Color Measurement Methods for Textile Fabrics

One of the key elements in successfully utilizing a color control system is the accurate and repeatable measurement of the samples being evaluated. Poor technique in sample measurement will greatly diminish the accuracy of the formulas produced by shade matching software and will provide misleading results from quality control software.

Measurement Technique

Before any permanent samples are measured and stored into the computer database, a repeatable measurement technique must be established and observed. Samples should always be measured multiple times with the largest area view available on the spectrophotometer being used as long as the samples are large enough to completely cover the viewing area. Sample conditioning should also be considered because variations in temperature and moisture content can contribute to variations in measurement data.

Sample Thickness

Two to four layers will be sufficient for most knitted and woven materials to achieve an opaque sample for presentation to the instrument. If the material is not opaque, light will pass through the sample and reflect off the backing material or sample holder and produce misleading reflectance data.

Lightweight and translucent materials will often require so many layers to become opaque that the material is forced into the interior of the instrument when measuring, causing inaccurate reflectance measurement. For these types of materials, repeatable results can be obtained by measuring only a few layers of material backed with a white ceramic tile similar to the instrument’s calibration tile. The portion of the reflectance due to the color of the backing can be ignored when comparing two samples if the backing is the same for both. When measuring a sample for new shade formulation, however, the reflectance due to the backing will lead to errors in the predicted dye formula.

Sample Positioning

Sample rotation and repositioning will reduce measurement variability due to fabric construction, directionality of yarns, and unlevel dyeings. A common practice in sample measurement is to place the sample at the instrument port and simply rotate the sample for four or more measurements. This technique is quick, but it will not account for variations due to unlevel dyeing and should be avoided. A better technique is to remove the sample from the instrument and refold or reposition it before additional readings. Care should always be taken to avoid any areas of the sample that are contaminated by dirt, fingerprints, creases, dye blotches, or other substances.

Developing a Repeatable Technique

An optimum measurement technique has been established when a sample can be measured, removed from the instrument, and remeasured with a variation of less than 0.15 DE(CMC) units. Higher variation will decrease the confidence level in the quality of the stored data and lead to less accurate match predictions.

A simple technique for determining the correct number of reads to use is to first produce an average reading for a sample by measuring it eight times -- being sure to rotate and reposition the sample after each read -- and saving the average. This should produce the most repeatable read even though it is not practical for day-to-day operations. Remove the sample and then measure it again using the same technique -- eight reads with rotation and repositioning. The color difference between these two averages should be very low. Remove the sample and then measure it again, but this time use only seven reads with rotation and repositioning. Repeat the process using six reads, five reads, four reads, three reads, and finally two reads.

After obtaining color difference data between each test and the original sample measured eight times, identify the point at which the DE(CMC) exceeds the desired limit of 0.15. As an example, if the DE(CMC) of the four read sample is 0.08 and the DE(CMC) of the three read sample is 0.21, samples should be read four times to ensure a variation of less than 0.15 DE(CMC). When the correct number of reads has been determined, measure the sample at least four more times using the required number of reads to confirm that all reads are less than 0.15 DE(CMC). If any of the measurements are greater than 0.15, the technique must be altered either by modifying sample placement or by taking additional reads. It may seem too time consuming to measure a sample three or more times, but the time taken in the beginning to ensure accurate measurements will translate into better results in the end. The measurement speed of modern spectrophotometers will reduce the time required to make additional reads to only a few seconds. A comparison of varying numbers of measurements using two instrument port sizes may be found at the end of this document.

Measurement repeatability is especially critical as it affects computer pass/fail programs in use in the quality control and final inspection areas. If a sample is measured and compared to a standard and the DE(CMC) is calculated as 0.80 but the measurement variability is 0.30, then the true reading may range from 0.50 to 1.10. This may mean the difference between a rating of pass or fail if the pass/fail tolerance is less than 1.10.

Sample Types and Presentation

Samples to be measured can be produced in an assortment of forms, from fiber to yarn to fabric. The type of sample produced is often dependent upon the equipment available or on the end-use of the material. Regardless of the form selected, an appropriate measurement technique should be developed as indicated above and the sample must represent the color of the batch as a whole. The contribution of the system operator to the measurement process cannot be overlooked and communication of proper techniques is critical.

Fabric

Flat woven and knit fabric samples provide the most repeatable measurements because of their uniform construction and size. A typical measurement technique for large samples involves four measurements using four layers of material and the spectrophotometer’s largest view port. Tests may show that as few as two reads are sufficient with fewer layers, but keep in mind that the deviation when repeating the sample measurement should be less than 0.15 DE(CMC). It is important to remember that simply rotating the sample without moving it to a new area on the sample will not produce the most accurate color assessment. Smaller samples may only allow for the measurement of one or two layers with the instrument’s smallest port size and will typically require more reads to guarantee repeatability.

Fabrics that are bulky or have a pile — such as fur, Berber, velvet, carpet, etc. — should be measured behind a glass plate to prevent the material from bulging into the spectrophotometer measurement area. It is critical that the instrument be configured to read in specular excluded mode to remove the glossy reflectance due to the glass. Other compensation factors may be required for shade formulation, but are not necessary for quality control if standards and batches are measured using the same piece of glass.

Loose Fiber

Loose fiber is especially difficult to measure repeatably. A mass of fiber placed at the port of a spectrophotometer tends to protrude into the sphere in much the same way as too many layers of a sheer material. Not only does this introduce error into the reflectance measurement, but there is also the risk of loose fibers falling into the instrument and interfering with the measurement process. Measurements made using a glass plate as mentioned previously will also improve measurement repeatability.

