INTERNATIONAL WOOL TEXTILE ORGANISATION

TECHNOLOGY & STANDARDS COMMITTEE **NICE MEETING**

Raw Wool Group **December, 1998**

Chairman: A.C. BOTES (South Africa) **Report No: RWG 08**

An International Round Trial Comparing Certified Tile Calibrations to Standard Wool Top Calibrations

By

G. R. Shepherd, T. J. Mahar and J. W. Marler

AWTA Ltd., cnr Byron & Military Rds, Guildford, N.S.W., Australia.

---

1. SUMMARY

The results of an international round trial comparing colour calibration media are reported. It is shown that colour measuring instruments can be successfully calibrated using a Certified Tile calibration and Illuminant D65 with the 10° Observer. While the precision of yellowness (Y-Z) is unchanged, a slight increase is experienced in the precision limits of X, Y and Z.

2. INTRODUCTION

During the late 1970's, the Wool Research Organisation of New Zealand (WRONZ) developed a Reference Wool to calibrate instruments used in measuring wool colour. This was done in response to unacceptable variation between colour measuring instruments and resulted in better agreement between such instruments[1]. However, such a calibration material does not measure colour in CIE units. CIE (Commission Internationale de l'Eclairge) is the organisation responsible for colour measurement standards. Furthermore, it has disadvantages such as being subject to soiling, and photobleaching by fluorescent light. While the calibration based on Reference Wool is transferred to a ceramic tile, the Reference Wool itself can only be used once. Thus, it would be desirable to have a more durable, certified, traceable calibration standard available to calibrate colour measuring instruments.

Recent work[2] demonstrated that a Certified Tile calibration can produce results that are linearly related to a Standard Wool calibration when samples of top are measured. All laboratories that participated in the trial had their instruments calibrated with the same set of certified tiles. This report describes a trial designed to determine if calibrating each instrument with a different set of tiles would also produce acceptable results.

Another feature of this trial was to calibrate and measure using Illuminant C and the 2° Observer (C/2°) on the Standard Wool calibration, while using Illuminant D65 and the 10° Observer (D65/10°) for the Certified Tile calibration. Most other industries involved in colour measurement (such as the dyeing industry) use the latter colour space. Therefore, it is appropriate for the wool industry to use the same system.

Changing to a Certified Tile calibration will cause a shift in several units for the certified results[3,4]. Furthermore, D65/10° produces slightly different results to C/2° for any given calibration. Hence, they should be incorporated at the same time to minimise disruption to the industry. A bareme between the Wool-C/2° calibration arrangement and the Tile-D65/10° arrangement is also established. This will assist in understanding the transition from the old to the new system. It should be noted that the bareme is indicative of what one would expect, but is not necessarily appropriate for each individual situation. However, it is still the best guide available for such comparisons.

3. MATERIALS AND METHODS

3.1 Laboratories and Instruments

Seven laboratories took part in the trial, using several different types of instruments. The laboratories were:

1. SGS Wool Testing Services - New Zealand
2. Wool Research Organisation of New Zealand
3. BWK - Bremen
4. Riverina Wool Combing Pty. Ltd.
5. Australian Wool Testing Authority Ltd. - Fremantle
6. Australian Wool Testing Authority Ltd. - Melbourne
7. Australian Wool Testing Authority Ltd. - Sydney

Note: The numbers above are arbitrary and are not related to the laboratory numbers described later in the report.

In an earlier trial[2], an instrument with a 0°/45° geometry could not be successfully calibrated with a certified tile. As such, all the instruments in this trial were of the 45°/0° arrangement. However, work undertaken since that trial[5] has shown that this does not necessarily occur with all 0°/45° instruments.

The participating laboratories all used spectrocolorimeters, each using one of the following types:

BYK-Gardner TCM
Hunterlab ColorQuest
ACS Chroma - Sensor CS - 3

3.2 Calibration Materials

Two calibration materials were used in order to make a comparison of the current situation involving Reference Wool for calibration and that of a proposed Certified Tile calibration.

3.2.1 Standard Wool

This was prepared to emulate the traditional Reference Wool calibration. A BYK-Gardner TCM spectrocolorimeter was calibrated with the existing Reference Wool calibration. Approximately 200 grams of commercially produced top was cut and Shirley Analysed. A 15 gram subsample was then taken for each laboratory and measured using an AWTA Ltd designed wool cell. Each sample was assigned its own set of tristimulus and reflectance values, as would occur with Reference Wool.

Each laboratory also received an uncertified ceramic ‘B4’ tile, to which the Standard Wool calibration was transferred. This was done in a fashion to mimic the transfer of a Reference Wool calibration to a tile.

3.2.2 Certified Tiles

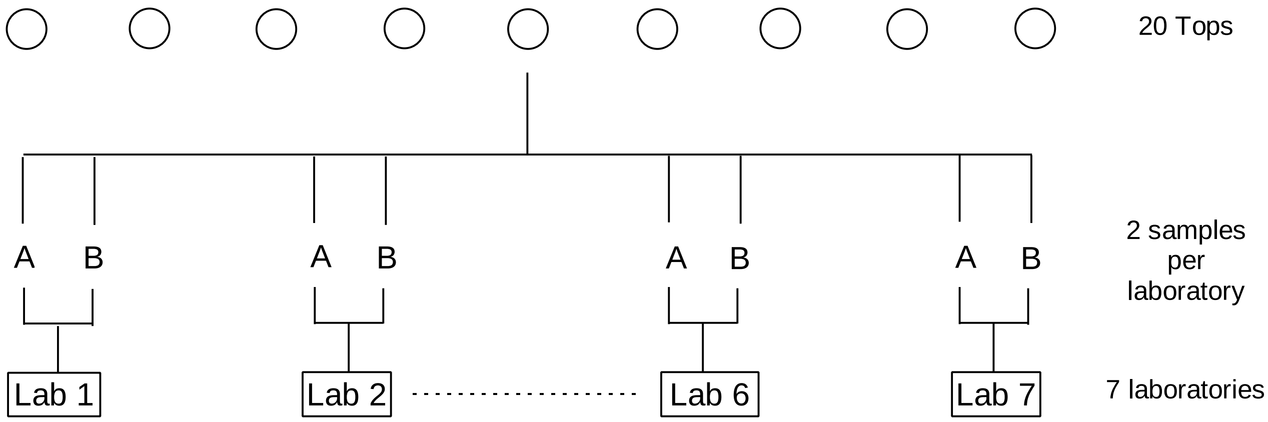
CERAM of the United Kingdom has developed certified colour tiles that can be successfully used to calibrate colour instruments[2]. Each participating laboratory purchased a set of these tiles. The black and white tiles were used to calibrate each instrument to CIE colour space. In addition, all the tiles in the set were used to ascertain the glass correction factors.

