Textile quality management

Mr Dale Carroll

CSIRO Textile and Fibre Technology

Testing and quality management

Quality management (QM) is the portion or section of the overall management function that determines and implements the quality policy. Quality is the collective features and characteristics of a product or service that reflects on its ability to satisfy stated or implied needs of the client.

Quality is fitness for purpose for the intended end use or customer.

Quality management requires a system of evaluations that may or may not require product testing to be carried out. In most cases involving textile products, some form of physical or chemical testing and evaluation will be required to determine conformance or non-compliance.

What does testing involve?

There is a wide range of test types available so you must be aware of the reason you are testing and for what purpose the test results will be used. The testing method must be determined before beginning the sampling and testing to ensure that the results are useable for all parties concerned. The test method or work instructions need to be documented.

Selecting the most appropriate test method

It is important to know exactly what you are trying to measure or verify and the reason why you are measuring it.

Testing may be carried out for one of the following purposes:

- **quality control** – for example, testing raw materials, finished product, appraisal testing
- **quality assurance** – testing samples on the run to allow changes to be made to improve the quality or confirm conformance of the product during or prior to production
- **conformance** – testing to show compliance with a specification or performance criteria.

Carrying out the test strictly in accordance with the test method

It is important that if you wish to compare results either for quality control testing, quality assurance or conformance testing that the testing is carried out strictly in accordance with all of the requirements of the test method.

Sampling, conditioning, test equipment, specimen preparation, testing procedure, evaluation and rating and reporting of results must all be carried out strictly in accordance with the prescribed test method. Failure to follow any or all of the details of the test method can result in significant differences in results between operators and laboratories.

International and Australian Test Methods are often updated, retaining the same test method number but changing the date of issue. It is important to be sure you are using the current and most up-to-date test method.

The Internet is an excellent way of verifying currency of test methods for all major Australian and International Test Methods. All major standards bodies have a search website available where it is possible to order a copy of the test method or check the current information available on the test method.

Analysing the results

Once the test results are derived, the precision of the result and uncertainty of the actual reported result need to be taken into consideration before an assessment is made on the compliance or non-compliance of a product based on one test result. It is important to understand the true meaning and implications of the test result.

Sampling

The most important step in testing is to select for testing a sample that is representative of the whole of the batch, consignment or production run. If the sample is not representative of the lot, the test will give a result that does not indicate the likely performance of the bulk of the lot.

Fabric sampling and preparation of test specimens

Sampling and sample preparation are the most important steps in evaluating a sample. If the sample is not representative and prepared in the correct manner the result will be of little value.

All major test methods have sections dedicated to sampling and sample preparation techniques prior to testing.

General guidelines for sampling: example

The following example considers tensile strength testing of fabrics.

Perform sampling in accordance with statistical rules (see ISO 2859-1).

Ensure throughout sampling and specimen preparation that handling imposes the minimum possible tensile stress so as to prevent incorrect extension of the textile fabric.

Selection of the laboratory sample

Select the laboratory sample from a test lot to be representative of properties of the textile fabric. Check the representative nature of sampling from the start or end of the textile fabric.

Take the laboratory sample from across the full fabric width.

Sampling of the test specimens from the laboratory sample

Before sampling the test specimens from the laboratory samples, condition the laboratory samples free from tension, for at least 18 hours on a smooth horizontal surface with free access of air exposed to the standard atmosphere.

For woven fabrics, take specimens so that each contains different weft threads.

Take the test specimens at least 100 millimetres from the edge distributed across the entire laboratory sample. Take a sufficient number of test specimens (at least three) to be in accordance with established statistical variation for the product.

For patterned fabrics or fabrics with a textured surface, take care that the specimens contain all characteristic parts of the pattern, ensuring that the parts of the pattern likely to be sensitive to abrasion are contained in the test specimens.

Take care that none of the cases selected for sampling shows signs of damage or dampness incurred during transit or storage.

Selecting packages of yarn

In the absence of a material specification, select 10 yarn packages from the bulk sample, taking as nearly as possible the same number of packages from each case and choosing packages at random from the top, middle and bottom layers in cases from the middle and sides of the layers.

Yarns from fabrics

If woven or knitted fabrics need to be sampled, the sample must be large enough to provide a sufficient number of test specimens.

Understanding what is being tested for

Consider prior to testing what you are trying to determine. Are you looking for the weakest places, mean result, peak result or subjective result? Correct sampling or incorrect sampling techniques can and will effect the accuracy and precision of all of the above.

