Procedures for calibrating AS - 9 swatch batches for use in determining reference batch equivalent percentage soil removal values when testing to AS/NZS 2040.1

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Version ***1.8***

Date: ***July 2021***

Background

At present, energy performance testing of clothes washers in Australia and New Zealand is conducted in accordance with the standard AS/NZS 2040.1:2005. This standard includes provision for determining the percentage soil removal of a clothes washer, which constitutes a minimum performance standard in the Australian/New Zealand regulatory scheme. In early 2021, a new edition of the standard was published, AS/NZS 2040.1:2021. When a new Commonwealth Determination is published, it will reference AS/NZS 2040.1:2021 and AS/NZS 2040.2:2021.

Measurement of soil removal performance relies upon the use of soiled swatches known as AS-9 swatch, as currently supplied by Centre for Test Materials in the Netherlands. This material is produced in batches on rolls of cotton base cloth. Experience over the past 20 years has shown that the soil swatch production process presents two main issues:

1. On occasion, a batch is produced whereby there is significant variation in the washability of the material, depending upon which section of the batch is selected for use.
2. Subtle variations in the processes and the use of some natural materials used to produce each batch mean that the washability of the swatches varies from batch to batch. This variation can be significant and testing of historical batches has shown variations in soil removal results of 10 percentage points or more (depending on the soil removal level).

Issue 1 is simply a quality control issue that requires occasional rejection of a batch where it cannot be demonstrated to have the specified minimum level of consistency across the batch. Issue 2 is a consequence of the production process when natural materials and soils are used and cannot be avoided. However, such variations from batch to batch can be normalised provided the washability of each batch is determined against a given standard (or reference batch). To this end AS/NZS 2040.1 notes as follows:

> *I5 NORMALIZATION OF RESULTS*
> *When the percentage soil removal for each swatch has been calculated the value shall be converted into a reference batch equivalent percentage soil removal value. This shall be performed using a graph or formula obtained from http://www.energyrating.gov.au website for the particular soiled swatch batch used for the test.*
>
> *All values of average soil removal and standard deviation reported in accordance with this Standard shall be calculated from the reference batch equivalent (i.e. normalized) values.*

The remainder of this document details the procedures for testing a swatch batch to determine:

- That it meets the validation criteria for consistency across the batch. This is measured for both the unwashed and the washed soil swatches.

- The normalisation formula (curve) for converting soil removal results obtained for the batch under test into a reference batch equivalent percentage soil removal

Overview of the calibration procedure

The swatch manufacturer prepares a swatch batch and then takes samples of that batch for testing. These samples are forwarded to the testing laboratory. The test laboratory then undertakes a soil removal test procedure on the sample swatches generally in accordance with AS/NZS 2040.1, except as noted otherwise in this document. A special calibration program on the Wascator reference machine and a special load is used for the calibration procedure.

In summary the procedure is as follows:

1. Each swatch to be tested is marked with a unique identifier that can be cross referenced to determine the batch it has come from as well as its position in the batch roll.
2. The test laboratory pre-measures the reflectance of each swatch in the sample to determine if the unwashed sample meets the verification criteria for consistency of the unwashed swatches. If it meets the criteria, the testing can proceed, if not the batch is rejected.
3. The test laboratory then selects designated swatches from the delivered samples and attaches those swatches to the reference wash load items[1]. In addition, the test laboratory also attaches a number of samples from a "verification swatch batch"[2] to the wash load. The verification swatch batch is selected to give a known wash performance (within certain tolerances) during the calibration procedure. Failure to achieve the expected wash performance for the verification swatch batch is an indication that something in the wash process may have been in some way compromised, so the test is invalidated. A re-test may be undertaken.
4. The wash load, along with the swatch samples, is then loaded into a Wascator reference machine and washed on a specified program (and program time) using a set quantity and type of detergent.
5. At the end of the program, the load is removed, the swatches detached, dried, ironed and measured to determine % soil removal as per the requirements of AS/NZS 2040.1.
6. This process (3-5) is undertaken three times, each time using a different wash program with different wash times. Each of the three programs used are designed to produce different levels of soil removal.
7. The results are then evaluated to determine:
   - If the test was valid.
   - If the batch meets the consistency verification criteria.
   - What the appropriate normalisation formula (curve) is for the batch.