The calibration so generated was transferred to the same B4 tile that was used for the Standard Wool calibration, with the transfer being carried out against port. This tile was then used (along with the black tile) to calibrate behind glass. Appropriate equations (as described in DRAFT TM-56-97[6]) were then used to correct for the effects of the glass.

3.3 Top Samples

Twenty different tops covering a yellowness (Y-Z) range of approximately 0-14 were used in this trial. Each laboratory received 2 subsamples of sufficient top to perform a colour test. Figure 1 illustrates the trial design.

Figure 1: Schematic of trial design



4. LABORATORY PROCEDURES

4.1 Instrument Check

To ensure the instruments to be used in the trial could measure satisfactorily, an instrument check was carried out prior to commencement of the trial. The instrument was calibrated with the CERAM white tile against port and all the CERAM tiles were then measured. If the tiles could not return a value within ±1.0 unit of the certified value, the instrument was deemed to be incapable of measuring in CIE colour space and was not to be used in the trial. All the instruments passed this test.

4.2 Transfer of Calibrations

In order to mimic a normal laboratory situation, each of the participants transferred both the Standard Wool calibration and Certified Tile calibration to the B4 tile supplied by AWTA Ltd.

4.3 Glass Correction

When measuring samples on an instrument that has been calibrated using a Certified Tile, it is necessary to apply corrections to take account of the glass in order to retain traceability[2,7]. Participants followed the procedure outlined in DRAFT TM-56-97[6] to calculate these laboratory/instrument-specific glass correction equations.

4.4 Preparation of Material

Each laboratory randomised the samples prior to measurement according to DRAFT TM-56-97[6].

4.5 Top Measurement

The colour instrument was set to the C/2° configuration and calibrated behind glass with the B4 tile. This was done using the calibration that had been transferred from the Standard Wool. All samples were then measured according to DRAFT TM-56-97[6].

The instrument was then changed to the D65/10° configuration and again calibrated behind glass with the B4 tile. This time, the calibration that had been transferred from the CERAM white tile was used. All samples were again measured according to DRAFT TM-56-97[6]. Although the range limits would probably be affected by a change in the magnitude of the result, the current range limits were used in order to simplify the procedure. The corrections for glass were then applied to the results on the Certified Tile calibration.

The results obtained by the two methods were compared and analysed. Due to the need to make valid comparisons between the two calibration techniques, it was necessary to convert the measured values to the same colour space using a suitable bareme. In order to minimise confusion, the following terminology will be used:

Wool C/2° - results obtained from calibrating with the Standard Wool
Tile D65/10° - results obtained from calibrating with the Certified Tile (including glass correction)
Wool D65/10° - results from wool calibration, converted to the Certified Tile D65/10° colour space using the appropriate bareme
Tile C/2° - results from tile calibration (including glass correction), converted to the Standard Wool C/2° colour space using the appropriate bareme.

5. RESULTS AND DISCUSSION

5.1 Top Measurements

A summary of the results obtained on the two calibrations is shown in Table 1. It can be seen that the Certified Tile calibration results are higher by several units than the results obtained using the Standard Wool calibration. This is the result of two changes in the calibration. It has been shown previously[3,4] that a Certified Tile calibration causes a shift in the magnitude of colour values as it is measuring in a traceable CIE colour space, whereas a Standard Wool calibration includes the effects generated through the use of the WRONZ wool cell in the Zeiss PMQ3 primary instrument[8]. Furthermore, the change from C/2° to D65/10° will also have an impact on the measured results due to the different colour space in which the samples were measured.

Table 1: Laboratory averages for Standard Wool calibration and Certified Tile calibration

Laboratory	Certified Tile Calibration (D65/10°)				Standard Wool calibration (C/2°)			
	X	Y	Z	Y-Z	X	Y	Z	Y-Z
1	62.4	65.6	53.6	12.0	58.3	59.8	55.5	4.3
2	63.7	67.0	55.4	11.7	58.3	59.7	55.3	4.4
3	62.9	66.1	53.7	12.4	58.5	60.0	55.7	4.3
4	63.3	66.6	54.9	11.7	58.6	60.1	55.6	4.5
5	62.3	65.6	53.5	12.0	58.3	59.8	54.9	5.0
6	63.0	67.0	55.2	11.8	58.9	60.3	55.5	4.9
7	64.4	67.3	55.4	11.9	57.9	59.4	54.6	4.8
Range	2.1	1.8	1.9	0.8	1.0	1.0	1.1	0.7

The between-laboratories range for the Certified Tile calibration is approximately twice that of the Standard Wool calibration for X, Y and Z but similar for Y-Z.

5.2 Comparisons Between Calibrations (ie Wool C/2° versus Tile D65/10°)

Previous research[3,4] has shown that there is a linear relationship between a Certified Tile calibration and a Reference Wool calibration. Furthermore, analysis of the data from the current trial demonstrates there is a linear relationship between a Standard Wool calibration using C/2° and a Certified Tile calibration using D65/10°. Figure 2 illustrates the relationship for Y. Table 2 shows that X and Z also exhibited a linear response.

