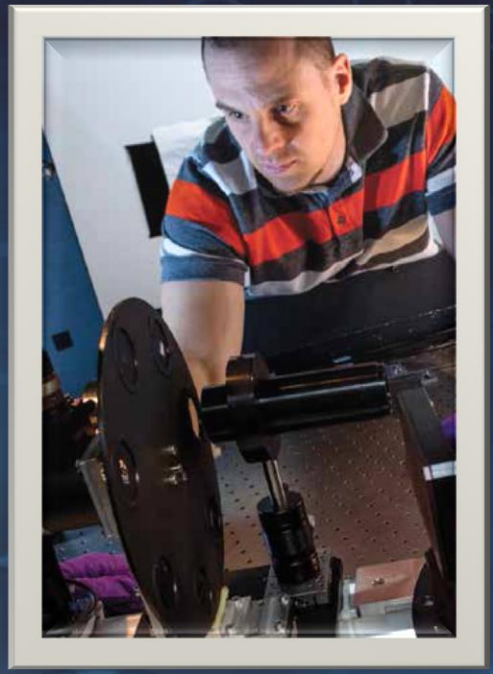
NRC·CNRC

Investigation of Converging and Collimated Beam Instrument Geometry on Specular Gloss Measurements



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*** National Research Council Canada**

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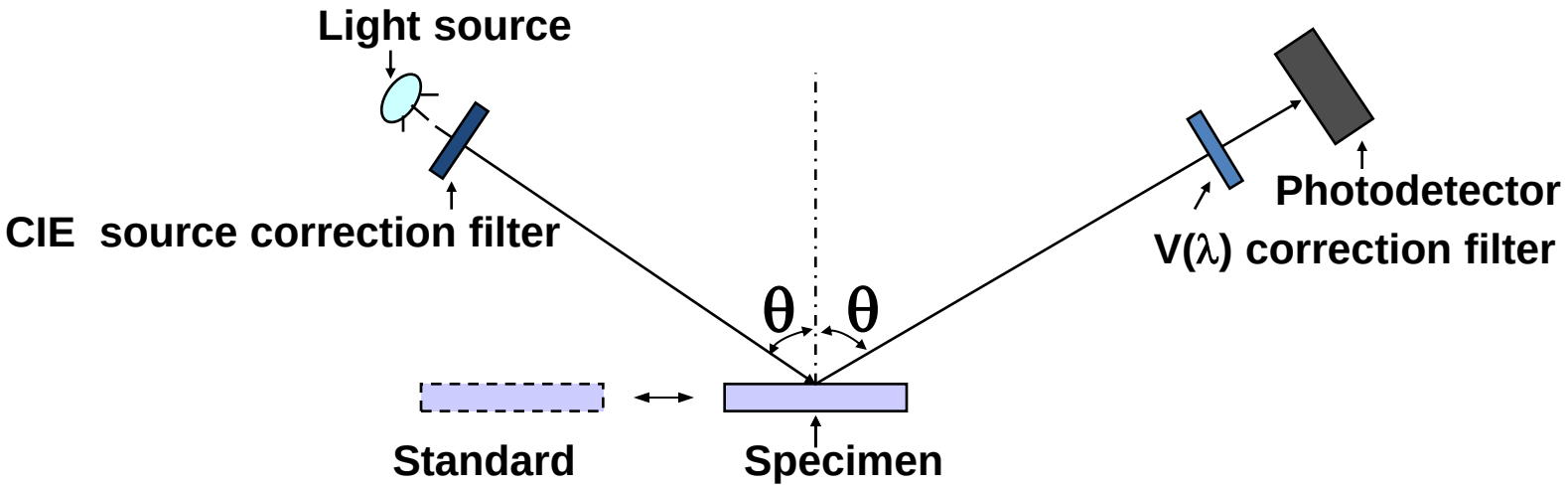
Outline

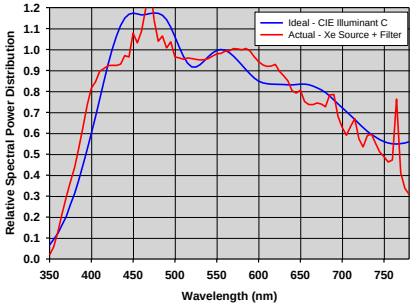
- Gloss Measurement
  - Principles
  - Standardization
- Current situation
  - Repeatability & Reproducibility
  - Q. What is impact of beam geometry: converging or collimated?
- NRC gloss study
  - NRC Reference Goniospectrophotometer (GSP)
  - Comparison samples
  - Results for different beam geometries
- Conclusions

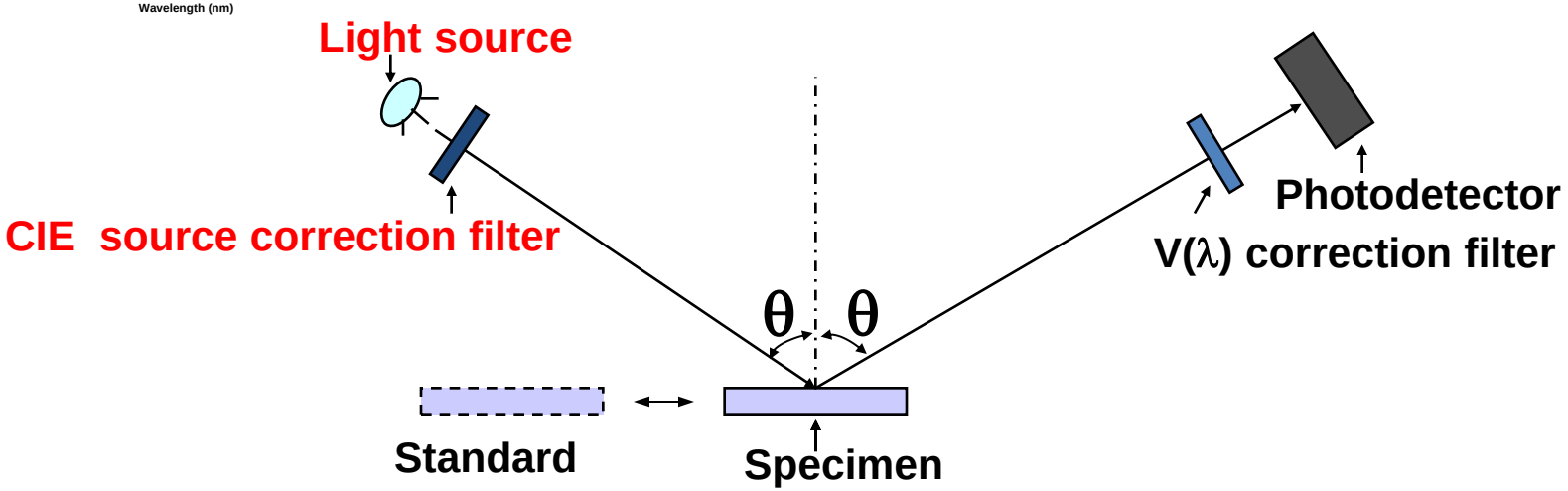
Introduction

Specular gloss measurements are used by industry to describe the surface shininess or roughness of materials by detecting the mirror-like (specular) reflection.

