Developing Steady State Exposure Conditions in an ASTM G154 Fluorescent UV Test Chamber for Backsheet Materials

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Purpose

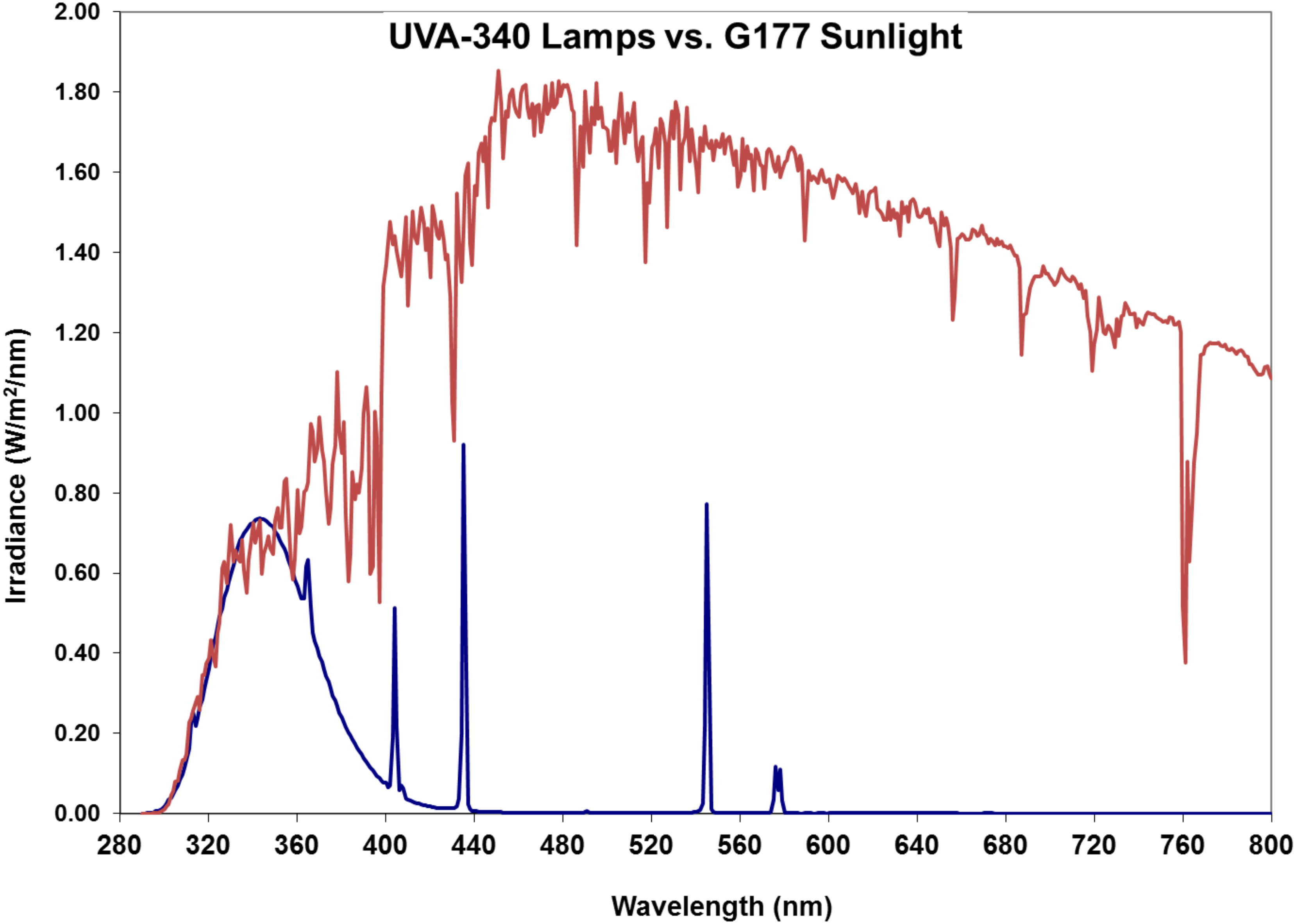
Fluorescent UV test chambers are commonly used for weathering tests of durable polymeric materials.

UVA-340 type lamps are a good match to the noon summer sunlight spectrum from the cut-on (295 nm) to approximately 350-360 nm

What are the best test conditions for achieving the same dosage of UV radiation as a backsheet would see in 1 year?

For a 6 month test, how many years of energy dosage could be achieved at various irradiance set points in the weathering chamber?

Caution: This exercise is done to provide an estimate of the approximate exposure time in a test chamber. It is useful for time budgeting purposes only. It does not account for the effects of temperature and moisture on the long term durability of any material. Also, reciprocity of UV exposure should never be assumed. Assuming that a laboratory exposure of equivalent energy dosage to a given outdoor exposure will result in equivalent degradation normally leads to gross errors.