Table 2 gives the transformation equations for converting between the two calibration types for each of X, Y and Z. These have been generated from the grand mean for each sample. The high correlations and low standard errors indicate the robustness of the relationships in all three instances.

Figure 2: Relationship between Wool and Tile Calibrations for Y (based on grand means)

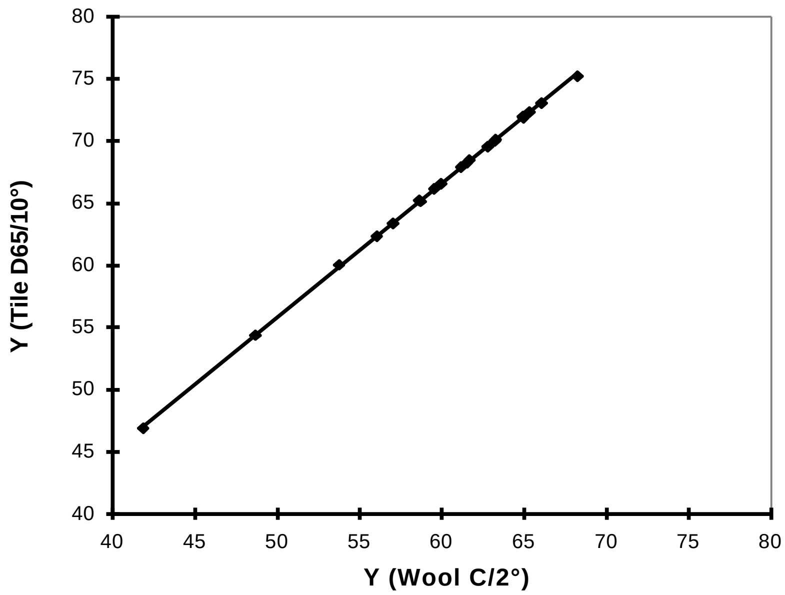


Table 2: Transformation equations for converting values generated using a Standard Wool calibration (C/2°) to a Certified Tile calibration (D65/10°) colour space

Equation (standard errors in parentheses)	R^2	SE
$X_T = 1.017\ (\pm 0.004)\ X_W + 3.756\ (\pm 0.229)$	0.9997	0.102
$Y_T = 1.076\ (\pm 0.004)\ Y_W + 2.071\ (\pm 0.213)$	0.9998	0.096
$Z_T = 0.961\ (\pm 0.007)\ Z_W + 1.394\ (\pm 0.186)$	0.9998	0.146

Such relationships can be used to convert from a Standard Wool calibration to a Certified Tile calibration and *vice versa*. During the change from C/2° to D65/10°, it may be desirable to report colour results in both the new and old colour spaces for an interim period. This will allow all sectors of the industry to adapt to the new values over a period of time.

Table 3 gives an indication of the change in magnitude to be expected for Y and Z when converting from a Standard Wool calibration to a Certified Tile calibration. These values have been generated using the equations in Table 2.

Table 3: A comparison of Y and Z values for a wool calibration (C/2°) and a tile calibration (D65/10°)

Y			Z		
Calibration			Calibration		
Wool C/2°	Tile D65/10°	Difference	Wool C/2°	Tile D65/10°	Difference
30.0	34.3	4.3	30.0	30.2	+0.2
32.0	36.5	4.5	32.0	32.2	+0.2
34.0	38.6	4.6	34.0	34.1	+0.1
36.0	40.8	4.8	36.0	36.0	0.0
38.0	42.9	4.9	38.0	37.9	-0.1
40.0	45.1	5.1	40.0	39.8	-0.2
42.0	47.2	5.2	42.0	41.8	-0.2
44.0	49.4	5.4	44.0	43.7	-0.3
46.0	51.5	5.5	46.0	45.6	-0.4
48.0	53.7	5.7	48.0	47.5	-0.5
50.0	55.8	5.8	50.0	49.5	-0.5
52.0	58.0	6.0	52.0	51.4	-0.6
54.0	60.1	6.1	54.0	53.3	-0.7
56.0	62.3	6.3	56.0	55.2	-0.8
58.0	64.5	6.5	58.0	57.1	-0.9
60.0	66.6	6.6	60.0	59.1	-0.9
62.0	68.8	6.8	62.0	61.0	-1.0
64.0	70.9	6.9	64.0	62.9	-1.1
66.0	73.1	7.1	66.0	64.8	-1.2
68.0	75.2	7.2	68.0	66.8	-1.2
70.0	77.4	7.4	70.0	68.7	-1.3

The typical change expected for Y-Z is presented in Table 4. The results were calculated from a bareme established using the Wool C/2° and Tile D65/10° results. This bareme was only established to give an indication of the likely differences between the two types of calibration for Y-Z. The typical change for Y-Z is presented in Table 4.

Table 4: A comparison of Y- Z values for a wool calibration (C/2°) and a tile calibration (D65/10°)

Calibration		
Wool C/2°	Tile D65/10°	Difference
-2.0	6.8	+8.8
-1.0	7.6	+8.6
0.0	8.4	+8.4
1.0	9.1	+8.1
2.0	9.9	+7.9
3.0	10.7	+7.7
4.0	11.5	+7.5
5.0	12.3	+7.3
6.0	13.0	+7.0
7.0	13.8	+6.8
8.0	14.6	+6.6
9.0	15.4	+6.4
10.0	16.2	+6.2
11.0	16.9	+5.9
12.0	17.7	+5.7
13.0	18.5	+5.5
14.0	19.3	+5.3

By using the equations in Table 2, the results obtained on the wool calibration can be converted to give results in the same colour space as the Certified Tile calibration results. Figures 3 and 4 show the difference between these sets of results for Y. The axes on these graphs have been chosen to highlight differences between the laboratories. It should be noted that research has shown that “observers could not distinguish any differences less than about 1.8 in Y or 1.1 in Y-Z” [9]. Thus, the differences between laboratory results and the grand mean are generally smaller than what can be discerned by visual appraisal.

