

High-irradiance laboratory weathering testing of polymers using fluorescent ultraviolet laboratory apparatus

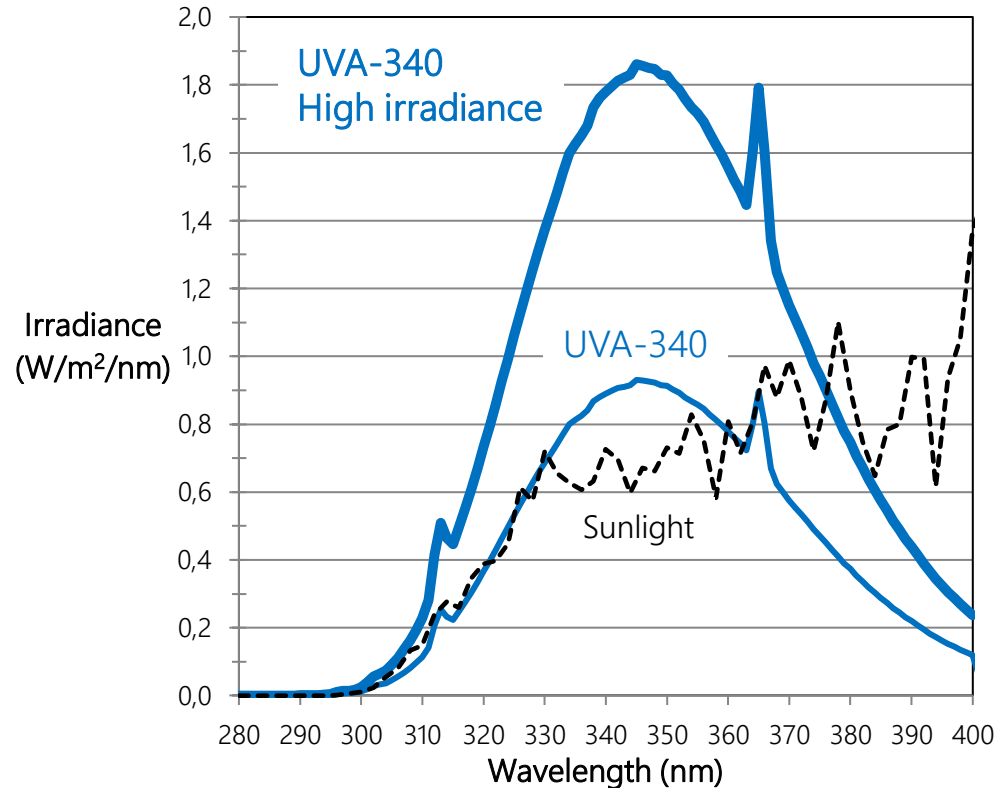
Dr. Andy Francis

Marketing Director

Q-Lab

High Irradiance Testing in UV Fluorescent Apparatus

- UV fluorescent testers are capable of delivering high levels of UV light to specimens
- There may be cases where high-irradiance testing delivers fast results
 - Otherwise, no one would perform accelerated laboratory testing!
- This presentation will look at some examples of high-irradiance UV fluorescent testing of polymers and assess their value for matching outdoor weathering data



Reciprocity

Reciprocity is the concept that underlies high-irradiance testing:

- Increase irradiance, decrease exposure time by a reciprocal amount, and still get the same results.
- Achieving faster results is a powerful motivator!

There are many reasons why this may not be true though!

Same energy ...
Different result!



Accelerated Testing

Reciprocity Failure



2.24×10^{32} J
over millions of years



2.24×10^{32} J
over 5 seconds



Reciprocity is Difficult to Achieve in Weathering Testing

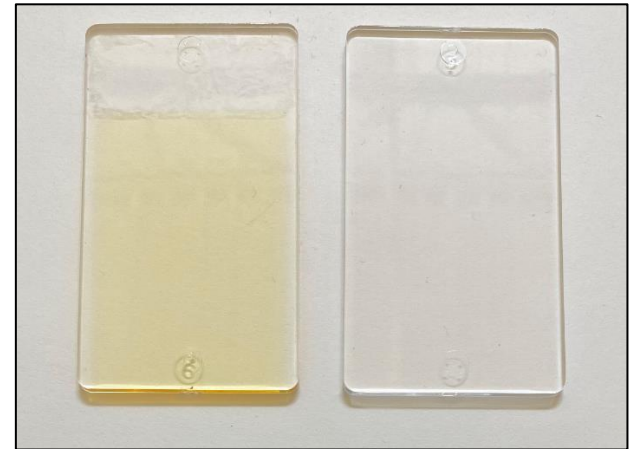
For irradiance reciprocity to hold *exactly*, all of these conditions need to be true:

- The material contains only one compound that is affected by light
 - There is only one photo-chemical pathway within that compound
 - That pathway is not affected by heat
 - That photochemical pathway is not subject to saturation effects.
 - Byproducts of the photochemical reaction do not accumulate and interfere with future photochemical reactions
 - Byproducts of the primary reaction do not engage in secondary reactions with other compounds within the material
 - UV absorbers and UV stabilizers do not deplete over time
 - There are no oxidation reactions that are independent of light
 - There are no reactions of any kind that are independent of light
 - There is only one kind of degradation that occurs
 - Exposure to water has no effect on degradation of any component of the material
 - Wet / dry cycling has no effect on degradation of any component of the material
 - Absorbed humidity has no effect on degradation of any component of the material
 - Thermal cycling has no effect on degradation of any component of the material.
- OR we need to set expectations for what we expect to learn from high-irradiance testing