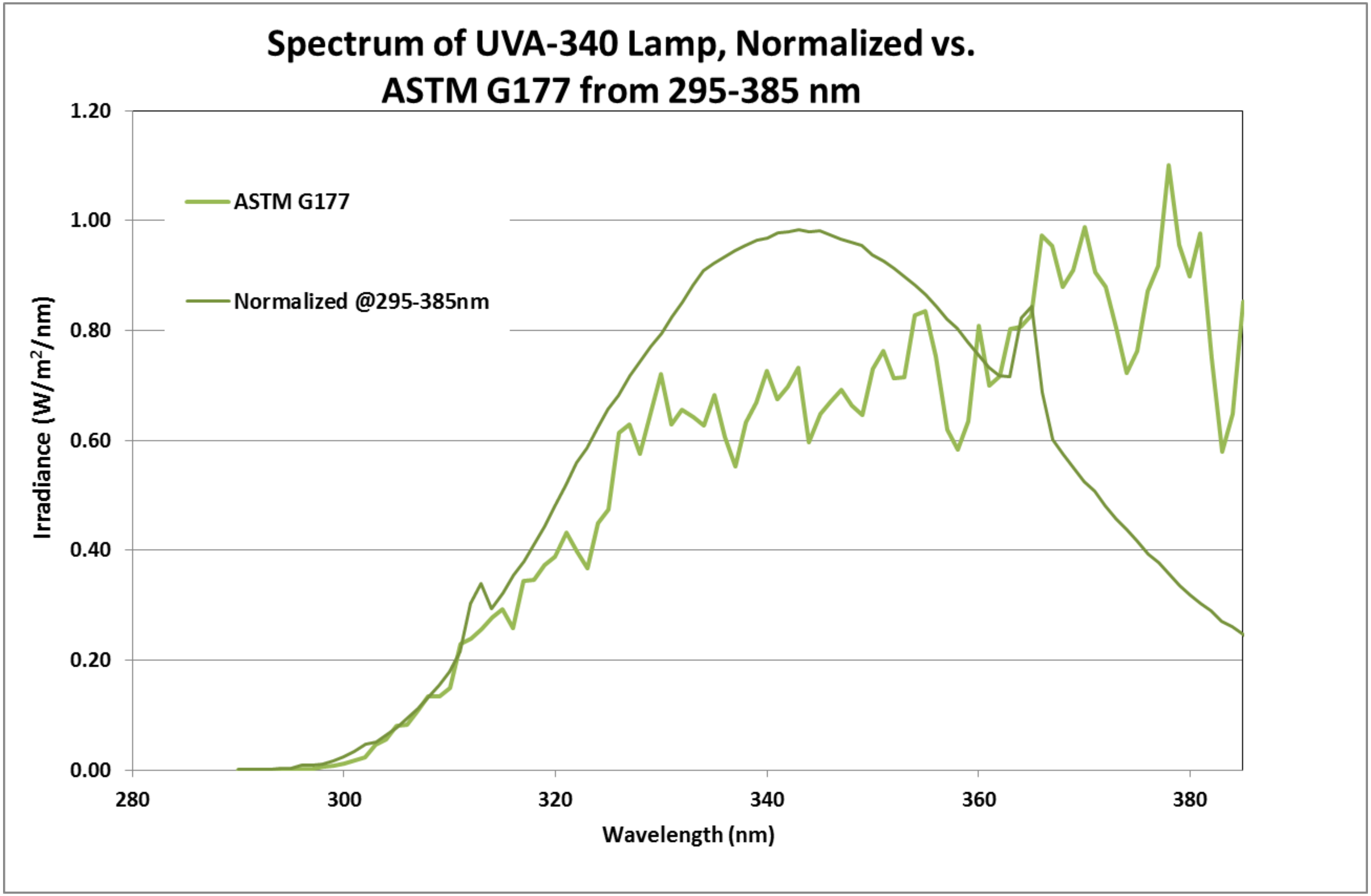
UVA-340 Lamps vs. G177 Sunlight
Irradiance (W/m²/nm)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
280
320
360
400
440
480
520
560
600
640
680
720
760
800
Wavelength (nm)

The Challenges

- Outdoor weathering site data measures energy dosage in range from 295-385 nm
- UVA-340 lamps only have a good match to sunlight through approximately 340 or 360 nm, making direct dosage comparisons difficult
- Matching the dosage in the entire UV range causes a spectral mismatch error

Questions

- What wavelength range should be used to compare the chosen sunlight spectrum (G177) to the UVA-340 lamp?
- Over this wavelength range, what multiplier is used to convert outdoor sunlight data into data for UVA-340 dosage calculations?
- Putting this all together, calculate exposure times using fluorescent UV weathering chambers to achieve dosages very similar to the outdoor sites



Integrated irradiance is the same for both curves.

