TABER INDUSTRIES
AS9100B & ISO 9001:2008 CERTIFIED

Memo

To: Dr. Frank Buckel

From: Alan Jaenecke

CC: IGPG Participating Labs

Date: June 6, 2011

Re: IGPG Taber Round Robin Results

I have analyzed the data presented in your report 2011-05-27 and identified a minimum of four potential sources of variation. Below are my observations.

	1	2	3	4	5	6	7	8	9	10	11
Method	D1044	D1044	D1044	ECE R43	ECE R43			D1044	ECE R43	ECE R43	ECE R43
Lot#	DW23D2	EE12D2	DD17D2	DD15D3	DW22D2	DD15D3	EH19D2	DS04D1	DY22D2	DY22D2	DW22D2
Load	500g										
Vacuum Gap	1/32"	1 mm	1.1 mm					0.8 mm	1.6 mm	0.8 mm	0.8 - 1.6 mm
Suction Level			100%						100%	100%	100%
Refacing Medium	ST-11	ST-11	ST-11	ST-11	ST-11	ST-11	ST-11	ST-11	ST-11	ST-11	See Comment
Nozzle	11mm	11mm	11mm	8mm	11mm	11mm	11mm	11mm	11mm	8mm	11mm
Hazemeter	Byk-Gardner		Byk-Gardner	Byk-Gardner	LMT Berlin	Byk Gardner		Byk-Gardner	Byk-Gardner	Byk-Gardner	Byk-Gardner
Taber Holder	Yes							Yes			
Conditioning	40 hrs		>40 hrs			36 hrs		36 hrs			
Abraser s/n	968627	894601	20001106	904928	Model 503	20081633	904865	955822-8	771189	771189	71000
Calibration Date	4/14/2011	Jun-10	3/30/2011	Oct-10	22.03.2011	3/9/2011	26.09.2008				20.08.2010

Glass	1	2	3	4	5	6	7	8	9	10	11
initial haze	0.32	0.10	0.11	0.18	0.18	0.09	0.08	0.13	0.17	0.13	0.10
σ initial haze	*0.02*	*0.00*	*0.03*	*0.02*	*0.02*	*0.02*	*0.03*	*0.05*	*0.06*	*0.06*	*0.01*
Δ Haze	1.42	0.80	1.27	0.92	1.14	1.51	0.65	0.92	1.47	1.90	0.82
σ Delta haze	*0.15*	*0.00*	*0.03*	*0.08*	*0.05*	*0.12*	*0.09*	*0.07*	*0.12*	*0.17*	*0.11*
PMMA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
initial haze	0.36	0.20	0.30	0.17	0.10	0.11	0.20	0.38	0.30	0.37	0.22
σ initial haze	*0.12*	*0.00*	*0.03*	*0.01*	*0.01*	*0.01*	*0.05*	*0.28*	*0.00*	*0.06*	*0.01*
Δ Haze	13.46	7.40	34.99	28.33	3.54	19.75	7.58	9.26	14.67	25.93	6.35
σ Delta haze	*2.24*	*1.87*	*5.94*	*5.44*	*0.13*	*0.64*	*0.46*	*1.04*	*4.34*	*6.69*	*1.91*
PC	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
initial haze	0.33	0.30	0.20	0.19	0.28	0.12	0.33	0.25	0.33	0.40	0.18
σ initial haze	*0.14*	*0.17*	*0.03*	*0.01*	*0.20*	*0.02*	*0.42*	*0.02*	*0.06*	*0.26*	*0.01*
Δ Haze	2.33	2.37	14.40	8.71	2.31	4.51	1.83	3.52	39.07	34.10	2.61
σ Delta haze	*0.80*	*0.23*	*3.16*	*1.40*	*0.02*	*0.54*	*0.11*	*0.57*	*1.72*	*3.42*	*0.54*

Lab 1: Initial haze values are higher than average initial haze of all labs

Lab 3: Specimen cleaning before & after abrasion used "commercial washing-up liquid in water, rinse with demineralised water"

Lab 4: 8mm vacuum nozzle orifice

Lab 5: Hazemeter manufactured by LMT Berlin; diameter of measuring field 7 ±1mm

Lab 9: Date of manufacture for instrument is 1977, no calibration information provided

Lab 10: 8mm vacuum nozzle orifice (see comment Lab 9)

Lab 11: Reface with diamond tool refacer, followed by 100 cycles on ST-11 stone, followed by 500 cycles on glass

