

Liquid Moisture Management Properties of Textile Fabrics

Developed in 2009 by AATCC Committee RA63

1. Purpose and Scope

1.1 This test method is for the measurement, evaluation and classification of liquid moisture management properties of textile fabrics. The test method produces objective measurements of liquid moisture management properties of knitted, woven and nonwoven textile fabrics.

1.2 The results obtained with this test method are based on water resistance, water repellency and water absorption characteristics of the fabric structure, including the fabric's geometric and internal structure and the wicking characteristics of its fibers and yarns.

2. Principle

2.1 The liquid moisture management properties of a textile are evaluated by placing a fabric specimen between two horizontal (upper and lower) electrical sensors each with seven concentric pins. A predetermined amount of test solution that aids the measurement of electrical conductivity changes is dropped onto the center of the upward-facing test specimen surface. The test solution is free to move in three directions: radial spreading on the top surface, movement through the specimen from top surface to the bottom surface, and radial spreading on the bottom surface of the specimen. During the test, changes in electrical resistance of specimen are measured and recorded.

2.2 The electrical resistance readings are used to calculate fabric liquid moisture content changes that quantify dynamic liquid moisture transport behaviors in multiple directions of the specimen. The summary of the measured results are used to grade the liquid moisture management properties of a fabric by using predetermined indices.

3. Terminology

3.1 **absorption rate – (AR_T) (top surface) and (AR_B) (bottom surface)**, n.—the average speed of liquid moisture absorption for the top and bottom surfaces of the specimen during the initial change of water content during a test.

3.2 **accumulative one-way transport capability – (R)**, n.—the difference between the area of the liquid moisture content curves of the top and bottom surfaces

of a specimen with respect to time.

3.3 **bottom surface – (B)**, n.—for testing purposes, the side of the specimen placed down against the lower electrical sensor which is the side of the fabric that would be the outer exposed surface of a garment when it is worn or product when it is used.

3.4 **maximum wetted radius – (MWR_T) and (MWR_B) (mm)**, n.—the greatest ring radius measured on the top and bottom surfaces.

3.5 **moisture management**, n.—for liquid moisture management testing, the engineered or inherent transport of aqueous liquids such as perspiration or water (relates to comfort) and includes both liquid and vapor forms of water.

3.6 **overall (liquid) moisture management capability (OMMC)**, n.—an index of the overall capability of a fabric to transport liquid moisture as calculated by combining three measured attributes of performance: the liquid moisture absorption rate on the bottom surface (AR_B) the one way liquid transport capability (R), and the maximum liquid moisture spreading speed on the bottom surface (SS_B).

3.7 **spreading speed, (SS_i)**, n.—the accumulated rate of surface wetting from the center of the specimen where the test solution is dropped to the maximum wetted radius.

3.8 **top surface – (T)**, n.—for testing purposes, the side of a specimen that, when the specimen is placed on the lower electrical sensor, is facing the upper sensor. This is the side of the fabric that would come in contact with the skin when a garment is worn or when a product is used.

3.9 **total water content – (U) (%)**, n.—the sum of the percent water content of the top and bottom surfaces.

NOTE: Total water content measurements may be more accurately termed, "total surface water content" particularly in the case of fabric with cellulosic content. Total water content implies that all water in the specimen is being measured which may be the case with some manufactured fabrics. However, when testing cellulosic fibers, moisture trapped in the interior of the fiber (for example, in the lumen of cotton fibers) will not be included with a specimen's detected surface liquid moisture.

3.10 **wetting time – (WT_T) (top surface) and (WT_B) (bottom surface)**, n.—the time in seconds when the top and bot-

tom surfaces of the specimen begin to be wetted after the test is started.

4. Safety Precautions

NOTE: These safety precautions are for information purposes only. The precautions are ancillary to the testing procedures and are not intended to be all-inclusive. It is the users' responsibility to use safe and proper techniques in handling materials in this test method. Manufacturers MUST be consulted for specific details such as material safety data sheets and other manufacturers' recommendations. All OSHA standards and rules must also be consulted and followed.

