"You Can't Know What You Don't Measure!" a Road Map for Manufacturing Quality Control and Certification of Rolled Erosion Control Products!

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Abstract

Accurate reporting of characteristic properties of rolled erosion control products (RECPs) in brochures, certifications, or trade journals requires that product manufacturing include rigorous quality controls. Manufacturers must implement a comprehensive, integrated quality control and certification program which includes systematic and frequent sampling and testing as well as proper management of test data and consistent compliance with standards. If any of these elements are missing, the reported data may be inaccurate.

This paper presents a comprehensive manufacturing quality control and certification protocol for RECPs which, if followed by all manufacturers of RECPs, will assure statistical accuracy and uniformity in the reporting of basic RECP material properties. Detailed guidance is given on the establishment of a quality control lab, as well as the use of applicable ASTM standards for sampling frequency, specimen preparation, and test implementation. Further, certification of specification conformance based on industry standard statistical analyses will be reviewed.

Introduction to Manufacturing Quality Control (QC)

If products are to be manufactured in a manner consistent with a desired level of quality, it is necessary for the manufacturer to have a system of routine checks in the manufacturing process. The checks may include continuous instrumented monitoring and periodic visual (human) observations of the production line. But, thorough quality control will always include frequent, random sampling of the production for in-house laboratory evaluation and property verification. These laboratory evaluations will be based on a plan that sets forth the test methods and the minimum testing frequencies appropriate for the products being manufactured.

Only those property values obtained using standardized testing procedures and statistically relevant sampling frequencies of each production lot can be certified with a known level of confidence (desired level of quality). Typically, product manufacturers refer to ASTM International standards for standardized testing procedures and for guidance on the appropriate frequency for taking samples from production for testing.

It is important to note that QC tests do not have to be complicated, and it is not necessary to run

lots of different tests. More important is that the tests (and associated laboratory equipment) be very repeatable (performed the same every time) and run frequently. Frequent tracking of one or two important "index" properties with simple, quick tests will often provide the manufacturer with better information for maintaining the quality of the production than a limited number of results from complex tests that take a long time to run in the laboratory. The more frequent, quick index results will enable the manufacturer to make frequent, small adjustments to the production line before it can drift "out of control" and produce "off-quality" products.

To a manufacturer, making off-quality products means down-grades or waste, or worse, providing deficient products to customers.

RECP Test Development

Rolled erosion control products (RECPs) may be for temporary use only while the grass is germinating and during initial growth or for longer-term use to extend the protection limits of vegetation. Temporary RECPs are typically made of degradable natural fibers like straw, wood shavings, or coconut. Nondegradable RECPs are made of synthetic materials.

In 1997, the Erosion Control Technology Council (ECTC), an organization of RECP manufacturers, issued a Technical Guidance Manual detailing terminology and testing procedures. The ECTC then began a concentrated effort to work through the ASTM International to achieve consensus standardization of these RECP testing procedures.

A significant advantage of RECPs over site-constructed alternatives is that they can be subjected to rigorous manufacturing quality control using these standardized testing. To this end, RECP manufacturers use standard index tests performed on a production basis to evaluate product integrity, quality and continuity, and to assess the impact of changes in production methodology on product properties. These "quality control" index test results can be reported with statistical relevance when they are run with sufficient frequency. This frequency will be discussed later.

Following are the index test methods used for RECPs quality control:

- Mass per Unit Area**:** ASTM D 6475, "Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets"**;** ASTM D 6566, "Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats"**.**
- Thickness**:** ASTM D 6525, "Standard Test Method for Measuring Nominal Thickness of Permanent Rolled Erosion Control Products"**.**
- Tensile Strength**:** ASTM D 6818, "Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats"**.**
- Light Penetration: ASTM D 6567, "Standard Test Method for Measuring the Light Penetration of a Turf Reinforcement Mat (TRM)".
- Water Absorption: ASTM D 1117 Section 5.4 and ECTC-TASC 00197, "Standard Guide for Evaluating Nonwoven Fabrics – Absorptive Capacity Test (for Larger Test Specimens)".
- Specific Gravity: ASTM D 792, Method A, "Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement".