Polystyrene Reference material

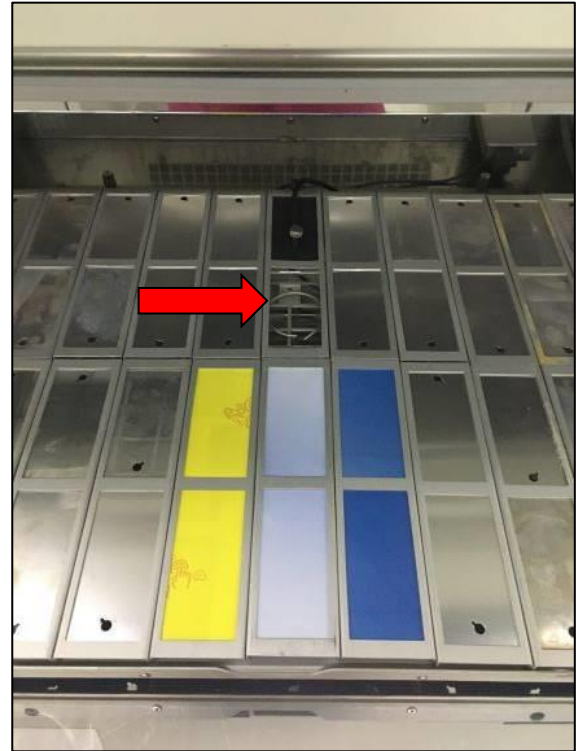
Polystyrene (PS) reference material

- Polystyrene is used as a reference weathering material in SAE J2527 and J2412
- Limits for yellowing (Δb) are established for PS to ensure that tester is delivering proper conditions
- Sensitive to light as well as heat
- No longer mandatory; still widely used





Polystyrene Measurement

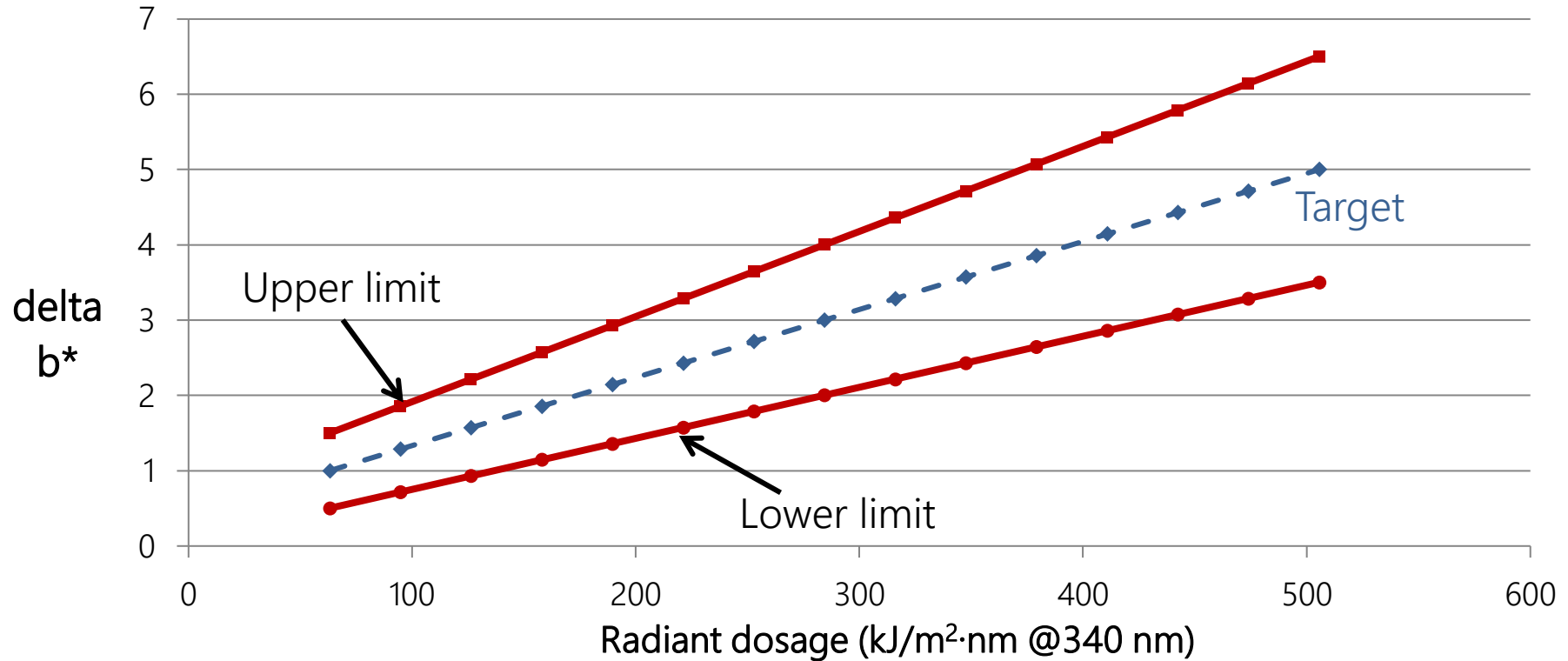
- Mount polystyrene in specimen holder close or directly next to the black panel
- Use mesh (open) tray for airflow
- Perform test
- Record color measurement
 - Instrumental color, CIELAB, D65 illuminant, 10° observer
 - Back with white calibration tile, not paper



