

NBSIR 78-1332

MCCA

MANUFACTURERS COUNCIL ON COLOR AND APPEARANCE

**COLLABORATIVE REFERENCE PROGRAM
COLOR AND APPEARANCE**

RETROREFLECTANCE

REPORT NO. 4

**U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards**



NBS COLLABORATIVE REFERENCE PROGRAMS

TAPPI Paper and Board (6 times per year)

Bursting strength	Smoothness
Tearing strength	Surface pick strength
Tensile breaking strength	K & N ink absorption
Elongation to break	pH
Tensile energy absorption	Opacity
Folding endurance	Blue reflectance (brightness)
Stiffness	Specular gloss, 75°
Air resistance	Thickness
Grammage	Concora (flat crush)
	Ring crush

FKI KRAFTBOARD (48 times per year)

Mullen burst of linerboard
Concora test of medium

MCCA Color and Appearance (4 times per year)

Gloss at 60°
Color and color difference
Retroreflectivity

Rubber (4 times per year)

Tensile strength, ultimate elongation and tensile stress
Hardness
Mooney viscosity
Vulcanization properties

ASTM Textiles (3 times per year)

Flammability (FF3-71 and FF5-74)

ASTM Cement (2 times per year)

Chemical (11 chemical components)
Physical (8 characteristics)

AASHTO Bituminous

Asphalt cement (2 times per year)
Cutbacks (once a year)



Collaborative Reference Programs
B360 Polymer Bldg.
National Bureau of Standards
Washington, D.C. 20234

**MANUFACTURERS COUNCIL ON
COLOR AND APPEARANCE**

**COLLABORATIVE REFERENCE PROGRAM
FOR
COLOR AND APPEARANCE**

RETROREFLECTANCE

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**U. S. DEPARTMENT OF COMMERCE
National Bureau of Standards**

Introduction

Sample sets of retroreflective road-sign sheeting material were sent to 18 laboratories participating in this Collaborative Reference Program. The sample set consisted of two specimens each of silver sheeting and of orange sheeting. Ten laboratories returned data taken in accordance with Federal Specification L-S-300 (A or B) or a close modification thereof, and two laboratories followed "other" methods.

If there are any questions on the notes, the analyses, or this report in general, please contact Jeff Stevenson or Jeffrey Horlick on (301) 921-2946.

March 6, 1978

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KEY TO TABLES AND GRAPHS

- MEAN - The average of individual TEST DETERMINATIONS. The number of TEST DETERMINATIONS in the mean is given in the upper right corner of the first table (TEST D.) and again at the bottom of this table.
- GRAND MEAN - (GR. MEAN) The average of the individual laboratory MEANS, excluding laboratories flagged (see column F) with an X or #.
- DEV - The DEVIation of difference of the laboratory MEAN from the GRAND MEAN.
- N. DEV - The Normal DEVIate or ratio of the DEV to the SD OF MEANS; an indication of the degree of divergence of the laboratory MEAN from the GRAND MEAN.
- INST CODE - Code for instrument type or variation in condition, see second table.
- F - Flag, with following meaning:
- # - Excluded because data were not understood or because analysis indicated extreme performance values or non-compliance with required test procedures.
 - X - Excluded because plotted point would fall outside of the 99% error ellipse, (see below for explanation of Graph).
 - * - Included in grand means but plotted point would fall outside of the 95% error ellipse.
 - 0 - Included in grand mean and inside 95% error ellipse.

Graph - For each laboratory the MEAN for the second sample is plotted against the MEAN for the first sample, with each point representing a laboratory. The horizontal and vertical lines are the GRAND MEANS. The dashed line is drawn at 45°. The solid sloping line, which may or may not lie close to the 45° line, is along the major axis of the error ellipse. The ellipse is drawn so that, on the average, it will include 95% of the points representing the laboratories.

Plotted symbols are as explained above (under F). A participant whose plotted point falls outside of the ellipse or the rectangular area should carefully re-examine the testing procedure he is following.

Note: Graphs are plotted with an ellipse when there are 20 or more instruments in the analysis.

MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 1
RETROREFLECTANCE

LAB CODE	SAMPLE S01 MEAN	SILVER AT -4,.2 DEGREES					SAMPLE 001 MEAN	ORANGE AT -4,.2 DEGREES					TEST D. = 4		
		DEV	N.DEV	SDR	R.SDR	DEV		N.DEV	SDR	R.SDR	VAR	F	LAB		
C200	127.3	12.7	1.76	1.3	.52	45.5	3.2	.92	.1	.19	72A	0	C200		
C428	115.5	.9	.12	3.5	1.44	41.0	-1.4	-.40	1.2	2.27	72A	0	C428		
C462	114.2	-.5	-.06	1.2	.47	43.6	1.3	.37	.4	.72	72A	0	C462		
C471	118.5	3.5	.54	1.1	.44	46.2	3.8	1.11	.6	1.22	72C	0	C471		
C480	110.2	-4.4	-.61	2.1	.86	42.8	.5	.13	.5	1.06	72A	0	C480		
C481	107.9	-6.7	-.93	6.2	2.55	38.3	-4.1	-1.19	.1	.23	72A	0	C481		
C486	119.7	5.1	.71	1.5	.62	43.1	.7	.21	.0	.00	72A	0	C486		
C488	111.0	-3.6	-.50	.8	.34	43.5	1.1	.33	.6	1.13	72C	0	C488		
C490	101.1	-13.6	-1.88	7.1	2.91	37.3	-5.1	-1.48	1.5	2.95	72A	0	C490		
C507	119.1	4.5	.63	1.0	.40	48.3	5.9	1.73	.0	.00	72A	0	C507		
C522	108.9	-5.8	-.80	1.6	.67	40.8	-1.6	-.45	.1	.28	72A	0	C522		
C533	122.0	7.4	1.03	1.9	.77	37.9	-4.4	-1.28	1.0	1.96	72A	0	C533		

GR. MEAN = 114.6 CP/FT-C/SQFT GRAND MEAN = 42.4 CP/FT-C/SQFT TEST DETERMINATIONS = 4
SD MEANS = 7.2 CP/FT-C/SQFT SD OF MEANS = 3.4 CP/FT-C/SQFT 12 LABS IN GRAND MEANS
AVERAGE SDR = 2.4 CP/FT-C/SQFT AVERAGE SDR = .5 CP/FT-C/SQFT

TOTAL NUMBER OF LABORATORIES REPORTING = 12

MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 2
RETROREFLECTANCE

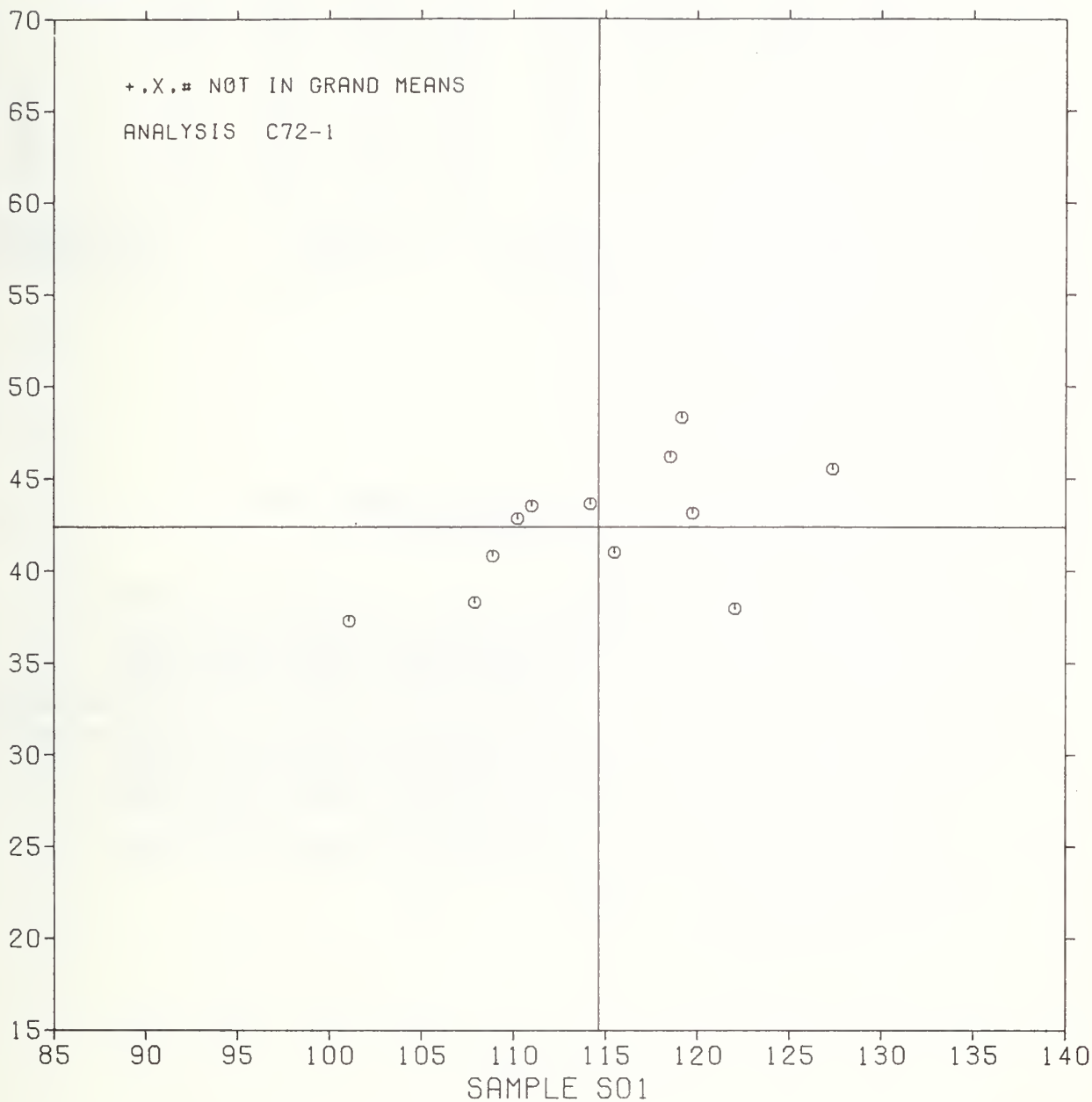
LAB CODE	F	MEANS		COORDINATES		AVG		PROPERTY---TEST INSTRUMENT---CONDITIONS
		S01	001	MAJOR	MINOR	R.SDR	VAR	
C490	0	101.1	37.3	-14.5	-.9	2.93	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C481	0	107.9	38.3	-7.6	-1.9	1.39	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C522	0	108.9	40.8	-6.0	.2	.47	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C480	0	110.2	42.8	-4.1	1.7	.96	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C488	0	111.0	43.5	-3.1	2.2	.73	72C	RETROREFLECTANCE, METHOD AND INSTRUMENTATION SPECIFIED
C462	0	114.2	43.6	-.1	1.3	.60	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C428	0	115.5	41.0	.4	-1.6	1.85	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C471	0	118.5	46.2	4.8	2.5	.83	72C	RETROREFLECTANCE, METHOD AND INSTRUMENTATION SPECIFIED
C507	0	119.1	48.3	6.1	4.4	.20	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C486	0	119.7	43.1	5.1	-.8	.31	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C533	0	122.0	37.9	5.8	-6.4	1.37	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C200	0	127.3	45.5	13.1	-.7	.36	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B