Figure 3: Differences from Grand Mean for Y on Tile Calibration - D65/10°

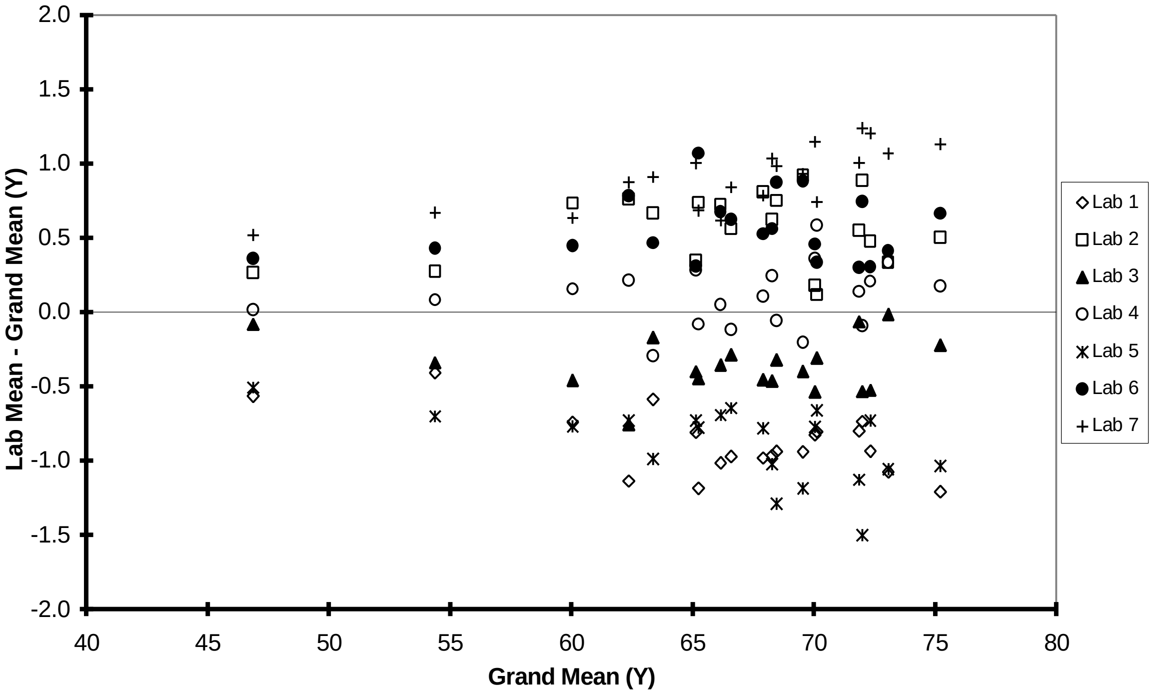
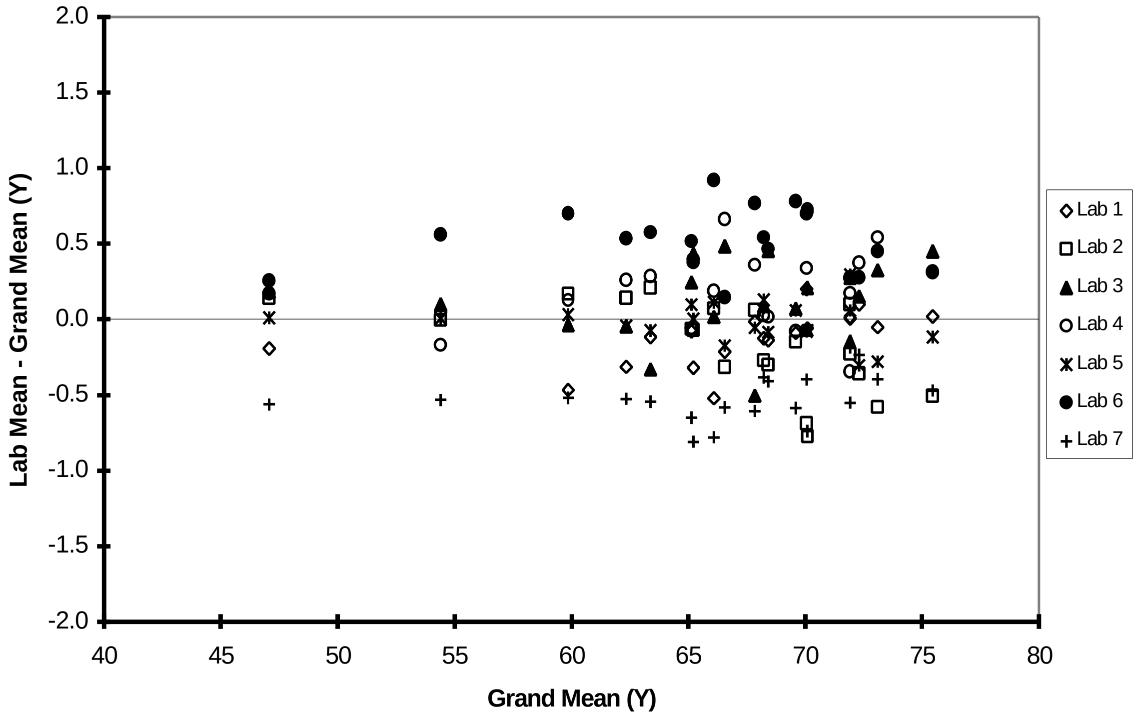


Figure 4: Differences from Grand Mean for Y on Wool Calibration - D65/10°



An analysis of the precision estimates for the Wool D65/10° and Tile D65/10° calibrations is presented in Table 5. While there is a slight level dependence apparent with the tile calibration, the trend is not large enough to warrant applying anything other than uniform precision limits (refer to Appendix).

