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Coatings Trends & Technologies SUMMIT

Evaluation of UV Resistant Epoxies for Protective Coating Applications

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Agenda

- Safety Share
- Experiment purpose and overview
  - Low yellowing epoxies
  - Experiment plan
- Evaluation results
  - System properties
  - QUV-A results
- Conclusion and questions

Safety Share

ZERO HARM

Experiment purpose and overview

Purpose of experiment

- Epoxy based protective coatings –
  - Typically provide excellent adhesion, chemical resistance, strength, and durability
  - Limited gloss retention and yellowing resistance under UV exposure
    - Most common epoxides have aromatic chemical structure
    - In use often aliphatic polyurethane, polyurea or acrylic topcoats are specified
- Cycloaliphatic resins and hardeners allow formulation of epoxies for maximized UV stability
  - Cycloaliphatic systems have better gloss retention and reduced yellowing compared to standard aromatic epoxies but are often hindered by slow cure times without heat
- Low yellowing epoxy systems could eliminate the need for a traditional 3 coat system
  - Potential to reduce project time and raw material costs with 1 or 2 coat systems

Experiment Parameters

- Neat resin & hardeners (unmodified and without filler) evaluated as clear coatings
  - 3 cycloaliphatic epoxy resins and 3 formulated cycloaliphatic amines hardeners
  - Aromatic Bis-A DGE liquid epoxy resin was used as the epoxy control
- Solvent borne polyurethane based clear top coating used as a commercial technology benchmark
- Testing Protocol
  - Physical properties were measured on standard Q-panels
  - QUV-A exposure test according to ASTM G-53 using clear glass panels

Raw Material Specifications

Number	Type	Solids Content %	Color, Gardner	Viscosity @ 25 °C, cp	EEW g/eq	AHEW g/eq
Resin A	BADGE	100	< 1	12500	187	
Resin B	Hydrogenated BADGE	100	< 100 APHA	1900	220	
Resin C	Accelerated HBADGE	100	< 3	3250	200	
Resin D	Cycloaliphatic Glycidyl Ester	100	< 100 APHA	800	170	
Hardener 1	Cycloaliphatic Polyamine	100	< 1	610		115
Hardener 2	Cycloaliphatic Polyamine	100	< 60 APHA	275		115
Hardener 3	Cycloaliphatic Polyamine	100	< 100 APHA	500		95

Test Formulations

Clear coating formulas were used without adding any additives:

Hardener 1 Formulas, weight in grams				
Resin A	100			
Resin B		100		
Resin C			100	
Resin D				100
Hardener 1	61.6	52.2	57.5	67.5

Hardener 2 Formulas, weight in grams				
Resin A	100			
Resin B		100		
Resin C			100	
Resin D				100
Hardener 2	61.6	52.2	57.5	67.5

Hardener 3 Formulas, weight in grams				
Resin A	100			
Resin B		100		
Resin C			100	
Resin D				100
Hardener 3	50.8	43.3	47.5	56

Experiment Results

System Properties

Systems:	Gel Time, mins	Dry To Touch, hours	Dry Through, hours	7 Days Pendulum Hardness , s	7 Days Shore D Hardness
A-1	21.8	2	3	319	85
B-1	56.3	3	4	218	79
C-1	30.6	2.5	4	258	83
D-1	23.5	3	4	209	85
A-2	114.3	3	7.5	246	78
B-2	237.7	9	13	110	70
C-2	215.7	8	12	127	75
D-2	124.7	3.5	8	87	65
A-3	117.9			301	83
B-3	605.2			67	79
C-3	246.1			134	81
D-3	158.8			62	70