[1] Reference wash load is made up of polyester cotton make weights.
[2] Note: The "verification swatch batch" was formerly referred to as the "reference batch".

Swatch Sampling Procedures

Sampling Method
A minimum of three × 1 metre transverse sections must be cut from any roll to be calibrated. Samples must be taken at the start and end of the roll and also at a maximum 40 metre intervals along the length of the roll. Figure 1 below shows how a typical 200 metre roll should be sampled (approximately 1 metre long sampled transverse sections are shown in grey). Note that rolls are typically around 1 metre wide, so the transverse section is approximately square.

Each sampled transverse section shall then be divided into swatches as illustrated in **Error! Reference source not found.** below (i.e. each 1 metre wide strip taken from the roll is divided into 8 sections across the width of the roll each 110mm wide and 7 sections along the length of the roll, each 140 mm long) and marked accordingly e.g. Batch 016 – 40m – Row 1, Batch 016 – 40m – Row 2 etc. Samples for testing are taken from Row 1, Row 3, Row 6 and Row 8 only (i.e. the green shaded swatches shown in Figure 2). Normally swatches are pre-cut by CFT prior to packaging and shipment.

Figure 1: Roll sampling – transverse sections through the batch
Note: this is schematic representation of a roll – each section is approximately square.

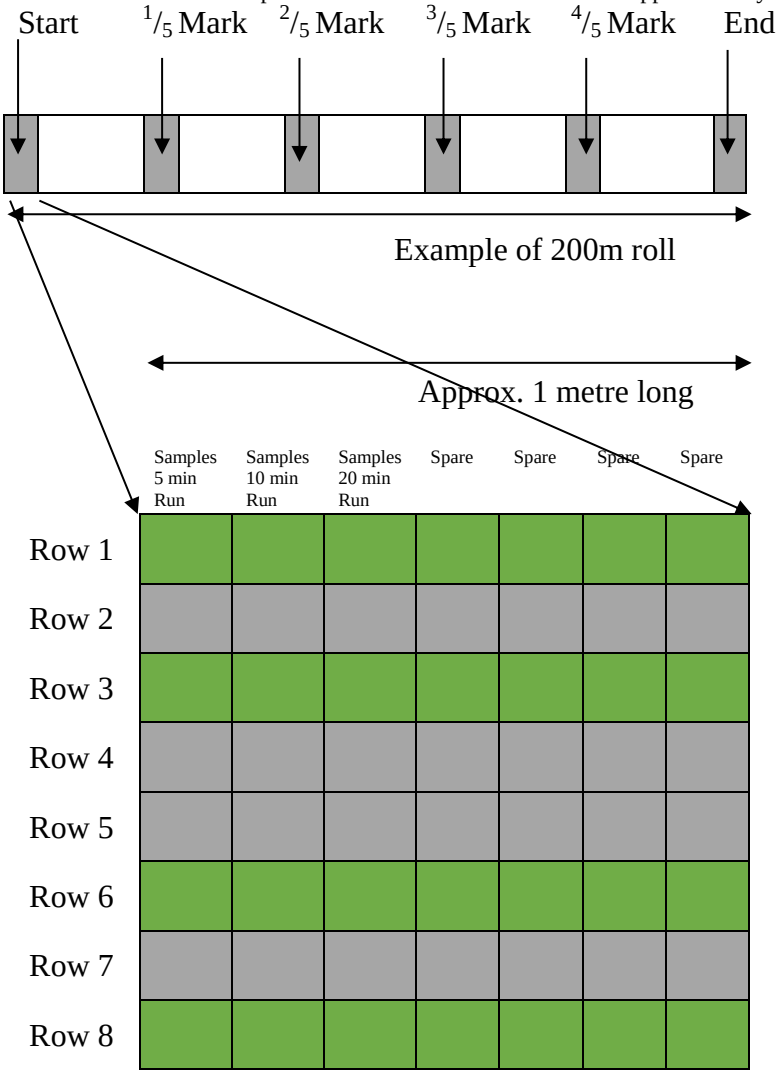


Figure 2: Division of each transverse section into swatches for testing

For each test run undertaken, a sample from each row (Rows 1, 3, 6 and 8 as shown above) in each section (each of the 6 sections in this case) shall be included (24 swatches from a 200m long roll). Added to these 24 swatches from the test batch are 6 swatches from the verification swatch batch (i.e. a total of 30 swatches in each run).

Test Procedure Specifications

The test procedure for determining % soil removal is generally as per the method described in AS/NZS 2040.1. However, for this process there are some particular set-up requirements as well as some modifications to the standard test procedure. These are described in Table 1 and Table 2 below.

Table 1: Test Procedure specifications

Parameter	Specification
Test Machine	Wascator FOM 71 CLS
Detergent Type	IEC type B
Detergent Quantity	See program details below
Perborate Quantity	0 g
Detergent Delivery	Dry via the dispenser
Anti Foam agent	Anti-sudsing agent LN1414
Anti Foam quantity	10g
Test Load Type	Nylon makeweights : Manufacturer: wfk-Testgewebe Name: Polyester Make-weights base load according IEC60456 30 x 30 cm, Annex C.3, IEC60456:2010 Order code: 99199
Test Load makeup	80 makeweights
