Bonded.

Specimen	Burst resistance (average)	Burst resistance (without membrane correction*)	Average height at burst
Before washing	551 kPa	695 kPa	28 mm
After 15 cycles	610 kPa	716 kPa	28 mm
After 50 cycles	522 kPa	723 kPa	28 mm
After 100 cycles	506 kPa	710 kPa	28 mm
Reference	≥400 for class I 300<&>400 for class II		

*Membrane deformation value used to correct the values is 144 before washing, 106 kPa after 15 cycles, 201 kPa after 50 cycles, 204 kPa after 100 cycles.

Due to the higher strengthen and “rigidity” of the fabric, the burst resistance of the Sensitive Plus Bonded is remarkably higher with respect to reference value, also after 100 cycles of washing.

SENSITIVE POWER EVO TROUSERS

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The trousers have been evaluated after washing and drying and the following observations have been reported in Table 37.

Table 37. Evaluation of seams appearance in apparel after domestic washing.

Specimen	Change of aspects of seams
After 15 cycles	5
After 50 cycles	5
After 100 cycles	5
Reference	≥4

In finished textile product, the appearance of seams is evaluated, according to the standards "Photographic Seam Smoothness appearance" for a single stitched seam and double stitched seam AATCC Test Method 88B. The value of 5 in evaluation scale refers to the best level of seam appearance.

After washing treatments, no alteration in the surface/structural appearance of the garment was observed after laundering cycles in Sensitive Power Evo trousers, as clearly visible in Figure 5. Appearance of Sensitive Power Evo trousers before and after 15, 50, 100 cycles of washing and drying.

Only moderate button degradation is observed after 15 cycles and distinct button degradation after 50 and 100 cycles, but clearly this is not dependent on fabric.

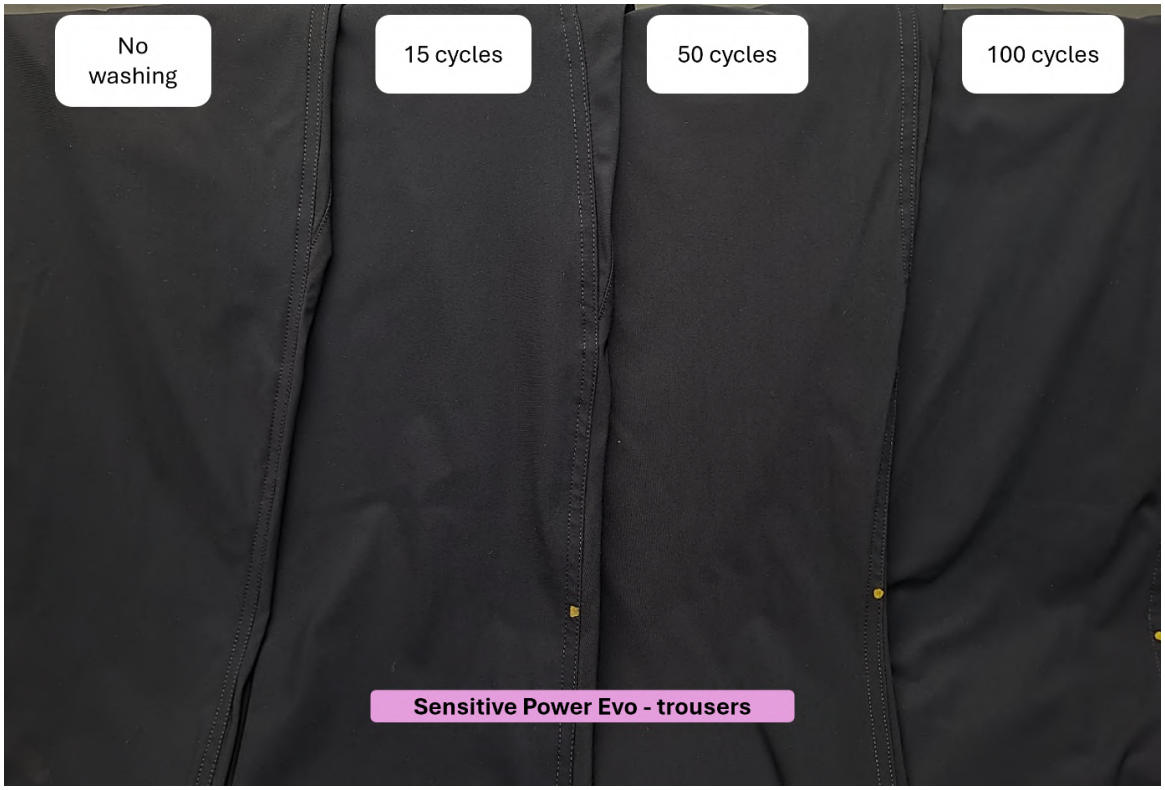

Figure 5. Appearance of Sensitive Power Evo trousers before and after 15, 50, 100 cycles of washing and drying.

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the trousers before treatment.

Table 38. Dimensional change for the Sensitive Power Evo trousers, measured in different points.