GMEANS: 114.6 42.4 1.00
95% ELLIPSE: 22.6 8.3 WITH GAMMA = 17 DEGREES

RETROREFLECTANCE

SAMPLE S01 = 115. CP/FT-C/SQFT SAMPLE 001 = 42. CP/FT-C/SQFT

SAMPLE 001



MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 1
RETROREFLECTANCE

LAB CODE	SAMPLE S02 MEAN	SILVER AT 30.2 DEGREES					SAMPLE 002 MEAN	ORANGE AT 30.2 DEGREES					TEST D. * 4		
		DEV	N.DEV	SDR	R.SDR	DEV		N.DEV	SDR	R.SDR	VAR	F	LAB		
C200	56.07	10.24	1.36	1.72	.52	26.87	2.69	1.26	.25	.43	72A	0	C200		
C428	47.75	1.92	.25	5.12	1.56	23.50	-.69	-.32	.58	1.00	72A	0	C428		
C462	53.95	8.12	1.08	2.85	.87	25.55	1.36	.64	.24	.41	72A	0	C462		
C471	45.25	-.58	-.08	2.83	.86	24.60	.41	.19	.94	1.63	72C	0	C471		
C480	42.10	-3.73	-.50	2.13	.65	25.52	1.34	.63	.62	1.08	72A	0	C480		
C481	50.71	4.88	.65	4.91	1.49	24.59	.40	.19	.97	1.68	72A	0	C481		
C486	54.11	8.28	1.10	3.70	1.12	23.60	-.59	-.28	.35	.60	72A	0	C486		
C488	45.00	-.83	-.11	4.08	1.24	24.00	-.19	-.09	.00	.00	72C	0	C488		
C490	35.48	-10.35	-1.37	4.37	1.33	19.75	-4.44	-2.08	.91	1.58	72A	0	C490		
C507	47.07	1.24	.17	2.49	.76	27.25	3.06	1.44	.87	1.50	72A	0	C507		
C522	41.22	-4.61	-.61	2.56	.78	21.25	-2.94	-1.38	.10	.17	72A	0	C522		
C533	31.25	-14.58	-1.94	2.72	.83	23.75	-.44	-.20	1.11	1.92	72A	0	C533		