No. of swatches per run	30 in total for a 200m roll 4 samples from 6 locations plus 6 samples from the “verification swatch batch”
Wash Programs	Three programs to be run Short, Medium, Long See Table 2 below
Water flow rate	Approximately 10 litres / minute
Spectrophotometer measurement specifications	Instrument – as specified in AS/NZS 2040.1 Aperture Diameter = 20mm min Tristimulus = Y Observer = 10^{o} Illuminant = D65 Geometry = D8 Specular - excluded
Pre-conditioning of the makeweights	Pre-conditioning of makeweights is required for any new makeweights, a total of 10 pre-conditioning runs shall be carried out
Cleaning the makeweights	Following each test run, the makeweights shall be washed using a rinse program (main wash + 2 rinses) on a machine other than the reference machine with no detergent. Set the makeweights to dry to ambient humidity before re-using.
Cleaning the reference machine	Between each calibration run, conduct a cleaning run using the medium (40°C) wash program noted below run without detergent or any load.
Parameters to be recorded during the test	• Detergent batch • Elapsed time of test • Water volume • Electrical energy consumption • Final spun mass of the makeweights

	• Cold and hot water fill flowrate

Table 2: Wash program specification (see appendix A for detailed programming)

Program ID		**AS9-5**	**AS9-10**	**AS9-20**
Run Number ID for analysis spreadsheet		**2**	**3**	**4**
Program Name		**Short (5)**	**Medium (10)**	**Long (20)**
Wash (hot & cold fill)	Water volume (L)	30	30	30
	Time (sec)	528[1]	1009[1]	2200[1]
	Temp (°C)	40[2]	40[2]	40[2]
	Action / rpm	normal / 52	normal / 52	normal / 52
	Detergent dose (g)	See Following section	See Following section	See Following section
	Antifoam dose (g)	10.0	10.0	10.0
Spin 1	Time (sec)	60	60	60
	rpm	1100	1100	1100
Rinse (cold only fill)	Water volume (L)	15	15	15
	Temp (°C)	20	20	20
	Time (sec)	180	180	180
	Action / rpm	normal / 52	normal / 52	normal / 52
Spin 2	Time (sec)	60	60	60
	rpm	1100	1100	1100

Note 1: The machine is set to start counting down the wash time as soon as the fill is complete. It is noted that at this point the wash temperature will be at or slightly lower than 40°C. This means that during the first few minutes of the wash cycle some internal heating may occur in circumstances where the initial mix of inlet hot and cold water results in a temperature below 40°C. To be able to measure the wash duration from the point in time when the wash water temperature first reaches 40°C (as was originally envisaged) would require a hardware change to the Wascator as this cannot be achieved via software alterations – this was considered to be impractical.