RECP QC Tests

Obtaining Specimens for Manufacturing Quality Control Tests. As noted above, ASTM D4354 provides guidance on how frequently to take sample rolls from the production line to support a manufacturing quality control program. Once a QC sample is taken from a sampled roll and delivered to the laboratory, the cutting and conditioning of specimens for testing is governed by the individual test methods. Each quality control sample shall be sent to the quality control lab immediately upon being sampled from production. Full identification of the sampled shipment roll shall be provided with the sample. Table 1 lists the tests and corresponding specimens which are normally run on every sample received in the Q.C. lab.

Table 1. Common tests and corresponding specimens used in Q.C. testing

Test Property	RECP Type	Test Method	# of Specimens
Mass/Area	All	ASTM D6475/D6566	5
Thickness	All	ASTM D6525	10
Tensile / Elongation	All*	ASTM D6818	5MD/5CD
Light Penetration	All	ASTM D6567	5
Absorption	Temporary	ECTC	5
Specific Gravity	Long-term	ASTM D792, Method A	5

Key: MD=machine direction, CD=cross-machine direction; *Typically, tensile strength of temporary RECPs are based on netting manufacturer Certificate of Analysis (COA) in lieu of finished product MQC testing.

Figure 1 shows typical laboratory specimen cutting for QC testing. A standard "template" for taking specimens, such as the diagonal layout shown, assures that randomness is maintained and truly representative specimens are obtained. Some laboratories will cut oversized "coupons" from the roll sample and then die-cut test specimens using a die cutter as shown in Figure 2. All specimens are maintained in controlled environmental conditions of 20°C and 60% RH for 24 hours prior to testing.

Figure 1. Specimens or coupons are cut from the sample across the roll width

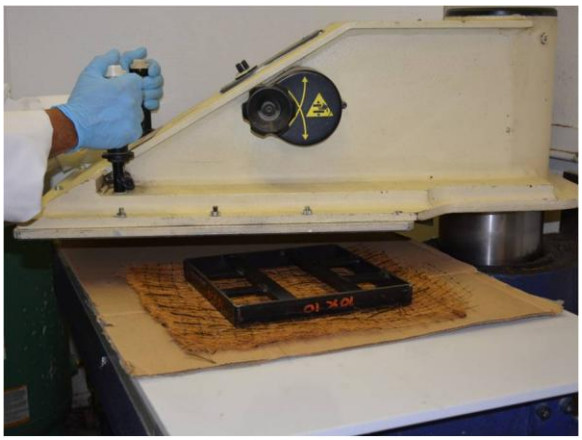

Figure 2. Coupons are die cut to specific specimen dimensions

Mass per Unit Area via ASTM D6475, "Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets" & via ASTM D6566, "Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats"**.** The mass per unit area, also known as the "weight" per square yard of a sample, is an important quality control property. The ECB (temporary RECP) test uses five specimens that have been dried at 50° overnight. Specimen size is a minimum 23,000 mm^2 (35.6 in^2). A typical size is 12"x14". The TRM (long-term RECP) test uses five specimens (minimum 23,000 mm^2 (35.6 in^2)) at ambient laboratory conditions. Typically 10"x10" specimens are used. Caution is necessary to avoid loss of filler during cutting and handling of specimens.

Figure 3. Temporary RECP specimens are oven dried.

Figure 4. Weigh specimens (after oven drying if ECB)

Thickness via ASTM D6525, "Standard Test Method for Measuring Nominal Thickness of Permanent Rolled Erosion Control Products". Thickness is another important quality control property which is measured after application of a 6-inch diameter presser foot under a 0.029 psi pressure and recording the reading 5 seconds after load is applied.

Figure 5. Thickness measuring apparatus.

Tensile Strength via ASTM D6818, "Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats". The ASTM tensile test method for RECPs uses specimens that are at least 4"x6" and clamps with parallel jaw faces 1 inch tall and at least 1 inch wider than the sample. Using a standard constant rate of extension tensile testing machine, the specimen is tensioned at 12 in/min. The test is terminated after specimen ruptures. Jaw and edge breaks need to be recognized and discarded. Special preparation techniques may be needed to avoid fiber loss and grip damage. Figure 6 shows a typical test setup.