Table 5: Within- (σ^2_W) and Between- (σ^2_B) laboratory components of variance and 95% Confidence Limits for X, Y, Z and Y-Z on both the Certified Tile and Standard Wool calibrations

	Tile Calibration (D65/10°)			Wool Calibration (D65/10°)			Wool Calibration (C/2°)		
	Variance			Variance			Variance		
	σ^2_w	σ^2_B	95% CL	σ^2_w	σ^2_B	95% CL	σ^2_w	σ^2_B	95% CL
X	0.07	0.57	1.56	0.07	0.10	0.81	0.06	0.10	0.79
Y	0.09	0.53	1.54	0.08	0.12	0.88	0.07	0.11	0.81
Z	0.13	0.82	1.91	0.12	0.19	1.08	0.13	0.20	1.12
Y-Z	0.04	0.09	0.71	0.04	0.10	0.72	0.04	0.10	0.75

The results above are reported to two decimal places in order to highlight the relevant differences. In the Standard, it would be appropriate to report to only one decimal place.

The within-laboratory variance is very similar for both calibration techniques, but the between laboratory-variance for X, Y and Z is greater for the Certified Tile calibration. Earlier work[2] found the components of variance were similar for both types of calibration in C/2° colour space; however, that work was based on one operator and one set of tiles.

Figures 5 and 6 show the laboratory differences for Y-Z for Tile D65/10° and Wool D65/10° respectively. It can be seen that tiles provide an equally precise result to wool for Y-Z. It should be noted that in the case of Figure 6 the Wool D65/10° results were obtained by transforming the Y and Z results, then calculating the Y-Z results by difference.

Figure 5: Differences from Grand Mean for Y-Z on Tile Calibration - D65/10°

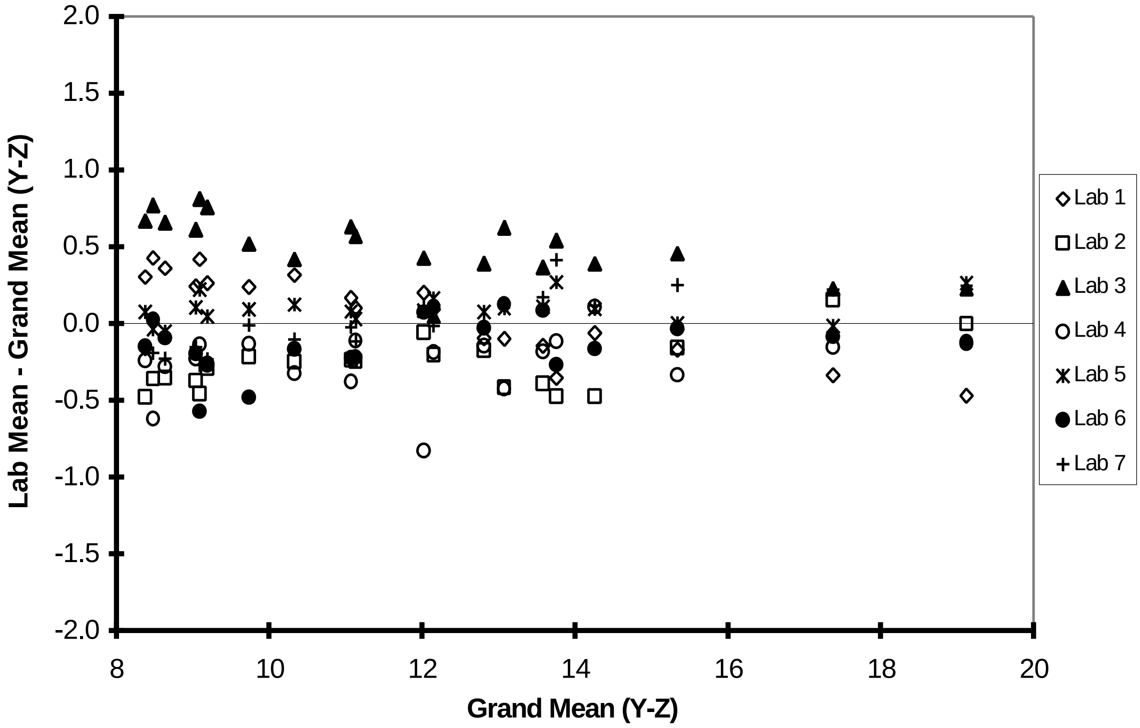
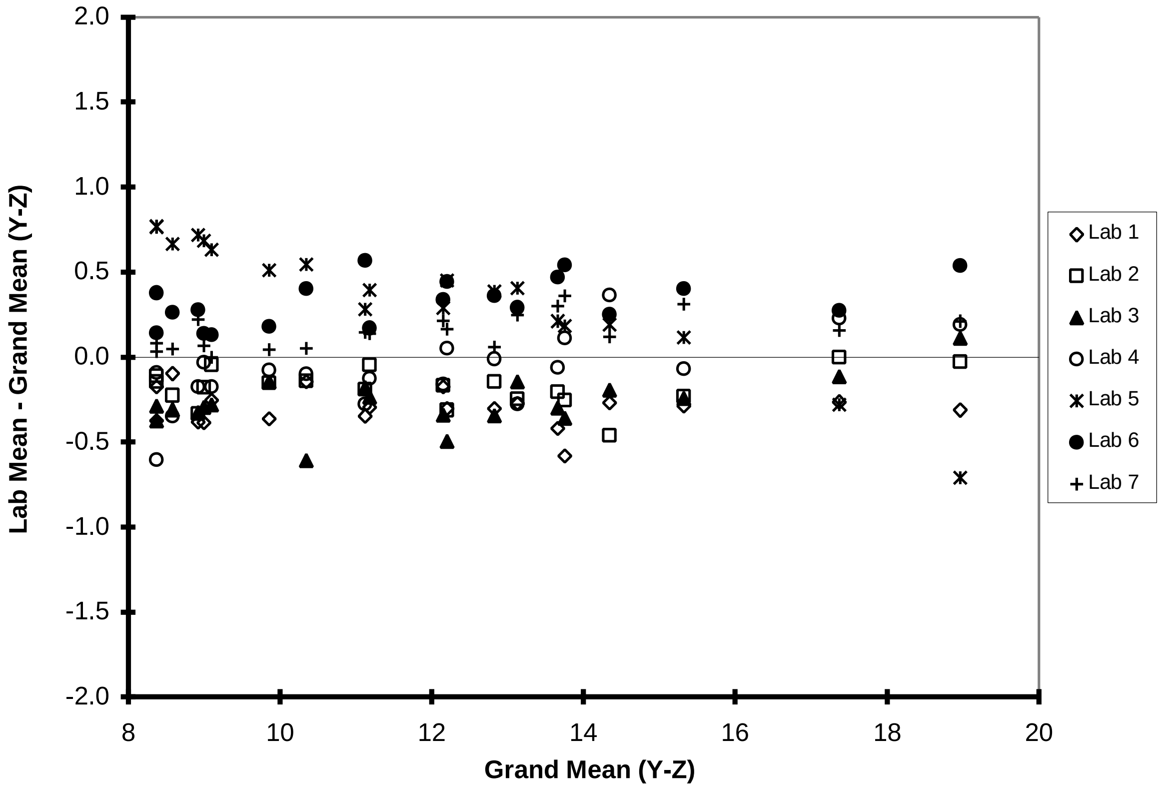