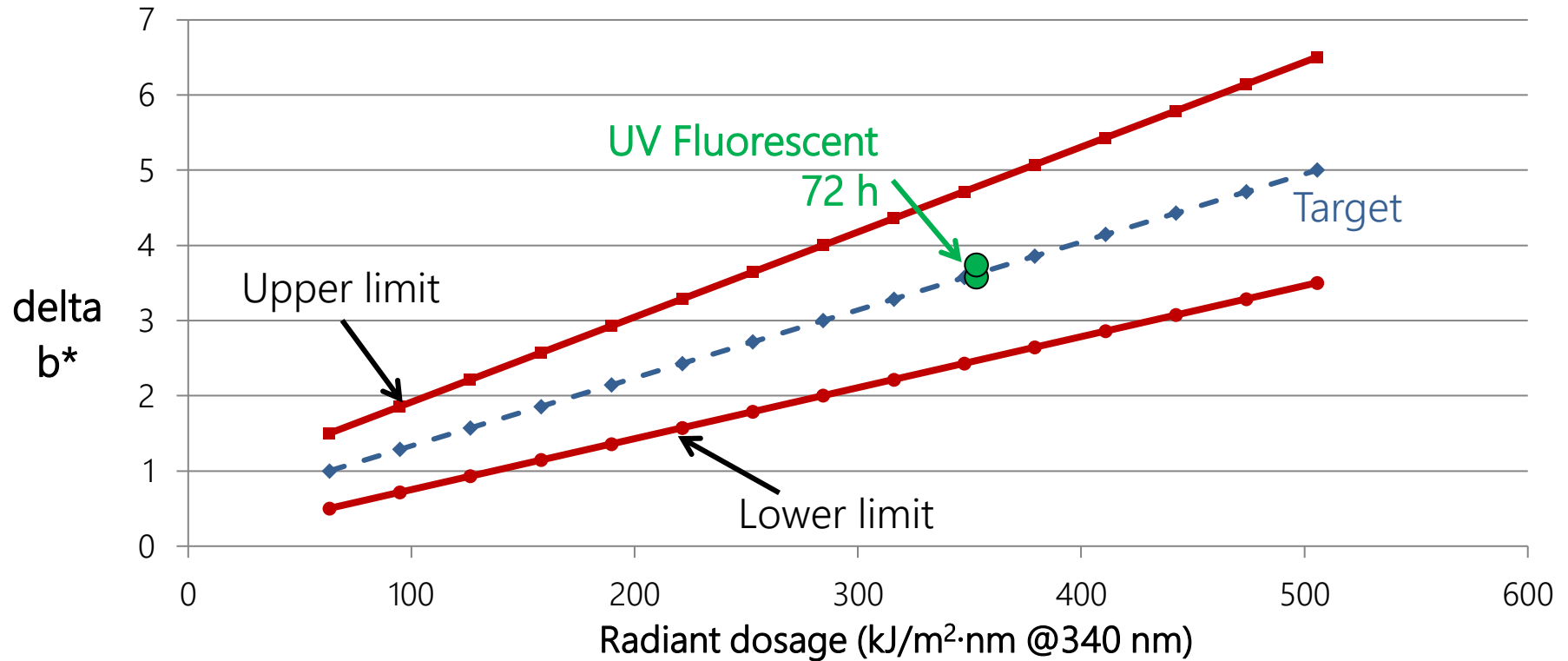
Experimental

Test Type	Irradiance	Heat	Water
<p>Xenon arc (SAE J2527)</p> 	<ul style="list-style-type: none">• 0.55 W/m² @340 nm• Full-spectrum• Dark 1 h in 3h cycle	<ul style="list-style-type: none">• 70 °C BP• 47 °C CAT	<ul style="list-style-type: none">• Dark spray (1 h)• Light spray (20 min)
<p>UV fluorescent</p> 	<ul style="list-style-type: none">• 2.04 W/m²@340 nm• UV only (UVA-340)• Dark 4 h in 12 h cycle	<ul style="list-style-type: none">• 60 °C BP (light)• 50 °C BP (cond.)	<ul style="list-style-type: none">• Condensation (4 h)

