Transmittance Haze Measurement by DIN 5036 Part 3

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This paper presents the analysis and results of transmittance haze by using DIN 5036 part 3. From the simulation, diffuse transmittance is strongly dependent on reflectance of the integrating sphere, which also makes transmittance haze deeply affected. The measured data were compared to the data from double compensation method to prove the simulation result.

INTRODUCTION

Transmittance haze inconsistencies exist among various measurement methods. In 1st APMP pilot study, some commonly used methods in Asia-Pacific area, ASTM D1003, ISO14782, BS:2782 Part5, double beam method, and double compensation method were discussed, and the reasons causing non-equivalent transmittance haze among NMIs were also analysed. Because there is no standards specifying the measurement method for such high range, while many products labelled ‘high haze’, the second TCI project (APMP.PR-P3.1) focus on studying in depth the technique of haze measurement including high haze level measurements. In 2019, CIE TC 2-94 was founded by most members that participated in the APMP pilot study. The purpose is to write a CIE Technical Report on measurement methods of total transmittance, diffuse transmittance, and transmittance haze, including their advantages and disadvantages and guidance for determination of measurement uncertainties. The 1st and 2nd pilot study results will be included in TC2-94, and the other commonly used methods, such as DIN 5036 part 3 discussed in this article, will also be analysed in this TC.

PRINCIPLE AND DISCUSSION

Total transmittance (*TT*) of DIN 5036 Part 3 is shown as step (i) and (ii) in Fig. 1, while diffuse transmittance (*DT*) is shown as step (i) to (iv)[1]. I_1 to I_4 are the measured values from step (i) to step (iv), respectively. According to the definition of transmittance haze (*TH*), ratio of *DT* to *TT*, *TH* can be calculated although there is no description about *TH* measurement in this standard document.

The sphere multiplier M for each measurement step is shown in equation (1) where ρ_o is the initial reflectance for incident flux, ρ_s is the reflectance for integrating sphere wall, ρ_i is the reflectance for port i and f_i is the fractional area of port i to the sphere internal surface area. Therefore, sphere multiplier M_0 in step (i) equals to M_t in step (ii) and M_s in step (iii) equals to M_d in step (iv) due to the same configuration.

$$M = \frac{\rho_0}{1-\rho_s(1-\sum_{i=1}^{n} f_i)-\sum_{i=1}^{n}\rho_i f_i} \tag{1}$$

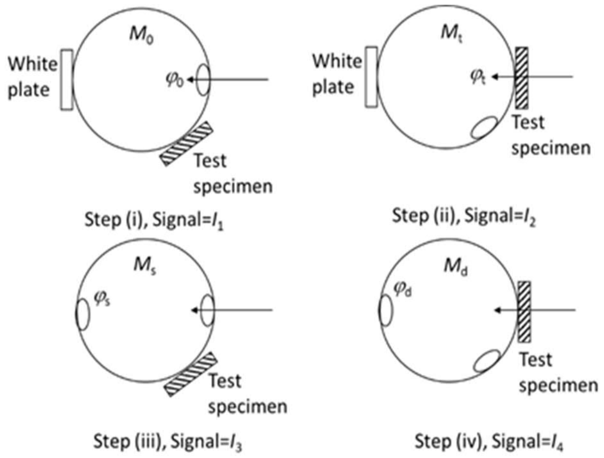

Figure 1 The method specified in DIN 5036 part 3. $TT=I_2/I_1$, $DT=(I_4-TT\cdot I_3)/(I_1-I_3)$, and $TH=DT/TT$.

Because M_0 equals to M_t, *TT* from DIN 5036 Part 3 can be measured accurately if the structure of the measurement system can be designed properly. However, some discrepancies exist during *DT* measurement process. The equation of *DT* can be rewritten as equation (2), where φ_d, φ_s and φ_0 are incident flux in step (iv), (iii), and (i), respectively.

$$DT = \frac{I_4 - TT\times I_3}{I_1 - I_3} = \frac{M_d\times\varphi_d - M_s\times TT\times\varphi_s}{M_0\times\varphi_0 - M_s\times\varphi_s} \tag{2}$$

Equation (2) shows that the sphere multiplier will affect *DT*. Assume that f_i for all ports is 0.01, *TT* is 0.95, the reflectance for the test specimen ρ_t is 0.1, φ_d, φ_s and φ_0 are 0.2, 0.01 and 1 respectively, the theoretical *DT* can be calculated under the same sphere configuration from equation (3), and the value is 0.1905.

$$DT = \frac{M_d\times\varphi_d - M_s\times TT\times\varphi_s}{M_0\times\varphi_0 - M_s\times\varphi_s} \cong \frac{\varphi_d - TT\times\varphi_s}{\varphi_0} = 0.1905 \tag{3}$$

The numerical simulation result of *DT* by changing the reflectance of sphere (ρ_s) is shown in Fig. 2, which shows that *DT* is strongly dependent on ρ_s. Except for small ρ_s, *DT* is usually smaller than its theoretical value of 0.1905. In this case, *DT* is close to the theoretical value when ρ_s is down to 0.5. However, measured signals would be greatly reduced due to low ρ_s, and usually such low reflectance material is not used for the integrating sphere wall.