Note 2: The target wash temperature is set at 40°C ±2K - this is to stop the hot supply shutting off if the machine measures a temperature in excess of 40°C during the fill.

Detergent Dose

The standard detergent dose to be used for each program, as noted in Table 2, shall be 70g.

However, it is recognised that the levels of active ingredients in the specified reference detergent (IEC B) can vary from batch to batch, and where such variations are significant, this can adversely affect the wash performance scores obtained on both the batch under test and the verification swatch batch (reference batch). If the results on the verification swatch batch are found to vary to the extent that an invalid result is consistently returned (according to the specified validity criteria) when changing detergent batches, then the dose of the detergent may be adjusted in order that the verification swatch batch results again meet the criteria for a valid test. Such an adjustment should only be undertaken after all other potential sources of error have been eliminated (e.g. program variation within the Wascator, reflectometer, etc.).

Where an adjustment to the dosage is to be made, this must be informed by a chemical analysis of both the old and the new detergent, in particular, the level of active ingredients. Generally the detergent dosage should be adjusted such that the total mass of active ingredients remains constant (e.g. a 50% reduction in active surfactant would necessitate a doubling of the standard dose).

As an alternative to adjusting the detergent dose, an alternative rectification method is to adjust the wash durations. This should only ever be done if adjustments to the detergent dose and other checks fail to produce a valid result in the verification batch. Any proposals to alter the wash durations must be approved by the relevant standards committee.

Data processing to determine the normalisation

A spreadsheet is provided to automate the data processing of the results [file name: Final AS-9-XXX FN - EES Swatch Calibration Calculator VYY.xlsm which is updated as required including for each new reference batch].

Test results are input into the "Input Data" sheet in 2 parts:

- Base cloth readings (unsoiled)
- Sample Swatch readings.

Base cloth Measurements

The following data shall be recorded (fields in red are optional) for 16 samples of the unsoiled base cloth. The results shall be input into fields X12 to AR28 (highlighted in blue) of the input data tab.

Measurement ID
Product ID
Extra ID
Date
[tristimulus value, viewer angle (degrees), illuminant]
X 10\D65
Y 10\D65
Z 10\D65
X 2\D65
Y 2\D65
Z 2\D65
X 2\A
Y 2\A
Z 2\A
X 10\A
Y 10\A
Z 10\A
For all readings:

- UV Setting Measurement Type (100%)
- Geometry (D8)
- Specular Component (Excluded)

- Measurement Area (minimum 20mm diameter)

The averaged values (across the 16 samples) for each of the tristimulus/illuminant combinations are published on the Energy Rating website for use by anyone wanting to use them. Note however that the standard (AS/NZS 2040.1) now only permits the use of Y 10/D65. The value determined for Y tristimulus 10/D65 is also used to determine the unsoiled cloth constant value which is in turn used in the Kubelka-Munk equations in AS/NZS 2040.1 to calculate the percentage soil removal for each swatch tested.

Sample Swatch Readings

The table below details the type and format required for each swatch reading undertaken in the calibration process. Details of the particular input requirements into each column can be found immediately below the sample input table.

The data is input into fields B12 to H500 (highlighted in blue) of the input data tab. There is one line for each swatch including the verification swatches. For the 3 test runs on a typical 200 metre roll there would normally be 90 readings (ie 90 lines of data).

Table 3: Example of sample swatch reading data input format

Batch No:	**55**					
Run	Transverse Strip	Longitudinal strip (row)	Swatch No	Y Initial	Y Final	%SR
3	1	1	1001	42.29	66.97	80.18339
3	1	3	1003	42.7	68.25	81.6981
3	1	6	1006	43.14	68.33	81.34031
3	1	8	1008	43.4	68.54	81.37839

Batch No – This is the nominated batch number as detailed by CFT.