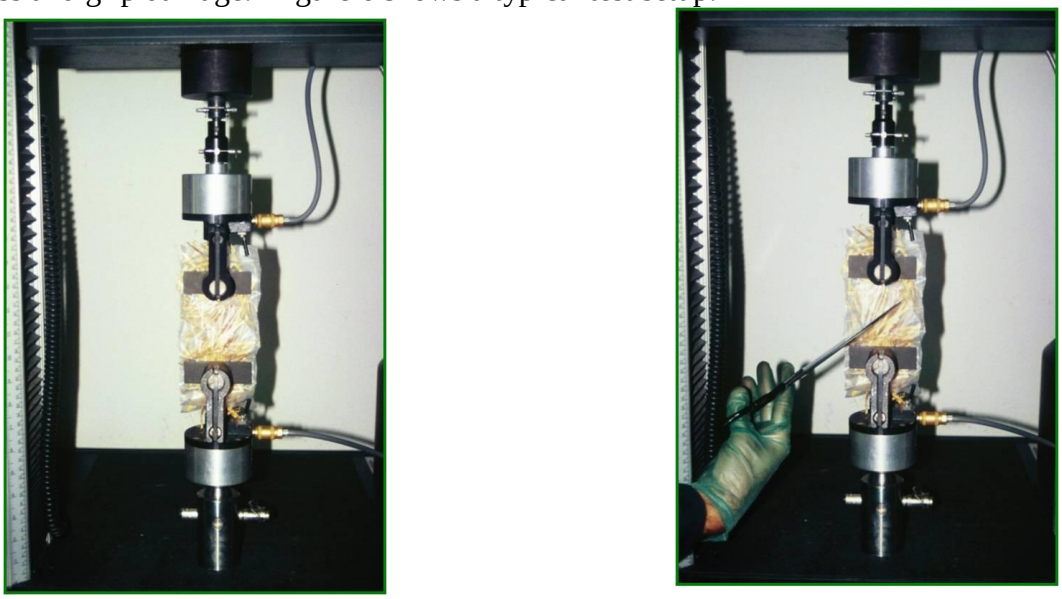

Figure 6. Tensile specimen in grips with plastic wrap to minimize fiber loss and tape to prevent damage under the grips. When used, the plastic wrap is cut prior to testing.

Light Penetration: ASTM D6567, "Standard Test Method for Measuring the Light Penetration of a Turf Reinforcement Mat (TRM)". Within a light box, a calibrated meter measures the amount of light that is able to pass through the specimen from a 150 watt light source on the other side of the specimen. The light reading is recorded with no specimen, and then with the specimen in place in the light box. The ratio is the percent light penetration. Some materials (single net straw for example) may be difficult to place with the light box horizontal. May be necessary to orient the box vertically and support fragile materials with a open mesh screen. Figure 7 shows a light box setup.

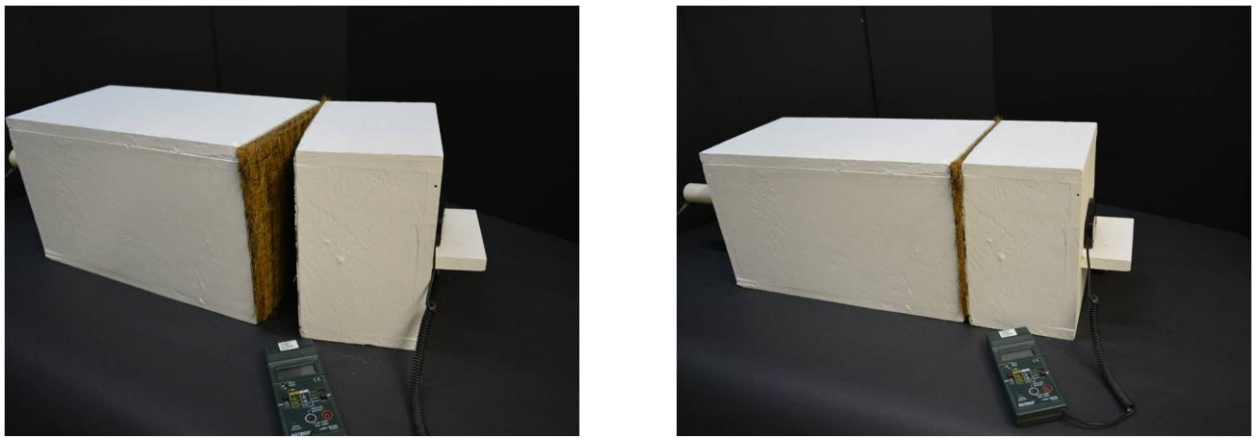

Figure 7. A light box with a specimen in place. The light source is on a moveable rod (to the left) and the light is read by meter at the (right) end of the box.