How well does the UVA-340 lamp match sunlight?

- Designed to match the UV portion of noon summer sunlight
- ASTM G177 is a reference noon summer sunlight standard, based on SMARTS2
- Method
  - Normalize UVA-340 spectrum to match ASTM G177 integrated irradiance
    - 295-385 nm
    - 295-360 nm
    - 295-350 nm
    - 295-340 nm
  - Compare the resulting normalized spectrum to the reference
    - Calculate a correlation coefficient
      - Standard deviation using a Pearson Chi-square statistic
      - 1.0 means perfect correlation
  - Use the longest wavelength that results in > 0.90 coefficient

Correlation Coefficient: 1 Minus the Standard Deviation Using a Pearson Chi-square Statistic

$$1-\sqrt{\frac{\sum_{\lambda=295}^{\lambda=x}\frac{\left(I_{G177}-I_{UVA340}\right)^2}{I_{G177}}}{x-295}}$$

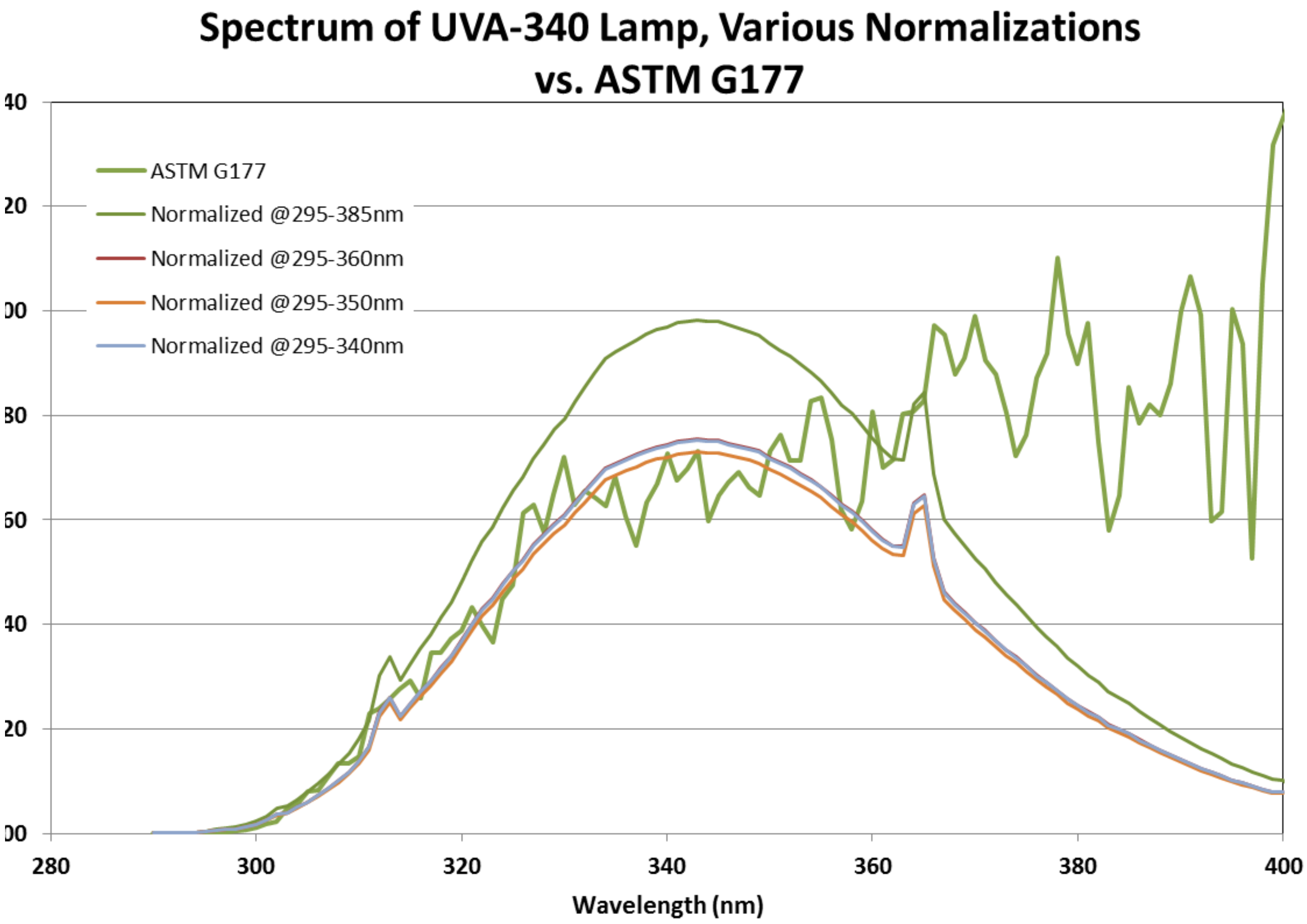
Where

I_{G177}	= Spectral irradiance according to ASTM G177
I_{UVA340}	= Spectral irradiance of UVA-340 Lamp
x	= integration upper limit
λ	= wavelength in nanometers