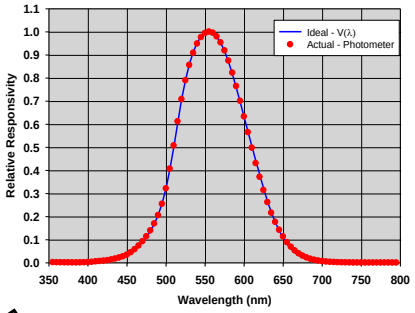


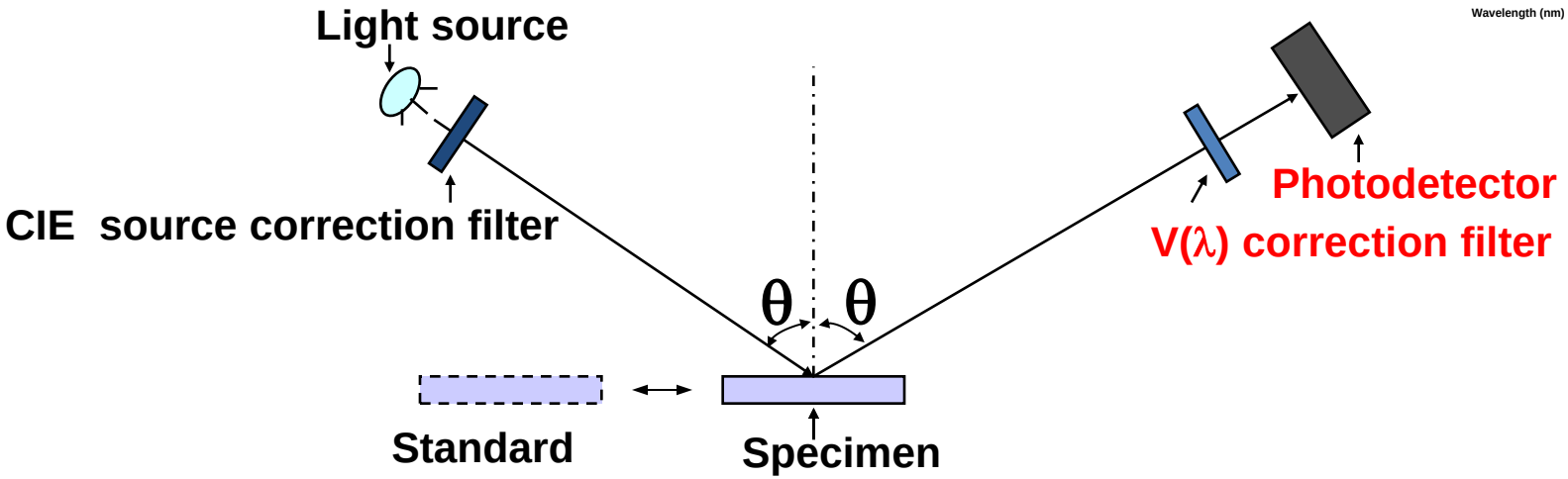
Standardization of Gloss Measurements: Source





Standardization of Gloss Measurements: Detector

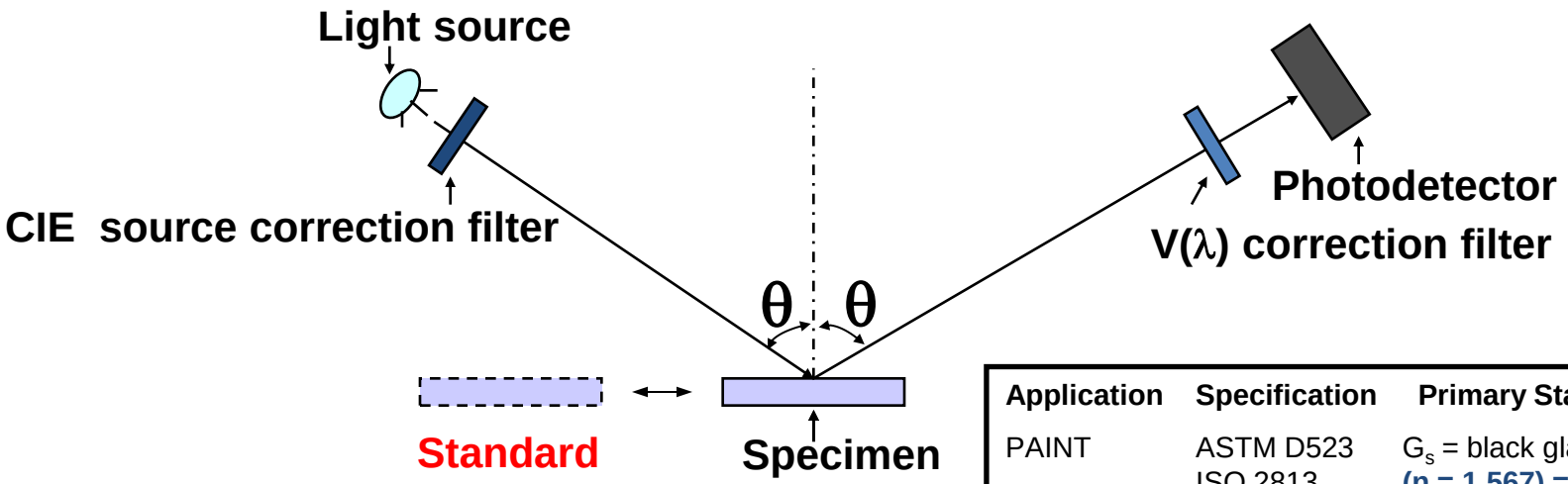




Standardization of Gloss Measurements: Standard

Depends on Application

NOTE: also depends on Specification



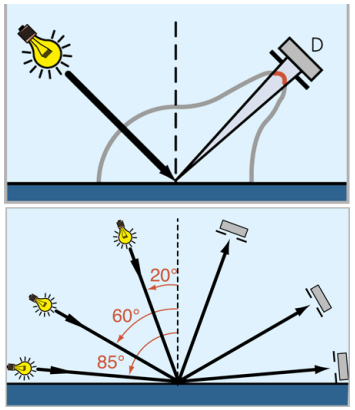
Application	Specification	Primary Standard
PAINT	ASTM D523 ISO 2813	G_s = black glass **(n = 1.567) = 100**
PLASTICS	ASTM D2457	G_s = perfect mirror = **1000**
PAPER	TAPPI T653 ISO 8254-3 ISO 8254-1	G_s = black glass **(n_D = 1.540) = 100**