Dimensional changes of	After 15 cycles	After 50 cycles	After 100 cycles
Waist width	0%	+2.0%	+4.0%
Front leg-crocth length	0%	0%	-2.0%
Back leg-crocth length	-0.5%	0%	-1.5%
Outside leg length with belt and unseamed hem	-1.0%	-1.0%	-2.0%
Internal leg-crotch length	-1.0%	-1.0%	-2.0%
Half leg width	0%	0%	+1.0%

As in the case of fabric, the reference value can be set at ≤3% dimensional change after several cycles of care. After 100 cycles of washing and drying a slight increase is visible, especially in waist width, compared to the dimensional change until 50 cycles.

Slippage resistance of yarn at a seam

The slippage resistance test is performed on sample (seam) already present on the finished garment, to test robustness of seams during use.

Table 39. Slippage measured in mm of aperture in trousers' single stitched seam.

Specimen	Slippage
Before washing	1 mm
After 15 cycles	1 mm
After 50 cycles	1 mm
After 100 cycles	1 mm

The resulting values reported in Table 39 refer to the slippage expressed in mm of aperture of the single stitched seam, under a constant load (120 N). No reference value is available, but a comparison could be done between the seam in trousers before washing and the seam in trousers after 100 cycles of washing. As reported in the results table, no change in seam resistance is detected after simulated use.

SENSITIVE PLUS BONDED BLAZER

Method for assessing appearance of apparel and other textile end products after domestic washing and drying

The blazer has been evaluated after washing and drying and the following observations have been observed.

Table 40. Evaluation of seams appearance in apparel after domestic washing.

Specimen	Change of aspects of seams
After 15 cycles	5
After 50 cycles	5
After 100 cycles	5
Reference	≥4

In finished textile product, the appearance of seams is evaluated, according to the standards “Photographic Seam Smoothness appearance” for a single stitched seam and double stitched seam AATCC Test Method 88B. The value of 5 in evaluation scale refers to the best level of seam appearance.

After washing treatments, no alteration in the surface/structural appearance of the garment was observed after laundering cycles in Sensitive Plus Bonded blazer, as clearly visible in Figure 6.

Only moderate button degradation is observed after 15 cycles and distinct button degradation after 50 and 100 cycles, but clearly, as for the trousers, this is not dependent on fabric.

Figure 6. Appearance of Sensitive Plus Bonded blazer before and after 15, 50, 100 cycles of washing and drying

Dimensional change in domestic wet washing and drying

The dimensional change in domestic wet washing and drying is expressed as a percentage after different cycles of washing and drying, in comparison with the blazer before treatment.

Table 41. Dimensional change for the Sensitive Plus Bonded blazer, measured in different points.

Dimensional changes of	After 15 cycles		After 50 cycles	After 100 cycles
Collar length	-0.5%		-0.5%	-0.5%
Total side length	-1.0%		-1.0%	-1.0%
Shoulder point	-2.0%		-2.0%	-2.0%
Center back length	-1.5%		-1.5%	-2.0%
Length seam back length	-0.5%		-0.5%	-1.0%
Bottom sleeve width	0%	0%	-1.0%	

The reference value of durability is set at ≤3% of dimensional change.

Slippage resistance of yarn at a seam

The slippage resistance test is performed on sample (seam) already present on the finished garment, to test robustness of seams during use.

Table 42. Slippage measured in mm of aperture in blazer's single stitched seam.

Specimen	Slippage
Before washing	1 mm
After 15 cycles	1 mm
After 50 cycles	1 mm
After 100 cycles	1 mm

The resulting values reported in Table 42 refer to the slippage expressed in mm of aperture of the single stitched seam, under a constant load (120 N).

No reference value is available, but a comparison could be done between the seam in blazer before washing and the seam in blazer after 100 cycles of washing. As reported in the results table, no change in seam resistance is detected after simulated use.

5. CONCLUSIONS

Product durability and longevity are fundamental in circularity of textiles since 40% of all reasons for consumers discarding clothes are linked to physical damages.

Testing durability by means of laboratory tests is the most straightforward way to obtain scientific proof of duration of products, by simulating use and by testing fabrics' resistance to abrasion and pilling, tear resistance, strength and elasticity, felting and shrinkage, investigating the formation of damage that usually leads to the disposal of garments.

In the present study report, an experimental protocol has been developed in order to determine fabric properties, by simulating home laundry (washing and drying) and testing after-care modifications.

The assessment of the durability of 4 samples of Sensitive fabric (**Sensitive Classic**, **Sensitive Plus**, **Sensitive Power Evo**, **Sensitive Plus Bonded**) and 2 samples of garments (**blazer** made with Sensitive Plus Bonded and **trousers** made of Sensitive Power Evo) has been reported.

Each sample was subjected to 15, 50 and 100 cycles of laundry and analytical results have been compared with the *as is* samples (before washing), to simulate different degrees of use and care.

The results of the present durability study, in general, show high longevity of samples, with almost no variations after 15 cycles of washing and drying, being in agreement with the proposed target values from Technical Working Groups, but also minimal variation after 50 and 100 cycles of care, that is far most challenging.