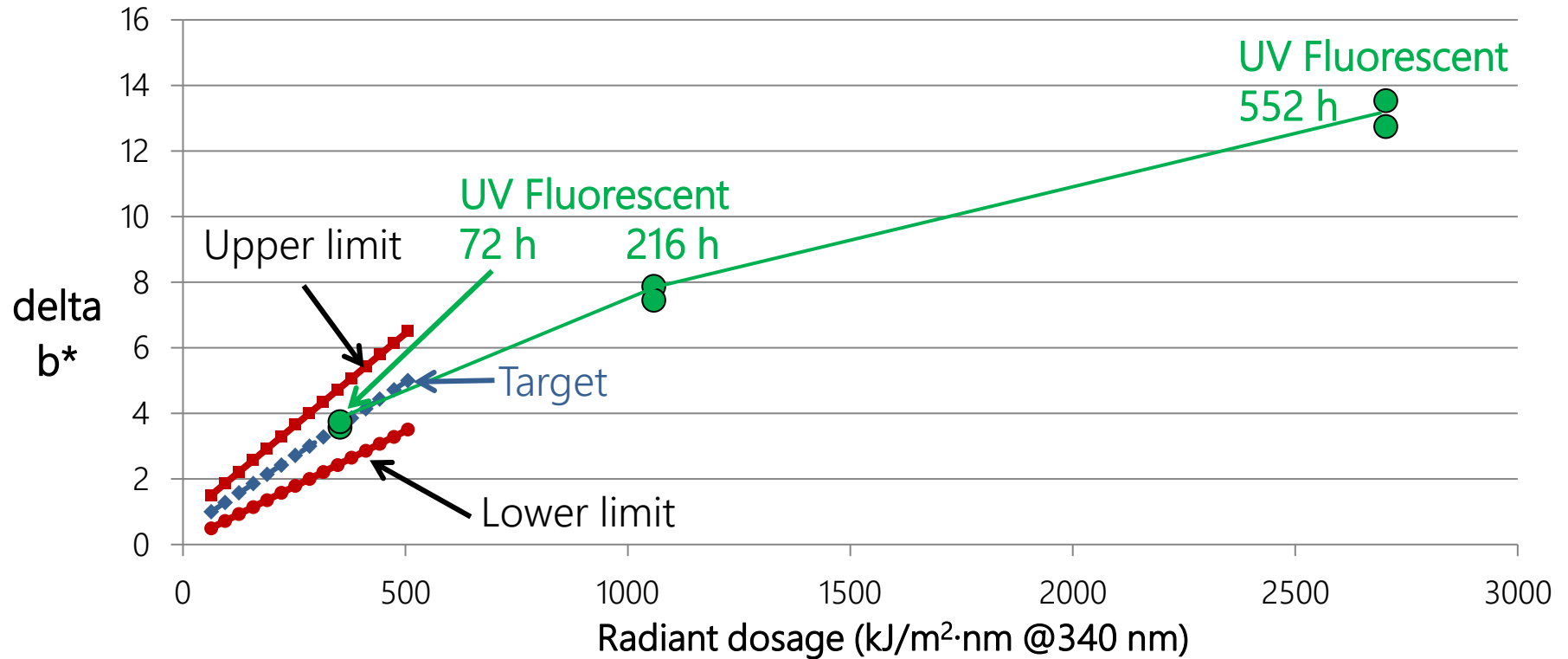
PS yellowing: xenon arc normal irradiance



PS yellowing: UV fluorescent high irradiance



PS yellowing: UV fluorescent high irradiance



Test Comparison with High-Irradiance UV Fluorescent and Natural Outdoor Testing

ASA, PBT, PA6

High-irradiance polymer testing

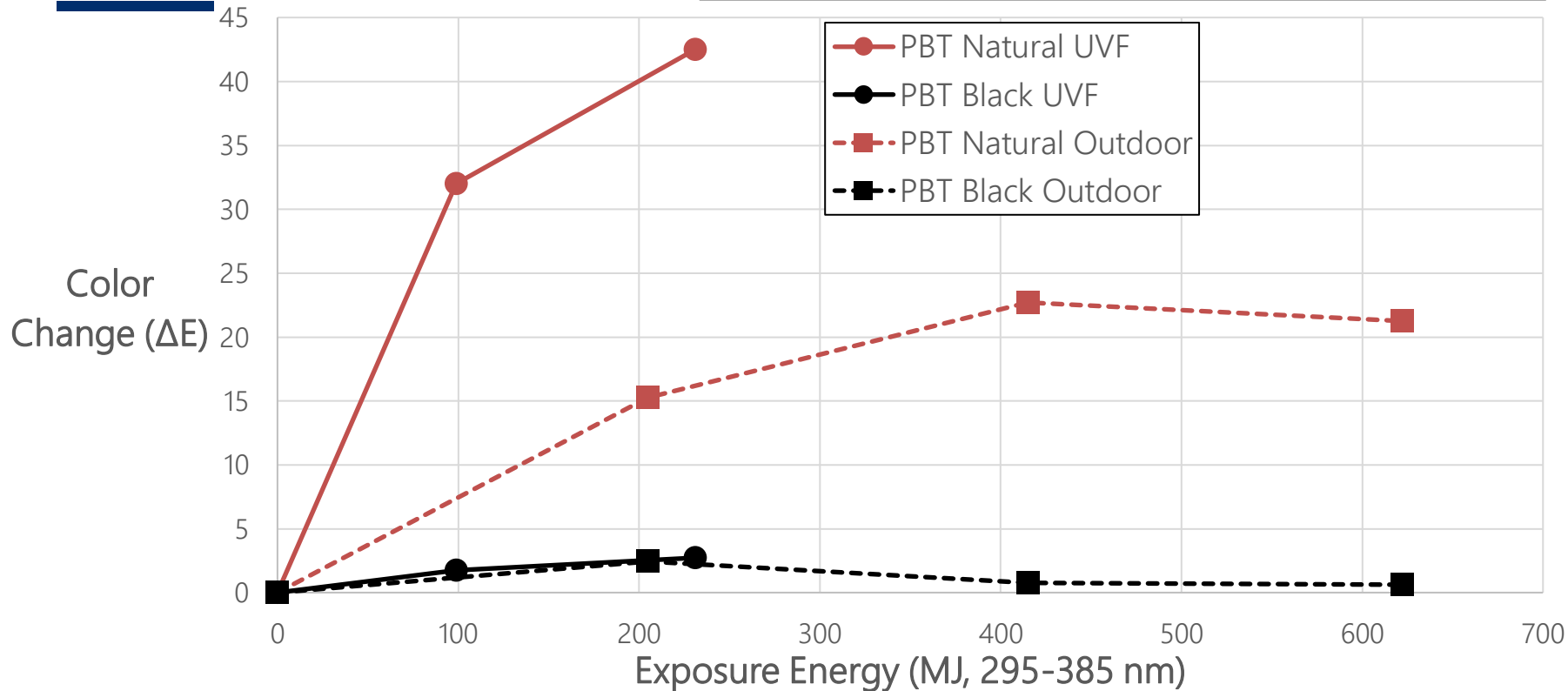
- Plastics tested
 - Acrylonitrile styrene acrylate (ASA)
 - Polycaprolactam nylon (PA6)
 - Polybutylene terephthalate (PBT)
- Colors
 - Black
 - Natural