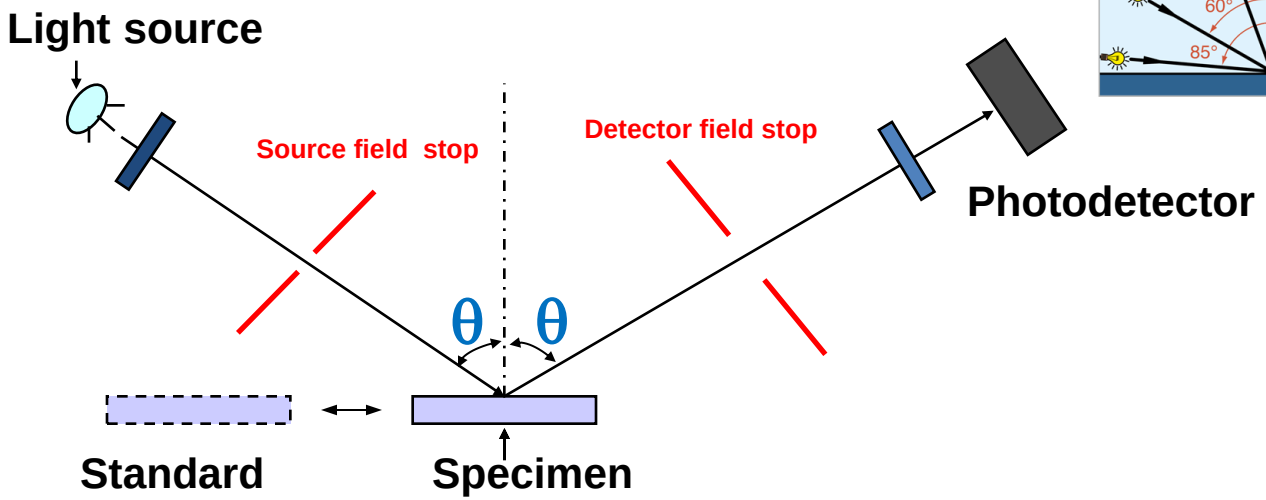
Application	Specification	Primary Standard
PAPER	ISO 8254-2	G_s = black glass **(n = 1.567) = 100**

Measurement of Specular Gloss: Definition

Measured gloss depends on specular angle

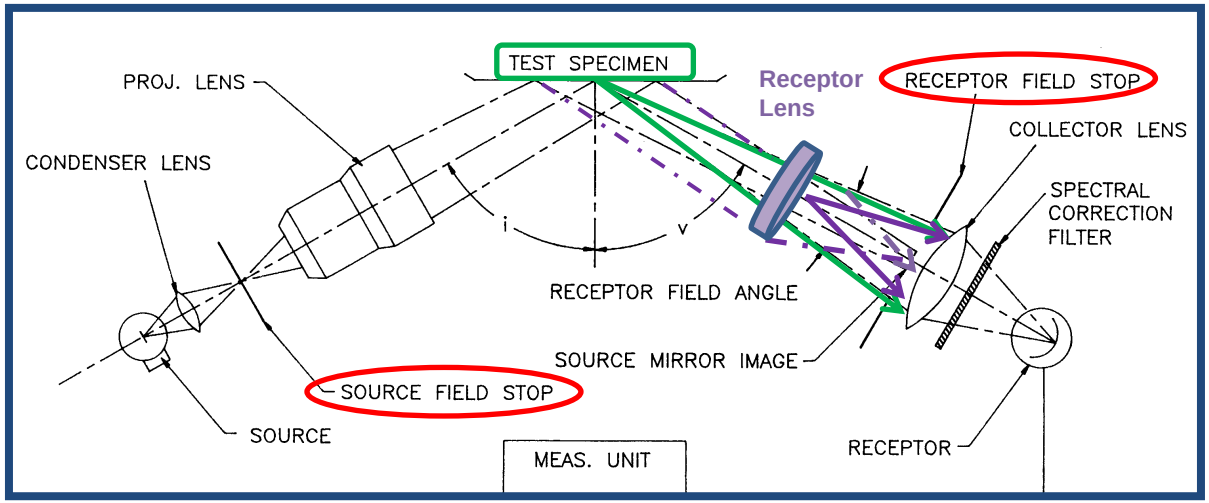
NOTE: also depends on other geometric conditions





$$\text{Gloss} = \frac{I_r}{I_0} = \frac{\text{received light (through detector field stop)}}{\text{incident light (through source field stop)}}$$

Standardization of Gloss Measurements: Geometry



Converging beam

or Collimated (Parallel) beam

ASTM D523 specifications for source and receptor apertures cf. NRC Goniospectrophotometer

Apertures	In Plane (°)		Normal to Plane (°)	
	ASTM	NRC	ASTM.	NRC
Source	0.75 ± 0.25	0.75 ± 0.01	3.0 ± 0.5	3.00 ± 0.01
20° receptor	1.80 ± 0.05	1.81 ± 0.01	3.6 ± 0.1	3.62 ± 0.01
60° receptor	4.40 ± 0.25	4.42 ± 0.01	11.7 ± 0.2	11.75 ± 0.01
85° receptor	4.00 ± 0.25	4.02 ± 0.01	6.0 ± 0.3	6.02 ± 0.01
Specular angle	20, 60, 85 ±1	20, 60, 85 ±0.05		

Depends on Specification

Depends on Beam Geometry

Standardization of Gloss Measurements: Summary

Spectral Conditions:

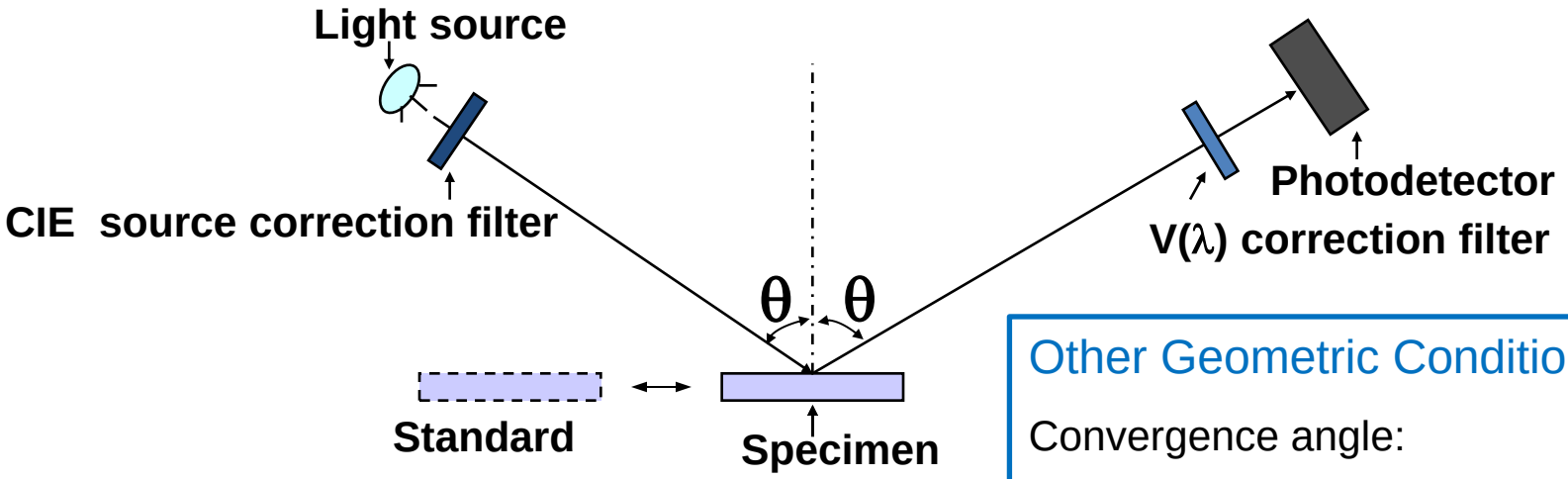
spectral nature of the illumination

spectral responsivity of the detection system

Geometric Conditions:

Angle of incidence

Source and receptor aperture dimensions



Other Geometric Conditions:

Convergence angle:

converging or collimated beam

Impact not been studied

Gloss Scale:

Definition of primary gloss standard

Gloss – Standard Test Methods: 75° and 20° Geometries

75º Gloss: Paper and Board

- ISO 8254-1 *Measurement of specular gloss – Part 1: 75º gloss with a converging beam: TAPPI method*
- ISO 8254-2 *Measurement of specular gloss – Part 2: 75º gloss with a parallel beam: DIN method*
- TAPPI T480 *Specular gloss of paper and paperboard at 75°*

20º Gloss: Paper and Board

- ISO 8254-3 *Measurement of specular gloss – Part 3: 20º gloss with a converging beam: TAPPI method*
- TAPPI T653 *Specular gloss of paper and paperboard at 20°*

20º Gloss: Paint and General Material

- ISO 2813/ ASTM D523 *Standard test method for specular gloss*

Instrument geometry: converging beam; collimated beam
Primary gloss standard refractive index: 1.540 (TAPPI); 1.567 (DIN)

Glossmeters: Repeatability & Reproducibility

Manufacturer specifications (20°/60°/85° geometry)

- Repeatability: ±0.1 to 0.2 GU
- Reproducibility: ±0.5 GU

c.f. Standards specifications (ASTM D523/ ISO 2813)

- Repeatability: ±0.8 to 1.7 GU
- Reproducibility: ±2.0 to 7.2 GU

c.f. In practice (6 commercial glossmeters; 25 samples)*:

- Repeatability: ±0.4 to ± 17.1 GU
- Reproducibility: ±0. 8 to 14.3 GU

* F.B. Leloup et.*al*, *Repeatability and reproducibility of specular gloss meters in theory and practice*, J. Coat.Technol. Res., Vol. 13 (2016)

TAPPI 20° Gloss Round Robin (RR) Study (2016)

Background:

Optical Properties Committee of TAPPI's P&PQ Division requested CTS to conduct a RR study to answer:

- **Q.** Can the technical parameters of TAPPI Method T653: *Specular gloss of paper and paperboard at 20°* be loosened?

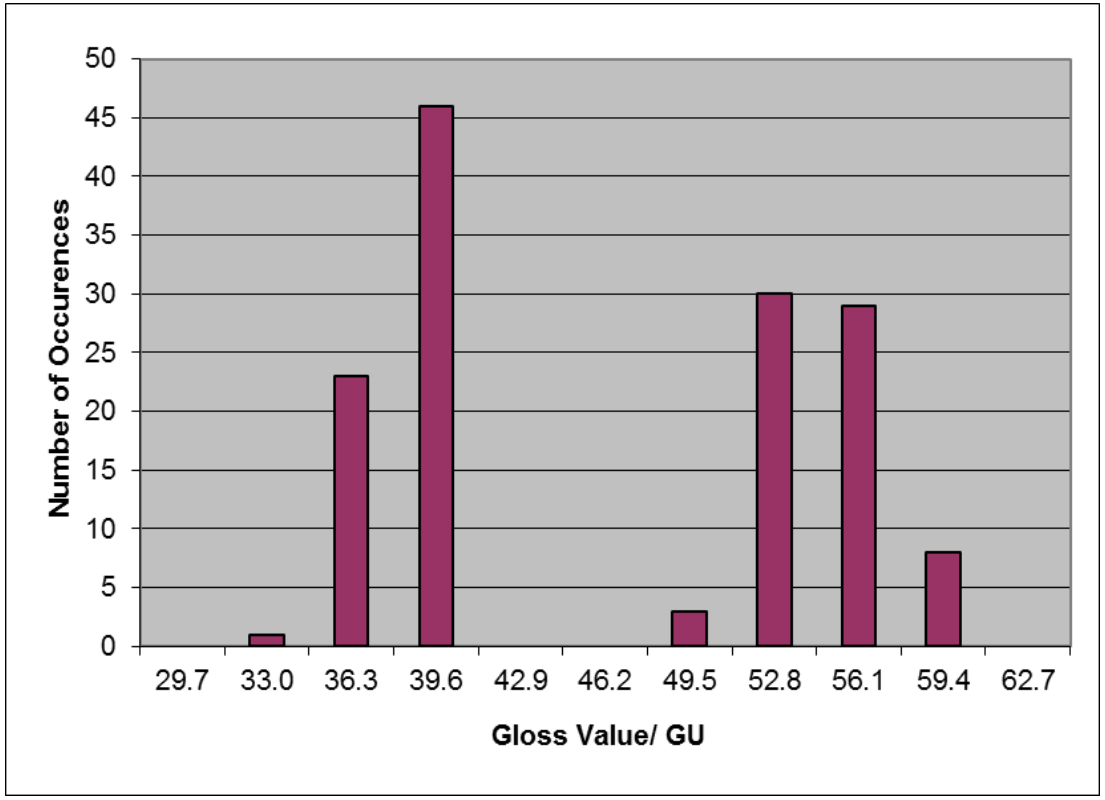
RR Protocol:

- Test Sample: Medium gloss paper (RG01) of 30 specimens (sheets)
- Measure each sheet in upstream and downstream direction

  e.g. 1st meas = 20.7 GU
  rotate sheet 180°
  2nd meas = 21.4 GU
  Reported value = 21.05 GU

- No. of participants: 14 Labs

CTS Results for TAPPI 20° Gloss RR Study



Grand Mean: 44.9 GU
Standard deviation (SD): 8.7 GU

NRC Reference Goniospectrophotometer (GSP)

- **Developed for multi-functional purposes:**
  - Gloss at 20,60,85^0 (ASTM D523 – paints)
  - Gloss at 75^0 (TAPPI T480 – paper)
  - Gonioreflectance measurements (metallic and pearlescent colors)

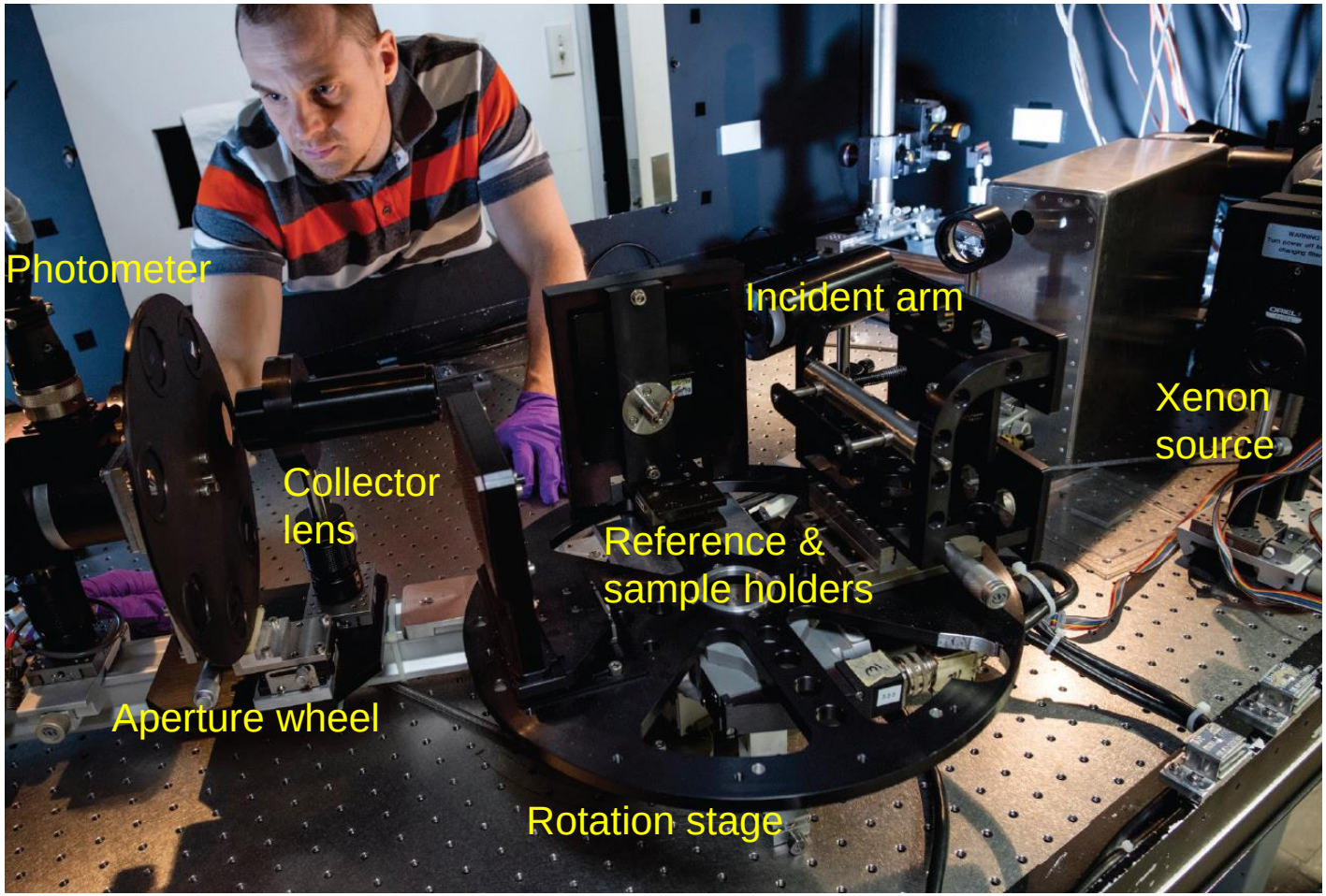
- **Versatile instrument design:**
  - rapid conversion between converging & collimated beam geometries

- **Spectral and geometric properties of instrument:**
  - measured and compared with standard requirements[1]