4.1 Good laboratory practices should be followed. Wear safety glasses in all laboratory areas.

5. Uses and Limitations

5.1 This test method focuses on liquid moisture transport in the flat state. The test method may be applicable to the evaluation of fabrics in garments or textile products as they would be exposed to liquid moisture (e.g. perspiration) present on the surface of human skin. It does not measure gaseous moisture transport properties (e.g. water vapor transmission) or tactile properties that also influence human perceptions of comfort.

5.2 Because human perceptions of comfort are influenced by multiple liquid movement properties, as well as ergonomic (garment fit) factors, the use of a single unit of measurement from this test method or any other test method could be misleading as explained in the AATCC/ASTM International Moisture Management Technical Supplement as Related to Textile Apparel, Linens and Soft Goods (see 13.1). Consequently, this test method alone will not give an overall rating of the comfort of a garment or textile product. Overall performance schemes, such as the Grading Graph in 9.2.1, should be developed when trying to correlate a combination of absorption, wicking, liquid and vapor movement that can be related to the environment and preferences of fit and style in which the textile product is to be used and worn.

5.3 This method may not be applicable to coated, laminated, or complex fabric constructions. Caution should be used when analyzing fabrics with repellent surface finishes. This method may not be applicable to specimens exhibiting high overall absorbent capacity such as terry cloth or other thick knitted and woven

fabrics. Thicker or highly absorbent fabrics may not allow for proper liquid moisture movement to be analyzed using the test solution volume.

5.4 This test method does not measure drying performance directly. Drying performance is inferred based on the area of liquid moisture spreading.

5.5 The wetting times measured in this method may be related to absorbency as measured by AATCC Test Method 79, Absorbency of Textiles (see 13.1).

5.6 The maximum wetted radius defined in 3.4 above should not be used to infer maximum spread areas. As this testing apparatus employs the use of concentric circular rings for measuring wetted radius, for specimens that exhibit non-circular, elliptical or amoeboid spread patterns, the radius may be misrepresented. For example, fabrics with a linear symmetry such as ribbed knits or fabrics with repellent finishes may exhibit irregular spreading patterns.

6. Apparatus and Materials

6.1 Moisture Management Tester (MMT) (see 13.2, Figures 1 and 2).

6.2 Computer with MMT software installed.

6.3 Distilled water.

6.4 Sodium chloride solution (0.9% NaCl).



Fig. 1—Moisture management tester

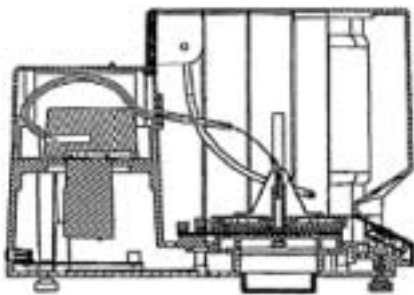


Fig. 2—A cross-sectional side view of the equipment

6.5 Conductivity meter.

6.6 White AATCC Textile Blotting Paper (see 13.1) or soft paper towels.

7. Test Specimens

7.1 Before cutting specimens, launder the sample(s) according to the conditions selected from the AATCC Monograph “Standardization of Home Laundry Test Conditions” (see 13.1) or as agreed between parties. It may be suitable to test a material unlaundered or after repeated launderings. Removal of sizing and/or finishes may affect the liquid moisture management properties of a fabric.

7.2 Cut five 8 × 8 cm specimens, taken diagonally across the width of a sample, to ensure that different sets of length and width yarns are in each specimen or from different sites on a product.

7.3 Place the specimens on a flat smooth, horizontal surface without tension before testing, to condition them to moisture equilibrium in an environment controlled at $21 \pm 1^\circ\text{C}$ ($70 \pm 2^\circ\text{F}$) and $65 \pm 2\%$ RH as recommended by ASTM D 1776, Standard Practice for Conditioning and Testing Textiles (see 13.4).

8. Procedure

8.1 Prepare the test solution by dissolving 9 g sodium chloride (USP Grade) in 1 L of distilled water and adjust its electrical conductivity to 16 ± 0.2 milli Siemens (mS) at 25°C (77°F) by adding sodium chloride or distilled water as necessary. The test solution is used to provide a conductive medium for the instrument’s sensors and does not duplicate perspiration.