Figure 6: Differences from Grand Mean for Y-Z on Wool Calibration - D65/10°



6. CONCLUSIONS

Certified ceramic tiles can be successfully used to calibrate colour measuring instruments. However, this leads to an increase in the Confidence Limits (for top measurement) from the current situation of approximately 0.9 to 1.5 units for each of X, Y and Z. The confidence limits for Y-Z were the same for the two calibration methods. The industry will have to decide if this is an acceptable compromise for being able to use a more durable, traceable and certified colour standard.

The baremes established from this trial can be used to transfer results obtained with a traditional Reference Wool calibration to that of a Certified Tile calibration and *vice versa*. Should the industry decide to adopt the use of Certified Tile calibrations, these transformation equations will provide the means for reporting two sets of results for an interim period. The relationships reported can also be used to update any industry database to the new measurement scale. This will assist the industry in adapting to measurements reported in the new colour space.

7. BIBLIOGRAPHY

1. Hammersley, M.J. and Thompson, B. (1975). Wool colour measurement II - Between-instrument variations. *Wool Research Organisation of New Zealand, Communication No. 27.*

2. Lindsay, A.R., Mahar, T.J. and Marler J.W. (1997). The calibration of colour instruments using a certified tile and a standard wool top. *International Wool Textile Organisation Tech. Cttee.* Nice Meeting, December 1997. Report No. 8.

3. Reed, P.J., Baird, K. and Marler, J.W. (1994). Colour measurement of wool: An international round trial evaluating three calibration procedures. *International Wool Textile Organisation Tech. Cttee*. New Delhi Meeting, March 1994. Report No. 13.

4. Reed, P.J. and Marler, J.W. (1994). Calibration of colour instruments with a certified ceramic tile and the WRONZ Reference Wool. *International Wool Textile Organisation Tech. Cttee*. Nice Meeting, December 1994. Report No. 12.

5. Ranford, S.R. (1998). *Personal communication*

6. DRAFT TM-56-97. Method for the measurement of base and "as-is" colour of wool. IWTO Draft Test Method, 1997.

7. Lindsay, A.R. (1996). The measurement of wool colour in CIE colour space. *International Wool Textile Organisation Tech. Cttee.* Cape Town Meeting, April 1996. Report No. 3.

8. Hammersely, M.J. and Thompson, B. (1978). Wool colour measurement: The preparation and measurement of a Reference Wool. *International Wool Textile Organisation Tech. Cttee*. Munich Meeting, June 1978. Report No. 14.

9. Thompson, B. And Whiteley, K.J. (1986). The visual perception of the colour of scoured wool. *J. Text. Instit.* **4:** 284-287.

8. ACKNOWLEDGMENTS

The authors would like to thank the staff involved from the seven participating laboratories for their time and patience in completing the numerous measurements involved with this trial.
We also greatly appreciate the efforts of the Wool Research Organisation of New Zealand, Riverina Wool Combing and the New Zealand Wool Testing Authority Ltd for supplying samples at short notice.
Further thanks go to Mr. Bob Couchman of the Woolmark Company for his willingness to act as an independent party in collecting the results.

9. APPENDIX

Table 6: Precision Estimates for Y

	Tiles (D65/10°)				Wool (D65/10°)			
Sample Number	Mean	Within Lab Variance	Between Lab Variance	95% Confidence Limit	Mean	Within Lab Variance	Between Lab Variance	95% Confidence Limit
1	72.0	0.0259	0.9808	1.97	71.9	0.0815	0.0169	0.61
2	63.4	0.0746	0.4500	1.42	63.4	0.0628	0.1157	0.83
3	75.2	0.1193	0.7038	1.78	75.5	0.0678	0.1146	0.84
4	65.2	0.1174	0.3824	1.39	65.2	0.1165	0.1502	1.01
5	66.6	0.2691	0.3434	1.53	66.5	0.2279	0.0874	1.10
6	68.5	0.1323	0.7573	1.85	68.4	0.0480	0.0938	0.74
7	71.9	0.1226	0.4950	1.54	71.9	0.1232	0.0286	0.76
8	67.9	0.1231	0.4950	1.54	67.9	0.1125	0.1681	1.04
9	62.4	0.0598	0.7029	1.71	62.3	0.0376	0.1068	0.74
10	73.1	0.0472	0.6119	1.59	73.1	0.0386	0.1765	0.91
11	46.9	0.0458	0.1521	0.87	47.1	0.0282	0.0695	0.61
12	69.5	0.0846	0.7878	1.83	69.6	0.1325	0.0999	0.94
13	66.2	0.0734	0.4631	1.44	66.1	0.0809	0.2566	1.14
14	65.2	0.0629	0.6958	1.71	65.1	0.1472	0.0555	0.88
15	60.1	0.0814	0.3782	1.33	59.9	0.0403	0.1507	0.86
16	70.0	0.0540	0.5147	1.48	70.1	0.0369	0.1964	0.95
17	72.3	0.0362	0.5644	1.52	72.3	0.0619	0.0565	0.67
18	70.1	0.1127	0.3099	1.27	70.1	0.0508	0.3468	1.24
19	68.3	0.0238	0.6591	1.62	68.2	0.0076	0.0886	0.61
20	54.4	0.0588	0.2186	1.03	54.4	0.0115	0.1007	0.66
Average	**66.4**	**0.0862**	**0.5333**	**1.54**	**66.4**	**0.0757**	**0.1240**	**0.88**