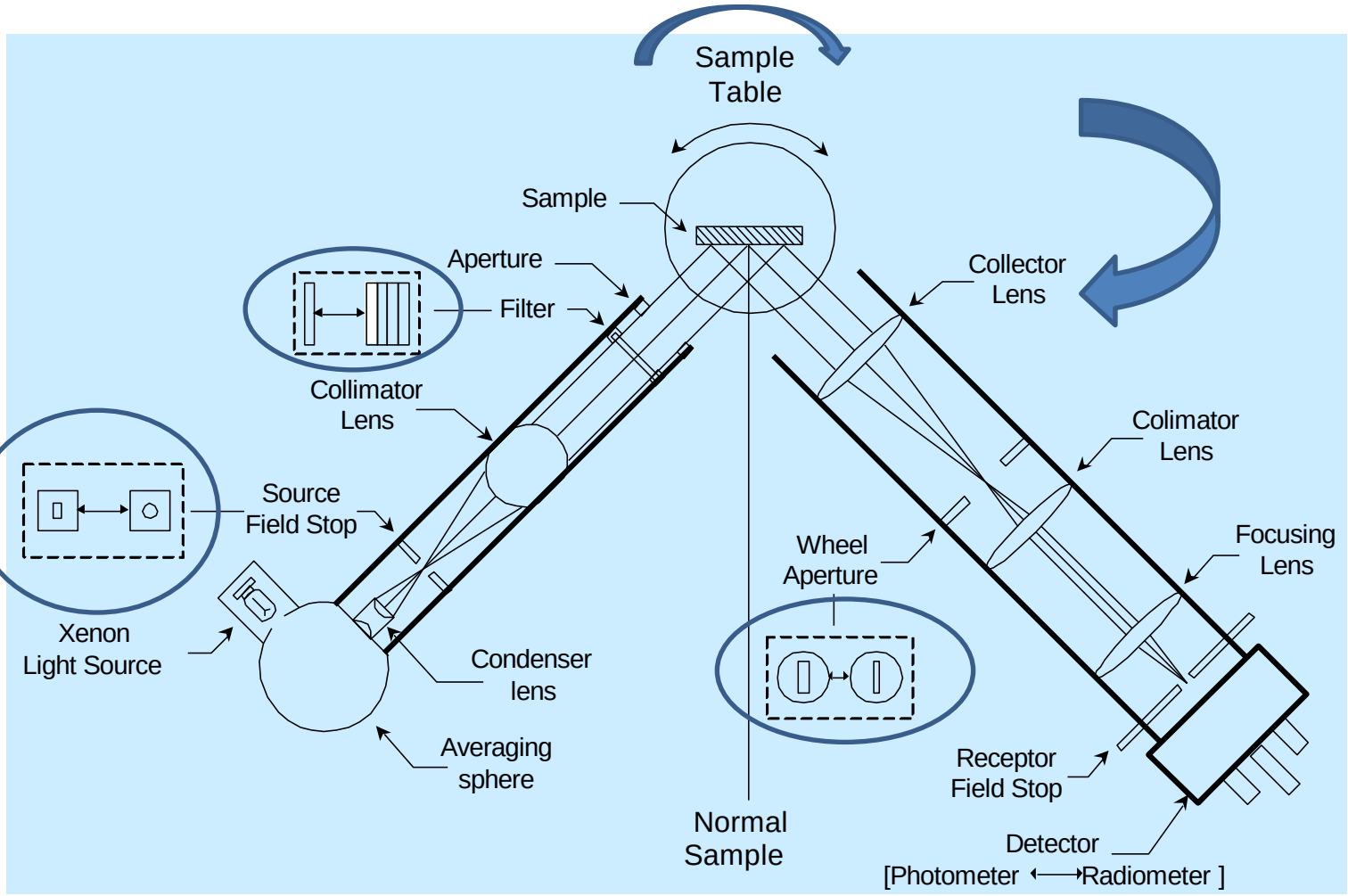
- **Uncertainties in gloss measurements have been estimated:**[2]
  - Modelling deviation from standard requirements
  - Measurement intercomparisons (NRC Glossmeter and CTS)
  - Comparison with calculated values

[1] J. Liu, M. Noel and J. Zwinkels, *Appl. Opt*., **44**, 4631-4638 (2005)
[2] M. Noel, J. Zwinkels and J. Liu, *Appl. Opt*., **45**, 3712-3720 (2006)

NRC Reference Goniospectrophotometer (GSP)

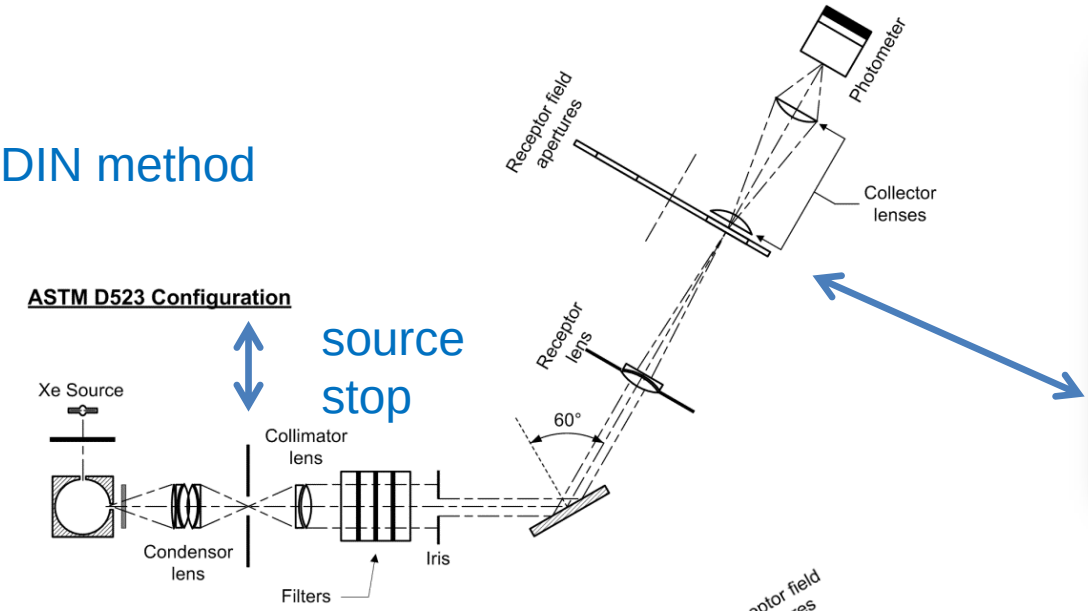


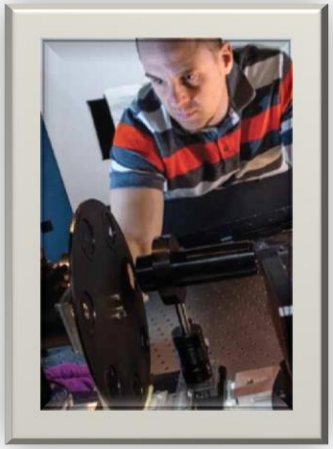
NRC Reference Goniospectrophotometer (GSP)



