



ATLETE II PROJECT

Appliance Testing for Washing Machines Energy Label & Ecodesign Evaluation

Work Package 6: Appliances testing: product verification and laboratory capacity building Deliverable 6.4

Report on the statistical analysis of compliance verification results

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Report on the statistical analysis of compliance verification results

1. Introduction

This document is prepared within the new Task 6.4 *Statistical Analysis* of WP6 *Appliances testing: product verification and laboratory capacity building* of the ATLETE II project. The project has been financed by the European Commission programme Intelligent Energy Europe to support the EU and Member States Authorities dealing with compliance and verification issues, in order to help optimizing the available human, financial and time resources and minimizing the inconveniences for all stakeholders when enforcing legislation concerning Energy Labelling and Eco-design requirements.

The main objective of the new T6.4 analysis is twofold: (i) the analysis of the elementary test results for the tested washing machines for the standard cotton 60°C and 40°C programmes and (ii) the analysis of the resource consumption of other non-standard cotton washing cycles for the same washing machine models for comparison. The statistical analyses were developed by the company Precision Consulting, selected on the basis of a public Call for Tender (see Annex I).

The outcome of the new Task is this document: D6.4 *Report on the statistical analysis of compliance verification results*.

2. Analysis of the measured values for the investigated parameters

2.1 The analysis approach

The tested parameters for washing machine within ATLETE II were:

- energy consumption (labelling and ecodesign)
- power consumption (in two low power modes: off mode and left-on mode)
- water consumption (labelling and ecodesign)
- washing performance (ecodesign)
- spinning performance (labelling)
- cycle and low power modes duration (labelling and ecodesign)
- generic requirements (under ecodesign, in case some will enter into force during the project development)

Measured values for the tested parameters are included for each model in the test report delivered by the involved laboratories. In order to develop a statistical analysis, the first step was the preparation of a specific database, in the form of an excel file for the collection and aggregation of the elementary measurement results in a suitable form for the following analysis.

The list of the elementary data to be included in the excel file are:

- For the 40°C and 60°C cotton programmes(s) at full and partial load
 - energy consumption
 - water consumption
 - spinning speed
 - remaining water content
 - cycle time
 - washing liquor temperature (proxi of the washing cycle temperature)
 - washing performance
- For each washing machine model
 - Load capacity
 - weighted Power consumption in the off-mode
 - weighted Power consumption in the left-on mode
 - weighted energy and water consumption
 - weighted washing performance
 - weighted remaining water content (spin drying performance).

Once the database was prepared, a statistical analysis was performed in order to identify the possible relations between these parameters.

The aim is to understand if there is any relationship between load capacity, energy consumption, water consumption, spinning speed, remaining water content, cycle time, washing performance, washing temperature (or its best proxi), for both the average weighted washing cycle and the 60°C standard cotton programme at full and partial load and the 40°C standard cotton programme at partial load.

An additional important outcome of the statistical analysis was the assessment of any statistical difference among the measured parameters in the different laboratories.

2.2 Statistical analysis methodology

The following statistical procedures were used:

- *Descriptive Statistics*: mean, standard deviation
- *Pearson's Correlation coefficients (r)*: this coefficient indicates the extent to which 2 variables are related. It ranges from -1 to +1, with -1 indicating perfect negative correlation, +1 indicating perfect positive correlation, and 0 indicating no relationship.
 - r in [0, 0.2]: weak relationship
 - r in [0.2, 0.5]: moderate relationship
 - r in [0.5, 1.0]: strong relationship
- *Binomial Test*: tests whether the median of a variable is equal to a given value.
Example: “Is the difference between reported and measured value of AEC significantly different from 0”?
- *Kruskal-Wallis Test*: tests whether the median of three or more subsamples are equal.
Example: “Is the measured-reported difference in AEC significantly different by manufacturing country?”
- *Mann-Whitney U Test*: Similar to Kruskal-Wallis, but for 2 subsamples instead of 3+.

Nonparametric tests were preferred over parametric ones (such as one-way ANOVA) as they are more robust to outliers and do not place assumptions on the probability distribution of the data. For those tests, the significance level was set to the standard 0,05 value.

The washing machine load capacity was recoded so that the sample size within each capacity category would be adequate:

- “Up to 5kg” includes models with capacity of 5kg or less (n = 11)
- “Up to 6kg” includes models with more than 5kg and up to 6kg (n=16)
- “Up to 7kg” includes models with more than 6kg and up to 7kg (n=16)
- “Up to 8kg” includes models with more than 7kg and up to 8kg (n=8)

for a total of 51 models.

2.3 Statistical analysis main results

The detailed results of the statistical analysis are reported by the Consultant in Annex II. Main results are shown in Table 1.