Another factor that may have influence on *DT* is the incident flux φ_s due to the imperfect collimated beam. In this case, assume that ρ_s is 0.9, φ_s is variable, the result in Fig. 3 shows that *DT* is still smaller than its theoretical value, even though the incident light is a perfectly collimated beam($\varphi_s = 0$).

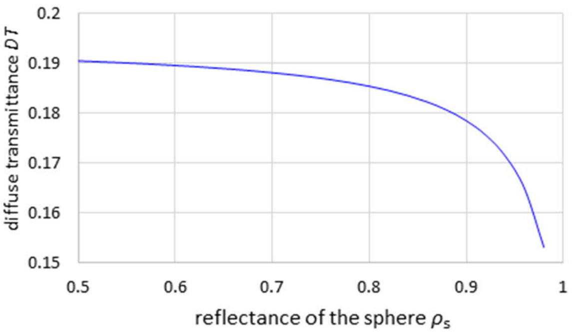

Figure 2 Numerical simulation - reflectance of the sphere ρ_s versus diffuse transmittance *DT*

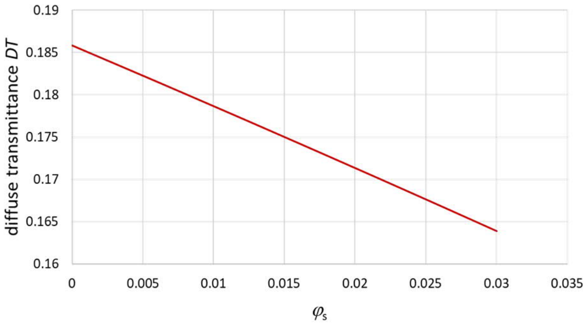

Figure 3 Numerical simulation - incident flux from imperfect collimated beam φ_s versus diffuse transmittance *DT*

COMPARISON OF DIFFERENT METHODS

To prove the above simulation of DIN 5036 part 3, four transmittance haze plates were used as test specimens. All plates were measured by DIN 5036 part 3 and double compensation method shown in Fig.4, which can be used to measure theoretically accurate *TT*, *DT* and *TH* if the structure of the measurement system can be designed properly under the same configuration in each step.

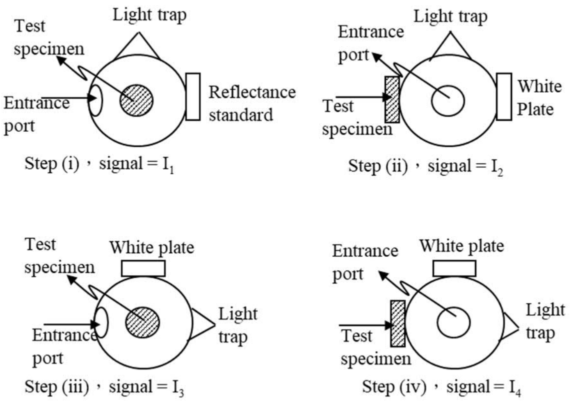

Figure 4 The method of double compensation. $TT=I_2/I_1$, $DT= (I_4-TT\cdot I_3)/ (I_1-I_3)$, and $TH=DT/TT$.

Tables 1 to 3 show the *DT TT* and *TH* results from the two methods, respectively. From table 1 and table 2, the *DT* values from DIN 5036 part 3 are all smaller than the values from double compensation method, and the *TT* values from the two methods are very close. These results show that the *TT* can be measured accurately by using DIN 5036 part 3, but *DT* is smaller than the theoretical value. Due to the definition of transmittance haze (*TH*), *DT*/*TT*, it is known that *TH* from DIN 5036 part 3 is also smaller than the theoretical value as shown in table 3.

Table 1 *DT* from two methods

Test Specimen Method	H20	H40	H70	H90
DIN 5036 part3	13.50	33.82	62.08	80.04
Double Compensation	14.18	35.85	65.82	84.87

Table 2 *TT* from two methods

Test Specimen Method	H20	H40	H70	H90
DIN 5036 part3	84.95	91.46	90.81	89.99
Double Compensation	84.95	91.43	90.85	89.83

Table 3 *TH* form two methods

Test Specimen Method	H20	H40	H70	H90
DIN 5036 part3	15.88	36.94	68.30	88.84
Double Compensation	16.68	39.18	72.40	94.37

CONCLUSION

TT data can be measured accurately by DIN 5036 part 3, but the obtained *DT* data are smaller than theoretical values. Therefore, *TH* data from this method are also smaller than the theoretical values. This is because *DT* from DIN 5036 is highly dependent on reflectance of the integrating sphere, and higher reflectance causes greater differences from the theoretical values.

REFERENCE

1. Methods of measurement for photometric and spectral radiometric characteristic numbers, DIN 5036 part 3, 1979.