Run – Each run using a differing program is assigned a number. The 3 runs used to undertake the 3 different wash programs are detailed in Table 2. These are numbered as Run 2 (Short), Run 3 (Medium) and Run 4 (Long). Run numbers 1 and 5 are reserved for extra short and extra long runs respectively that may be undertaken.

Transverse strip – This indicates the section of the roll (along its length) from where the sample was taken. Transverse strips from the batch under test are numbered from left to right starting at 1. A 200m roll typically has 6 transverse strips (numbered 1 to 6 inclusive). Swatches from the verification swatch batch are designated as Transverse strip 0.

Longitudinal Strip – The width of the roll is divided up into strips from which the swatches are cut. The longitudinal strips from the batch under test are numbered from top to bottom starting at 1 ie if a total of 8 strips (rows) are used then the numbering will be 1 to 8, noting that strips (rows) 1, 3, 6 and 8 are normally the ones used for calibration).

Swatch number – This is optional to complete and is simply a reference number marked on the swatch as used by the laboratory to identify the particular swatch.

Y initial – This is the initial reflectance reading for the unwashed swatch.

Y Final – This is the final reflectance reading for the washed swatch.

% SR – This is the soil removal result as calculated from the:

- Unsoiled cloth readings (see base cloth measurements section above)
- Soiled swatch unwashed readings
- Soiled swatch washed readings

using the method as noted in AS/NZS 2040.1 using the Kubelka-Munk equations I(1) and I(2).

Acceptance Criteria

The acceptance criteria for part or all of a batch is set out in the "check" tab of the spreadsheet (follow the steps).

In summary the checks to perform are as follows:

1. Check that the initial soiled but unwashed swatch readings (excluding the verification swatch samples) are within acceptable limits of consistency. The acceptable range across the entire set of unwashed samples is 3 percentage points of reflectance (absolute e.g. 48 ± 3).

2. Check that the verification swatch soil removal results are within the limits of acceptability. The acceptable range is as follows:

- Short Wash: ± 2.5 percentage points of the target (absolute)
- Medium Wash: ± 2 percentage points of the target (absolute)
- Long Wash: ± 2 percentage points of the target (absolute).

For the verification swatch batch, the target soil removal results are as noted in the following table:

	Verification Swatch Batch Number					
Wash program	28	367	416	495		
Short Wash	70.88	77.65	74.75	78.40		
Medium Wash	76.43	82.38	80.59	84.60		
Long Wash	81.04	86.51	84.73	88.90		

3. Check which sections of the batch, if any, meet the acceptance criteria for consistency. Averaged results across each longitudinal section and each transverse section of a batch must meet the acceptance criteria if that section is to be approved. Variation across any set of longitudinal or transverse sections of the batch (averaged) must not exceed 2 percentage points for the medium or long wash programs or 3 percentage points for the short wash program. Part sections of the batch may be approved, but only the approved parts may be included in the calculation of the calibration curve. For the purposes of approval, a part section must include at least 3

contiguous transverse sections and 2 contiguous longitudinal sections or 2 contiguous transverse sections and 3 contiguous longitudinal sections.

Calculating the Calibration curve

The calibration curve for a batch is described by a curve with the form:

$a * SR^2 + b * SR$
where:
SR = the measured soil removal
a = a constant
b = a constant

The constants a and b are determined for 2 cases, one to suit the use of top load detergent and one to suit the use of IEC type B detergent.