Water Absorption: ASTM D1117 Section 5.4 and ECTC-TASC 00197, "Standard Guide for Evaluating Nonwoven Fabrics – Absorptive Capacity Test (for Larger Test Specimens)". Water absorption is a measure of a material's capacity to absorb water and is generally applicable to organic RECPs. 5 oven dry test specimens are weighed, placed in stacked trays allowing room for expansion, and stacked trays are placed in a container filled with DI water and soaked for 24 hours. After 24 hours, remove the specimens, allow them to drain for 10 minutes (drain time is critical), and then weigh specimens immediately. The materials require room to expand while soaking and some materials may become unstable during the soaking process.

Figure 8. Conditioned samples are weighed, soaked, drained, and weighed

Specific Gravity: ASTM D792, Method A, "Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement". Specific gravity is the ratio of the unit weight of a material to that of water. Specimens are weighed to 0.0001 g on an analytical balance when suspended under the analytical balance submerged in water as shown in Figure 9. Any air bubbles trapped in the specimen will affect results.

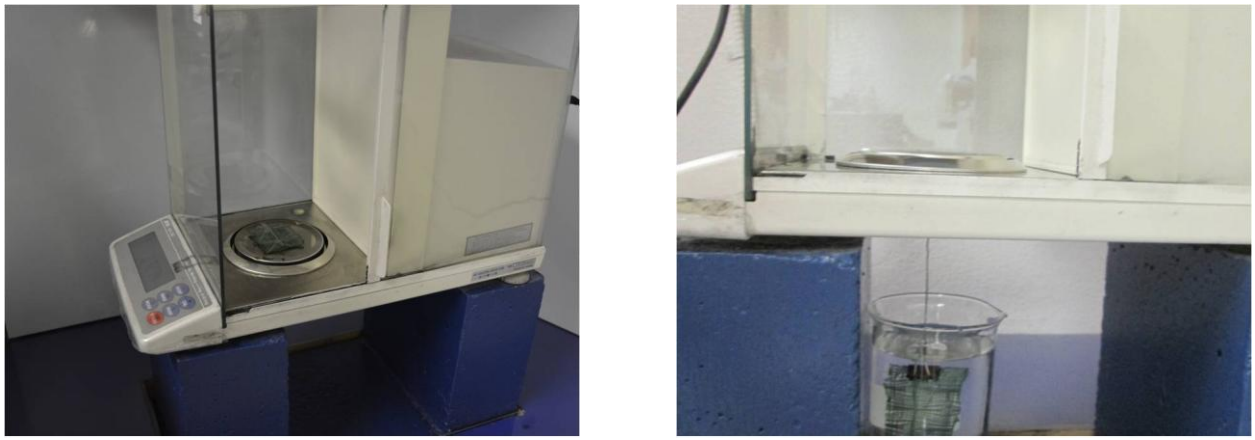

Figure 9. Specific gravity measurements require a highly accurate scale.

Handling QC Test Results

The results for each roll sampled and tested are given as average roll values. The average roll value, which is also called the sampling average, is the average of all the specimens tested in the same orientation (i.e. machine direction or cross-machine direction, also referred to as MD or CD) from a sample using a specific test method. Regardless of the individual specimen results, it is the average of all specimens - the average roll value - which characterizes the sample.