GR. MEAN = 45.83 CP/FT-C/SQFT GRAND MEAN = 24.19 CP/FT-C/SQFT TEST DETERMINATIONS * 4
 SD MEANS = 7.53 CP/FT-C/SQFT SD OF MEANS = 2.13 CP/FT-C/SQFT 12 LABS IN GRAND MEANS
 AVERAGE SDR = 3.29 CP/FT-C/SQFT AVERAGE SDR = .58 CP/FT-C/SQFT
 TOTAL NUMBER OF LABORATORIES REPORTING = 12

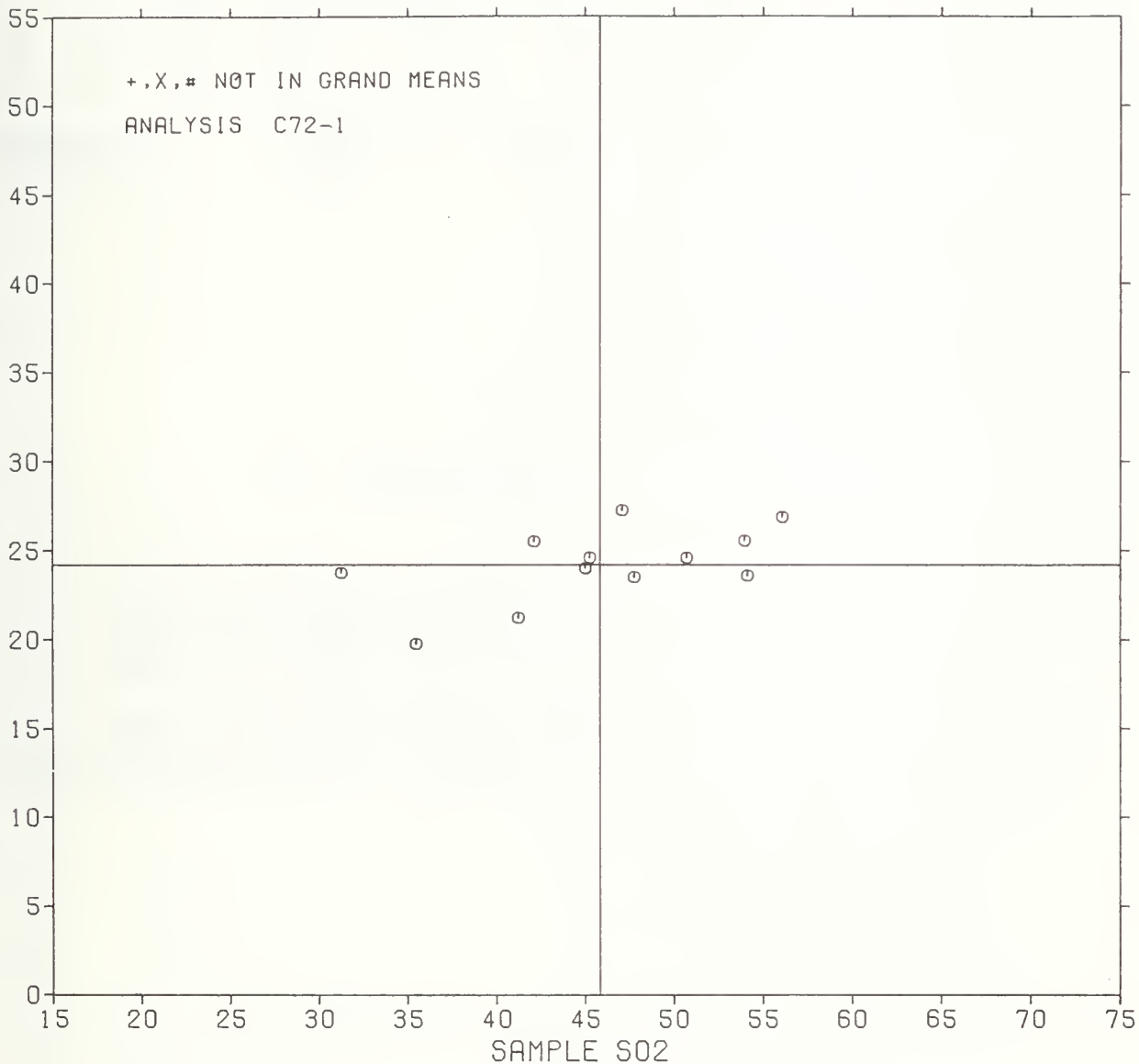
MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 2
RETROREFLECTANCE

