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Mesdan Aqualab

Aqualab: general description

- Instrument to determine the moisture content and the moisture regain of cotton fiber.
- The moisture measurement is obtained through an innovative measurement method based on microwave low power resonance technology.
- The measurement is very fast and independent of the density of the tested sample.
- The target group of users is: ginners, cotton traders, cotton spinning mills, research testing labs.

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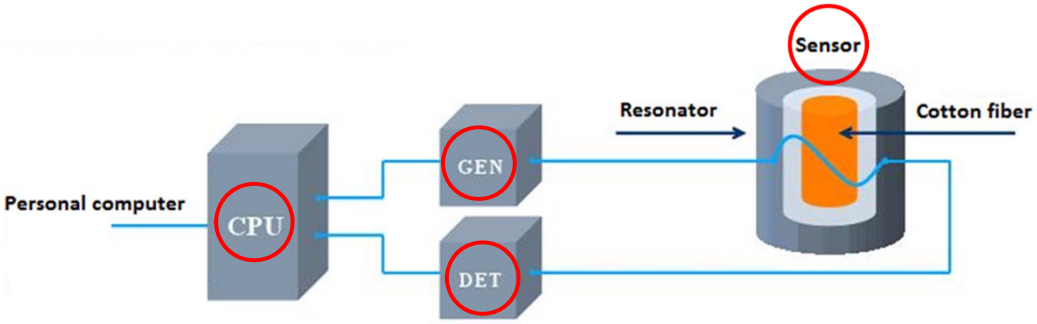
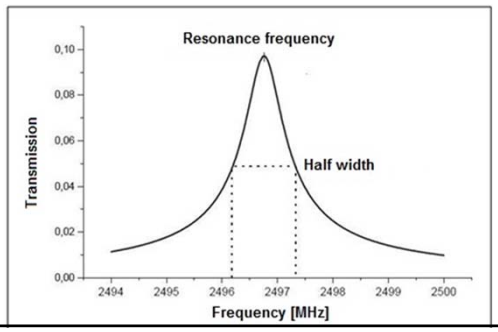
Aqualab: instrument's blocks



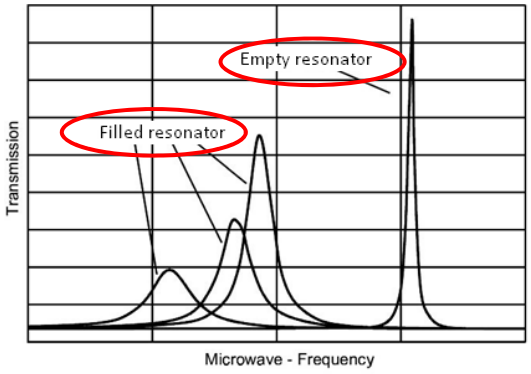
- **GENERATOR:** is a microwave generator at low power (microwave responsible for the phenomenon of resonance internal to the sensor)
- **DETECTOR:** detects the characteristics of the resonance and any changes to it due to the presence of water in the cotton fiber in the analysis
- **SENSOR:** is a microwave resonator; out of the resonances produced by this resonator we use only a specific resonance ideal for water content measurement
- **CENTRAL PROCESSING UNIT:** controls the macro blocks and interfaces to the personal computer

Aqualab: function principle

- Difference of permittivity between water (ε' ≈80) and dry material (ε' ≈1,5-3)
- A microwave resonator has got several resonances: only one resonance is used for moisture measurement
- Resonance curve is characterized by two parameters:
  - Resonance frequency
  - Half-width of the resonance (width of the resonance curve at half level)
- Algorythm for moisture content and moisture regain measurement (independent from mass of tested material).



Aqualab: function principle



- Every resonator has an empty resonance characterized by the two resonance parameters (resonance frequency, half-width of the resonance)
- When material is placed inside the resonator:
  - The resonance frequency decreases (f_0 = empty frequency)

$$A = f_0 - f_m$$

  - The half-width of the resonance curve increases (w_0 = empty half-width of the resonance)

$$B = w_m - w_0$$

- The parameters A and B are both mass-dependent in the same way, whereas they are influenced by moisture in a different way.
- Therefore the quotient "B/A" is mass-independent and it only depends on the moisture of the measured material.

Aqualab: function principle

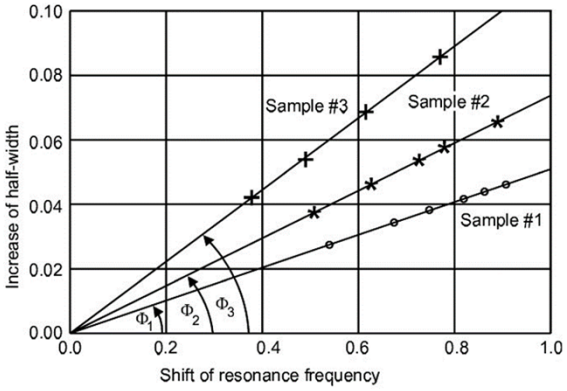
- Based on codomain reduction of function, it is calculated:

$$\Phi = \arctan\left(\frac{B}{A}\right) \quad \longrightarrow \quad \text{mass independent microwave moisture value}$$