High-irradiance polymer testing

- Tests performed
 - “3-sun” irradiance of 2.04 W/m²/nm (ASTM G154 proposed)
 - Natural outdoors in Arizona (hot, dry)
- Evaluations
 - Gloss, 60 °
 - Color change (ΔE)

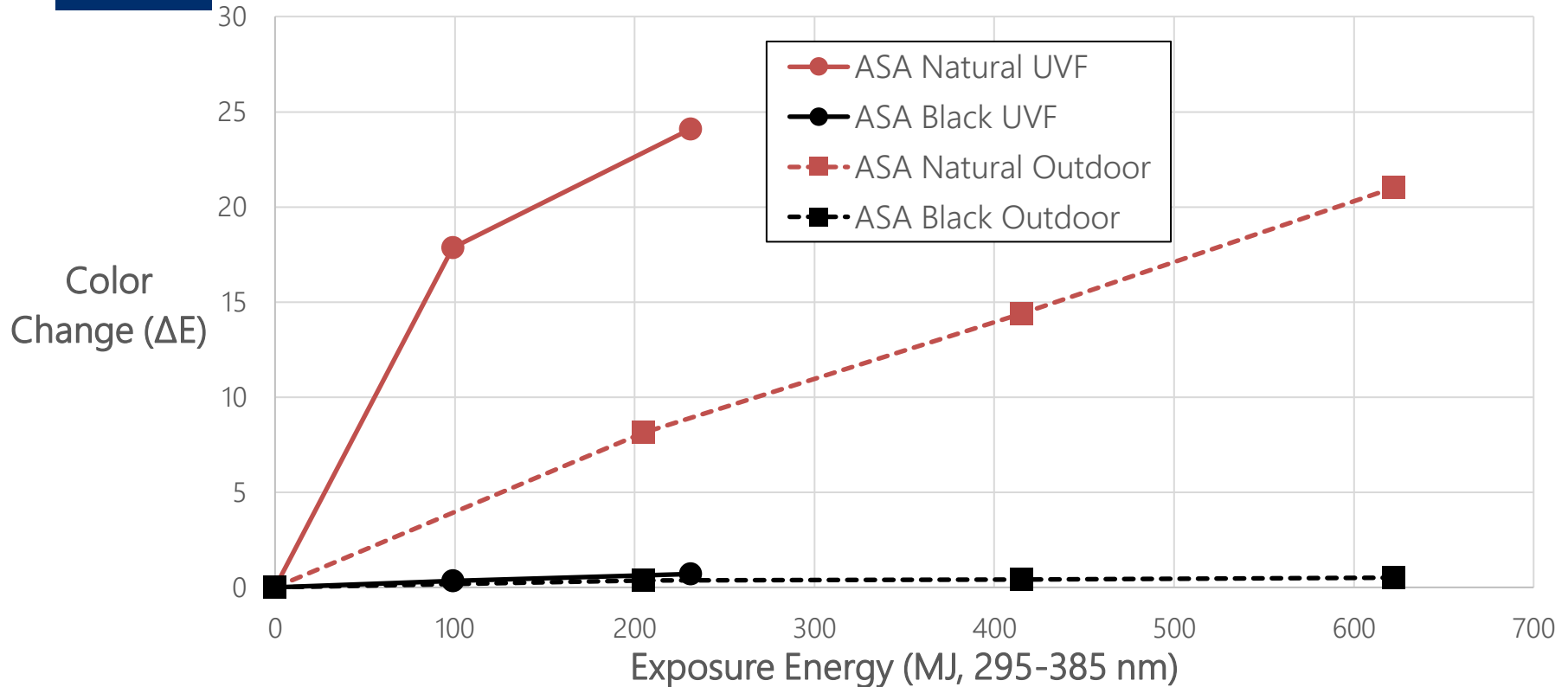
PBT Color Change

- Rank ordering correct; good predictor
- Faster on dosage basis for natural



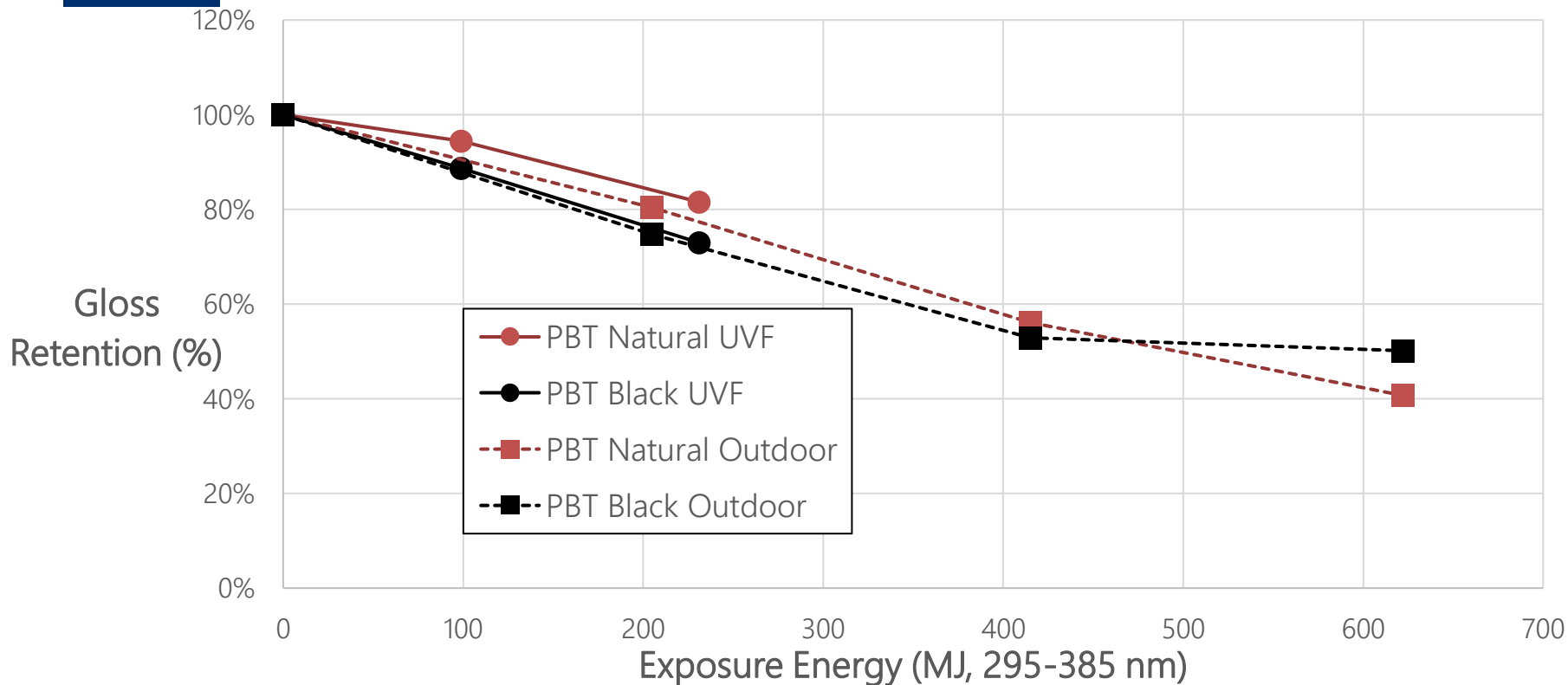
ASA Color Change

- Rank ordering correct; good predictor
- Faster on dosage basis for natural