LAB CODE	F	MEANS		COORDINATES		AVG		PROPERTY---TEST	INSTRUMENT---CONDITIONS
		S02	002	MAJOR	MINOR	R.SDR	VAR		
C533	0	31.25	23.75	-14.45	1.98	1.37	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C490	0	35.48	19.75	-10.54	-2.67	1.45	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C522	0	41.22	21.25	-5.03	-2.14	.48	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C480	0	42.10	25.52	-3.46	1.94	.86	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C488	0	45.00	24.00	-.85	-.05	.62	72C	RETROREFLECTANCE, METHOD AND INSTRUMENTATION SPECIFIED	
C471	0	45.25	24.60	-.51	.50	1.24	72C	RETROREFLECTANCE, METHOD AND INSTRUMENTATION SPECIFIED	
C507	0	47.07	27.25	1.73	2.82	1.13	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C428	0	47.75	23.50	1.78	-.59	1.28	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C481	0	50.71	24.55	4.88	-.41	1.59	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C462	0	53.95	25.55	8.23	.00	.64	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C486	0	54.11	23.60	8.07	-1.95	.86	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
C200	0	56.07	26.87	10.55	.56	.48	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B	
GMEANS:		45.83	24.19			1.00			
		95% ELLIPSE:		22.93	5.23	WITH GAMMA = 9 DEGREES			

RETROREFLECTANCE

SAMPLE S02 = 45.8 CP/FT-C/SQFT SAMPLE 002 = 24.2 CP/FT-C/SQFT

SAMPLE 002



MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 1
RETROREFLECTANCE

LAB CODE	SILVER AT -4,2. DEGREES					ORANGE AT -4,2. DEGREES					TEST D. = 4		
	SAMPLE S03 MEAN	DEV	N.DEV	SDR	R.SDR	SAMPLE O03 MEAN	DEV	N.DEV	SDR	R.SDR	VAR	F	LAB
C200	5.35	.18	.47	.06	.41	2.70	.37	1.19	.00	.00	72A	Ø	C200
C428	5.15	-.02	-.06	.17	1.23	2.12	-.21	-.67	.05	.48	72A	Ø	C428
C462	5.50	.33	.87	.00	.00	2.50	.17	.55	.23	2.23	72A	Ø	C462
C471	5.72	.55	1.47	.15	1.07	2.60	.27	.87	.12	1.12	72C	Ø	C471
C480	4.77	-.41	-1.08	.13	.56	2.23	-.10	-.31	.15	1.48	72A	Ø	C480
C481	4.97	-.20	-.53	.33	2.35	2.10	-.23	-.75	.00	.00	72A	Ø	C481
C490	4.54	-.63	-1.68	.24	1.68	1.85	-.48	-1.56	.17	1.68	72A	Ø	C490
C507	5.45	.28	.74	.10	.71	2.72	.39	1.27	.15	1.45	72A	Ø	C507
C522	5.10	-.07	-.20	.08	.58	2.15	-.18	-.59	.06	.56	72A	Ø	C522
C533	13.05	7.88	21.02	.26	1.88	2.85	.52	1.68	.06	.56	72A	#	C533

GR. MEAN = 5.17 CP/FT-C/SQFT GRAND MEAN = 2.33 CP/FT-C/SQFT TEST DETERMINATIONS = 4
SD MEANS = .37 CP/FT-C/SQFT SD OF MEANS = .31 CP/FT-C/SQFT 9 LABS IN GRAND MEANS
AVERAGE SDR = .14 CP/FT-C/SQFT AVERAGE SDR = .10 CP/FT-C/SQFT
TOTAL NUMBER OF LABORATORIES REPORTING = 10