- Measured microwave parameters "A" and "B" for three samples with varying moisture contents:

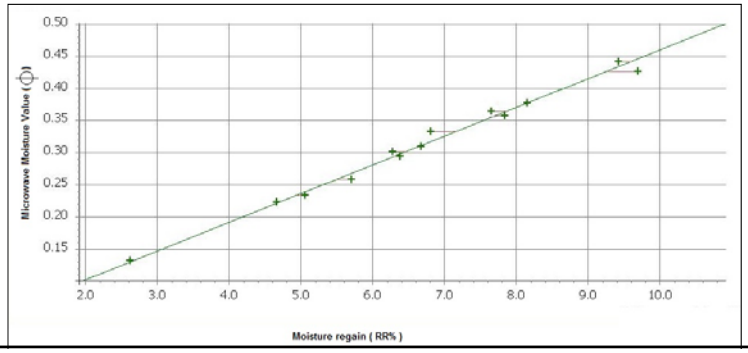
Moisture (sample#3) > moisture(sample#2) > moisture(sample#1)

- Each sample has measured with varying mass in the resonator:
  - more mass → higher values of A and B are measured
  - Φ_1, Φ_2 and Φ_3 independent on the mass
  - Φ_1, Φ_2 and Φ_3 only depend on the moisture content



Aqualab: calibration procedure

- CALIBRATION PROCEDURE:
  - Production of calibration samples conditioned at different levels of relative humidity
  - Every calibration sample is tested with Aqualab in order to determine Φ (mass independent microwave moisture value)
  - Moisture regain value (RR%) of the calibration sample is measured with the oven drying according to reference standard
  - RR% is associated with Φ thus obtaining a calibration point
  - The calibration curve is created by the calibration software on the base of calibration points.
- Note: Calibration curve for different fiber materials and blends can be created



Aqualab: testing procedure

To perform the tests the operator must:

- Enter the number of tests to be executed in the testing session
- Select the textile material to be tested.
- Start the test.
- Insert the sample in the sensor.
- Confirm the measurement results

Note: Auto check of the empty sensor resonance (f_0, w_0) is performed before each test.

Aqualab: test results

Automatically calculated	• RR% moisture regain (moisture on dry weight) • U% moisture content (moisture on wet weight) • CM% mass correction based on commercial regain rate
Optional results	• WET WEIGHT of sample/lot • COMMERCIAL WEIGHT of sample/lot • DRY WEIGHT of sample/lot (only if optional test parameter are entered by the operator)

See chapter 7.1 for definition of test parameter

Aqualab: usefulness / benefits

- No need for a special preparation of the sample.
- No need to weigh the sample analyzed.
- No waste of material: no variation of chemical-physical characteristics, no heating.
- Simple test execution, ideal for unskilled personnel.
- Very fast measurement, only few second.
- Measurement independent of density.
- No settings or calibration requested before use.
- Low power consumption, about 0.125 kWh → typical oven-drying 10 kWh!
- Free of maintenance: no consumables, no wear, no aging.
- No special environment conditions required.

Aqualab: Repeatability

- 6 subsamples taken from the same sample of raw cotton conditioned at different levels of relative humidity
- 5 measurements on each of these subsamples

	Subsample 1		Subsample 2		Subsample 3		Subsample 4		Subsample 5		Subsample 6	
	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]
Measure 1	10,019	9,107	7,452	6,935	6,063	5,716	5,396	5,12	3,835	3,693	2,875	2,795
Measure 2	10,03	9,116	7,421	6,908	6,062	5,716	5,419	5,14	3,835	3,693	2,875	2,795
Measure 3	9,918	9,023	7,425	6,912	6,092	5,742	5,391	5,115	3,943	3,793	2,974	2,888
Measure 4	9,915	9,021	7,438	6,923	6,134	5,779	5,437	5,157	3,928	3,78	2,959	2,874
Measure 5	9,891	9,001	7,405	6,894	6,073	5,725	5,421	5,142	3,984	3,831	2,988	2,901
Mean [%]	9,955	9,054	7,428	6,914	6,085	5,736	5,413	5,135	3,905	3,758	2,934	2,851
CV %	0,653	0,596	0,242	0,231	0,493	0,453	0,351	0,331	1,716	1,65	1,875	1,824
Standard deviation [%]	0,065	0,054	0,018	0,016	0,03	0,026	0,019	0,017	0,067	0,062	0,055	0,052

