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Automotive Xenon Arc Test Methods: A Correlation Study

Don Vesey, Supervisor, Advanced Materials & Materials COC, Chrysler LLC
Rick Luxgrandt, Material Specialist, Exterior Material Engineering, Chrysler LLC
Lynn Pattison, Development Associate, BASF Corporation
Ronald Roberts, Director of Sales, Q-Lab Corporation
Jeffrey Quill, Director of Technical Applications, Q-Lab Corporation

Abstract

The Society of Automotive Engineers (SAE) has recently approved two new performance-based weathering test methods to replace the older hardwarebased methods. The new methods describe the exposure conditions and control tolerances rather than describing a specific hardware configuration. The publication of these new test methods was the result of years of development by the Automotive Materials Association and the SAE.

This paper reports on a cooperative research program conducted by Chrysler, BASF Corporation and Q-Lab Corporation. The goal of the research was to test the performance of the new performance-based test methods and to qualify newer xenon arc test equipment for use in automotive testing. Specifically, the research compared the results of test exposures conducted in the old-style rotating drum style testers mandated in J1960 and J1885 to exposures performed in the newer testers, covered by J2412 and J2527.

SAE J2413 is a guide for comparing the performance of test equipment. Among other things, it recommends comparisons of standard reference materials. Once these initial correlations were established, the study moved on to encompass an array of automotive materials in current use.

Thirty-four different materials were exposed; including painted metal, coated plastics, uncoated plastics, and various waxed finishes. Specimens were exposed in both flat array and rotating drum testers. Instrumental color and gloss measurements were performed at regular intervals.

The research confirms the efficacy of the performance-based approach to testing. However, it also points the way for further possible refinements in the test methods themselves.

Background

Prior to 1989, no international standards body published a common xenon arc accelerated weathering test method specifically developed for the automotive industry. In 1989, the Society of Automotive Engineers (SAE) published J1960 “*Accelerated Exposure of Automotive Exterior Material Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus*” and J1885 "*Accelerated Exposure of Automotive Interior Trim Components Using a Controlled IrradianceWater Cooled Xenon Arc Apparatus*.”

SAE J1960 and J1885 gave automotive manufacturers the opportunity to standardize common test procedures. Unfortunately, these weathering test standards were based on a specific type of equipment architecture. They specifically required using one of two equipment models from a single manufacturer.

This decision had two major consequences. First, it stifled technical development, providing instrument manufacturers no incentive to produce more accurate or realistic weathering testers. Second, it acted to keep the cost of testing artificially high by discouraging competition.

While the automotive industry leads the world in many areas, they have lagged behind in the adoption of performance-based weathering standards. SAE began to address this shortcoming in their accelerated weathering test standards in the late 1990s, culminating in the publication of three new accelerated weathering standards:

SAE J2527 "Accelerated Exposure of Exterior Automotive Material Using a Controlled Irradiance Xenon Arc Device," a performance-based replacement for J1960, published October 2003.

SAE J2412 "Accelerated Exposure of Automotive Interior Trim Components Using a Controlled Irradiance Xenon Arc Apparatus," a performance-based replacement for J1885, published February 2004.

SAE J2413 "Protocol to Verify Performance of New Xenon Arc Test Apparatus," a method of verifying that a particular design of xenon arc weathering equipment can perform a specified test procedure, published December 2003.

The major difference between the new performance-based weathering standards and the old hardware-based standards was the removal of all manufacturer specific references. Sections of the test standards referring to a manufacturer's trade names were replaced with generic definitions.

An example of this change is seen in how the optical filters used in the test have been re-defined. In the old hardware-based test standards, the optical filters were referred to as "a quartz inner filter and a Type S Borosilicate outer filter." The use of a trade name within the test standards might have made ordering replacement filters easier, but it did not define the spectrum produced by using this particular filter type. In the new performance-based test standards, trade names for optical filters have been eliminated and replaced with a description of the required spectral power distribution (SPD).