If the sampling is not representative of the bulk of the material, the result may be of little meaning.

Textile testing laboratory conditions

There are a number of different types of tests, but when testing strictly according to a test method, controlled testing conditions will be required. In this case all testing will be carried out at standard conditions to ensure repeatability of test results from one location to another and from one day to the next.

It is important that all samples are tested in the same conditions. The standard testing conditions for testing textiles are 20 ±2°C and 65 ±3% R.H.

All samples must be pre-conditioned prior to testing. This involves placing the samples in an atmosphere of higher temperature and low humidity to ensure the samples after pre-conditioning (or pre-dried) approach standard conditions (that is, standard level of moisture in the sample) from the dry side. After pre-conditioning the sample must be allowed to condition in the standard atmosphere until moisture equilibrium is reached.

All tests must be carried out strictly in accordance with the documented test method. This is designed to give consistency within the testing and allows the ability to compare test results from various laboratories and at various times.

Regular inter-laboratory trials are conducted by various organisations, such as Interwoolabs, NATA and Testex, to allow accredited laboratories to compare differences between laboratories and within laboratory variations.

Effects of moisture

As natural fibres take up far more moisture than synthetic fibres, pre-condition and conditioning of samples have a significant effect on their physical properties.

The tensile strength and extensibility of wool trends to decrease when it is wet compared with cotton, whose tensile strength increases when it is wet.

A number of performance properties of wool are affected by changes in moisture within the fibre.

In the case of polypropylene, tensile properties do not change as no significant amount of moisture is taken up by the fibre.

Moisture variation will have no effect on most mechanical properties of synthetic fibres.

Reasons for testing

Client confidence

Testing can be carried out to give a manufacturer or client an understanding of the characteristics of a particular product and give them confidence that a product will meet their expectations.

Research and development

In the area of research, testing is used to look at variations and the effects they may have on various performance criteria.

It is used to evaluate the ability of the experimental product to meet the required end use.

In the area of product development, testing is used as a way of measuring improvement in a product's performance compared to the current product.

In all of these evaluation processes it is important that the testing is always carried out in a standard manner to allow a true comparison of test results and, therefore, performance.

Natural fibres, such as wool and cotton, take up far more moisture at standard conditions than do synthetic fibres, such as nylon, polyester and polypropylene. Therefore, it is very important that all fibres and fabrics are tested after standard conditioning. That is when moisture equilibrium is reached in each fibre type. Moisture equilibrium will occur in a much shorter time for synthetic fibres than natural fibres.

For standard testing, the time to reach equilibrium for each fibre must be determined by each individual laboratory, depending upon the air conditioning circulation and methods used.

Types of tests

Physical testing

Physical tests involve such processes as breaking, stretching, abrading and flexing All of the physical attributes of fibres, yarn or fabrics may be tested, including the parameters of the manufacturing process.

Chemical testing

Chemical tests involve fibre identification and dissolving or removing substances from fibres, yarns or fabrics and testing the composition or make-up of items. Chemical tests include testing the performance of additives such as dyes or surface finishes and their reaction to certain reagents, such as sunlight or water.

Performance testing

Performance tests normally measure the attributes of the fibre or fabric, such as flammability, electrostatic propensity, moisture and thermal resistance.

Appearance testing

Appearance tests involve subjectively determining the change in appearance of a fabric after use; that is, creasing, wrinkling, frosting and puckering.

Trouble shooting and dispute resolution testing

These tests all arise from the above test types but are usually a combination of tests used to diagnose the source of the problem.

This can be related to the raw material, production, finishing, condition of use, or something the product has been subjected to after manufacture. These tests are usually carried out on the final product.

What tests do you use?

It is important to pick the test type that meets your requirements.

There is no point of doing a three-day test in a laboratory to check a production machine during its operation when it is too late to instigate any corrective action if the product is out of specification.

For process testing (online testing) the method needs to be instantaneous so that a 'typical result' can be obtained quickly to allow a production parameter to be changed if necessary on the run. It may not be the same result that would be obtained in a standard testing laboratory, but with experience it allows trained operators to make the necessary changes to ensure the product conforms to the specification at that point of the manufacturing process. Process testing and the results obtained are essential to ensure a product or manufacturing process is under control.