Table 7: Precision Estimates for Y-Z

	Tiles (D65/10°)				Wool (D65/10°)			
Sample Number	Mean	Within Lab Variance	Between Lab Variance	95% Confidence Limit	Mean	Within Lab Variance	Between Lab Variance	95% Confidence Limit
1	8.5	0.0512	0.1960	0.97	8.4	0.0210	0.1935	0.91
2	13.6	0.0693	0.0306	0.62	13.7	0.0735	0.0742	0.75
3	8.4	0.0679	0.1133	0.83	8.4	0.0481	0.1298	0.83
4	13.8	0.0773	0.1239	0.88	13.8	0.0241	0.1547	0.83
5	12.0	0.0549	0.1295	0.84	12.2	0.0722	0.0373	0.65
6	11.1	0.0289	0.0638	0.60	11.2	0.0266	0.0473	0.53
7	8.6	0.0154	0.1309	0.75	8.6	0.0173	0.1232	0.73
8	12.2	0.1068	-0.0323	0.53	12.2	0.0925	0.0973	0.85
9	14.3	0.0057	0.0713	0.54	14.3	0.0628	0.0636	0.70
10	9.1	0.0213	0.2417	1.01	9.0	0.0531	0.1003	0.77
11	19.1	0.0069	0.0686	0.54	19.0	0.0093	0.1600	0.81
12	10.3	0.0833	0.0413	0.69	10.3	0.0478	0.1229	0.81
13	12.8	0.0232	0.0253	0.43	12.8	0.0179	0.0767	0.60
14	13.1	0.0347	0.1141	0.76	13.1	0.0359	0.0723	0.64
15	15.3	0.0190	0.0636	0.56	15.3	0.0241	0.0666	0.59
16	9.2	0.0297	0.1396	0.81	9.1	0.0209	0.0878	0.65
17	9.0	0.0190	0.1071	0.70	8.9	0.0497	0.1473	0.87
18	9.7	0.0692	0.0702	0.73	9.9	0.0248	0.0673	0.59
19	11.1	0.0125	0.1078	0.68	11.1	0.0234	0.1029	0.70
20	17.4	0.0096	0.0401	0.44	17.4	0.0144	0.0446	0.48
Average	**11.9**	**0.0403**	**0.0923**	**0.71**	**11.9**	**0.0380**	**0.0985**	**0.72**

Figure 7: Relationship between 95% Confidence Limit and Mean Y Value on Wool Calibration (D65/10°)

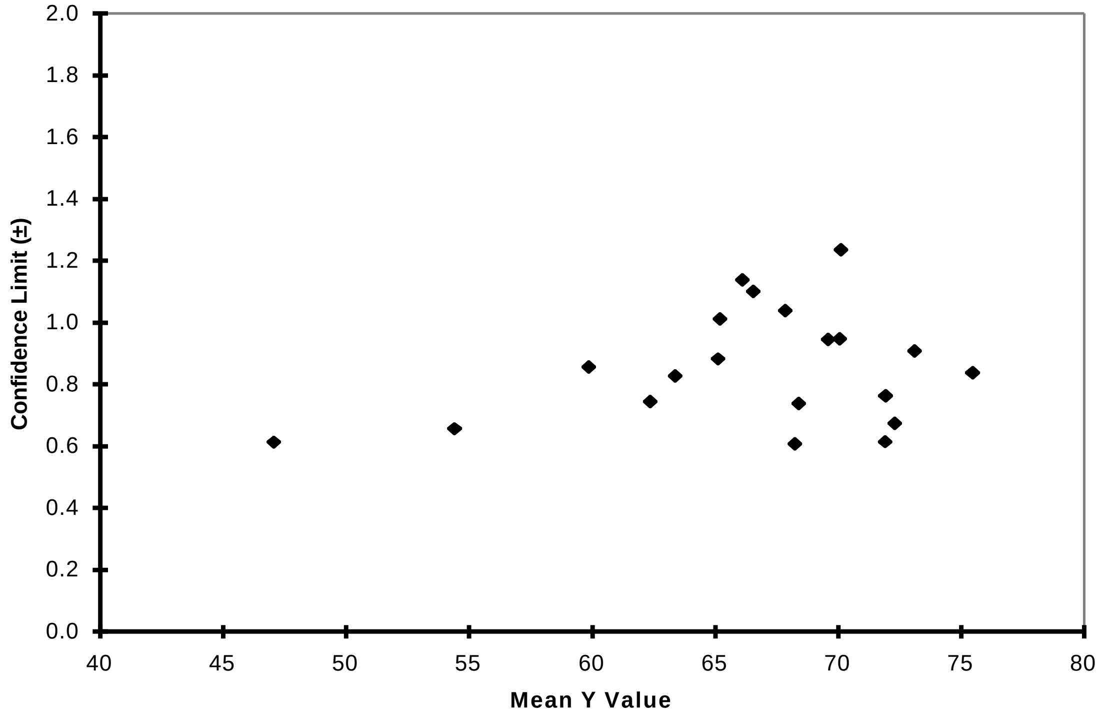


Figure 8: Relationship between 95% Confidence Limit and Mean Y Value on Tile Calibration (D65/10°)