8.2 Follow the manufacturer’s instructions for starting the instrument, addition of the test solution, and the computer software’s set up to collect test data.

8.3 Raise the upper sensor to its locked position and place a paper towel on the lower sensor. Press the “Pump” button for 1-2 min until the amount (0.22 cc) of test solution is drawn from the container and drips onto the paper towel and no air bubbles are present inside the tubing. Remove the paper towel.

8.4 Place the conditioned test specimen on the lower sensor with the specimen’s top surface up (see 3.8). Release the upper sensor until it freely rests on the test specimen and shut the door of the tester. Confirm that the “Pump-On Time” is set at 20 s to assure the predetermined amount (0.22 cc) of test solution is dispensed. For each specimen, the percent (%) water content point on the graph should be 0.0 at the start of each test to avoid erroneous test results. Set the “Measure Time” for 120 s and start the test. At the end of the 120 s test time, the software will automatically stop the test and calculate all of the indices.

8.5 Raise the upper sensor and remove the tested specimen.

8.6 Before inserting the next specimen, keep the upper sensor in its locked position. Dry between the rings of pins on both upper and lower sensors using White AATCC Blotting Paper or a soft paper towel cut into narrow (0.5 cm) strips. Wait 1 min, or longer, to ensure there is no residual test solution present on the sensors, otherwise any leftover moisture will cause an erroneous start (see 8.4). If salt deposits are observed on the sensors after drying, use distilled water to remove.

8.7 Load a new specimen on top of the lower sensor with the fabric top surface up and repeat steps 8.4-8.6.

8.8 When testing has been completed for the day, use distilled water to clean and purge the pump and tubing.

9. Evaluation Measurement Units, Grading, and Classification

9.1 Measurement units – For each sample tested, compile the average values for each measurement unit as follows:

Wetting Time – WT_T (top surface) and WT_B (bottom surface),

Absorption Rate – AR_T (top surface) and AR_B (bottom surface),

Maximum Wetted Radius – MWR_T (top surface) and MWR_B (bottom surface),

Spreading Speed – SS_T (top surface) and SS_B (bottom surface),

Accumulative One-way Transport Capability – (R), and

Overall (liquid) Moisture Management Capability (OMMC).

9.1.1 Formulae used to calculate the units of measurement shown in 9.1 are given in Appendix A.

9.2 Grading – Using the average values from 9.1 and Table I, grade the tested sample(s). The grading developed is based on a study referenced in 13.2 which classifies material moving moisture from the back to the face with higher values.

9.2.1 Table II—Grading Summary Table can be used to summarize and illustrate the liquid moisture management properties of the tested sample(s).

9.2.2 Tables I and II are examples of grading schemes. Other schemes may be developed.

10. Report

10.1 Record the average and standard deviations of the measurements listed in 9.1.

10.2 Using the averages, grade the sample according to Table I and summarize using Table II.

10.3 Report the average, standard deviation and grade for each sample or the agreed upon measurements.

Table I—Grading Table of all Indices

Index		Grade				
		1	2	3	4	5
Wetting time (sec)	Top	≥ 120	20 – 119	5 – 19	3 – 5	< 3
	Bottom	≥ 120	20 – 119	5 – 19	3 – 5	< 3
Absorption rate (%/sec)	Top	0 – 9	10 – 29	30 – 49	50 – 100	> 100
	Bottom	0 – 9	10 – 29	30 – 49	50 – 100	> 100
Max wetted radius (mm)	Top	0 – 7	8 – 12	13 – 17	18 – 22	> 22
	Bottom	0 – 7	8 – 12	13 – 17	18 – 22	> 22
Spreading speed (mm/sec)	Top	0.0 – 0.9	1.0 – 1.9	2.0 – 2.9	3.0 – 4.0	> 4.0
	Bottom	0.0 – 0.9	1.0 – 1.9	2.0 – 2.9	3.0 – 4.0	> 4.0
One-way transport capability (R)		< -50	-50 – 99	100 – 199	200 – 400	> 400
Overall Moisture Management Capability (OMMC)		0.00 – 0.19	0.20 – 0.39	0.40 – 0.59	0.60 – 0.80	> 0.80