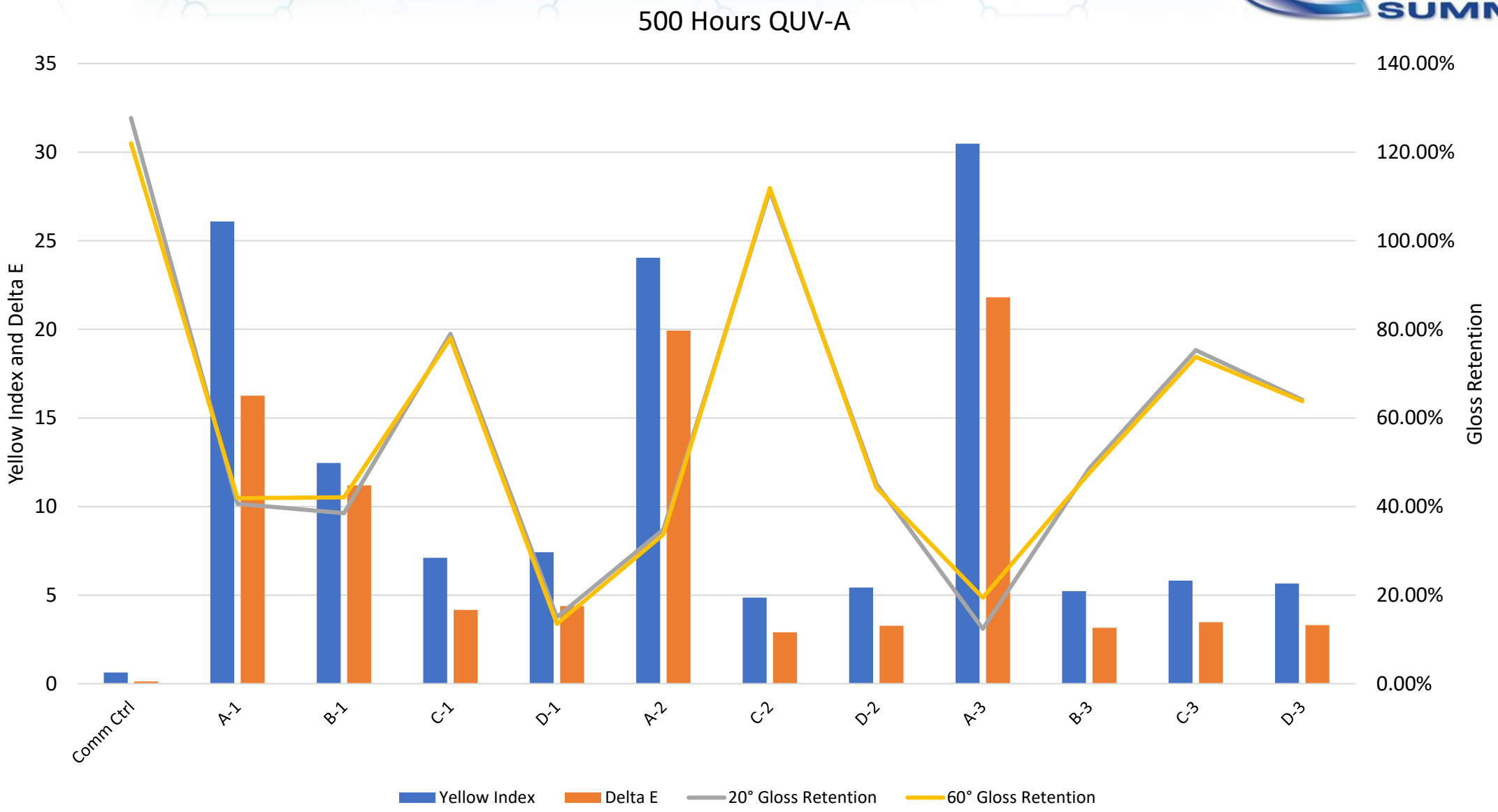
Experiment Results

500 Hours QUV-A

Systems:	Yellow Index	Delta E	20° Gloss Retention	60° Gloss Retention
Commercial Control	0.63	0.13	127.7%	122.0%
A-1	26.09	16.26	40.6%	41.9%
B-1	12.46	11.20	38.5%	42.1%
C-1	7.10	4.16	79.0%	78.0%
D-1	7.42	4.38	15.0%	13.5%
A-2	24.05	19.93	34.8%	33.7%
C-2	4.86	2.90	111.3%	111.9%
D-2	5.43	3.27	45.1%	44.3%
A-3	30.48	21.81	12.4%	19.4%
B-3	5.22	3.16	48.6%	47.6%
C-3	5.82	3.47	75.3%	73.8%
D-3	5.65	3.31	64.1%	63.8%