Anticipating the adoption of these three new test standards, in early 2002 Chrysler, BASF, and Q-Lab Corporation launched a test program to validate the new performance-based SAE test methods. The intent was to produce comparative data on the two types of testers. This was accomplished by performing the SAE J2413 Verification Protocol on two testers and comparing the results. One was a rotating drum tester (model Ci65A) run in accordance with J1960 and the other was a flat array tester (Q-SUN model Xe-3-HS) operated in accordance with J2527.

The importance of this validation became evident after the July 2001 announcement that the Ci65A was discontinued. With new Ci65As no longer available, industry was no longer able to purchase any xenon weathering testers that met the old hardware-based SAE test standards.

Hardware

Historically, the majority of xenon test chambers have had a lamp in the center. A cylindrical specimen mounting rack rotates around the lamp carrying the test specimens (figure 1). This configuration is frequently described as a "rotating drum" system. More recently, xenon testers have been introduced with a static, flat array specimen mounting system (figure 2).

One of the design goals of both types of chambers is to produce uniform irradiance, temperature, and humidity throughout the chamber. In reality, it is impossible to produce perfect uniformity. To compensate for this, the test specimens are repositioned (automatically or manually) during the test so that they are exposed to the same conditions. The rotating drum does this repositioning automatically in one dimension – horizontally around the lamp. The rotating drum cannot, however, compensate for variations in irradiance, temperature, and humidity in the vertical direction.

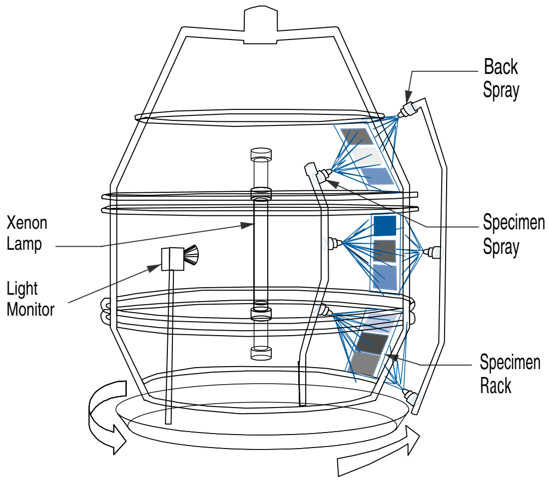

Figure 1 - Typical Rotating Drum Schematic

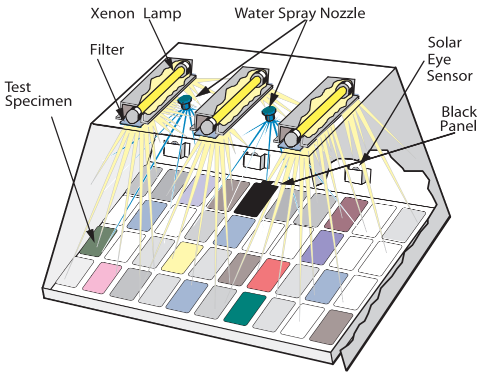

Figure 2 - Typical Static (Flat Array) Schematic

Experiment

To validate the new performance-based weathering standards, both testers were operated in accordance to the procedure detailed in SAE J2413. This new test protocol provides industry a tool that can be used to validate a new model of xenon arc weathering tester's ability to run the performance-based weathering and light-fastness test methods. Verification of the weathering tester's conformance is accomplished using several techniques.

First, the weathering tester must demonstrate that it can meet the specified test conditions. For this study, J2413 used the test conditions of J2527. Figure 3 shows the critical test parameters an Atlas Ci65A, while Figure 4 shows the same for a Q-Lab Xe-3-HS. The bold lines represent the set points, whereas the fine lines portray the actual values as measured inside the weathering chamber.