Results

Range	UVA-340 to G177 (W/m2) correlation
295-385	0.59
295-370	0.83
295-360	0.91
295-350	0.92
295-340	0.92

Use the integral 295-360 nm to compare UVA-340 to ASTM G177



Areas under the curve for UVA-340 equal G177 for the given wavelength range: for example, the curve for 295-360 nm has an equal integrated irradiance versus G177, also from 295-360 nm.

Results

- Outdoor UV dosages include energy from 295 nm to 385 nm
  - Using ASTM G177 as the reference, calculate a multiplier to convert dosage from 295-385nm into the dosage from 295-360nm
  - G177 Irradiance from 295-385 nm = 50.8 W/m^2
  - G177 Irradiance from 295-360 nm = 29.6 W/m^2

$$29.6 \div 50.8 = 0.583$$

Integrating UVA-340 Irradiance

UVA-340 Spectral Irradiance					
Wavelength	Irradiance	Wavelength	Irradiance	Wavelength	Irradiance
295	0.0029	331	0.6334	366	0.5278
296	0.0060	332	0.6538	367	0.4619
297	0.0072	333	0.6763	368	0.4405
298	0.0088	334	0.6982	369	0.4218
299	0.0123	335	0.7073	370	0.4029
300	0.0179	336	0.7164	371	0.3888
301	0.0254	337	0.7254	372	0.3696
302	0.0361	338	0.7327	373	0.3520
303	0.0394	339	0.7401	374	0.3369
304	0.0496	340	0.7435	375	0.3199
305	0.0600	341	0.7505	376	0.3019
306	0.0726	342	0.7516	377	0.2892
307	0.0865	343	0.7546	378	0.2742
308	0.1014	344	0.7521	379	0.2574
309	0.1181	345	0.7529	380	0.2448
310	0.1375	346	0.7467	381	0.2326
311	0.1657	347	0.7420	382	0.2218
312	0.2321	348	0.7373	383	0.2075
313	0.2600	349	0.7322	384	0.1997
314	0.2248	350	0.7196	385	0.1905
315	0.2466	351	0.7102	386	0.1789
316	0.2717	352	0.7001	387	0.1688
317	0.2911	353	0.6882	388	0.1600
318	0.3168	354	0.6767	389	0.1505
319	0.3405	355	0.6644	390	0.1415
320	0.3710	356	0.6472	391	0.1329
321	0.3989	357	0.6295	392	0.1237
322	0.4287	358	0.6166	393	0.1169
323	0.4495	359	0.5981	394	0.1097
324	0.4775	360	0.5804	395	0.1022
325	0.5037	361	0.5633	396	0.0965
326	0.5225	362	0.5506	397	0.0901
327	0.5508	363	0.5491	398	0.0841
328	0.5714	364	0.6312	399	0.0791
329	0.5922	365	0.6476	400	0.0785
330	0.6090				

From 295-360 nm

Irradiance = 29.58 W/m^2

At 340 nm

Irradiance = 0.7435 W/m^2

$29.58 \div 0.7435 = 39.79$

Use this multiplier to convert UVA-340 machine set point to integrated irradiance from 295-360 nm

Results

- Fluorescent UV test chambers typically control irradiance at 340 nm
  - To convert a 340 nm set point into irradiance from 295-360 nm, multiply by 39.79

Now, divide outdoor dosage by irradiance to calculated time in the test chamber

Example: 202 MJ ÷ (1.55 W/m^2 @340 x 39.79) ÷ 3600 seconds/hour

= 910 hours

UVA-340 Dosage vs. Outdoor Data

	Annual UV (295-385 nm)	Annual UV (295-360 nm)	time to 1 year at 340 nm set point			years @ 4200 hours		
Location	(MJ/m^2)	(MJ/m^2)	0.55	0.80	1.55	0.55	0.80	1.55
Phoenix--34° Rack	360	210	2663	1831	945	1.6	2.3	4.4
Sanary (from Atlas)	226	132	1672	1149	593	2.5	3.7	7.1
Miami--5° Rack	344	200	2544	1749	903	1.7	2.4	4.7

The ground facing side of a backsheet is subject to reflected radiation. The values above can be scaled to accommodate any albedo assumptions, such as 10%, 12% or 20%.