The values of the constants a and b are calculated by the analysis spreadsheet by using the following procedure:

- Open the tab entitled “Calibration”
- At the top of the page in the cells C8 to H15 select which sections of the batch have been accepted (ie based on the results from step 4 in the “checks” tab)
- The calibration curve specifications are calculated in the yellow cells (B53 to D57). Press Ctrl Q until both cells E56 and E57 note “Curve Fit OK” then press Ctrl Q twice more (the values for a and b should virtually remain unchanged)

Once the calibration process is completed the “output” file is ready to send to the program manager for integration into the published swatch calibration data sheets available at http://www.energyrating.gov.au/

Full details of the procedures for calibrating AS9 Swatches can be found in Appendix A of this document.

Verification Swatch batch

As noted, the calibration process utilizes a “verification swatch batch”. At present this is batch number 495 and as of February 2020 there were approximately 400 samples of this batch available for use. Should the reserves of this reference batch drop below 300 samples, a new verification swatch batch must be identified from existing stocks held by CFT. Verification swatch batches are typically chosen from batches with low variability across the batch (<1.0% is preferred).

The new target soil removal results for any new verification swatch batch are determined by undertaking test runs at each of the 3 wash durations using only swatches from the current verification batch and the proposed new verification batch. Provided the results for the current batch meet the validity criteria, then the results for the proposed new verification batch can then be used as target soil removal results for the new batch.

At least 3 valid repeat runs should be undertaken at each of the wash durations and the results averaged. Once a new verification swatch batch has been identified a minimum of 1000 samples should be reserved for future test runs.

Once new target soil removal results have been determined these must be input into the analysis spreadsheet in the “Checks” tab in cells B28 to B30.

Appendix A

Procedures for Calibrating AS9 Swatches

Fitting a calibration curve and calculating the “a” and “b” values in the equation that describes the calibration curve

Introduction

This brief note has been prepared in response to a query regarding the process for converting the "raw" soil removal values from a AS9 soil swatch calibration run into the normalisation factors "a" and "b" that are subsequently used in the normalisation calculator.

The process for determining the raw soil removal values is already described in the publication *Procedures for Calibrating AS-9 Swatch Batches when testing to AS/NZS 2040.1* – see https://www.energyrating.gov.au/document/report-procedures-calibrating-9-swatch-batches-when-testing-asnzs-20401-version-16

Background

The swatch normalisation calculator is used by test laboratories as part of the process of determining the soil removal performance of a clothes washing machine in accordance with Appendix D of AS/NZS 2040.1:2005. The calculator is used to compensate for known variations between batches of soil swatches (the test material used to gauge soil removal performance) by converting the measured values back to a 'reference batch equivalent' value.

Measurement of soil removal performance relies upon the use of soiled swatches known as AS-9 which is currently supplied by Centre for Test Materials in the Netherlands. This material is produced in batches on rolls of cotton base cloth. Experience over the past 15 years has shown that the production process presents 2 main issues:

1. On occasion a batch is produced whereby there is significant variation in the washability of the material depending upon which section of the batch is selected for use.
2. Subtle variations in the processes and materials used to produce each batch mean that the washability of the swatches varies from batch to batch. This variation can be significant and testing of historical batches has shown variations in soil removal results of 10 percentage points or more. This is to be expected as the soils are natural materials and there is some seasonal and batch variation in their composition. The cotton base cloth can also vary slightly.

Issue 1 is simply a quality control issue that requires occasional rejection of a batch if it cannot be demonstrated to have a minimum level of consistency across the batch. Issue 2 is a consequence of the production process and cannot be avoided, however such variations from batch to batch can be normalised provided the washability of each batch is determined against a given standard (or reference batch). To this end AS/NZS 2040.1 notes as follows:

> *I5 NORMALIZATION OF RESULTS*
> *When the percentage soil removal for each swatch has been calculated the value shall be converted into a reference batch equivalent percentage soil*

removal value. This shall be performed using a graph or formula obtained from http://www.energyrating.gov.au website for the particular soiled swatch batch used for the test.
All values of average soil removal and standard deviation reported in accordance with this Standard shall be calculated from the reference batch equivalent (i.e. normalized) values.