Re-configure GSP from collimated to converging beam

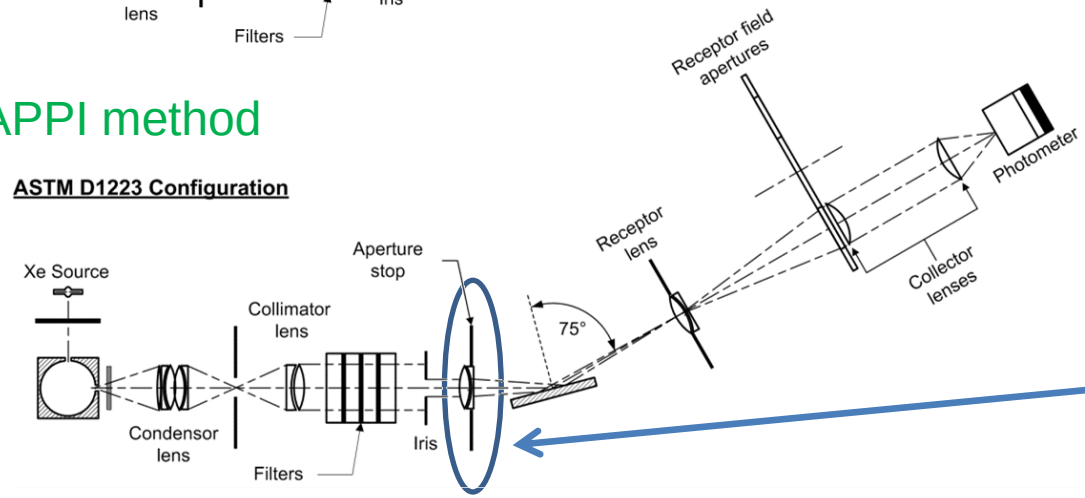
DIN method





detector stop

TAPPI method



Optional lens assembly
(aperture stop)

NRC Gloss Study: Impact of Beam Geometry

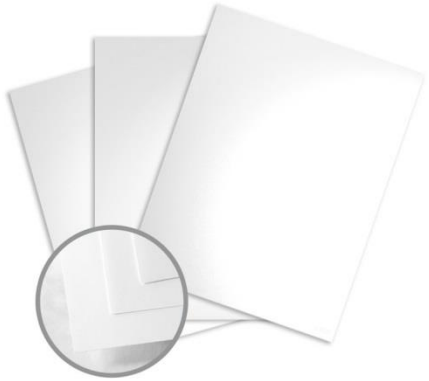
Paper Samples Tested (from CTS):

75° Geometry

ID	Type (# sheets)
GU53	Medium gloss (10)
GT53	High gloss (10)

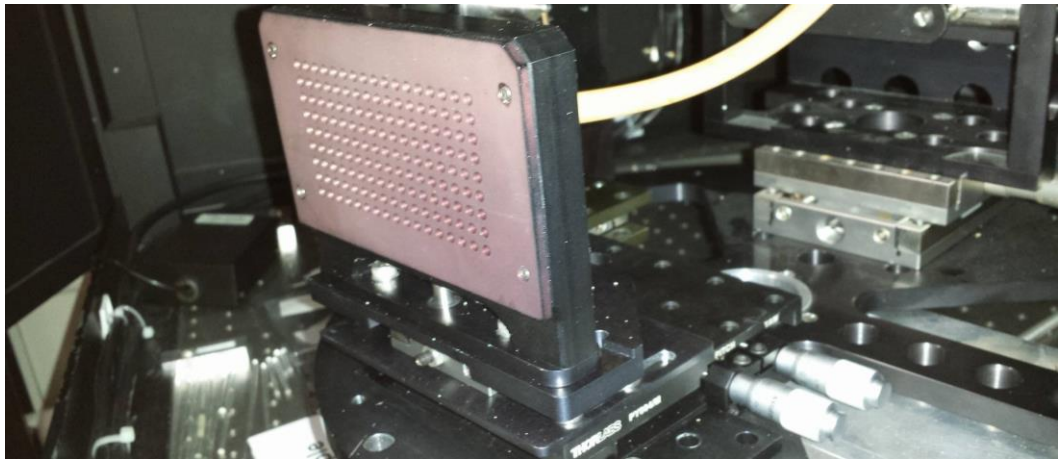
20° Geometry

ID	Type (# sheets)
RG01	Medium gloss (30)



Paper Sample Mount

Vacuum suction plate



Pitch and yaw mounting stage

GSP Measurement Procedure and Validation (Ex.)

20° Gloss - TAPPI Method; Sample: RG01; Run #1

#1	Meas 1	Meas 2	temp	Hum	#
1	36.065	35.795	27	21	681
2	38.072	34.722	27	21	683
3	36.859	35.961	27	21	685
4	35.317	36.441	27	21	687
5	36.444	37.588	27	21	689
6	36.595	36.521	27	21	691
7	36.302	36.075	27	21	693
8	36.8	33.925	27	21	696
9	34.842	34.532	27	21	698
10	35.678	35.005	27	21	700
11	37.13	36.431	27	21	702
12	36.536	36.244	27	21	704
13	36.071	35.504	27	20	706
14	36.019	34.963	27	20	708
15	36.638	35.965	27	21	710
16	36.88	35.19	27	21	714
17	36.39	35.688	27	21	716
18	35.869	36.379	27	21	718
19	35.77	34.794	27	21	720
20	34.723	34.38	27	20	722
21	36.924	36.5	27	20	724
22	36.249	36.563	27	20	726
23	34.657	34.352	27	20	728
24	35.989	35.797	27	20	730
25	37.119	35.839	27	20	732
26	36.32	36.287	27	20	734
27	35.989	37.23	27	20	736
28	36.226	35.789	27	20	738
29	36.671	36.814	27	20	740
30	36.757	35.697	27	20	742

	Meas	STD	Error	temp	Hum
NRC High	93.09	0.055	0.04	27	21
Vitrolite	86.86	0.075	0.07	27	21

NRC Quality System Validation Standards

	Meas	STD	Error	temp	Hum
Vitrolite	86.92	0.007	0.13	27	21

	Meas	STD	Error	temp	Hum
Vitrolite	87.119	0.0136	0.329	27	20
NRC High	93.36	0.0066	0.31	27	19