Experiment Results

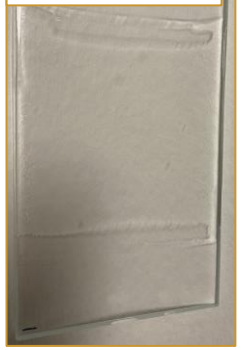
500 Hours QUV-A



500 Hours QUV-A

Initial

Control



C-1

C-2

C-3

A-2

500 Hours

Control

C-1

C-2

C-3

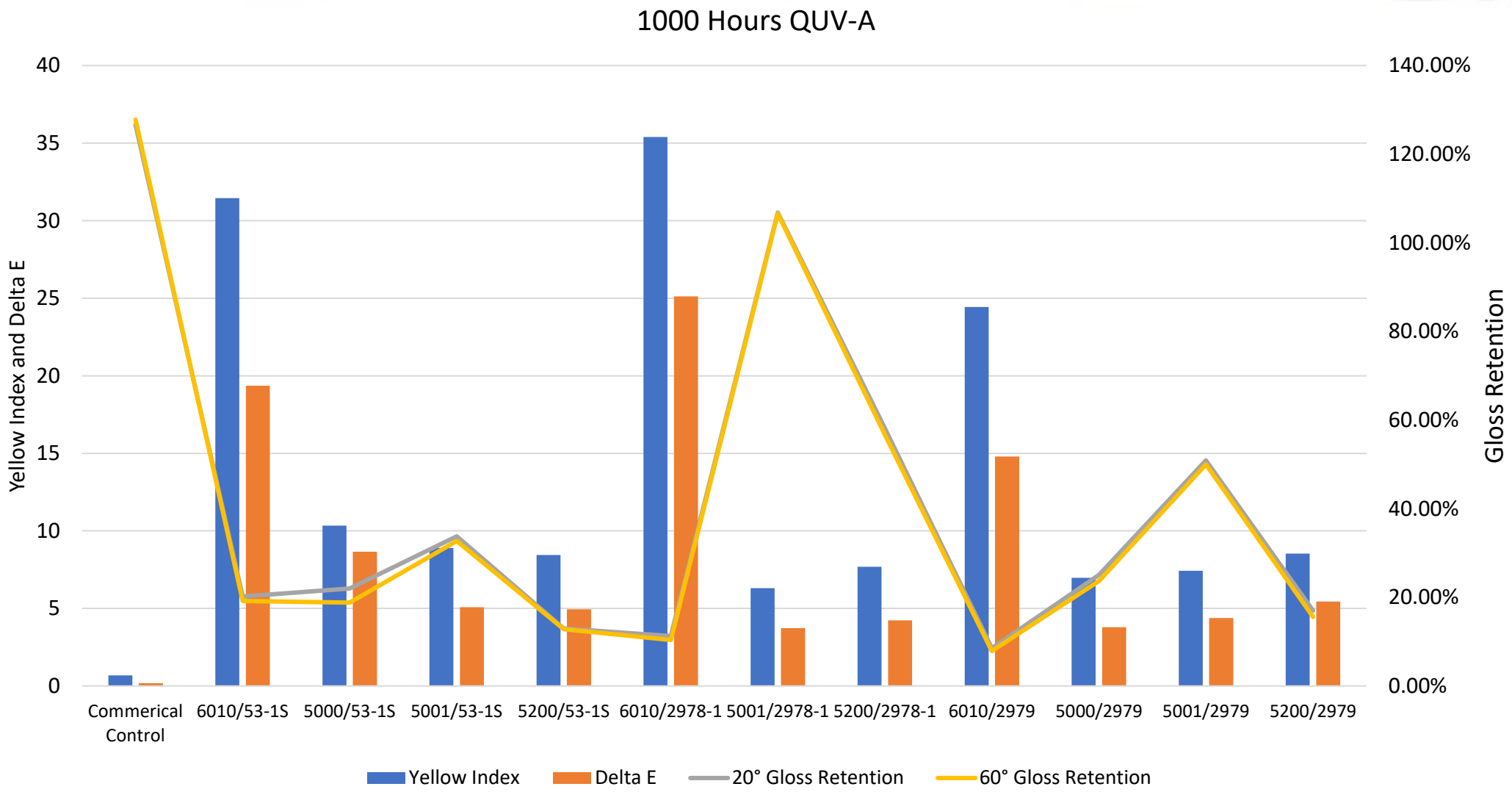
A-2

Experiment Results

1000 Hours QUV-A

Systems:	Yellow Index	Delta E	20° Gloss Retention	60° Gloss Retention
Commercial Control	0.68	0.19	126.60%	127.80%
A-1	31.46	19.36	20.20%	19.20%
B-1	10.34	8.65	22.00%	18.80%
C-1	8.9	5.08	33.80%	32.70%
D-1	8.45	4.94	13.00%	12.80%
A-2	35.4	25.11	11.30%	10.40%
C-2	6.31	3.73	106.80%	106.60%
D-2	7.69	4.23	58.10%	56.70%
A-3	24.43	14.79	8.50%	7.90%
B-3	6.97	3.79	25.10%	23.70%
C-3	7.43	4.38	50.90%	50.00%
D-3	8.54	5.45	17.00%	15.60%