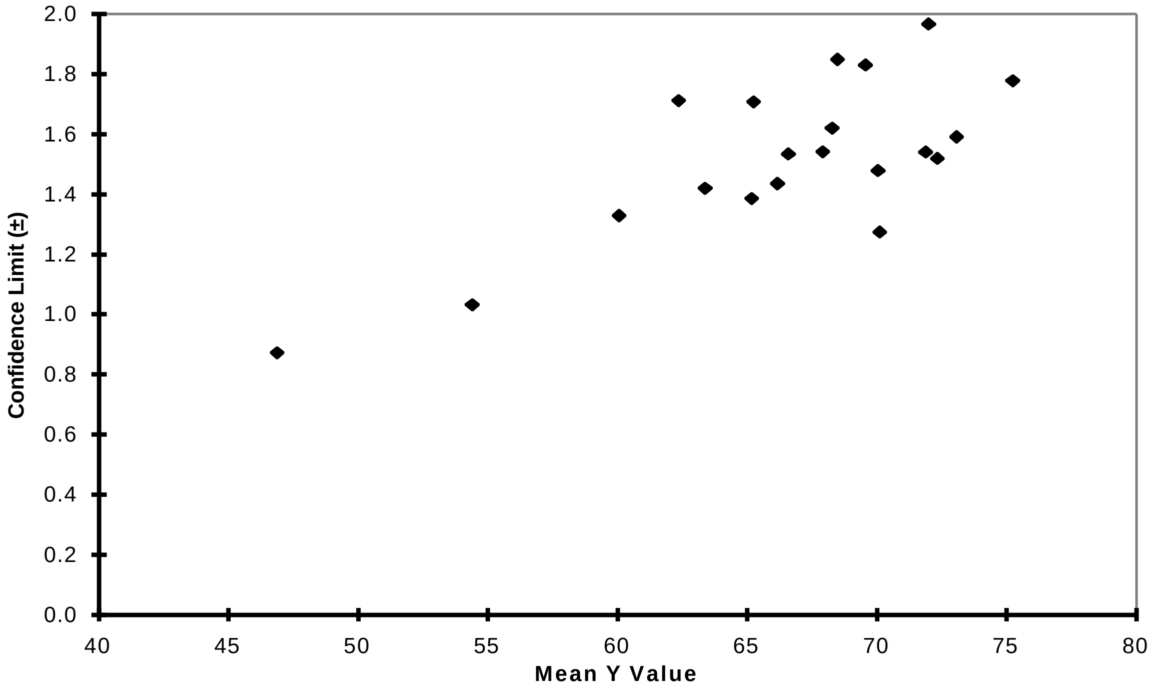


Figure 9: Relationship between 95% Confidence Limit and Mean Y-Z Value on Wool Calibration (D65/10°)

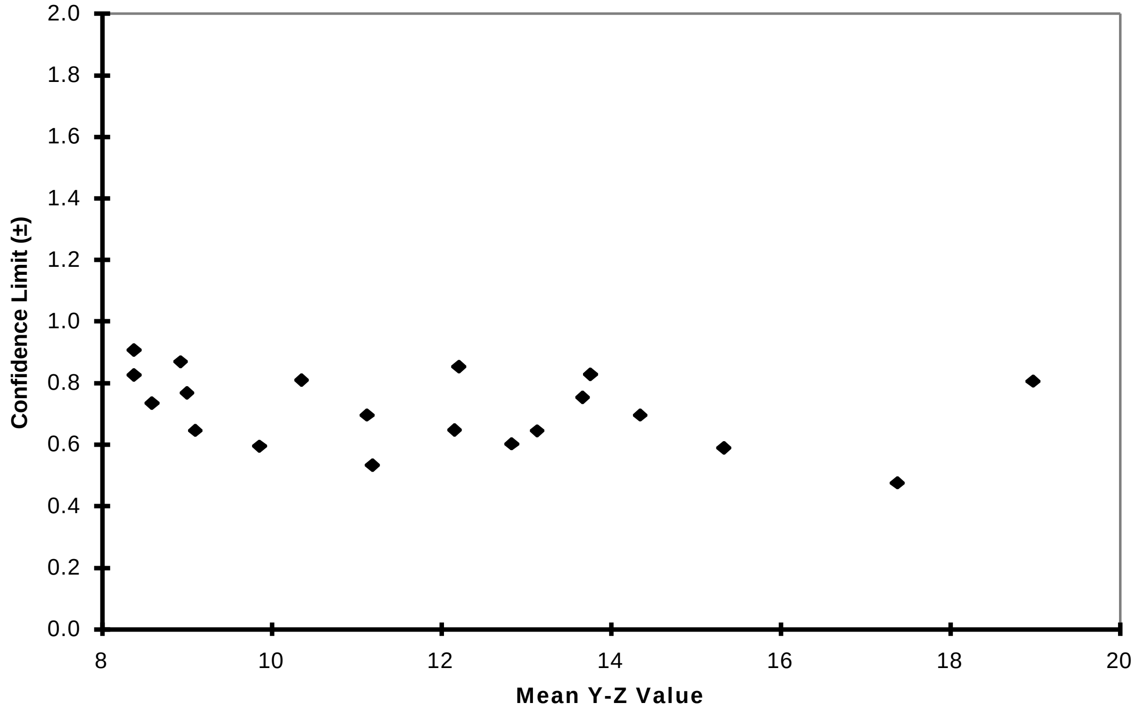


Figure 10: Relationship between 95% Confidence Limit and Mean Y-Z Value on Tile Calibration (D65/10°)