1. On average, measured values tended to be better than declared ones (i.e. more favourable for the consumer).
 - exception: spin speed, with -3.7% lower value than declared.

2. Except for program time, all differences were significantly different from 0 (Binomial Test p from <.001 to 0.049).

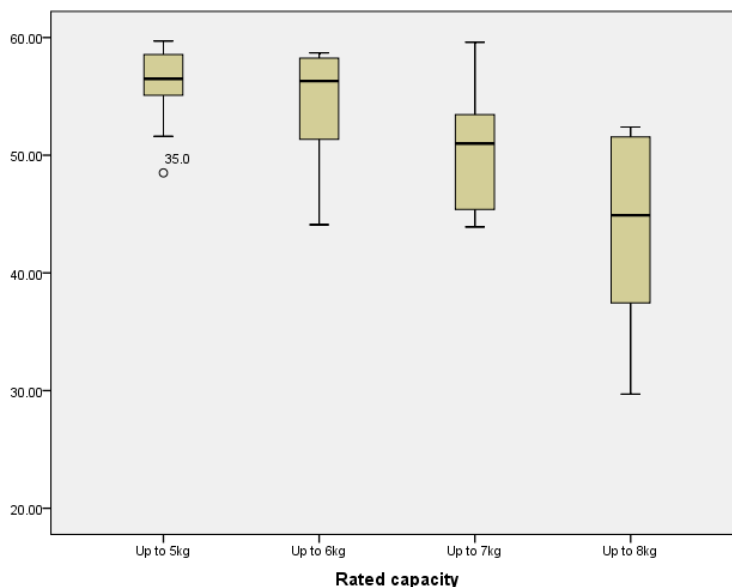
Table 1: Results of the statistical analysis

Variable	Declared	Measured	Difference	Tolerance	p (vs 0)	Compliance %
Weighted AEC	160.24	170.04	-5.5%	10.0%	<0.001*	100%
Programme time	2h.54m	2h.53m	-0.8%	10.0%	0.401	100%
Water consumption	65.98	48.01	-27.1%	10.0%	<0.001*	100%
AWC	9426.39	9245.58	-1.9%	10.0%	0.011*	100%
Remaining moisture content	57.76	56.33	-2.1%	10.0%	0.049*	100%
Power consumption(P1)	1.43	0.56	-33.8%	10.0%	<0.001*	100%
Power consumption(P0)	0.35	0.21	-31.9%	10.0%	<0.001*	100%
Spin Speed	1196.08	1151.46	-3.7%	-10.0%	<0.001*	94%
Washing Performance	1.03	1.04	1.4%	-4.0%	0.002*	100%

* significant at the 0,05 level

3. 100% of models were within the permitted tolerance values, except again for spin speed, with 94% compliant models.
4. Significant differences were found in EEI (Figure 1) by capacity (Kruskal-Wallis test $p = .002$)
 - 7kg and 8kg models have a significantly lower EEI than 5kg and 6kg models.
 - No significant difference between 5kg and 6kg, and between 7kg and 8kg.

Figure1: EEI for rated capacity of the tested washing machines



5. weak inverse relationship between EEI and annual water consumption (Correlation coefficient = -0.369).

6. All variables, except spin speed, showed significant differences across treatments (Friedman's ANOVA $p < 0,05$ in all cases).
7. Standard errors are generally lowest when measuring the 40 ½ treatment, except for remaining moisture and spin speed.
8. Assessment of the laboratories: two-way MANOVA was conducted, using Capacity and Testing Lab as predictors
 - No significant differences were found among labs after controlling for model capacity
 - Marginally significant difference in Remaining Moisture Content measurement between two labs
9. Levene's Equality of Variances test was used to compare the standard error of measurements across testing labs:
 - No significant differences in standard error found across testing labs.

The complete results of the statistical analysis are reported in Annex II.

3. Analysis of the information in the instruction booklets

3.1 Description of the investigation

A database was prepared (again in the form of an excel sheet, see Annex II) of available declared indicative information in the booklet of instructions about:

- load capacity
- energy consumption
- water consumption
- spinning speed
- remaining water content
- cycle time

for the 40°C and 60°C standard and non-standard cotton programmes(s) for the same 50 models of washing machines.

The statistical analysis of these data was run to compare the declared values for the above parameters for the 60°C standard cotton programme at full and partial load and the 40°C standard cotton programme at partial load (and if possible at full load) with the declared indicative values for the non-standard 60°C and 40°C cotton programmes reported in the instruction booklets.

The result of the above comparison will be useful to assess if a (statistically significant) difference does exist between the resource consumption (energy and water) and the duration of the standard programmes compared to similar non-standard washing programmes.