Repositioning the sample for multiple reads using only the instrument’s standard sample holder arm may provide measurements that are sufficiently repeatable. A better technique is to place an exact mass of fiber into a compression cell and apply a constant amount of pressure. This will eliminate errors due to gaps between fibers that exist under conditions of minimal pressure.

Yarn

The most common method for measuring yarn is to obtain a small skein and simply place it against a small measurement port and rotate the sample for two or three measurements. The repeatability of this particular measurement method is questionable and must be confirmed as mentioned earlier. Individual yarns in the skein must be aligned to prevent the formation of shadows that the instrument would detect as depth of shade. The skein must also be thick enough to prevent light from passing through the strands and reflecting off the background, which is typically the sample holder.

Yarns that are very bulky should be measured behind a glass plate to prevent the yarn from bulging into the spectrophotometer measurement area. Use the instrument’s specular excluded mode to remove the glossy reflectance from the glass surface. Loose pile goods such as carpet and towels can be measured in the same way to prevent the yarns from protruding into the instrument and to prevent fibers from falling into sphere instruments.

Other useful techniques for yarn measurement include winding the yarn around a card or tab and using specially designed devices with springs that clamp the yarn securely to a plate. Yarn tension is a concern in either case and must be controlled from sample to sample to prevent measurement errors.

Measurement Repeatability Evaluation

The following table has been prepared to provide information regarding typical measurement variability that may be expected when taking multiple readings using two common sizes of instrument apertures. For each fabric type, a standard was measured using a 20mm aperture designated MAV for Medium Area View and a 9mm aperture designated SAV for Small Area View. The same sample was then remeasured using four, three, and two readings and compared to the standard to produce the DE(CMC) values listed. All samples except corduroy were measured using two layers with repositioning and 90° rotation between measurements. The column labeled 2V represents color differences obtained when measuring the standard and sample twice, with vertical repositioning only. The corduroy samples were measured using only one layer. The DE(CMC) values represent the maximum observed color difference for several repeat measurements of the various materials, though lower values were also observed. Columns displaying a dash (-) indicate that no tests were performed as results for the higher number of measurements were already unacceptable.

	MAV: 20mm				*SAV: 9mm*			
Fabric Type (Double Layer w/90° rotation)	***4***	***3***	***2***	***2 V***	***4***	***3***	***2***	***2V***
Woven Twill, Canvas, Crepe, Poplin	0.03	0.10	0.10	0.10	0.05	0.12	0.11	0.23
Satin, Taffeta	0.07	0.07	0.09	0.19	0.11	0.12	0.20	0.29
Seersucker, Wafflecloth, Ribstop	0.09	0.10	0.13	0.11	0.07	0.10	0.18	0.10
Brushed Terry, Napped (non-fleece)	0.04	0.07	0.07	0.13	0.14	0.17	0.23	0.31
Corduroy	0.13	0.31	0.64	0.16	0.55	-	-	0.66
Knit Interlock, Pique, Jersey	0.12	0.11	0.16	0.21	0.14	0.13	0.20	0.27
Thermal, Narrow Rib	0.05	0.12	0.13	0.14	0.07	0.18	0.24	0.25
Pointelle	0.17	0.20	0.23	0.10	0.60	-	-	0.59
Popcorn Knit, Pleated	0.03	0.07	0.07	0.24	0.04	0.27	0.20	0.44
Fleece (brushed/napped side)	0.11	0.12	0.19	0.11	0.15	0.40	0.46	0.45
Chenille, Panne	0.08	0.11	0.12	0.16	0.56	-	-	1.05
Mesh	0.03	0.07	0.12	0.09	0.14	0.21	0.35	0.27
Wide/Variegated Rib	0.20	0.30	0.51	0.11	0.30	0.68	-	0.53

Use of a larger aperture such as the 30mm Large Area View will produce lower DE(CMC) values as the area of measurement is significantly increased. Large aperture sizes may only be used however when measuring large samples that completely cover the aperture opening when using two or more layers, though one layer may provide acceptable results for opaque materials.

Materials listed in the following table represent those bulky and pile fabric types that normally protrude into the instrument during measurement. For these materials, measurement behind glass allows for more repeatable measurement. Measurement variation without the glass aperture increases significantly with changes in the amount of pressure applied to the sample by the sample-holder arm on the instrument.

Fabric Type (Single Layer ***w/90° rotation)***	***LAV: 30mm w/Glass***	***4***	***3***	***2***	***LAV: 30mm No Glass***	***4***	***3***	***2***
Velvet		0.15	0.34	0.52	*No Pressure*	0.21	0.52	-
					w/Pressure	0.13	0.46	0.63
Fur		0.13	0.16	0.20	*No Pressure*	0.25	0.58	-
					w/Pressure	0.59	0.74	-
Berber		0.05	0.04	0.06	*No Pressure*	0.10	0.14	0.15
					w/Pressure	0.30	0.35	0.39
Fleece (bulky)		0.09	0.17	0.16	*No Pressure*	0.08	0.90	0.99
					w/Pressure	0.21	0.71	0.92

Conclusion

If any degree of success is to be expected from spectrophotometers and computer formulation and quality control systems, repeatable techniques for measuring dyed samples must be established. Failure to establish a repeatable measurement technique will introduce a significant potential for error into all aspects of the formulation and quality control programs.

A repeatable measurement technique includes specification of the number of layers of material to use, the positioning of samples, the number of measurements to make, instrument settings, and clear communication with the system operators. Failure to fully test and confirm the quality of a measurement technique will be a source of error for the life of the program. While the tables above may be used as a guide for the number of measurements required on most materials to obtain repeatable results, it is recommended that system users evaluate their own specific materials to confirm the final established measurement method.

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