Quality assurance (QA) testing

QA tests are designed to ensure a manufactured product conforms to the specification. It is carried out prior to the next process. It may involve testing the raw material or ingoing material or testing at any part of the production or supply pipeline that allows for a non-conforming product to be isolated or modified to meet the required specification.

Quality control (QC) testing

QC testing is appraisal testing, which occurs after the product has been completed. It usually involves testing for compliance with a specification or customer requirements. Normally, if the product fails QC testing there is nothing that can be done to gain conformance to the specification. It is normally a pass/fail test.

Specifications

It is important that all of the requirements of a specification are fully understood and agreed upon by all parties prior to entering into a contract.

The specification usually involves the product's composition, required physical properties, actual test methods to be used to determine each of the required properties and the specification requirements or pass/fail criteria.

After a specification has been agreed upon there is no point in debating the non-conformance of a particular requirement as being too demanding to be met. These discussions need to be clarified prior to accepting a specification. Failure to do so can be a very costly experience.

Specifications may be written for a particular product or end use or may be generic in nature, such as The Woolmark Specifications or Australian Garment Mark, or they may be very specific for a particular fabric for a specialised end use.

Who produces test methods?

There is a wide range of test methods being produced throughout the world. Each standardisation body produces test methods applicable to their environment and conditions of use. The test methods are usually put together with the cooperation of a large group of technical experts specialising in the particular field. The proposed test method is then normally distributed to a wide user audience for comment. Once all of the comments are received and considered, the final test method is produced.

Standards Australia's test methods are the most commonly used within Australia but, as an industry body, they are attempting wherever practical to adopt ISO (International Organization for Standardization) test methods, but retain the Australian Standards Committee for making input into the ISO test methods and making final decisions on whether or not particular standards will be adopted in Australia.

When do we test?

To ensure conformance to a specification or requirement it is important to test or verify your product as soon as possible in the production pipeline.

Ideally, carry out QA testing of raw materials. Manufacturing process checks and testing along the production line ensure conformance.

Quality control testing in a controlled environment should be carried out when the final product has been produced to confirm conformance to the required specification.

Testing as early as possible in the production pipeline allows any potential non-conformance to be identified and corrective actions taken to rectify the non-conformance and prevent a non-compliant product from being produced.

Reasons for testing

Testing is usually an integral part of a quality management program.

The quality management program revolves around controlling inputs, processes and output. Testing is one of the best ways of ensuring conformance of product and process. It is not only a matter of checking materials. The whole manufacturing process needs to be controlled.

The process conditions used need to conform to the processing specifications and product specifications.

The output at each stage of the manufacturing pipeline needs to be confirmed and conform to the specification at each step of the process.

The output of each step of the process and the final product needs to be tested to confirm compliance to the specification.

This does not necessarily mean carrying out physical or chemical testing. The testing or verification process will vary from product to product and depend on the compliance requirements. In some cases a visual inspection (QC) is all that is required.

It is not practical or possible to test every article produced so a well constructed sampling plan that gives you the confidence you require must be put in place.

There is a wide range of statistically sound sampling plans available but many sampling plans are developed with experience in producing a particular product and its inherent variability.

Range of testing

Fibre tests

Fibre tests include diameter, cross section, length, length distribution, strength, extension at break, extractable matter, colour and moisture content.

Tests for rovings, slubbings, slivers and tops include mass/unit length, eveness, extractable matter, fibre bundle strength, fibre composition and contamination.

Yarn testing

Yarn testing involves measuring linear density (mass/unit length), tensile strength and extension, evenness of yarn, irregularity, shape, twist singles and folded, extractable matter of the yarn or finishes, yarn friction against itself, metal or ceramic, and hairiness of the yarn.

Woven fabric

Woven fabric tests for evaluating physical performance include construction parameters, tensile strength and extension, tear strength, seam strength or yarn slippage, abrasion resistance, pilling or fuzzing, and stiffness or drape.

Tailorability

Testing for tailorability involve predicting the performance of a fabric during make-up or in use by measure of number of key performance indicators using equipment such as the CSIRO Fast system.

Knitted fabric

Tests used to evaluate knitted fabrics differ slightly from those for woven fabrics and include tests for construction, bursting force, pilling and fuzzing, drape and air permeability.

General test methods

It is critical that all fabrics have good dimensional stability characteristics to washing (resistance to shrinkage) if the garment or fabric is to be washed in use. The washing conditions the fabric shall be tested against should reflect the washing instructions on the care label.