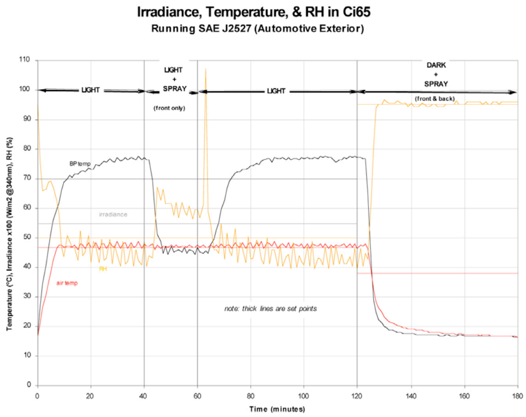

Figure 3 - Atlas Ci65A Running SAE J2527

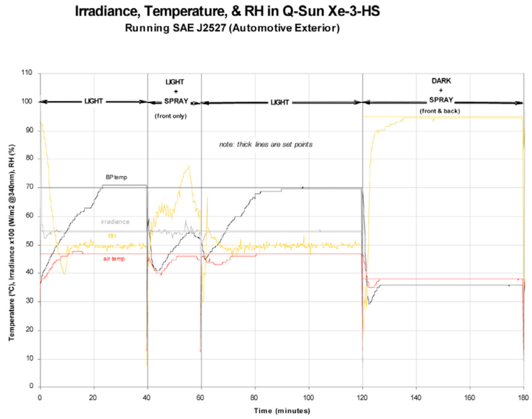

Figure 4 - Q-Lab Q-SUN Xe-3-HS Running J2527

Next, the weathering testers need to demonstrate the ability to degrade a standard reference material in a predictable manner. Demonstrations of both repeatability and reproducibility are required. Repeatability is demonstrated by evaluating the degradation of a standard reference material, run multiple times in one single tester. Reproducibility is demonstrated by evaluating the degradation of a standard reference material, run once in multiple testers. For this set of experiments, a polystyrene plaque was used. This polystyrene plaque is used by SAE as a standard reference material and its degradation characteristics and tolerances are defined by the SAE Standard Reference Committee. Lot Six polystyrene plaques were used to demonstrate both repeatability and reproducibility.

Figures 5 and 6 provide data demonstrating repeatability in an Atlas Ci65A and a Q-SUN® Xe-3-HS, respectively. Figures 7 and 8 provide data demonstrating reproducibility of three Atlas® Ci65A and three Q-SUN Xe-3-HS testers. It is clearly evident that both testers are able to comply with this requirement of J2413.