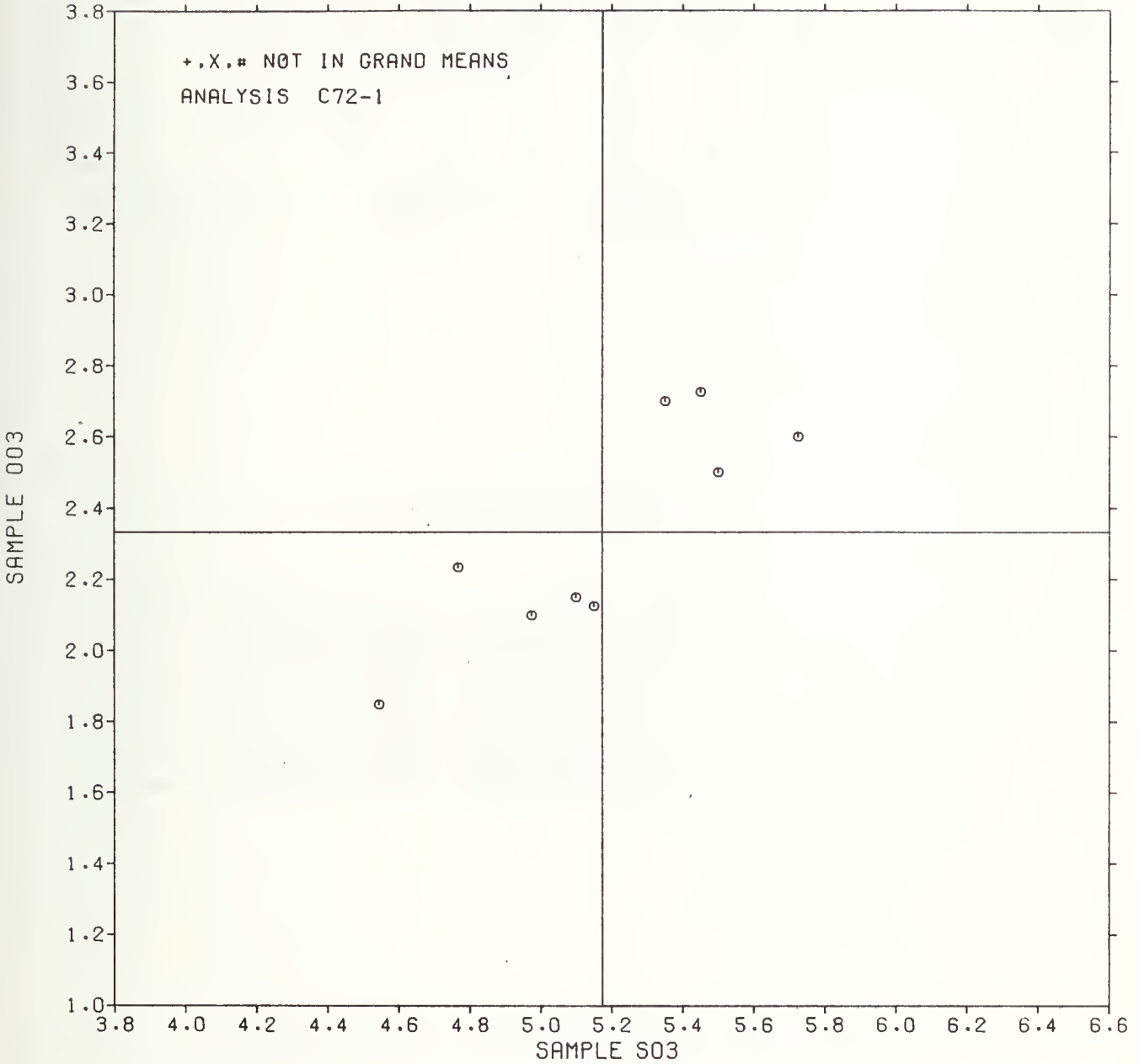
MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 2
RETROREFLECTANCE

LAB CODE	F	MEANS		COORDINATES		AVG		PROPERTY---TEST	INSTRUMENT---	CONDITIONS
		S03	O03	MAJOR	MINOR	R.SDR	VAR			
C490	Ø	4.54	1.85	-.79	.01	1.68	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C480	Ø	4.77	2.23	-.38	.18	1.22	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C481	Ø	4.97	2.10	-.30	-.06	1.18	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C522	Ø	5.10	2.15	-.17	-.10	.57	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C428	Ø	5.15	2.12	-.15	-.15	.86	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C200	Ø	5.35	2.70	.37	.18	.21	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C507	Ø	5.45	2.72	.46	.14	1.08	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C462	Ø	5.50	2.50	.36	-.07	1.12	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B
C471	Ø	5.72	2.60	.60	-.13	1.09	72C	RETROREFLECTANCE,	METHOD AND INSTRUMENTATION	SPECIFIED
C533	#	13.05	2.85	6.49	-4.50	1.22	72A	RETROREFLECTANCE,	METHOD	LS300A ØR LS300B