More in detail, the evaluation for each sample gave the following results:

- **Sensitive Classic Fabric** showed high degree of durability, with high performance especially considering appearance (colour, surface, smoothness), dimensional stability, spirality, abrasion resistance, resistance to pilling and colour difference after 100 cycles of care.
  The fabric is very elastic and showed high degree of stretch, with the *basic level* of recovery (80%≤recovery≤85%). This elasticity also was higher after washing, preventing the sample from bursting during the burst resistance test.
- **Sensitive Plus Fabric** showed optimal durability, with high performance especially considering appearance (colour, surface, smoothness), spirality, abrasion resistance, resistance to pilling and colour difference after 100 cycles of care. The fabric demonstrated slightly lower dimensional stability, with values still falling within aspirational level (dimensional change <5%) after 15 cycles and still a *basic level* dimensional change (≤5%-7%) after 50 and 50 cycles. The fabric is also very elastic and showed high degree of stretch, with the *basic level* of recovery after 100 cycles. This elasticity also was higher after washing, preventing the sample from bursting during the burst resistance test.
- **Sensitive Power Evo Fabric** showed very high degree of durability, with good performance especially considering appearance (colour, surface, smoothness), dimensional stability, spirality, abrasion resistance, resistance to pilling and colour difference after 100 cycles of care.
  The fabric is more rigid, thus it demonstrated lower degree of stretch, with average values within *aspirational level* of recovery >90%) and high burst resistance values.
    - **Sensitive Power Evo Trousers** are highly durable garment, both for appearance (color, seams, creasing) and mechanical properties (seam resistance) after 100 cycles of washing and drying. The trousers also display good dimensional stability up to 50 cycles of laundering, slightly increasing in dimension after 100 cycles.

- **Sensitive Plus Bonded Fabric** showed the highest durability, with optimal performance considering appearance (colour, surface, smoothness), dimensional stability, spirality, abrasion resistance, resistance to pilling and colour difference after 100 cycles of care.
  The fabric is very rigid, demonstrating lower stretch and high value of recovery after stretching, as well as high values of burst resistance values also after 100 cycles.
    - **Sensitive Plus Bonded blazer** is highly durable garment, with optimal performance in appearance (color, seams, creasing), in mechanical properties (seam resistance) and in dimensional stability after 100 cycles of washing and drying.

The reference value used for evaluation of durability are form ongoing studies of technical Working Groups and should be considered with attention, nevertheless they are very useful tool to measure the duration of a product, as reported in the present evaluation.

Moreover, apart from numerical thresholds or reference values, the comparison between *as is* samples and fabric after 15, 50 and 100 washing cycles demonstrated that all the fabrics keep almost unaltered their peculiar product features, meaning that they are able to last long during use and care processes and the consumer will not dispose them after few cycles of use.

6. ATTACHED DOCUMENTS

Together to the present Technical Report, the following attachments are provided:

- Summary table named "Data_summary_Eurojersey_durability" with all average values from laboratory analysis for each sample, useful for rapid comparison.

- Test Reports generated from laboratory analysis containing values for each test. In particular, the test reports are:
    - 24RA10311 for Sensitive Plus Bonded fabric and blazer
    - 24RA10314 for Sensitive Power Evo fabric and trousers
    - 24RA10328 for Sensitive Classic fabric
    - 24RA10329 for Sensitive Plus fabric

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APPENDIX 1

BURSTING TEST WITH PNEUMATIC METHOD.

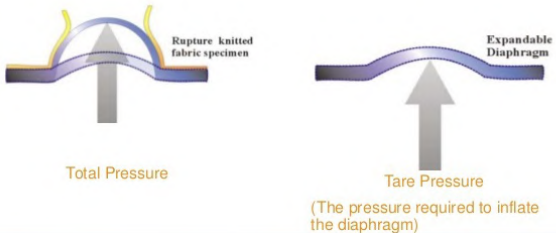
The bursting test is a crucial method to help the consumers learn about the product's breakage performance once applied a directional push force.

The pneumatic method for the determination of bursting strength and bursting distension (ISO 13938-2) is carried out by placing the sample of knitted fabric under a glass dome with a certain diameter, with an extendable diaphragm below.

During the test, the fabric expands and break (**bursting**) under the load applied to the fabric in a perpendicular way.

Bursting strength points are referred to the maximum force (pressure) measured during the process of pressing the fabric in the direction of the spherical top bar perpendicular to the plane of the specimen until it is broken.

It is a significant mechanical index of the fabric, directly reflecting the durability index of knitted fabric when the specimen is deformed and ruptured by the external pressure from the top.



In the bursting strength test, the larger the test area, the larger the test area of the specimen subjected to stress and the more yarns will be stressed on the fabric. Thus, with the increase in the test area, the bursting strength should be reduced.

In the present study, two different test areas were tested, namely 7.3 cm^3 and 10 cm^2, to see difference and set test parameters.

It was observed that for 10 cm^2 test area, the values of bursting strength for samples after different cycles of washing were almost the same but the samples did not burst, thus leading to incomplete analysis.

For this reason, the 7.3 cm^3 test area was considered more adequate, since the values of burst resistance showed some differences.

The value of bursting resistance in kPa were taken into account without the correction for the diaphragm, in order to be able to compare samples.