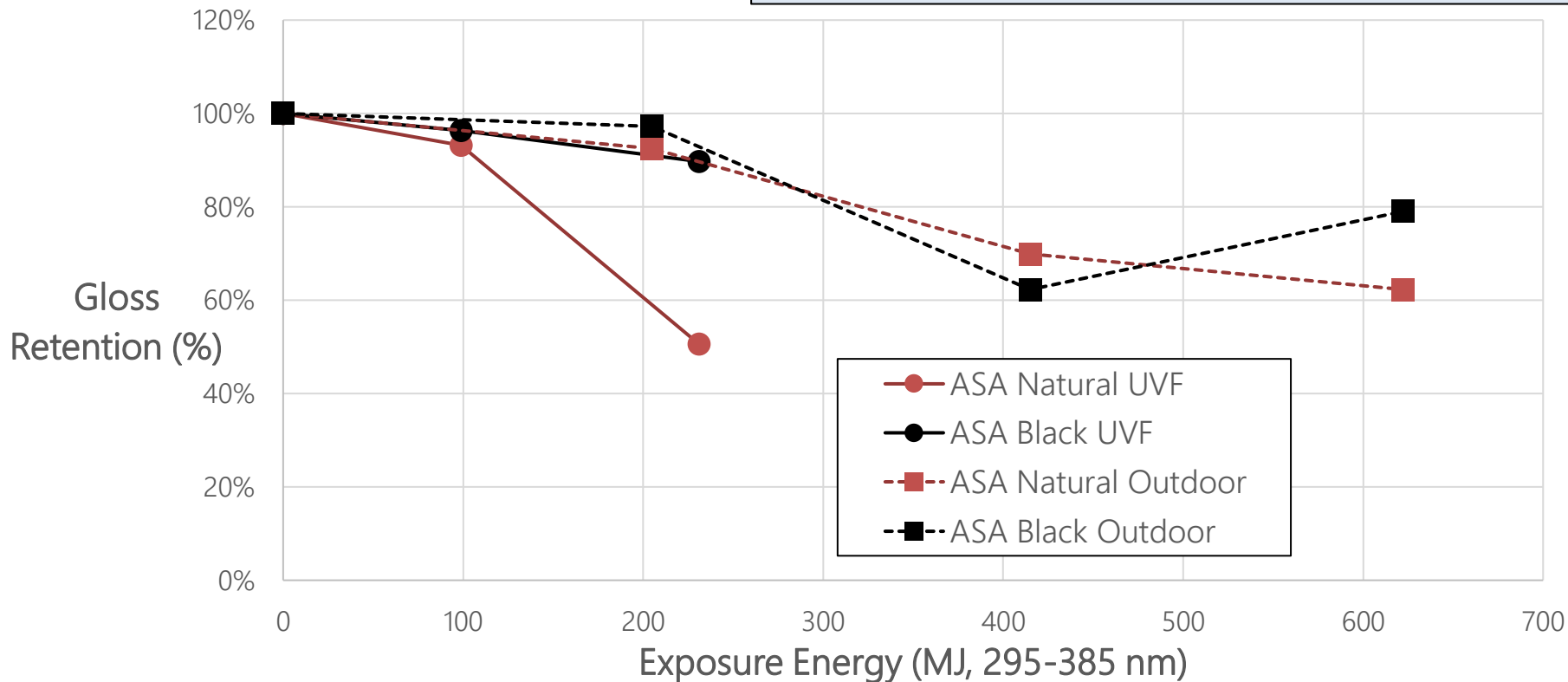
PBT Gloss Retention

Very good correlation



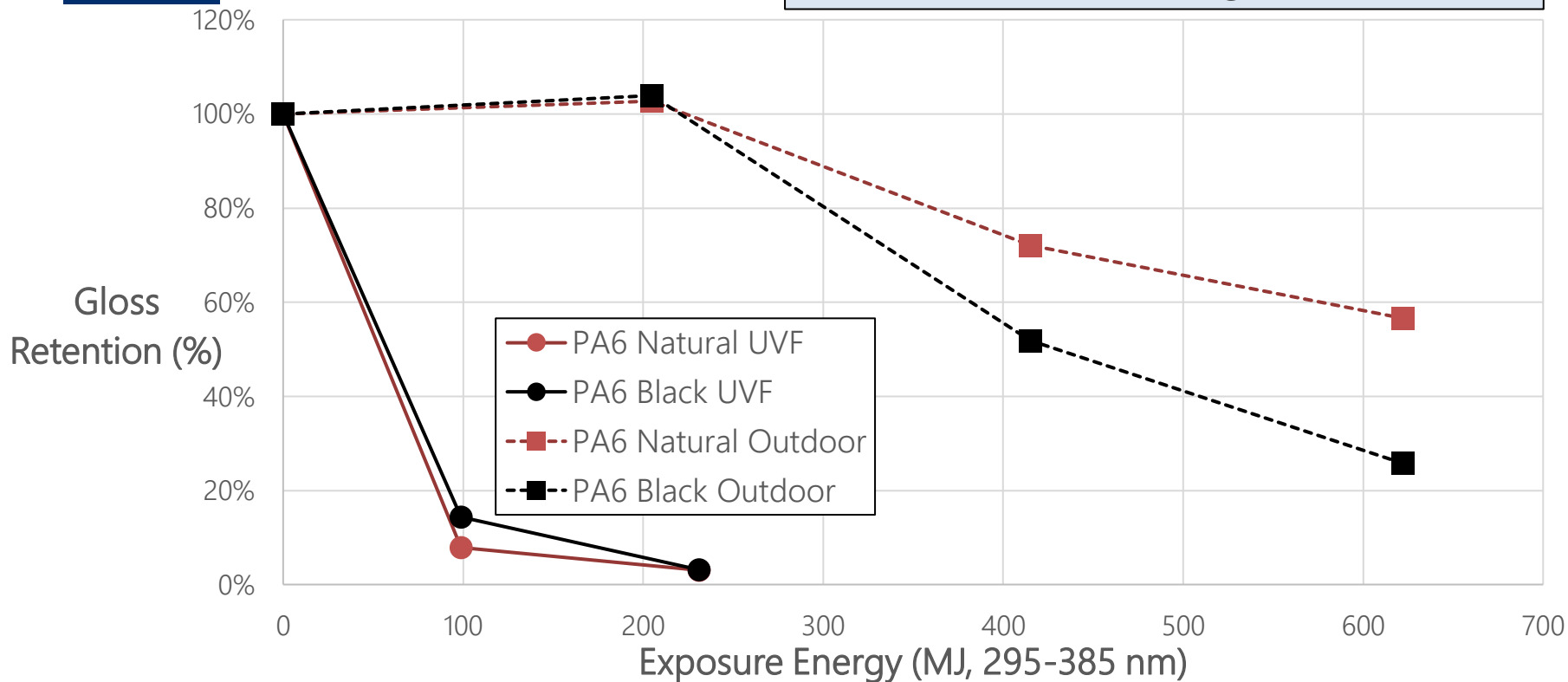
ASA Gloss Retention

- Very good correlation
- Natural changing quickly in accelerated



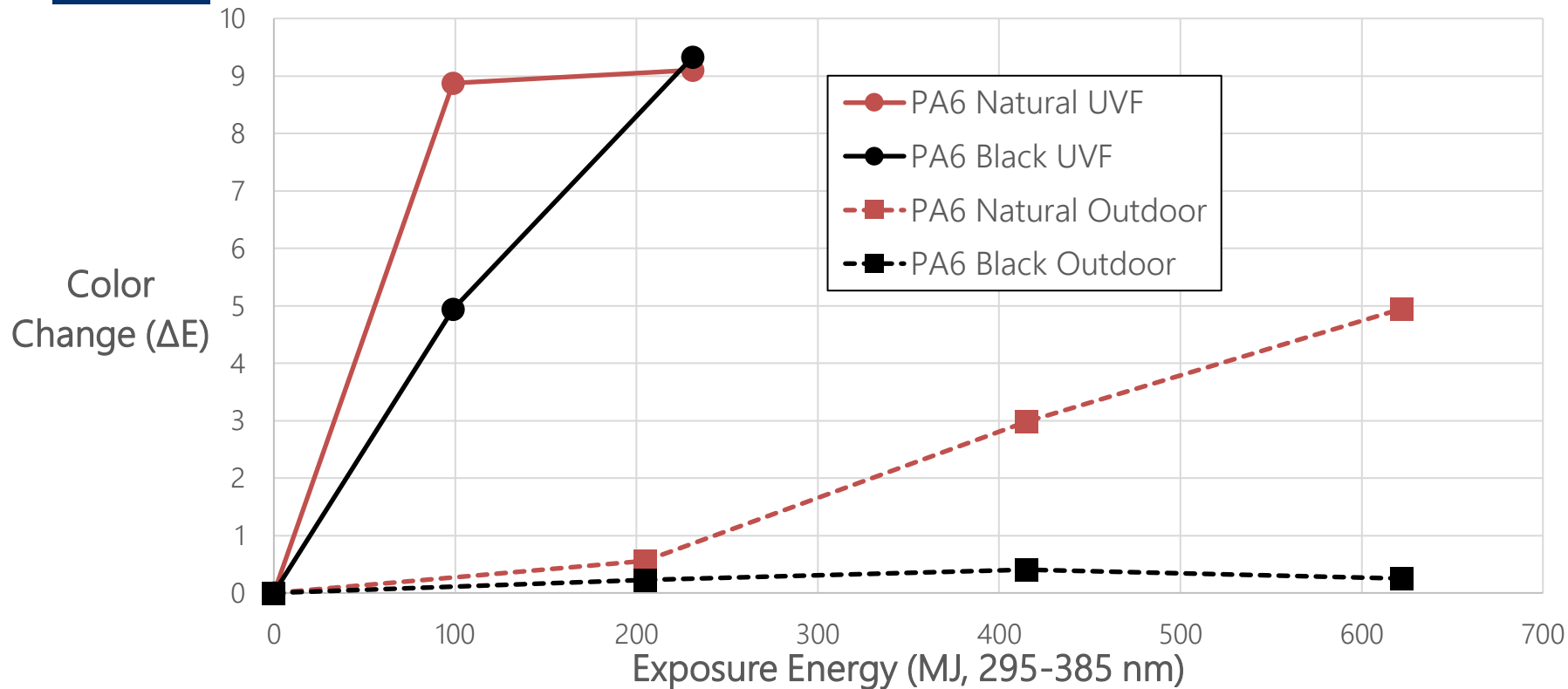
PA6 Gloss Retention

- UVF not well matched to outdoors
- Much faster on dosage basis



PA6 Color Change

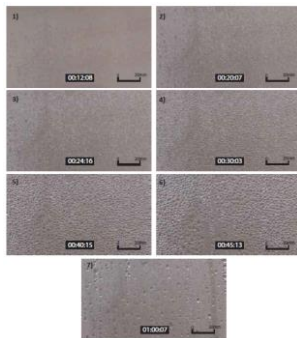
- Rank ordering correct UVF/Outdoors
- UVF much faster on dosage basis



PA6 vs Outdoors

PA6 shows faster gloss loss and color change on a dosage basis than outdoor weathering

- Why might that be?



QUV: Lots of water!

4h condensation per 12 hour period

Arizona: Not so much water!

It's a desert

Summary

- High-irradiance testing in UV fluorescent devices may be able to deliver reasonable results in a shorter time frame
 - Reciprocity is usually difficult to achieve in weathering
 - High irradiance testing should be performed with caution!
- QUV exposures at high irradiance of **2.04 W/m²** matched performance of polystyrene yellowing in xenon arc devices
 - More testing required for moderate QUV irradiances
- Good correlation observed for some color and gloss measurements
 - Color change shows good rank ordering and acceleration for PA6, ASA, PBT
 - Gloss loss results seem well correlated for ASA, PBT – not well matched for PA6
 - Water delivery in UV fluorescent vs Arizona outdoors may explain why

Thank you for your attention!

Questions?

Send your inquiry to:
afrancis@q-lab.com