Manufacturing Quality Control – Sampling Frequency

As noted above, "quality control" index test results can be reported with statistical relevance when they are run with sufficient frequency, i.e. on a sufficient number of samples from each production lot. ASTM D8102 provides guidance for comprehensive manufacturing quality control, including appropriate production sampling frequency. D8102 was developed for geotextile production and is commonly followed for the production of long-term RECPs. It can also guide the quality control programs for the manufacturing of temporary products. D8102 presents the following guidance as integral to manufacturing quality control programs that provide a suitable basis for certifying "minimum" property requirements:

- A "production lot" should be defined as that portion of production that represent a planned production quantity not to exceed 12 consecutive months that differs from other portions in specifications, style, or physical characteristics.
- The production lot sample size (number of sample rolls) for quality control testing shall be in accordance with ASTM D4354, "Standard Practice for Sampling of Geosynthetics and RECPs for Testing". Table 2 presents the MQC sampling requirements from D4354.

- The results for each roll sampled and tested are given as average roll values. The average roll value, which is also called the sampling average, is the average of all the specimens tested in the same orientation (i.e. machine direction or cross-machine direction, also referred to as MD or CD) from a sample using a specific test method. Regardless of the individual specimen results, it is the average of all specimens - the average roll value - which characterizes the sample.
- Production lot testing summaries are to be maintained, detailing the test results and typical value (aggregate mean), minimum, maximum, standard deviations, and MARV of each test property required for the production lot under consideration.
- Minimum Average Roll Values (MARV) are to be calculated for each lot for each test property required. MARV can then be calculated as:

$$MARV = \bar{x} - 2(s), \text{ where: } \bar{x} = \text{typical (mean) and } s = \text{standard deviation (roll data)}$$

(NOTE: 2 is a reasonable t-value for use in the above equation.
Other t-values may be used based on sample size.)

Table 2. Number of units to be selected as lot samples for specification conformance

Number of Units in Production Lot	Number of Units Sampled
1 to 2	1
3 to 8	2
9 to 27	3
28 to 64	4
65 to 125	5
126 to 216	6
217 to 343	7
344 to 512	8
513 to 729	9
730 to 1000	10
1001 to more	11

Example 1

Consider that a production lot of 1,000 rolls (10 truck loads) of Style X is to be produced, placed into inventory, and certified when shipped to projects from inventory.

QC Requirements: In accordance with Table 2, production line operators will be notified to take a sample from every 100th roll of production (10 total samples) and send the samples to the QC lab for testing. Certifications can only be issued after all production is complete.

Example 2

Consider that a production lot of 1,000 rolls (10 truck loads) of Style X is to be produced, shipped out as produced (100 rolls per truck load), and certified when shipped.

QC Requirements: In accordance with Table 2, production line operators will be notified to take a sample from every 20th roll of production (5 total samples) for the first 100 rolls, and then sample the 200th, 300th, 400th, 500th, and 800th rolls after that (total 10 samples) and send the samples to the QC lab for testing. Certifications can be issued with each truckload.

Manufacturing Quality Control – Lot Summary and Statistics

All quality control test results are maintained by the Quality Control Manager with the corresponding shipment roll identification. The Q.C. Manager makes lot testing summaries available, upon request, detailing the individual test results and aggregate mean, minimum, maximum and standard deviations of each test property for the shipment rolls under consideration. Table 3 presents an example of a lot summary based on Example 1.

Table 3. Common tests and corresponding specimens used in Q.C. testing

TEST RESULTS

Style: X ; Lot: X-18-1
# of Rolls Produced per Lot: 1000

Roll No.	Date	Mass/Area, g/m2	Thickness, mm	MD Tensile, kN/m	MD Elong., %	CD Tensile, kN/m	CD Elong., %	Light Penetr-ation, %	Absorp-tion, %
X-18-0100	1/3/2018	310	8.5	3.2	10.5	2.4	15.5	13	350
X-18-0200	1/3/2018	320	8.8	3.3	10.3	2.2	15.1	11	340
X-18-0300	1/3/2018	330	8.3	3.1	10.1	2.7	14.9	9	380
X-18-0400	1/4/2018	325	8.5	3.5	10.8	2.6	15.6	10	360
X-18-0500	1/4/2018	315	8.6	3.3	10.5	2.2	15.2	10	330
X-18-0600	1/4/2018	315	8.6	3.4	10.1	2.8	16.0	9	390
X-18-0700	1/5/2018	325	8.9	3.2	11.2	2.3	15.2	13	370
X-18-0800	1/5/2018	320	8.4	3.1	10.6	2.4	15.8	12	340
X-18-0900	1/5/2018	315	8.5	3.5	10.1	2.7	16.2	10	360
X-18-1000	1/6/2018	320	8.2	3.4	11.0	2.6	14.9	13	380
Average		320	8.5	3.3	10.5	2.5	15.4	11	360
Standard Deviation		6	0.2	0.1	0.4	0.2	0.5	2	20
Minimum		310	8.2	3.1	10.1	2.2	14.9	9	330
Maximum		330	8.9	3.5	11.2	2.8	16.2	13	390
MARV		308	8.1	3.0	9.7	2.1	14.5	8	320
Specification		*310*	*8.0*	*3.0*	*9.0*	*2.0*	*14.0*	*10*	*350*
Is specification satisfied ?		*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*