GMEANS: 5.17 2.33 1.00
95% ELLIPSE: 1.54 .43 WITH GAMMA = 38 DEGREES

RETROREFLECTANCE

SAMPLE S03 = 5.17 CP/FT-C/SQFT SAMPLE 003 = 2.33 CP/FT-C/SQFT



MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 1
RETROREFLECTANCE

LAB CODE	SAMPLE S04		SILVER AT 30,2. DEGREES				SAMPLE 004		ORANGE AT 30,2. DEGREES				TEST D. = 4		
	MEAN	DEV	N.DEV	SDR	R.SDR	MEAN	DEV	N.DEV	SDR	R.SDR	VAR	F	LAB		
C200	4.90	.13	.37	.12	.75	2.12	.09	.23	.05	.45	72A	0	C200		
C428	4.70	-.07	-.18	.18	1.19	1.75	-.29	-.80	.06	.52	72A	0	C428		
C462	5.15	.38	1.06	.10	.65	2.50	.46	1.27	.23	2.10	72A	0	C462		
C471	5.17	.41	1.13	.05	.33	2.15	.11	.30	.06	.52	72C	0	C471		
C480	4.28	-.49	-1.35	.22	1.42	1.70	-.34	-.94	.10	.90	72A	0	C480		
C481	4.77	.01	.02	.15	.98	1.90	-.14	-.38	.16	1.48	72A	0	C481		
C490	4.06	-.70	-1.94	.12	.81	1.52	-.51	-1.42	.15	1.36	72A	0	C490		
C507	5.00	.23	.64	.16	1.07	2.27	.24	.65	.05	.45	72A	0	C507		
C522	4.65	-.12	-.32	.13	.84	1.82	-.21	-.59	.05	.45	72A	0	C522		
C533	4.97	.21	.58	.30	1.95	2.65	.61	1.68	.19	1.74	72A	0	C533		

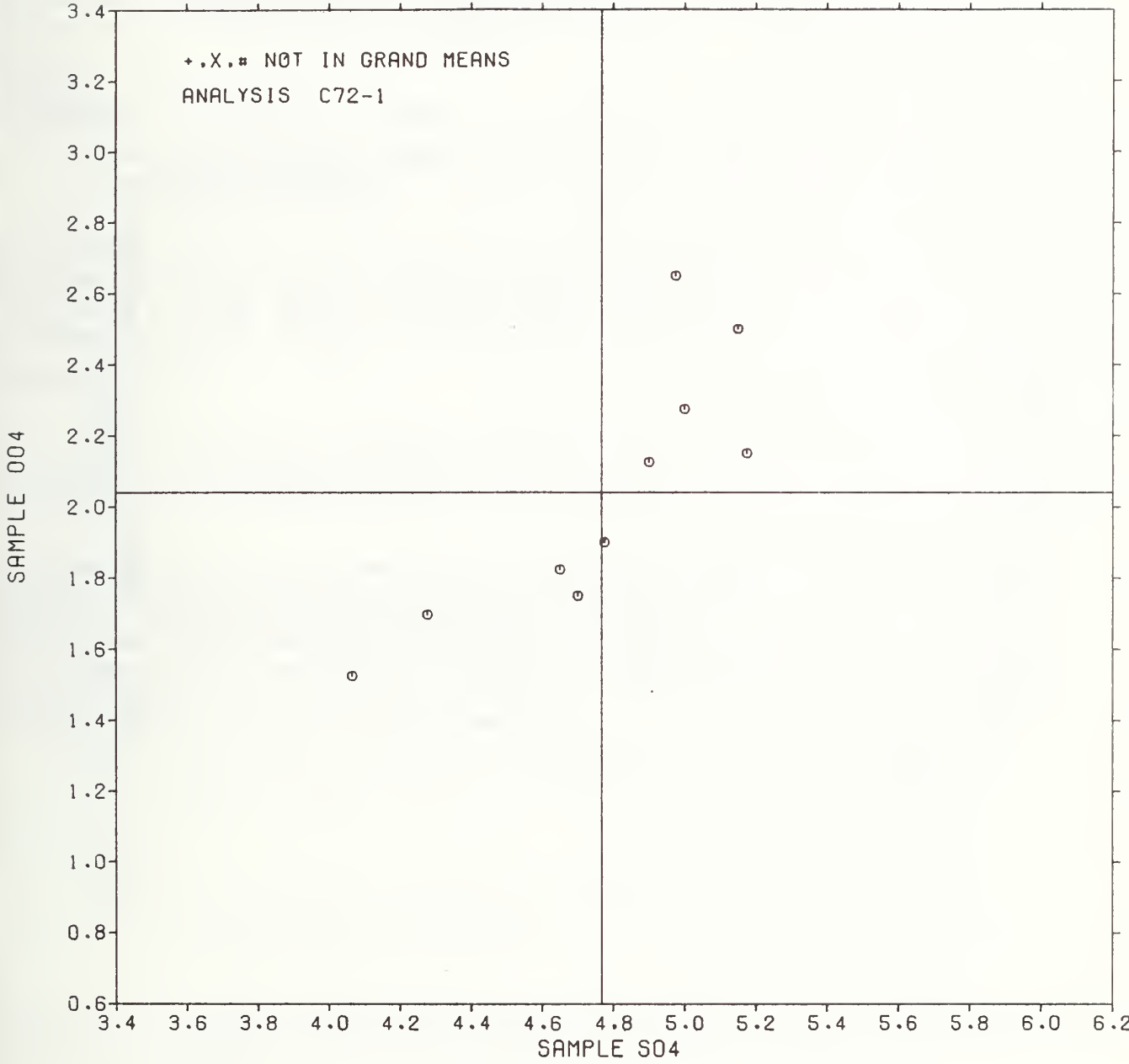
GR. MEAN = 4.77 CP/FT-C/SQFT GRAND MEAN = 2.04 CP/FT-C/SQFT TEST DETERMINATIONS = 4
SD MEANS = .36 CP/FT-C/SQFT SD OF MEANS = .36 CP/FT-C/SQFT 10 LABS IN GRAND MEANS
AVERAGE SDR = .15 CP/FT-C/SQFT AVERAGE SDR = .11 CP/FT-C/SQFT
TOTAL NUMBER OF LABORATORIES PARTICIPATING = 10