Genuine TABER

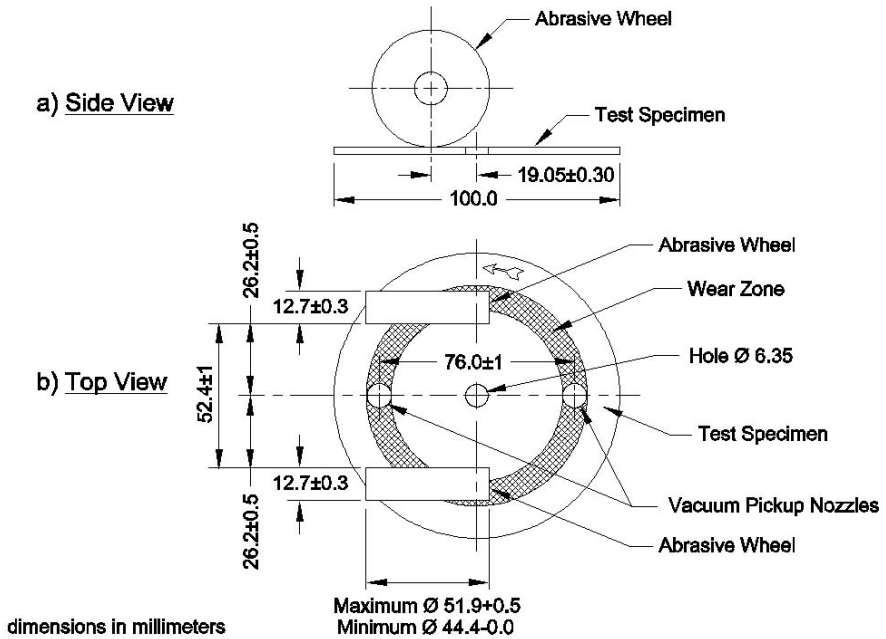
1) **Instrument Age** – The age of the instrument can be determined by the first 2 (prior to 2000) or 4 digits of the serial number. Considering the age of the instrument, wheel bearings and other aspects of the instrument *may be* worn and in need of servicing / replacement. The below lists the age of the instruments used in this study from oldest to newest.

Lab 11 – 71000 (1971)
Lab 9 / 10 – 771189 (1977)
Lab 5 – 730 2003 is not a Taber serial number, Model 503 were last manufactured in the early 1980's.
Lab 2 – 894601 (1989)
Lab 7 – 904865 (1990)
Lab 4 – 904928 (1990)
Lab 8 – 955822-8 (1995)
Lab 1 – 968627 (1996)
Lab 3 – 20001106 (2000)
Lab 6 – 20081633 (2008)

2) **Instrument Calibration** – It is essential that the Taber Abraser be calibrated on a regular basis to ensure proper operation. The critical parameters that should be evaluated include:

- Longitudinal alignment of abraser arm
- Transverse alignment of abraser arm
- Wheel tracking
- Bearing integrity
- Vacuum nozzle suction force
- Turntable rotation plane of travel ("wobble")
- Turntable speed
- Mass of abraser arms
- Mass of accessory weights

It has been Taber's experience that many companies claiming to be able to calibrate a Taber Abraser are not aware of the critical parameters. Nor do they know what the tolerances are that determine if an instrument is within calibration or not. Taber utilizes a proprietary gauging system to ensure that tolerances are set within manufacturing limits. It is important to note that many components are dependent upon each other {including bearing wear (looseness), wheel bearing shaft wear and alignment of the arms}.



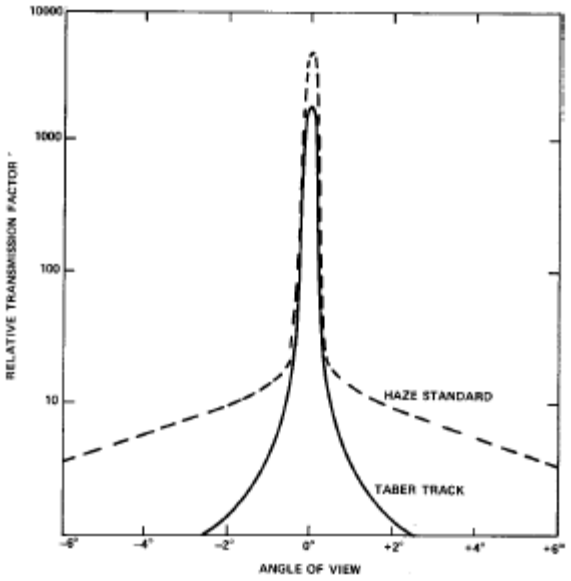
To generate valid data, it is essential the wheels sit perpendicular to the specimen during testing. Due to the tangential forces that act upon the wheels, instruments that have worn bearings tend to have wheel "toe-in" or "toe-out" conditions. If wheels do not sit perpendicular to the specimen, a smaller contact area occurs and hence, increased load. This typically produces higher abrasion.

Improper alignment of the abrasive arms can also lead to each wheel abrading a different path from its complementary wheel across the sample as well as the wheels on other machines. In an independent study conducted by the laminate flooring industry, it was determined that path surface area can differ by as much as 20% and the area abraded by both wheels on a sample could be less than 50% of the total abraded area for that sample.

3) **Instrument Set-up** – Two labs reported using a vacuum pick-up nozzle with 8mm orifice (this is the opening of the standard nozzle supplied with the Taber Abraser). Prior to the release of the Taber CS-10F Type IV wheels, validation testing indicated increased wear on the outer edges of the of the wear path. It was determined the 8mm openings were not effective at removing wear debris from across the entire wear path and three-body abrasion was being generated. The 11mm openings were found to significantly improve wear debris removal when combined with a vacuum suction of 100.