1000 Hours QUV-A



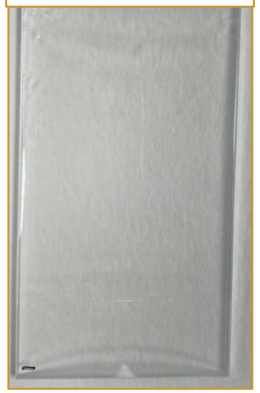
1000 Hours QUV-A

Initial

Control

C-2

D-2



C-3

A-2

1000 Hours

Control

C-2

D-2

C-3

A-2

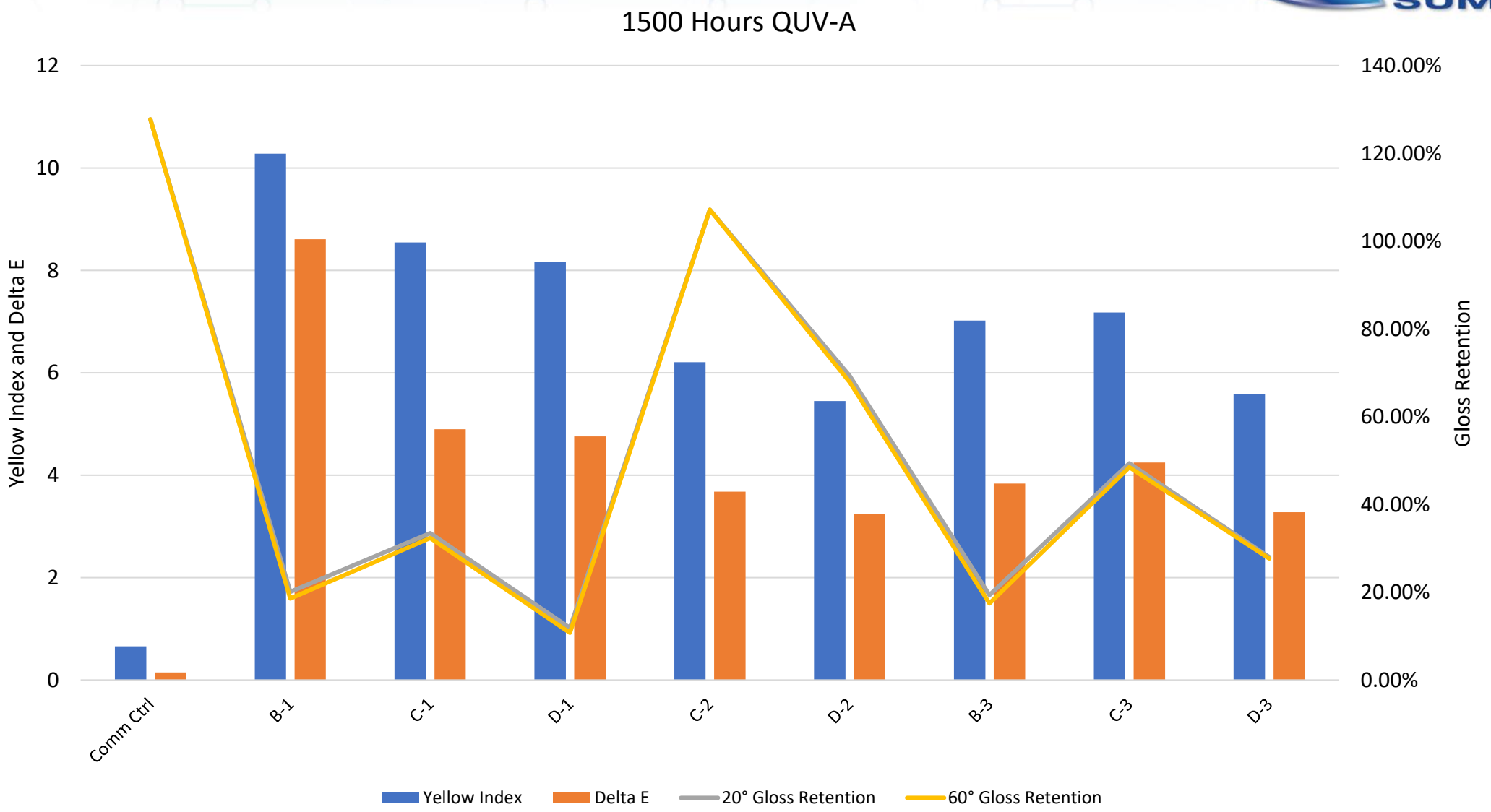
Experiment Results

1500 Hours QUV-A

Systems:	Yellow Index	Delta E	20° Gloss Retention	60° Gloss Retention
Commercial Control	0.66	0.15	127.8%	127.8%
B-1	10.28	8.61	20.1%	18.6%
C-1	8.55	4.90	33.5%	32.4%
D-1	8.17	4.76	11.9%	10.8%
C-2	6.21	3.68	107.2%	107.2%
D-2	5.45	3.25	69.3%	67.9%
B-3	7.02	3.84	19.4%	17.5%
C-3	7.18	4.25	49.4%	48.5%
D-3	5.59	3.28	28.0%	27.7%