GSP Measurements and Validation Procedure

20 deg. Gloss Validation

			DIN		TAPPI	
	NRC-Vitrolite	**NRC-High-gloss**	**RG01 #1**	**RG01 #2**	**RG01 #1**	**RG01 #2**
Set #1 of Meas.	86.88	93.26	35.95	34.95	58.85	58.85
			36.40	34.65	59.15	59.15
			36.45	34.10	59.50	57.45
			35.85	32.80	59.25	59.05
Mean	**86.88**	**93.26**	37.00	34.85	59.90	58.80
Std.dev.	**0.04**	**0.05**	36.55	34.00	58.95	58.40
			36.20	35.20	59.50	58.50
Set #2 of Meas.	86.97	93.28	35.35	36.40	58.70	59.40
			34.65	35.70	58.90	57.85
			35.35	34.15	59.15	59.90
			36.75	34.55	59.60	59.50
Mean	**86.97**	**93.28**	36.35	34.30	59.90	59.30
Std.dev.	**0.05**	**0.06**	35.80	35.15	58.70	58.75
			35.50	35.20	57.95	59.10
Set #3 of Meas.	86.90	93.24	36.30	35.20	58.55	60.55
			36.05	31.95	58.45	58.85
			36.05	36.70	58.55	59.20
			36.15	34.90	58.55	57.65
Mean	**86.90**	**93.24**	35.30	33.85	58.80	59.40
Std.dev.	**0.08**	**0.10**	34.55	32.00	56.95	59.50
			36.70	32.30	59.60	58.65
	86.88	93.26	36.40	35.85	59.05	58.05
	86.97	93.28	34.55	33.10	58.40	58.35
	86.90	93.24	35.90	35.50	58.55	57.90
Mean of means	**86.92**	**93.26**	36.45	35.80	59.25	60.65
Std.dev.	**0.05**	**0.02**	36.30	34.20	59.40	59.65
			36.60	35.70	59.30	59.00
			36.00	34.55	59.10	59.25
			36.75	34.35	59.65	58.70
			36.25	33.40	59.15	59.45
Historical Value,	**86.79**	**93.05**	**36.02**	**34.51**	**58.98**	**58.96**
Stdm	**0.02**	**0.19**	**0.65**	**1.22**	**0.61**	**0.76**
n	**113**	**60**				
Degree of Equivalence	**0.15%**	**0.22%**				

DoE = 0.2 %

NRC 75° Gloss Results

Collimated Beam (DIN method)

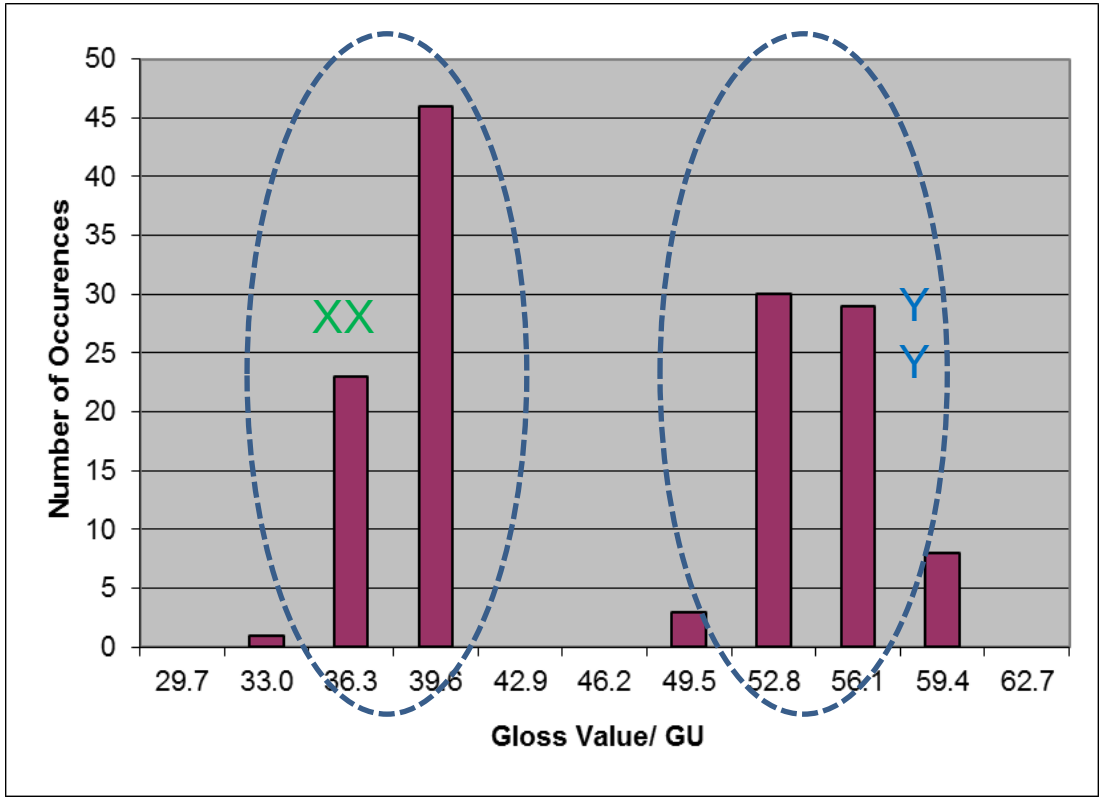
ID	Run 1 (GU)	Run 2 (GU)
GU53	33.03	31.03
S.D.	±0.75	±0.73
GT53	66.43	65.30
S.D.	±2.00	±2.36
Quartz Standard	92.65	92.65

Converging (TAPPI method)

ID	Run 1 (GU)	Run 2 (GU)
GU53	37.94	38.73
S.D.	±0.82	±0.83
GT53	73.38	73.98
S.D.	±1.94	±1.91
Quartz Standard	94.22	94.22

Statistically significant differences:
GU53: 35.18 ± 3.74 GU (c.f. GSP reproducibility: ± 0.78 GU)
GT53: 69.77 ± 4.54 GU (c.f. GSP reproducibility: ± 2.05 GU)

NRC Results for TAPPI 20° Gloss RR Study



X = TAPPI method

Run 1: 36.02 ± 0.65 GU
Run 2: 34.50 ± 1.22 GU

Y = DIN method

Run 1: 58.98 ± 0.61 GU
Run 2: 58.96 ± 0.76 GU

ΔGloss (DIN-TAPPI) = 23.7 GU

GSP reproducibility: ± 0.6 to 1.2 GU

c.f. CTS RR Results for TAPPI Method:
Grand Mean: 44.9 GU ± 8.7 GU (14 labs)
NRC Mean: 47.1 GU ± 13.7 GU (both methods)

Conclusions of this NRC gloss study

- For a given specular angle and given beam geometry, the reproducibility is ±0.6 – ±2.0 GU
- For both 20° and 75° geometries, for a change in beam geometry, the reproducibility is ±3.7 – ±13.7 GU
- For 20° geometry, the gloss values increase in going from converging to collimated beam geometry
- For 75° geometry, the gloss values decrease in going from converging to collimated beam geometry
- Results indicate that gloss differences observed in recent comparisons may be due to glossmeters with incorrect beam geometry

For optimum measurement reproducibility: instrument needs to strictly conform to geometric, spectral and photometric conditions of the specified standard test method, within specified tolerances
- Including requirements for beam geometry!

Questions???

Thank you

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