Dimensional stability (resistance to shrinkage) to water is also important. This is a static test, while the test for dimensional stability to washing is a dynamic test. The amount of shrinkage from these different tests could be quite different.

If a garment is labelled 'dry clean only', dimensional stability to dry cleaning becomes the important dimensional stability test.

Dimensional stability to other mediums such as steam, heat or cold may also be important, depending on the end use of the fabric. If any of these are important in the products end use it is essential to test to their effect.

Fabric performance properties

There are a large number of ways of measuring thermal properties of a fabric or multi-layer fabric. The same applies for moisture vapor resistance or the transfer of moisture through a fabric.

It is important to select the test method that best represent the end use or requirements of a fabric in the field.

Air permeability of the fabric is another method used in conjunction with the above test method to determine fabric comfort, especially in extreme conditions.

Electrostatic properties of fabrics are also important in many end use conditions and, again, there are a large number of methods of determining the electrostatic properties of fibres or fabrics.

Flammability is the measure of how easily a fabric combusts, burns, melts or smoulders and, in some cases, the by-products given off when combustion occurs.

There is a multitude of flammability test methods and variations and many industry bodies prescribe their own test methods and interpretations of the test results.

Cleanability of fabrics

The ability to remove soiling or stains from a fabric is very important in many end uses. The determination of the cleanability of a fabric can be evaluated by as many different ways as the number of fabrics to be tested. Again, there are a number of test methods developed to rate various aspects of fabric performance in this area.

Colourfastness

All textile fabrics change in colour with time from the day they are first finished during production till the day they have outlived their useful life. The degree of change and the acceptability of that degree of change to the end user is a measure of acceptable colourfastness performance.

The elements that a fabric is subjected to will have a significant effect on the dyes used and the required colourfastness properties of a product; for example, when considering colourfastness to UV light the minimum requirements for an outdoor canvas or umbrella that experiences continual UV exposure may be 6–7, for a floor covering or curtain it may be 5, for outer apparel, depending on fibre type and colour, it may be as low as 4, and for under garments 2–3 would be acceptable.

The wide range in required performance is due to location and end use and is finally determined by what would be considered acceptable by the end user.

The performance levels required vary according to the product and the re-agents the fabric is likely to come into contact with. For instance, colourfastness to chlorine would be extremely important in swimwear but of little importance in a fibre used in a fine suiting fabric.

It is important to predict or know the likely end use of a fabric and be sure that the re-agent it is likely to come into contact with will not have an adverse effect on the colour of the fabric.

Interpretation of results

Test results will be presented in a number of ways, depending on what the test is designed to measure. It could be simple pass/fail criteria for online testing, subjective observation or a number. It is important to know what you are expecting and understand the meaning of the test result.

A test method is not always designed to reproduce exactly what is likely to actually happen in a real-use situation but it is designed to be a guide to the relative performance of a particular product compared with other similar products. The correct interpretation and understanding of the test results is important.

There are two main methods of assessment: objective assessment and subjective assessment.

Objective assessment

Objective assessment occurs where a test method gives a ‘number’ or ‘result’ produced by a machine, which is measurable and quantitative.

Subjective assessment

Subjective assessment occurs where the test method has an assessment element and requires an operator or a number of operators to give a visual rating of the performance of a product.

With a subjective test method there are a number of areas that are not quantifiable and the quality of the test result will be dependent on the experience and capabilities of the assessors. Tests for colourfastness, pilling, wrinkling and appearance change, typically involve subjective ratings.

There is currently a great deal of work being carried out to design and correlate machines capable of carrying out these subjective assessments but, still, in the majority of cases, subjective assessments are carried out for these test methods.

Objective tests such as breaking force, extension and shrinkage give a number or numerical value that can be compared with an expected range of results for that test method and particular product.

The number is generated by using a calibrated piece of 'specified machinery' in a 'specific manner' in accordance to a test method. In the case of objective tests, it is very important to understand what the actual numbers mean.

Depending on the end use of the product, the same series of test results for individual test specimens may have a significantly different interpretation; for example, in a tensile strength result where five specimens are tested. Depending on the end use, the lowest individual breaking force value may be the most important. In other cases, the mean may be the most appropriate or it may be appropriate to consider the variation between individual results, which may be used to determine a confidence limit on the mean result. These variations on one particular test method highlight the importance of understanding the end use of the product and the need to interoperate the test result correctly.

The majority of international published test methods now give some guidance on precision and confidence limits on test results.