Experiment Results

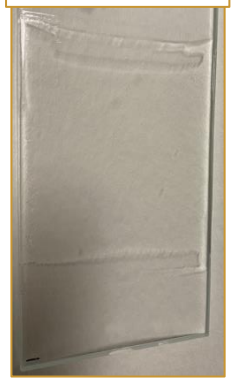
1500 Hours QUV-A



1500 Hours QUV-A

Initial

Control



D-2

C-2

C-3

1500 Hours

Control

D-2

C-2

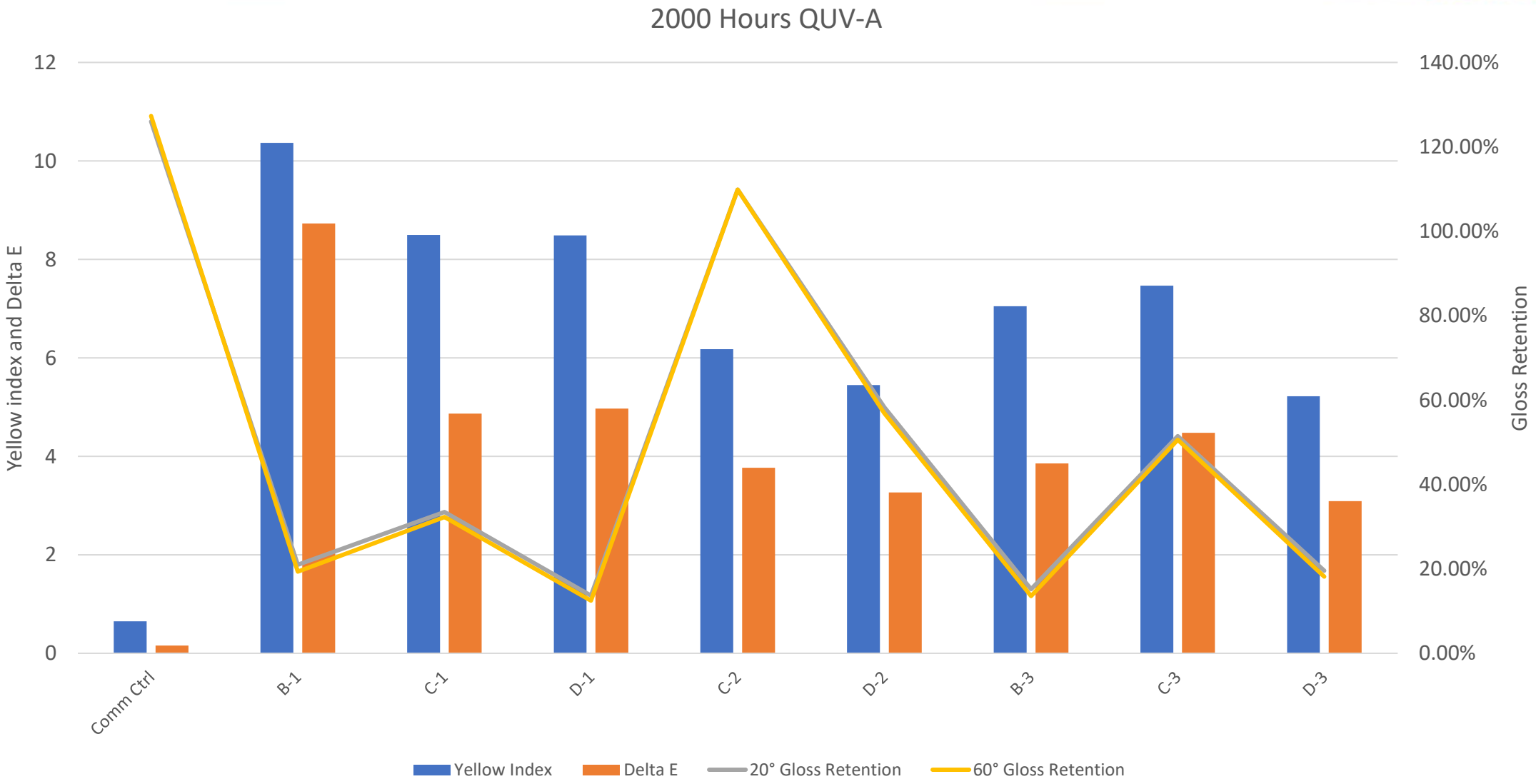
C-3

Experiment Results

2000 Hours QUV-A

Systems:	Yellow Index	Delta E	20° Gloss Retention	60° Gloss Retention
Commercial Control	0.65	0.16	126.00%	127.30%
B-1	10.37	8.73	21.00%	19.40%
C-1	8.5	4.87	33.50%	32.30%
D-1	8.49	4.97	13.70%	12.50%
C-2	6.18	3.77	109.90%	109.90%
D-2	5.45	3.27	58.30%	56.90%
B-3	7.05	3.86	15.20%	13.60%
C-3	7.47	4.48	51.50%	50.60%
D-3	5.22	3.09	19.60%	18.20%