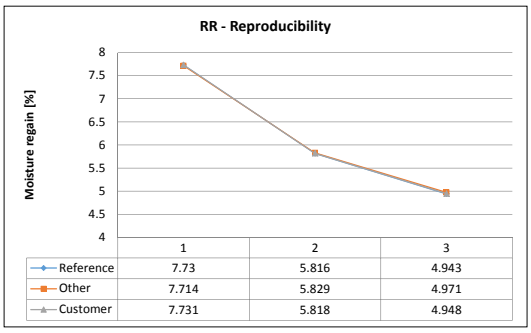
Aqualab: Reproducibility

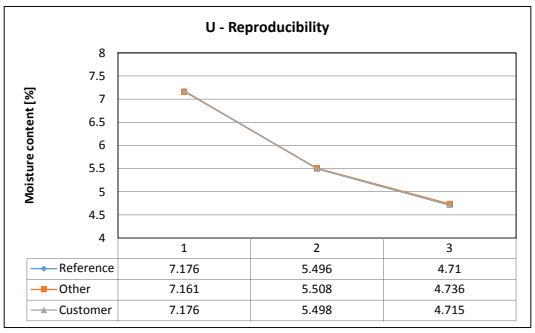
- 3 Mesdan Aqualab instruments, installed in an external laboratory of a textile company
- 3 subsamples of cotton fibers, taken from a single sample and conditioned in advance at a different level of temperature and humidity.
- Each subsample was tested with all 3 instruments, 5 measurements for each instrument, in order to also check the repeatability of the same.

	Mesdan Aqualab					
	Reference		Other		Customer	
	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]
Measure 1	4,96	4,726	4,95	4,717	4,917	4,687
Measure 2	4,937	4,705	4,985	4,748	4,971	4,736
Measure 3	4,982	4,746	5,003	4,765	4,927	4,696
Measure 4	4,893	4,665	4,95	4,717	4,974	4,738
Measure 5	4,941	4,708	4,968	4,733	4,95	4,717
Mean [%]	4,943	4,71	4,971	4,736	4,948	4,715
CV %	0,668	0,637	0,463	0,443	0,525	0,488
Standard deviation [%]	0,033	0,03	0,023	0,021	0,026	0,023

Aqualab: Reproducibility

- Mean values of each group of 5 measurements (for each instrument)

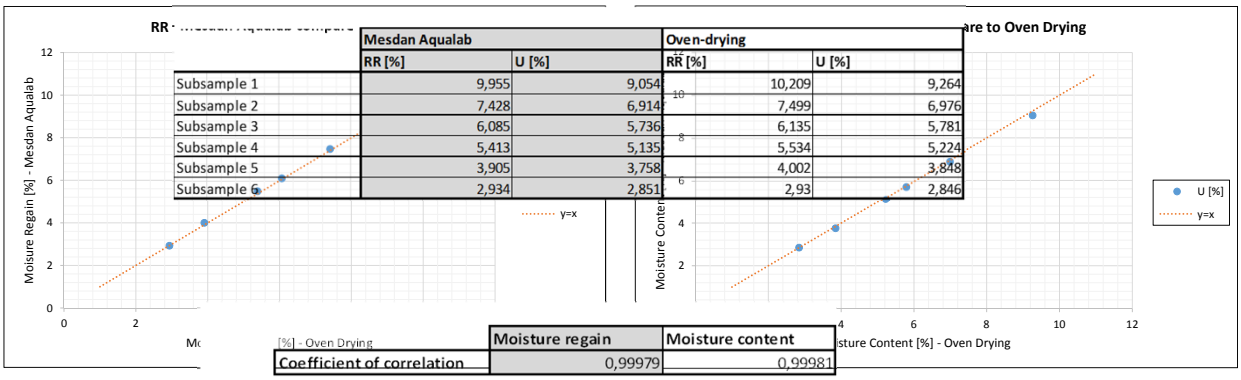




	Subsample 1		Subsample 2		Subsample 3	
	RR [%]	U [%]	RR [%]	U [%]	RR [%]	U [%]
Reference	7,73	7,176	5,816	5,496	4,943	4,71
Other	7,714	7,161	5,829	5,508	4,971	4,736
Customer	7,731	7,176	5,818	5,498	4,948	4,715
Mean [%]	7,725	7,171	5,821	5,501	4,954	4,72
CV %	0,129	0,126	0,12	0,109	0,303	0,297
Standard deviation [%]	0,01	0,009	0,007	0,006	0,015	0,014

Aqualab: comparison to reference method

- Each of the 6 sub-samples used in the tests of repeatability was tested with Mesdan "Scirocco" automatic oven-drying in compliance with International Standards



	Mesdan Aqualab		Oven-drying	
	RR [%]	U [%]	RR [%]	U [%]
Subsample 1	9,955	9,054	10,209	9,264
Subsample 2	7,428	6,914	7,499	6,976
Subsample 3	6,085	5,736	6,135	5,781
Subsample 4	5,413	5,135	5,534	5,224
Subsample 5	3,905	3,758	4,002	3,848
Subsample 6	2,934	2,851	2,93	2,846

	Moisture regain	Moisture content
Coefficient of correlation	0,99979	0,99981

Aqualab: external influences / meaurement uncertainty

- Resonance changes due to temperature variations or presence of dust in the sensor are negligible thanks to the auto check of the empty sensor resonance before each test.
- No special sample preparation → - only a simple manual opening of the fiber to obtain a good uniformity inside the sensor.
  - no sample weighing
  - correct quantity of cotton and absence of empty spaces are ensured by the slightly raised sensor cap
- Accurate cleaning o large foreign matters as they nly if:
  - foreign matter is very different
  - and
  - er is present in significant quantity