Understanding the test results

Definitions

- **Average,** for a series of observations, the total divided by the number of observations (arithmetic average, arithmetic mean, mean).
- **Degrees of freedom,** for a set, the number of values that can be assigned arbitrarily and still get the same value for each of one or more statistics calculated from the set of data.
- **Duplicate,** in experimenting or testing, to repeat a run so as to produce a duplicate.
- **Experimental error,** variability attributable only to a test method itself.
- **Standard deviation,** of a sample, a measure of the dispersion of variants observed in a sample expressed as the positive square root of the sample variance.
- **Variance,** of a sample, a measure of the dispersion of variants observed in a sample expressed as a function of the squared deviations from the sample average.

Measure of test variability

There a number of measures of test variability: one is the probability (p) that a test result will fall within a particular interval; the other is the positive square root of the variance, which is called the standard deviation (s). The standard deviation is sometimes expressed as a percentage of the average, which is called the coefficient of variation (CV%). Test variability due to lack of statistical control is unpredictable and therefore cannot be measured.

Averaging

Variation averages have less variation than individual measurements. The more measurements included in an average, the less its variation. Thus, the variation of test results can be reduced by averaging, but averaging will not improve the precision of a test method as measured by the variance of specimen selection and testing.

Confidence limits and uncertainty

Uncertainty

Uncertainty can be defined as 'a parameter associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measurand'. The parameter may be, for example, a 'standard deviation' or the 'width of a confidence interval'.

Uncertainty or measurement uncertainty usually comprises many components. Some of those components may be evaluated from the statistical distribution of the results of series of measurement and can be characterised by standard deviations. The other components, which also can be characterised by standard deviation, are evaluated from assumed probability distributions based on experience or other information.

Uncertainty sources

In practice, the uncertainty on the result may arise from many possible sources, including examples such as incomplete definition, sampling, matrix effects and interferences, environmental conditions, uncertainties of masses and volumetric equipment, reference values, approximations and assumptions incorporated in the measurement method and procedure, and random variation.

Error and uncertainty

It is important to distinguish between error and uncertainty. Error is defined as the difference between an individual result and the true value of the measurand. As such, error is a single value. In principle, the value of a known error can be applied as a correction to the result.

Uncertainty, on the other hand, takes the form of a range and, if estimated for a procedure and defined sample type, may apply to all determinations so described. In general, the value of the uncertainty cannot be used to correct a measurement result.

Random error typically arises from unpredictable variations of influence quantities. These random effects give rise to variations in repeated observations of the measurand. The random error of an analytical result cannot be compensated for, but it can usually be reduced by increasing the number of observations.

Systematic error is defined as a component of error that, in the course of a number of analyses of the same measurand, remains constant or varies in a predictable way. It is independent of the number of measurements made and cannot, therefore, be reduced by increasing the number of analyses under constant measurement conditions.

Typical sources of uncertainty are:

- sampling – where in-house or field sampling from part of the specified procedure, effects such as random variations between different samples and any potential for bias in the sampling procedure form components of uncertainty affecting the final results
- storage conditions – where test items are stored for any period prior to analysis, the storage conditions may affect the results. The duration of storage as well as conditions during storage should therefore be considered as uncertainty sources
- instrument effects – instrument effects may include the limits of accuracy on the calibration of an analytical balance, a tensile tester or a temperature controller.

Compliance against limits

Regulatory compliance often requires that a measurand, such as the tensile strength of a product, be shown to be above a particular limit. Measurement uncertainty clearly has implications for interpretation in this context. In particular:

- the uncertainty in the result may need to be taken into account when assessing compliance
- the limits may have been set with some allowance for measurement uncertainties.

Consideration should be given to both factors in any assessment. The following paragraphs give examples of common practice.

Assuming that limits were set with no allowance for uncertainty, four situations are apparent for the case of compliance with an upper limit:

1. the result exceeds the limit value plus the expanded uncertainty
2. the result exceeds the limiting value by less than the expanded uncertainty
3. the result is below the limiting value by less than the expanded uncertainty
4. the result is less than the limiting value minus the expanded uncertainty.

Where it is known or believed that limits have been set with some allowance for uncertainty, a judgment of compliance can reasonably be made only with knowledge of that allowance. An exception arises where compliance is set against a stated method operating in defined circumstances. Implicit in such a requirement is the assumption that the uncertainty, or at least reproducibility, of the stated method is small enough to ignore for practical purposes. In such a case, provided that appropriate quality control is in place, compliance is normally reported only on the value of the particular result. This will normally be stated in any standard taking this approach.