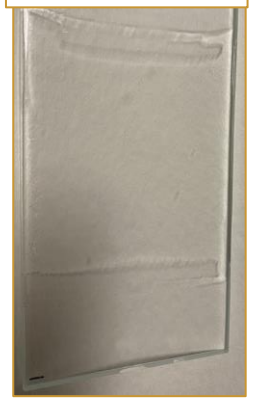
2000 Hours QUV-A



2000 Hours QUV-A

Initial

Control



D-2

C-2

C-3

2000 Hours

Control

D-2

C-2

C-3

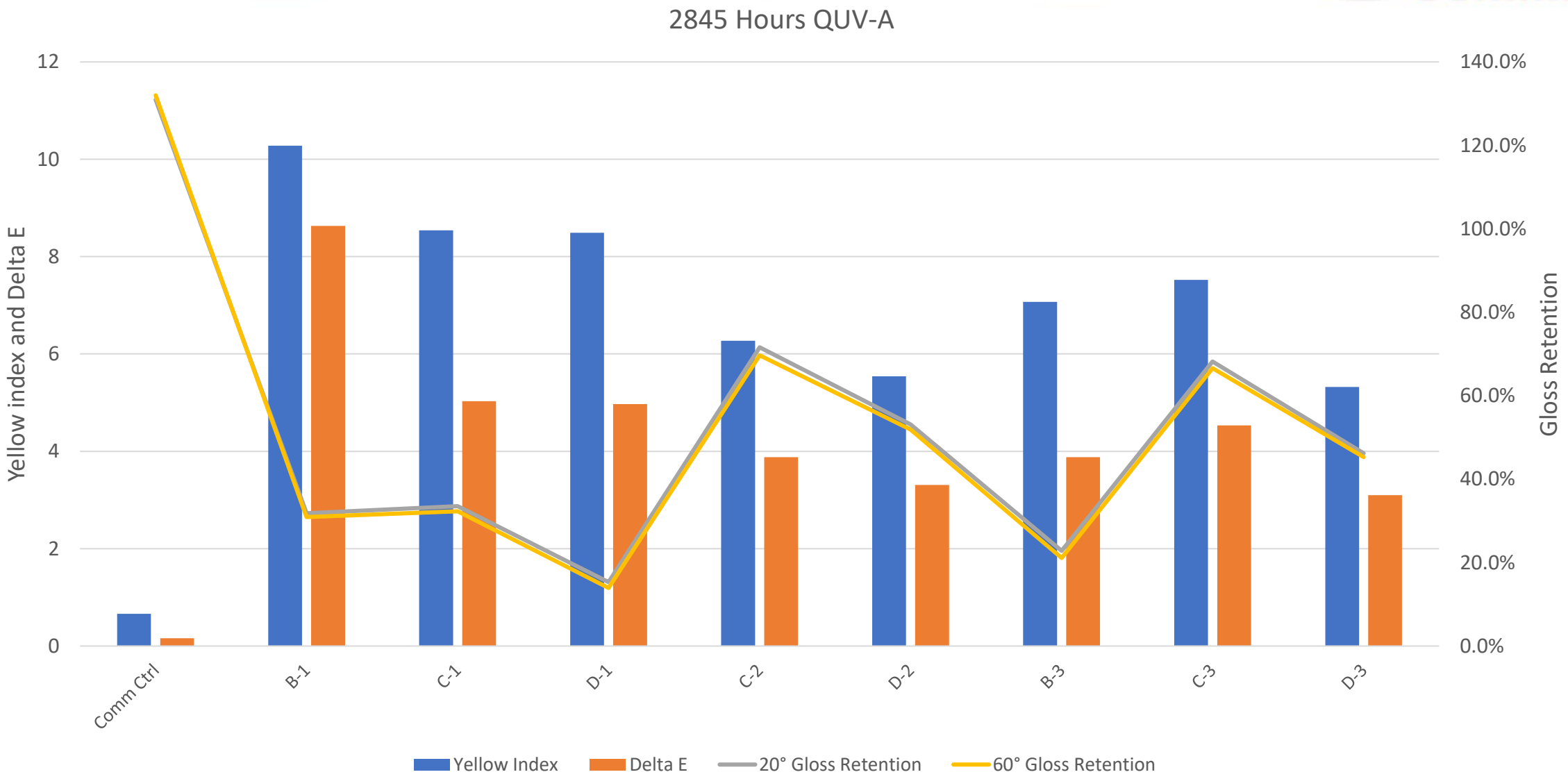
Experiment Results

2845 Hours QUV-A

Systems:	Yellow Index	Delta E	20° Gloss Retention	60° Gloss Retention
Commercial Control	0.66	0.16	130.9%	132.0%
B-1	10.28	8.63	31.8%	30.9%
C-1	8.54	5.03	33.5%	32.3%
D-1	8.49	4.97	15.3%	13.9%
C-2	6.27	3.88	71.6%	69.7%
D-2	5.54	3.31	53.1%	51.9%
B-3	7.07	3.88	22.8%	21.1%
C-3	7.52	4.53	68.2%	66.6%
D-3	5.32	3.1	46.2%	45.3%