MCCA COLLABORATIVE REFERENCE PROGRAM
ANALYSIS C72-1 TABLE 2
RETROREFLECTANCE

LAB CODE	F	MEANS		COORDINATES		AVG		PROPERTY---TEST INSTRUMENT---CONDITIONS
		S04	004	MAJOR	MINOR	R.SDR	VAR	
C490	0	4.06	1.52	-.86	.13	1.09	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C480	0	4.28	1.70	-.55	.11	1.16	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C522	0	4.65	1.82	-.23	-.07	.65	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C428	0	4.70	1.75	-.25	-.16	.86	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C481	0	4.77	1.90	-.09	-.10	1.23	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C200	0	4.90	2.12	.15	-.03	.60	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C533	0	4.97	2.65	.58	.28	1.85	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C507	0	5.00	2.27	.33	.00	.76	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C462	0	5.15	2.50	.60	.05	1.38	72A	RETROREFLECTANCE, METHOD LS300A OR LS300B
C471	0	5.17	2.15	.37	-.21	.43	72C	RETROREFLECTANCE, METHOD AND INSTRUMENTATION SPECIFIED
GMEANS:		4.77	2.04			1.00		
		95% ELLIPSE:		1.56	.47	WITH GAMMA = 45 DEGREES		

RETROREFLECTANCE

SAMPLE S04 = 4.8 CP/FT-C/SQFT SAMPLE 004 = 2.0 CP/FT-C/SQFT



PERCENT DIFFERENCE BETWEEN
LABORATORY MEANS AND GRAND MEANS

Sheeting	Silver	Orange	Silver	Orange	Silver	Orange	Silver	Orange	Silver	Orange
Incidence Angle	-4°	-4°	30°	30°	-4°	-4°	30°	30°	30°	30°
Divergence Angle	.2°	.2°	.2°	.2°	2.0°	2.0°	2.0°	2.0°	2.0°	2.0°
GRAND MEAN	114.6	42.4	45.83	24.19	5.17	2.33	4.77	2.04	4.77	2.04
Lab Code										
C200	11.08	7.31	22.34	11.08	3.48	15.88	2.73	3.92	2.73	3.92
C428	.79	-3.30	4.19	-2.85	-39	-9.01	-1.47	-14.22	-1.47	-14.22
C462	-.35	2.83	17.72	5.62	6.38	7.29	7.97	22.55	7.97	22.55
C471	3.40	8.96	-1.27	1.69	10.64	11.59	8.39	5.39	8.39	5.39
C480	-3.84	.94	-8.14	5.50	-7.74	-4.29	-10.27	-16.67	-10.27	-16.67
C481	-5.85	-9.67	10.64	1.65	-3.87	-9.87	0.0	-6.86	0.0	-6.86
C486	4.45	1.65	18.07	-2.44	---	---	---	---	---	---
C488	-3.14	2.59	-1.81	-.79	---	---	---	---	---	---
C490	-11.78	-12.02	-22.58	-18.35	-12.19	-20.60	-14.88	-25.49	-14.88	-25.49
C507	3.93	13.92	2.70	12.65	5.42	16.73	4.82	11.27	4.82	11.27
C522	-4.97	-3.77	-10.06	-12.15	-1.35	-7.73	-2.52	-10.78	-2.52	-10.78
C533	6.45	-10.61	-31.81	-1.82	152.42	22.32	4.19	29.90	4.19	29.90

$$\text{PERCENT DIFFERENCE} = \frac{\text{Laboratory Mean} - \text{Grand Mean}}{\text{Grand Mean}} \times 100$$

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