Using Manufacturing Quality Control Data to Prove Specification Compliance

It is important that the manufacturer know and be able to prove that its product satisfies a purchaser's specification with the required level of certainty. Typically, this means that the manufacturer can provide supporting index test data to show the average test values, minimum test values, or even minimum average roll values (MARVs) for the entire production lot that included the rolls provided. If the manufacturer has a comprehensive quality control program in place, as described above, this proof is readily available.

For example, Table 4 presents a hypothetical RECP purchase specification. The customer will expect the manufacturer to certify that its product satisfies the specification and provide supporting quality control data for the production lot from which the rolls supplied were taken. Table 3 shows the hypothetical specification values added to the manufacturer's lot summary for production lot X-18-1 of product style X. The highlighted statistical values confirm that the specifications are satisfied by all rolls manufactured in this production lot.

Table 4. Hypothetical Purchasing Specification for a Temporary RECP

Property	Unit	Test Method	Certification Basis	Required Value
Mass/Area	g/m^2	ASTM D6475	Minimum test value [A]	310
Thickness	mm	ASTM D6525	Minimum test value [A]	8.0
Tensile Strength, MD/CD	kN/m	ASTM D6818	MARV [B]	3.0 / 2.0
Tensile Elongation, MD/CD	%	ASTM D6818	MARV [B]	9.0 / 14.0
Light Penetration	%	ASTM D6567	Typical test value [C]	10
Absorption	%	ECTC & ASTM	Typical test value [C]	350

[A] Minimum: These values represent absolute minimum test values determined from Q.C. testing on all first quality lots produced.

[B] Third-party Certificate of Analysis (COA) is acceptable in lieu of manufacturer's own QC test data.

[C] Tpical: These values represent average test values determined from Q.C. testing on all first quality lots produced.

Setting Up Manufacturing Quality Control Testing

Is it complicated and expensive to set up a manufacturing quality control laboratory for RECP production? No! Table 5 provides estimated costs acquire the necessary laboratory equipment. In addition to equipment, test procedures need to be learned, so the test methods must be obtained from ASTM International (www.astm.org), procedures learned, and data sheets developed. The test methods aren't expensive. A $75 membership in ASTM entitles members to a book of standards free. The book of standards containing the above described index test methods in Volume 04.13.

Table 5. Estimated Costs for MQC Lab Setup

Index Test - Equipment	Test Method	Approx. Equipment Cost
Mass per Unit Area, incl. oven	ASTM D 6475/6566	$2,000
Ultimate Tensile Strength / Strain	ASTM D 6818	$15,000
Thickness	ASTM D 6525	$2,500
Ground Cover / Light Penetration	ASTM D 6567	$1,000
Water Absorption	ECTC-TASC 001	$500
Specific Gravity	ASTM D 792	$1,500
Conditioning Chamber	All	$1000
Drafting SOPs, Data Sheets, Spreadsheets, etc.	All	$1500

CONCLUSIONS

A comprehensive manufacturing quality control (MQC) and certification protocol, if developed and implemented by all manufacturers of RECPs, will assure statistical accuracy and uniformity in the reporting and certifying of basic RECP material properties. ASTM standards provide detailed guidance on MQC, including appropriate sampling frequencies, specimen preparation, and test implementation. It has been shown that MQC provides important supporting data for certification of specification conformance based on industry standard statistical analyses will be reviewed.