Table II—Grading Summary Table

Grade	1	2	3	4	5	
	----- ----- ----- ----- -----					Top wetting time (s)
	----- ----- ----- ----- -----					Top absorption rate (%/s)
	----- ----- ----- ----- -----					Top max wetted radius (mm)
	----- ----- ----- ----- -----					Top spreading speed (mm/s)
	----- ----- ----- ----- -----					Bottom wetting time (s)
	----- ----- ----- ----- -----					Bottom absorption rate (%/s)
	----- ----- ----- ----- -----					Bottom max wetted radius (mm)
	----- ----- ----- ----- -----					Bottom spreading speed (mm/s)
	----- ----- ----- ----- -----					One-way transport index (%)
	----- ----- ----- ----- -----					Overall moisture management
Grade	1	2	3	4	5	

11. Precision

11.1 A single-lab study was performed in November 2008 using a SDL Atlas Moisture Management Tester, Model 280, Software Version 3.06. The six fabrics tested are identified in Table III.

11.2 The samples were laundered one time in a single 1.8 kg (4 lb) load according to AATCC’s TM 135 (1)(III) Ai, Normal water level with 2003 AATCC Standard Reference Liquid Laundry Detergent. A normal tumble dry setting was used for a 30 min interval. Ten new specimens from each sample were tested three separate days by one operator. Specimens were conditioned 48 h and tested in prescribed standard atmospheres (see 7.2).

11.3 Table III Summary Data for Each MMT Measurement by Sample shows the

average values of each MMT unit of measurement for each sample. The table also shows the calculated standard deviation (SD), coefficient of variation percent (CV%), and 95% confidence interval for each sample. As noted in 5.2-5.5, caution in comparing data between selected samples or among all of the samples in the study cannot be made as the study samples represent different fabric types, yields, fiber contents and technology applications.

11.4 T-tests on all of the reported measurements for the three sets of 10 replicate data within a sample, at the 95% confidence level, do not show any statistically significant differences within a sample. Therefore, the confidence intervals may be used to suggest a range of values that may be obtained with each test measure-

ment for various types of samples.

11.5 *Between-laboratory* precision has not been established for this test method. Until such precision information is available, users of the method should use standard statistical techniques in making any comparison of test results for *between-laboratory* averages.