Experiment Results

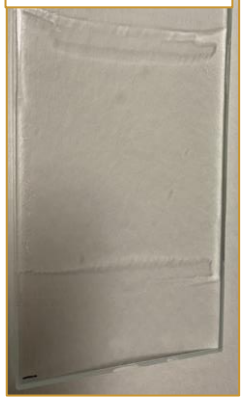
2845 Hours QUV-A



2845 Hours QUV-A

Initial

Control



D-2

C-2

C-3

2845 Hours

Control

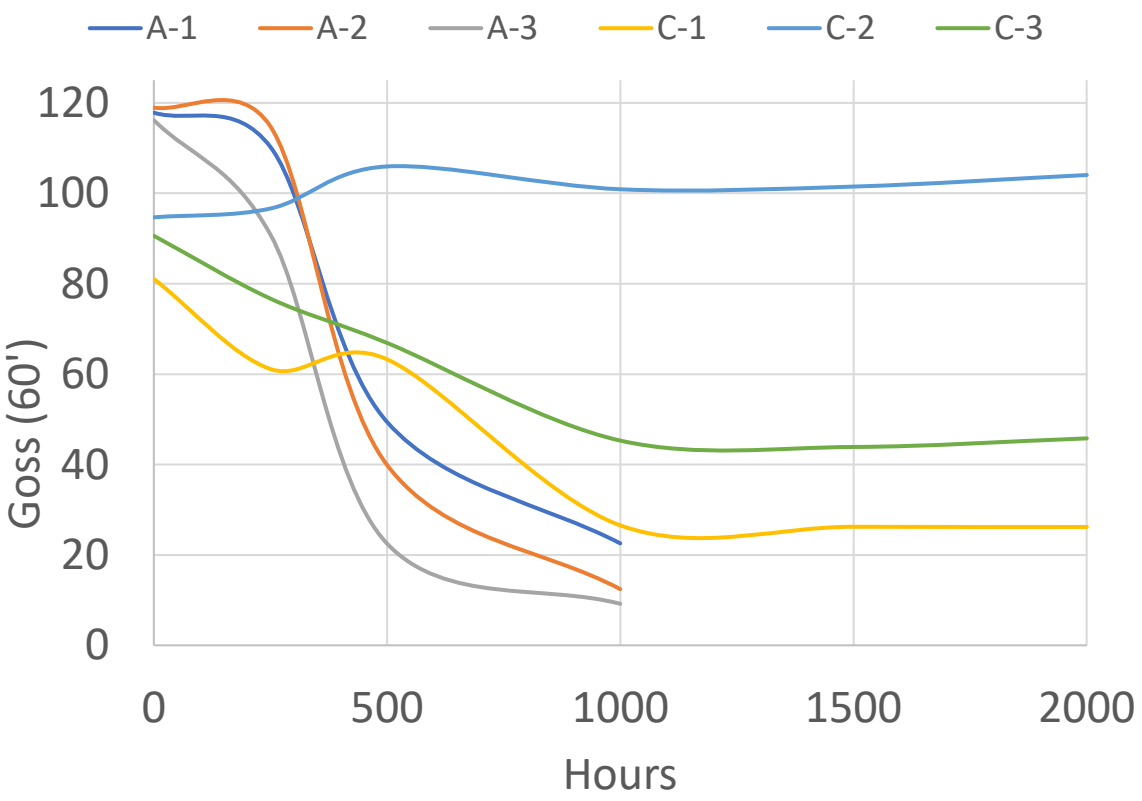
D-2

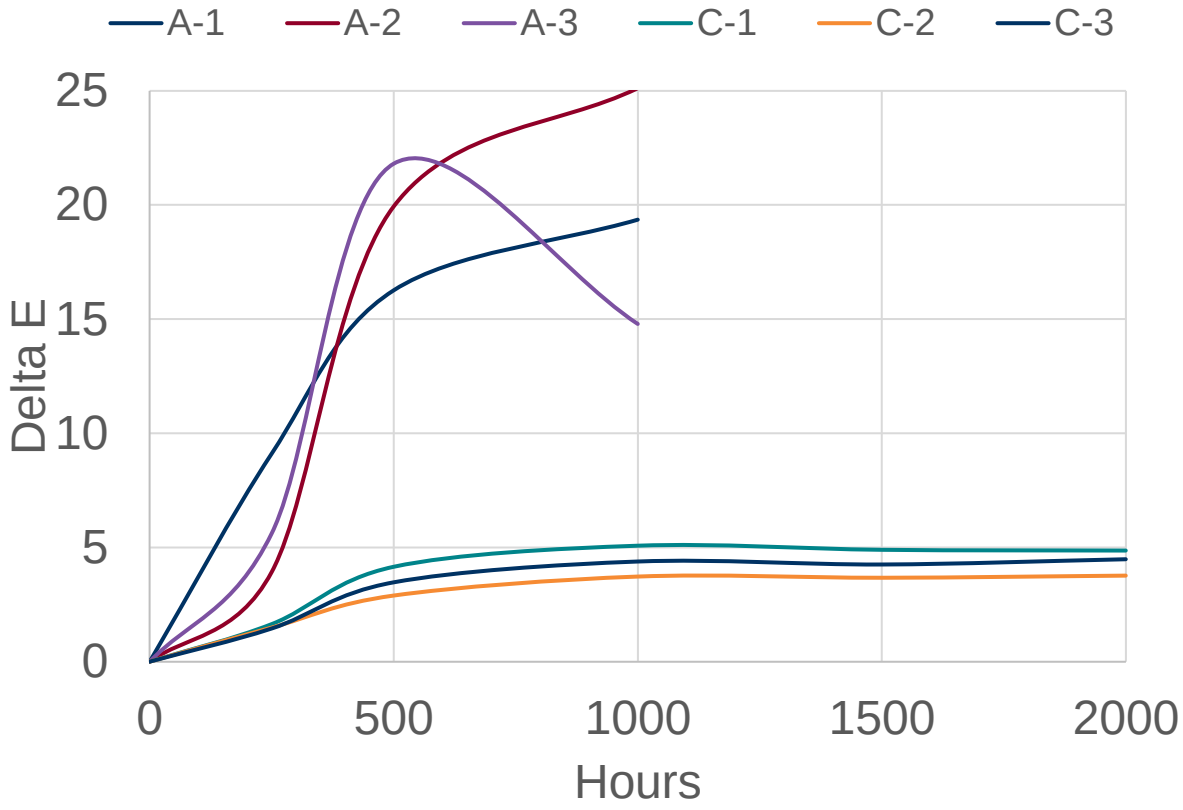
C-2

C-3

Conclusions and Future Work

BADGE systems vs Accelerated HBADGE





Accelerated HBADGE + Cycloaliphatic Polyamine (C-2) showed best overall performance

- Highest resin functionality and lowest overall aromatic content

Conclusions and Future Work Plan

- Cycloaliphatic systems show vastly superior performance compared to aromatic
  - Resin A severely yellowed by 500 hours and experienced failure before 1000 hours of QUV-A
- Faster reacting cycloaliphatic materials improved cure speed while still maintaining good mechanical and physical properties
- After almost 3000 hours of QUV-A exposure –
  - Tested cycloaliphatics showed good UV resistance without use of UV absorbers or HALS
  - Aromatic content in formulated amines contributed to yellowing
- Future Work
  - Additional QUV-A testing with formulated systems containing functional additives (UV stabilizers, UV inhibitors, etc)
  - Additional development of for UV resistant resins and faster cure hardeners

Acknowledgements

1. Coatings Trends & Technologies

2. Huntsman Advanced Materials Technical Service Team

Special thanks to:

Yong Zhang

Alicia Gamboa

Legal information

Discussion