The process for determining "a" and "b" values

As described in other documents, the reference process takes samples from each new swatch batch and undertakes a series of tightly controlled tests where they are subjected to what is effectively a highly consistent mechanical and chemical treatment process in a specified reference washing machine. This allows the washing performance for the new batch under each loading and wash program to be directly compared against the washing performance of previous batches.

Following is a step by step description of how the published values for "a" and "b", which are used in the formula to convert raw percentage soil removal results obtained for a particular swatch batch into a reference batch equivalent percentage soil removal value, are determined.

1. The results for the entire batch are analysed for consistency. Any sections of the batch that do not meet the consistency criteria on all three programs (short , medium and long duration) are eliminated.
2. The average value for soil removal across all viable sections of the batch are then determined for each wash duration, giving 3 data points.
3. These 3 data points are plotted on the horizontal axis of a chart against the 3 target reference values plotted against the vertical axis (target reference values were determined at the time of the creation of the swatch calibration process in the late 1990s by averaging the results of all batches measured up to that point).
4. The same process is undertaken using the measured values and the target reference values +2 percentage points. This second analysis is for the top loader detergent (Non drum type) which was determined by the standards committee to be less efficacious than the front load detergent by approximately 2 percentage points. The target reference soil removal values are detailed in the following table.

Detergent Type	**Short Run**	**Medium Run**	**Long Run**
Drum Type Detergent	72.20	78.95	82.48
Non-Drum type Detergent	74.20	80.95	84.48

5. The calibration curve for a batch is described by a curve based on a standard quadratic equation as follows:

$SR_{RBE} = a * SR_{TB}^2 + b \times SR_{TB} + c$

where:

SR_{RBE} = The reference batch equivalent soil removal

SR_{TB} = the measured test batch soil removal

a = a constant

b = a constant

c = a constant

Because a theoretical soil removal of zero in any batch should equate to zero soil removal in the reference batch (i.e. no washing is done), the constant "c" must equal zero and can therefore be ignored. Furthermore, because a theoretical soil removal of 100% in any batch should equate to 100% soil removal in the reference batch (perfectly washed swatches should be the same), the relationship between the constants "a" and "b" must be as follows:

$a = (1-b)/100$

Consequently the calibration curve can be expressed as follows:

$SR_{RBE} = ((1-b)/100) * SR_{TB}^2 + b * SR_{TB} + c$

6. An MS-Excel Goal seek function is then used to trial different values of b in the above swatch calibration formula in order that a best curve fit is achieved. A best curve fit is achieved when the difference between each of the three reference batch equivalent soil removal values (as described by the calibration curve) and the corresponding three target values (i.e. for the short, medium and long runs) is minimized. To gauge the goodness of fit of the calibration curve the following "sum of the square of the differences" formula is used:

$GOF = (SR_{RBE-SR} - SR_{TV-SR})^2 / SR_{TV-SR} + (SR_{RBE-MR} - SR_{TV-MR})^2 / SR_{TV-MR} + (SR_{RBE-LR} - SR_{TV-LR})^2 / SR_{TV-LR}$

Where:

GOF = Goodness of fit (where zero represents a perfect fit)