It is important to understand the true meaning of a test result. The reported result may be or may not comply with a specification by variance and uncertainty should be considered if it is important in the final discussion of compliance.

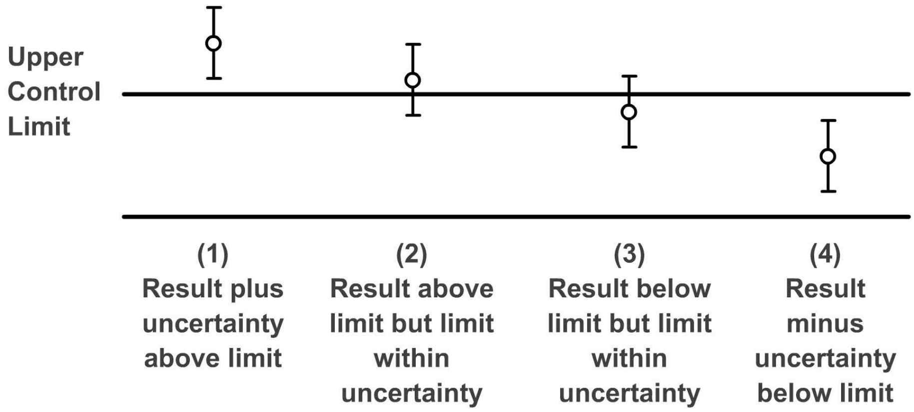

Figure 1: Uncertainty and compliance limits.

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Questions

1. What is quality management?
   a. Having a well defined management structure.
   b. Having all staff trained in all aspects of their job.
   c. Testing of products after manufacture.
   d. All of the sections of the overall management function that determine and implement the quality policy.
2. Why is correct sampling of a product important?
   a. To avoid selecting the weakest samples, as this will bias the test results.
   b. Samples should be taken at the very start of production as these will indicate what the rest of the product will be like.

c. Any samples tested must be representative of the whole of the batch or lot.

d. It gives the QC department a record of the lot produced and tested for later enquiries.

3. Why is textile testing carried out at 20 ±2ºC and 65% RH?

   a. These are ideal conditions for staff to work under.

   b. These conditions give the highest result for tensile strength of wool fibres.

   c. When samples are conditioned and tested at these conditions the aim is consistency within and between laboratories.

   d. These conditions are only important when testing wool, but are not important for testing any other fibres.

4. Why are samples preconditioned and reconditioned prior to testing?

   a. To bring the samples to moisture equilibrium prior to testing.

   b. To dry off excess oil and contamination from people's fingers.

   c. To produce consistent test results from one laboratory to another and from one time to another, allowing comparison of test results.

   d. To be sure any surface treatments are cured.

5. Which bodies can produce Test Methods?

   a. Only internationally accredited Standards bodies.

   b. Any body, as long as they are documented in a clear and unambiguous way.

   c. Government accredited bodies only.

   d. In the case of textiles, only members of the Textile Institute.

6. How is the pilling performance of a fabric normally predicted?

   a. Washing the samples and comparing the appearance before and after washing.

   b. Rubbing the samples 10 times with a crockmeter and rating their appearance.

   c. A large number of methods are available, such as random tumble, martindale abrasion, pill box and brush and sponge.

   d. Measuring the hairiness of the yarn prior to manufacture.

7. Martindale abrasion testing involves rubbing a test sample against a woven abradant until:

   a. the test specimen changes colour

   b. a certain mass loss of test specimen is attained

   c. the test specimen totally disappears from the holder

   d. two threads in either direction are broken.

8. A knitted fabric is normally tested for strength properties by:

   a. conducting a tensile strip test

   b. measuring bursting pressure of the fabric

   c. subjecting the fabric to a martindale abrasion test

   d. conducting a wing rip tear strength test on the sample.

9. Test methods that have a subjective nature:

   a. cannot be included in a documented specification

   b. require a machine to produce a reading and subsequent number

   c. are carried out by operators without the aid of a calibrated machine

   d. cannot be accredited test methods.

10. When ‘uncertainty’ of a measurement or test result is mentioned, we are talking about?

   a. A range or variation around a reported test result.

   b. Errors in measurement that occur in gaining a test result.

   c. Not being sure the test was conducted strictly according to the test method.

   d. The result being reported to too many decimal places.