4) **Vacuum Suction Force** – For older instruments using the original vacuum system, the amount of suction force may no longer be sufficient. When utilizing a vacuum suction gage placed in the opening of the vacuum pick-up nozzle base, Taber recommends a gage reading not lower than 55 inches of water column (137 millibar).

5) **Hazemeter** – Section 4.3 of ASTM D1044-08 states "Comparison of inter-laboratory data or the specification of a "haze" value has no significance if the hazemeter requirements given in 5.4 are not used. This is because light diffused from the surface of a Taber track is scattered at a narrow angle (Fig. 1 and Fig. 2) while light diffused internally by a specimen is scattered at a wide angle. In many hazemeters, when a diaphragm is inserted to limit the light beam to the width of the abraded track, the specular beam at the exit port becomes smaller. The dark annulus will then be greater than the 0.023 ± 0.002 rad (1.3 ± 0.1°) requirements of Test Method D 1003. Since a large percentage of the narrow-angle forward scattered light will not impinge on the sphere wall, "haze" readings become smaller. For hazemeters that have not been properly adjusted, the magnitude of this reduction is dependent both on the integrating sphere diameter and the reduction of the entrance beam. Section 5.4 further describes the hazemeter apparatus.



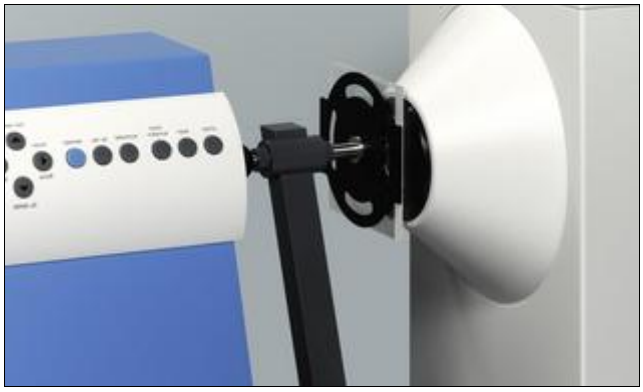
NOTE 1—This graph shows goniophotometric curves for Taber abraded tracks. The specular angle of transmission is at 180°.

FIG. 2 Light Scattering from Surface of Abraded Tracks (Graph)

5.4.1 An aperture or diaphragm shall be centrally inserted in the haze measuring apparatus to center the light beam on the abraded track and limit it to a diameter of 7 ± 1 mm [0.28 ± 0.04 in.] at the specimen.

5.4.2 When the reduced light beam is unobstructed by a specimen, its cross section at the exit port shall be approximately circular, sharply defined, uniformly bright, and concentric within the exit port, leaving an annulus of 0.023 6 0.002 rad (1.3 6 0.1°) subtended at the entrance port.

6) **Hazemeter Taber Holder** – Section 5.5 of ASTM D1044-08 requires the use of a suitable holder to position the abraded specimen on the hazemeter so that the light beam is centered in the abraded track and the specimen is flush at the measurement port. The procedure requires the abraded specimen to be placed in the holder with the abraded track against the entrance port of the integrating sphere (facing away from the light source).



Other observations worth noting:

The PMMA samples that were supplied from Polyplastic were imprinted with an identifier. If this identifier was included in the area when taking a haze reading, the values will be higher.

Lab 3 used a commercial cleaner prior to and after abrasion. It is not known if this cleaner had any influence on the coated PMMA and PC.

Lab 11 followed a refacing procedure of using the diamond tool refacer first; followed by 100 cycles on the fine side of the ST-11 refacing stone; and 500 cycles on a glass sample. Unless the CS-10F wheels are out of round, it is not necessary to reface with the diamond tool refacer. Because of the resilient binder used in the wheels, this step tends to remove the abrasive grit particles from the surface of the wheels. Although I have not verified this, I believe that 100 cycles on the fine side of the ST-11 refacing stone would be sufficient to re-establish the abrading characteristics of the wheel. Unfortunately, running the wheels for 500 cycles on a glass sample prior to testing negates the reason why the wheels are refreshed prior to testing. 500 cycles on a glass sample will cause the exposed abrasive particles to wear and the "sharp" edges of the abrasive grit will become rounded. Hence, this refacing procedure will likely result in lower abrasion values.

Labs 9 & 10 reported a Shore A hardness value of 90 and 92. The acceptable hardness range for the CS-10F wheel is 81 ±5 Shore A. Taber has established a stringent set of quality checks during our wheel manufacturing process to ensure a consistent product. Prior to approval, all wheels are evaluated for both abrasion characteristics and hardness values. Taber's procedure for measuring wheel hardness is done on the side of the wheel according to Taber document E06008A. This procedure requires (a) the gage be mounted to an operating stand; (b) a wheel alignment fixture be used to so the indentor pin contacts 6.1mm from the edge of the wheel; (c) readings be taken after a dwell time of 10 seconds; plus other critical aspects of measuring wheel hardness.

Labs 6 and 7 did not report which procedure was used. Lab 9 is reported as ECE R43, but a previous email stated a comparison between ECE Reg 43 and ASTM D1044 was to be made by one lab. Is it possible that Lab 9 should be listed as ASTM D1044?