11.6 Earlier studies regarding the Moisture Management Tester’s precision have been performed (see 13.3.)

11.7 Data from the 2008 study are on file at AATCC Headquarters for reference purposes.

12. Bias

12.1 Bias. The true value of liquid moisture management property of textile fabrics can be defined only in terms of a

Table III—Summary Data for Each MMT Measurement by Sample

	Yield G/M ²	Fiber Content		Top	Bottom	Top	Bottom	Top Max	Bottom Max	Top	Bottom	Accumulative One-Way Transport Index (%)	OMMC
				Wetting Time (sec)	Wetting Time (sec)	Absorption Rate (%/sec)	Absorption Rate (%/sec)	Wetted Radius (mm)	Wetted Radius (mm)	Spreading Speed (mm/sec)	Spreading Speed (mm/sec)		
Woven	117	100% C	average	2.32	2.37	86.55	71.22	30.00	30.00	8.22	8.07	-120.41	0.42
			min	2.05	2.20	82.44	66.70	30.00	30.00	7.96	7.69	-143.57	0.41
			max	2.59	2.59	90.09	75.10	30.00	30.00	8.50	8.27	-98.18	0.43
			std dev	0.11	0.10	1.71	1.69	0.00	0.00	0.14	0.13	11.11	0.0047
			cv %	0.05	0.04	0.02	0.02	0.00	0.00	0.02	0.02	-0.09	0.01
			95% CI	0.04	0.04	0.61	0.60	N/A	N/A	0.05	0.05	3.98	0.00
Knit	168	100% PET	average	2.93	3.06	57.11	48.52	23.50	22.50	4.53	4.42	-89.25	0.36
			min	2.77	2.77	52.54	44.19	20.00	20.00	4.11	4.08	-110.25	0.35
			max	3.41	3.41	94.06	52.44	25.00	25.00	4.93	4.93	-55.66	0.37
			std dev	0.13	0.14	7.26	2.28	2.33	2.54	0.22	0.21	12.54	0.01
			cv %	0.04	0.05	0.13	0.05	0.10	0.11	0.05	0.05	-0.14	0.03
			95% CI	0.05	0.05	2.60	0.82	0.83	0.91	0.08	0.08	4.49	0.00
Knit	204	100% C	average	5.28	4.33	38.12	56.21	52.50	27.67	4.97	5.73	417.00	0.87
			min	3.72	2.84	29.74	47.24	25.00	25.00	4.30	4.71	342.02	0.81
			max	6.84	5.64	98.17	64.78	30.00	30.00	5.91	6.88	507.58	0.90
			std dev	0.89	0.75	11.93	4.18	1.53	2.54	0.34	0.53	36.56	0.02
			cv %	0.17	0.17	0.31	0.07	0.03	0.09	0.07	0.09	0.09	0.02
			95% CI	0.32	0.27	4.27	1.50	0.55	0.91	0.12	0.19	13.08	0.01
Knit	199	100% C	average	3.65	3.06	39.25	49.63	20.17	20.67	3.74	4.23	296.73	0.74
			min	2.84	2.13	32.64	44.64	15.00	20.00	3.11	3.77	209.59	0.64
			max	4.44	3.64	43.90	54.07	25.00	25.00	4.78	5.41	378.72	0.85
			std dev	0.41	0.33	3.18	2.32	1.60	1.73	0.37	0.35	39.86	0.05
			cv %	0.11	0.11	0.08	0.05	0.08	0.08	0.10	0.08	0.13	0.07
			95% CI	0.15	0.12	1.14	0.83	0.57	0.62	0.13	0.13	14.26	0.02
Knit	648	65N/21PET/14EL	average	6.74	3.55	17.71	68.51	14.17	20.50	2.21	3.55	722.30	0.87
			min	3.80	3.08	11.73	50.45	10.00	20.00	1.10	3.32	649.96	0.81
			max	14.84	3.88	32.40	90.84	15.00	25.00	2.97	3.88	785.22	0.93
			std dev	2.67	0.21	5.11	14.57	1.90	1.53	0.52	0.13	36.53	0.04
			cv %	0.40	0.06	0.29	0.21	0.13	0.07	0.24	0.04	0.05	0.05
			95% CI	0.96	0.08	1.83	5.21	0.68	0.55	0.19	0.05	13.07	0.01
Knit	168	65N/21PET/14EL	average	7.16	6.23	54.94	80.52	10.00	11.00	1.29	1.43	233.47	0.52
			min	5.72	4.92	36.67	42.76	10.00	10.00	0.73	1.30	23.50	0.36
			max	14.67	7.08	106.95	168.13	10.00	15.00	1.51	1.75	574.27	0.77
			std dev	1.60	0.49	19.13	30.62	0.00	2.03	0.13	0.08	112.50	0.11
			cv %	0.22	0.08	0.35	0.38	0.00	0.18	0.10	0.06	0.48	0.21
			95% CI	0.57	0.18	6.85	10.96	N/A	0.73	0.05	0.03	40.26	0.04

test method. There is no independent method for determining the true value. In estimating this property, the test method has no known bias.

13. Notes

13.1 White AATCC Textile Blotting Paper, the *AATCC/ASTM International Moisture Management Technical Supplement as Related to Textile Apparel, Linens and Soft Goods*, and other noted documents are available from AATCC, P.O. Box 12215, Research Triangle Park NC 27709; tel: 919/549-8141;

fax: 919/549-8933; e-mail: orders@aatcc.org; web site: www.aatcc.org.

13.2 The information about the Moisture Management Tester is available from SDL Atlas L.L.C., 3934 Airway Drive, Rock Hill, SC 29732-9200, tel: 803-329-2110, fax:803-329-2133, e-mail: info@sdlatlas.com; web site: www.sdlatlas.com and may be built according to patent USP 6,499,338 B2 and information in the research paper "Moisture Management Tester: A Method to Characterize Fabric Liquid Moisture Management Properties," *Textile Research Journal*, Vol. 75(1), 2005, pp57-62 and the research paper "An Improved Test Method for Characterizing the Dynamic Liquid

Moisture Transfer in Porous Polymeric Materials," *Polymer Testing*, Vol. 25(2006), pp677-689.