3.2 Statistical analysis results

The descriptive statistics of variables on non-standard (normal) programs, as reported in instruction booklets is shown in Table 2.

The comparison of standard vs. non-standard programs shows that:

1. There were very few booklets that reported metrics on non-standard programmes. Therefore, the accuracy of statistical tests is compromised.
2. Significant differences between normal and standard (both reported) found as per Wilcoxon Signed-Rank Test:
 - 60° full load programme has higher energy consumption ($p = 0,003$, $n = 11$) and higher water consumption ($p = 0,012$, $n = 11$) on non-standard than on standard programmes
 - 60° full load programme has a lower duration ($p = 0,008$, $n = 9$) on non-standard than on standard programmes
 - No other differences at the 0,05 significance level were found.

Table 2: descriptive statistics of variables on non-standard programs in instruction booklets

	N*	Mean	Std Dev
Energy			
40°, full load	11	.76	.12
40°, 1/2 load	4	.66	.15
60°, full load	12	1.20	.22
60°, 1/2 load	3	.96	.22
Water			
40°, full load	13	61.31	11.95
40°, 1/2 load	4	45.63	8.01
60°, full load	12	56.88	8.72
60°, 1/2 load	3	42.50	6.14
Time			
40°, full load	11	142.18	29.82
40°, 1/2 load	4	130.50	27.44
60°, full load	10	144.80	33.64
60°, 1/2 load	3	122.00	5.20
Remaining Moisture			
40°, full load	8	53.63	6.91
40°, 1/2 load	4	48.25	4.65
60°, full load	7	52.14	4.88
60°, 1/2 load	4	49.75	3.69

* N represents the number of booklets reporting this information

Annex I: Call for Tender: Statistical analysis of the test results

ATLETE II Project Call for tender - Statistical analysis of the test results

The task is composed of two different streams of activities:

1. **Detailed analysis of the elementary data of the test reports**
2. **Analysis of the indicative information in the booklet of instructions**

1. Detailed analysis of the elementary data of the test reports

The main scope of the analysis is twofold: (i) the analysis of the elementary test results for the tested washing machines for the standard cotton programmes and (ii) the analysis of the resource consumption and functional performance of other cotton washing cycles for the same washing machine models for comparison

- a. **Data collection and database preparation:** The database will be in the form of an excel file. This will include also – if necessary – the contact (through CECED) with the test labs in order to clarify possible uncertain values. An indicative list (non-exhaustive) of the elementary data to be collected are:
 - For the 40°C and 60°C cotton programmes(s) at full and partial load
 - energy consumption
 - water consumption
 - spinning speed
 - remaining water content (spin drying performance)
 - cycle time
 - washing liquor temperature (proxi of the washing cycle temperature)
 - washing performance
 - For each washing machine model
 - Load capacity
 - weighted Power consumption in the off-mode
 - weighted Power consumption in the left-on mode
 - weighted energy and water consumption
 - weighted washing performance
 - weighted remaining water content (spin drying performance)
- b. **Statistical analysis** of the possible relations between these parameters. The consultant will have to run a statistical analysis of all available test reports elementary data. The aim is to understand if there is any relationship among one or more parameters. For example, if there is any relationship between load capacity, energy consumption, water consumption, spinning speed, remaining water content, cycle time, washing performance, washing temperature (or its best proxi), for both the average weighted washing cycle and the 60°C standard cotton programme at full and partial load and the 40°C standard cotton programme at partial load.

2. Analysis of the indicative information in the booklet of instructions

- a. **Data collection and database preparation.** The consultant will have to prepare a database (again in the form of an excel sheet) of all available declared indicative information in the booklet of instructions about:
 - load capacity

- energy consumption
- water consumption
- spinning speed
- remaining water content
- cycle time for the 40°C and 60°C cotton programmes(s) and perhaps of other textiles
- other important parameters, if any,

for the same 50 models of washing machines;

- b. **Technical and statistical analysis.** The consultant will have to run a statistical analysis of these data and compare with the values of the same parameters measured in test labs for the 60°C standard cotton programme at full and partial load and the 40°C standard cotton programme at partial load (and if possible at full load). The result of the above comparison will be useful to assess the relative duration of the standard programmes compared to similar non-standard washing programmes, as well as the relative use of energy/water.

We would expect to receive a proposal including description of action and associated costs **by 31st July 2014**. The analysis should be completed by **mid-October 2014 the latest**. Offers should be delivered to michal.zakrzewski@ceced.eu

Annex II: Report of the Consultant

II.1 Detailed report of the consultant on the performed analyses

The detailed report of the consultant is provided as an external file available on the ATLETE II project website

II.2 Database of the information from the booklets of instructions

The database is provided as an external file available on the ATLETE II project website