SR_{RBE-SR} = Reference Batch Equivalent Soil Removal Value for the short run

SR_{TV-SR} = Target Soil Removal Reference Value for the short run

SR_{RBE-MR} = Reference Batch Equivalent Soil Removal Value for the medium run

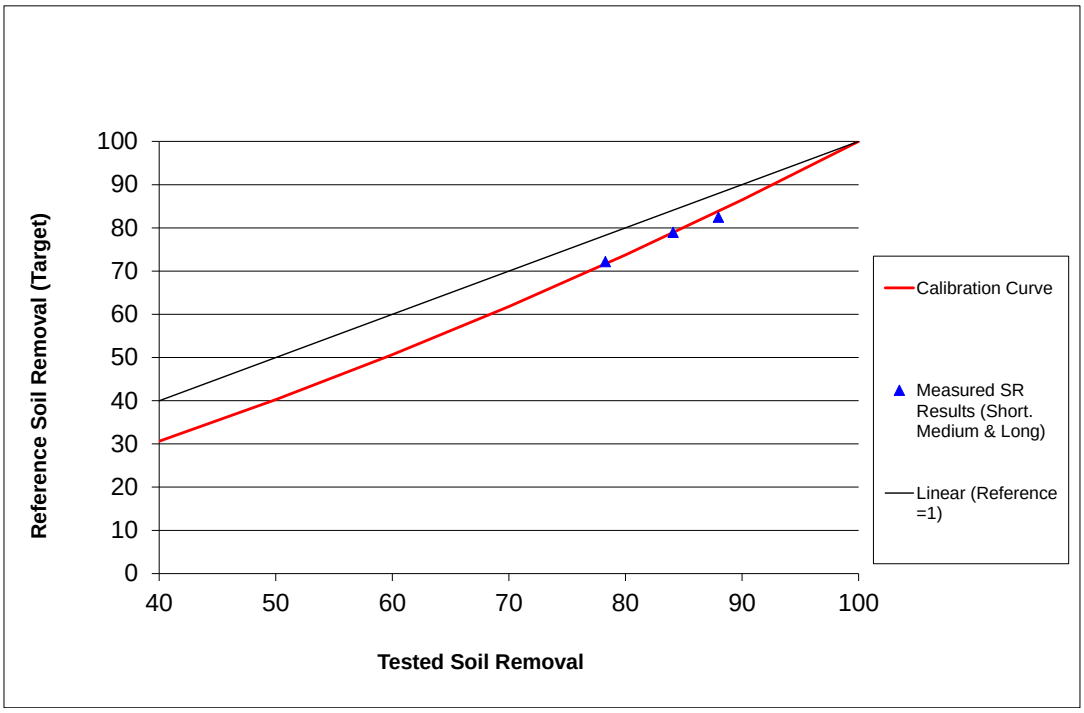
SR_{TV-MR} = Target Soil Removal Reference Value for the medium run

SR_{RBE-LR} = Reference Batch Equivalent Soil Removal Value for the long run

SR_{TV-LR} = Target Soil Removal Reference Value for the long run

7. The goal is to obtain a GOF value of less than 0.1, although a difference of up to 0.2 is considered acceptable. Values of GOF above 0.2 are not acceptable. Typically, for most batches the GOF is well below 0.1. An example of the output chart is provided below. The three measured values for soil removal are shown as blue triangles and the calibration curve fitted to those points using the process noted above is in red. The

medium wash measured value shows a measured soil removal value of ≈84% (horizontal axis) however, after calibration, this gets adjusted back to ≈79% soil removal (vertical axis).



Postscript to standard method for determining "a"and "b" values

In 2012 a problem was identified by industry with batches which appeared to be relatively easy to remove soil (i.e. their raw soil removal results were relatively high). What was apparent was that the calibration process (described in the preceding section) was tending to overcompensate for the ease with which these batches could be washed, thereby effectively marking down the reference batch equivalent soil removal score of these batches compared to historical batches.

CFT had also noticed this effect through a comparison of the calibration curves with their own in-house testing regime. It is not clear why this was the case. It may be related to sensitivity within the Kubelka-Munk equation, which tends to amplify the effect of relative changes in swatch reflectance. It could also be related to the curved shape of the calibration function that, by its nature, tends to increase negatively the correction of batches that sit below the neutral (45^0) line and increase positively those above the neutral (45°) line.

To deal with this observed effect, an empirically determined adjustment process was instituted to effectively boost the reference batch equivalent soil removal score for batches with relatively high raw soil removal results. This adjustment process was endorsed by a sub-committee of the Standards committee. The formula for adjusting the "a" value was as follows:

$a_{adjusted} = a \times 0.5293 - 0.0018125$

the adjusted “b” value was simply calculated from the adjusted “a” value using the formula:

$b = 1- (100 \times a_{adjusted})$

This adjustment process has been applied to all batches post batch 357.