13.3 "Precision of New Test Method for Characterizing Dynamic Liquid Moisture Transfer in Textile Fabrics" by Bao-guo Yao, Zhejiang University and The Hong Kong Polytechnic University and Yi Li and Yi-lin Kwok, the Hong Kong University, published in the *AATCC Review*, Vol. 8, No 7, July 2008.

13.4 Available from ASTM, 100 Barr Harbor Dr., W. Conshohocken PA 19428-2959; tel: 610/832-9555; fax: 610/832-9555; web site: www.astm.org.

APPENDIX A

A1. Formulae Used in the Moisture Management Tester Software for the Calculation of Units of Measurement

A1.1 Absorption rate AR_T and AR_B (%/sec) formulae are:

AR_T = Average (SLOPE_T) and AR_B = Average (SLOPE_B)

A1.2 Spreading speed (S_i) formulae are:

$$S_i = \frac{\Delta r_i}{\Delta t_i} = \frac{\Delta r_i}{t_i - t_{i-1}}$$

Where:

concentric ring = i ($i = 1, 2, 3, 4, 5, \text{ or } 6$)
wetting time + t_i , I = the liquid moisture spreading speed (S_i) from ring $i-1$ to ring i
the distance between ring i and ring $i-1$ = Δr_i

A1.3 Accumulative Spreading Speeds (SS_T and SS_B) formulae are:

$$SS_T = \sum_{i=1}^{N_T} S_i = \sum_{i=1}^{N_T} \frac{\Delta r_i}{t_i - t_{i-1}},$$

$$SS_B = \sum_{i=1}^{N_B} S_i = \sum_{i=1}^{N_B} \frac{\Delta r_i}{t_i - t_{i-1}}$$

Where:

N_T and N_B are the numbers of the maximum wetted rings of the top and bottom surfaces

A1.4 Accumulative one-way transport capability (R) formula is:

$$[\text{Area } (U_B) - \text{Area } (U_T)] / \text{Total testing time.}$$

A1.5 Overall moisture management capability (OMMC) formula is:

$$\text{OMMC} = C_1 * AR_{B_ndv} + C_2 * R_{ndv} + C_3 * SS_{B_ndv}$$

Where:

C_1 , C_2 , and C_3 are the weighting values * for AR_{B_ndv} , R_{ndv} and SS_{B_ndv}
(AR_B) = absorption rate
(R) = one-way transport capability, and
(SS_B) = spreading speed

$$AR_{B_ndv} = \begin{cases} 1 & , AR_B \geq AR_{B_max} \\ \frac{AR_B - AR_{B_min}}{AR_{B_max} - AR_{B_min}} & , AR_B \in [AR_{B_min}, AR_{B_max}] \\ 0 & , AR_B \leq AR_{B_min} \end{cases}$$

$$R_{ndv} = \begin{cases} 1 & , R \geq R_{max} \\ \frac{R - R_{min}}{R_{max} - R_{min}} & , R \in [R_{min}, R_{max}] \\ 0 & , R \leq R_{min} \end{cases}$$

$$SS_{B_ndv} = \begin{cases} 1 & , SS_B \geq SS_{B_max} \\ \frac{SS_B - SS_{B_min}}{SS_{B_max} - SS_{B_min}} & , SS_B \in [SS_{B_min}, SS_{B_max}] \\ 0 & , SS_B \leq SS_{B_min} \end{cases}$$

AR_{B_max} , AR_{B_min} , R_{max} , R_{min} , SS_{B_max} and SS_{B_min} are the maximum and the minimum grading values for each index for summed specimens tested from a sample.

* C_1 , C_2 , and C_3 can be adjusted according to the relative importance of the three indices based on the type of fabric and the end use of the product. The weighting values used in the development of the MMT software were $C_1 = 0.25$, $C_2 = 0.5$ and $C_3 = 0.25$, based on human perception studies, in which the one-way transport capability was found to be twice as important as absorption rate and spreading speed.