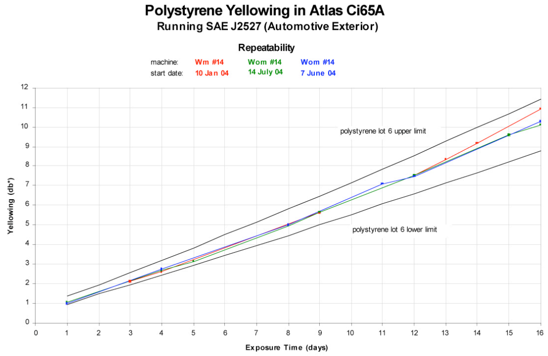

Figure 5 - Ci65A Demonstrating Repeatability

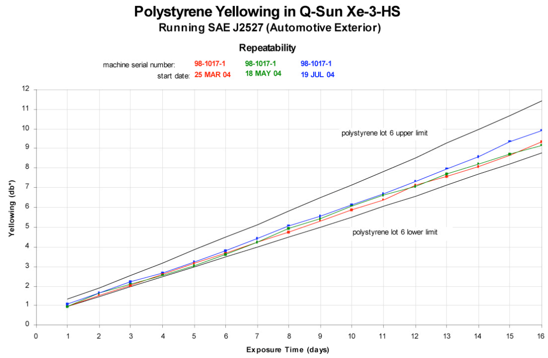

Figure 6 - Q-SUN Xe-3-HS
Demonstrating Repeatability

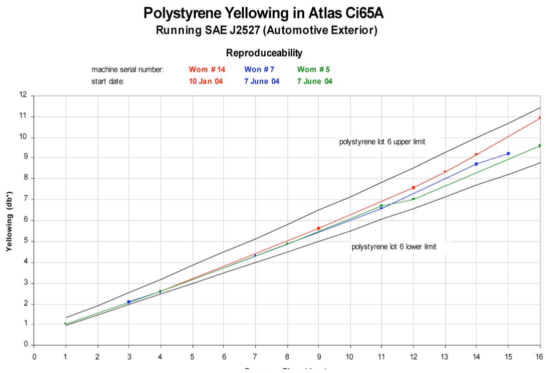

Figure 7 - Ci65A Demonstrating Reproducibility

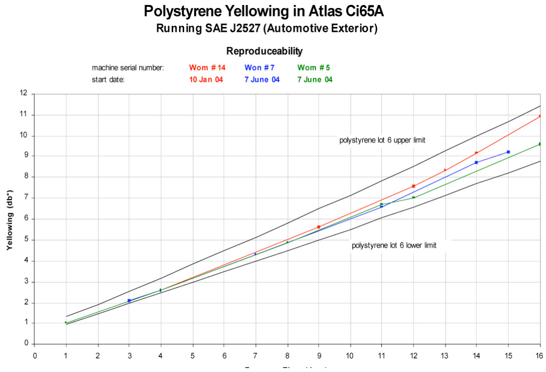

Figure 8 - Q-SUN Xe-3-HS Demonstrating Reproducibility

The last mandatory section of J2413 requires the manufacturer of the xenon weathering chamber to demonstrate within-chamber uniformity. A comprehensive comparison of within-chamber uniformity previously has been performed and the results presented at the 1st European Weathering Symposium, in Prague, Czech Republic, in 2003. The paper "Within-Chamber Uniformity of Xenon Test Chambers (Rotating & Static Specimen Mounting Compared)," by Fedor et al, presented the results of numerous tests, performed on a wide variety of standard reference materials, and represents the most comprehensive within-chamber uniformity study performed to date.

Pertinent to this research was the uniformity of the Ci65A and the Q-SUN Xe-3-HS performing SAE J2527. In their experiment, nine replicates of the polystyrene reference plaques were placed in a Ci65A, while 48 replicates were placed in the Q-SUN Xe-3-HS. Color measurements were taken every day and the Delta b* readings were recorded. Uniformity was then expressed as ± two times the coefficient of variation, where the coefficient of variation is the standard deviation divided by the mean.

Their experiment showed that the uniformity for the rotating drum ranged from ±3% to ±13%, while the flat array ranged from ±3% to ±8%. When running SAE J2527, the Ci65A uniformity was ±3% and the Xe-3-HS was ±5%.

It is important to note that the uniformity values also include variations in the standard reference material itself and variations in the measurement procedure.

Performance Benchmarking

Demonstrating how xenon arc weathering equipment of different architecture can produce the same environmental conditions is one step in demonstrating that performance standards work.

The next question is how to compare weathering devices that spring from different design philosophies. A number of experiments were conducted in an effort to explore whether these design philosophies can affect test results.

Chrysler selected 37 materials for testing to SAE J1960 and J2527. T wo replicates of each specimen were tested, for a total of 148 specimens. The set contained ASA, PP/PA alloy, ABS, SMC, PET, PP, PA, ASA/ABS extrusion, TPO, and painted steel.

The testing and evaluations were performed at BASF automotive development center located in Southfield MI, USA. BASF, Southfield is an ISO 17025 accredited laboratory; their scope of accreditation includes SAE J1960 and J2527.

The specimens were exposed for 2500 Kj, with evaluations of color and gloss taken every 500 Kj. The results show that for most of the materials, the flat array and the rotating drum gave comparable results, as shown in Figures 9 and 10. Two of the specimens gave different results, as shown in Figures 11 and 12.

While a majority of the specimens showed similar degradation when looking at instrumental measurements (color and gloss), several of the specimens showed differences in visual degradation. It appeared that some of the plastic specimens showed surface deformations that, while present on the rotating drum specimens, were larger and more pronounced on the specimens from the flat array.

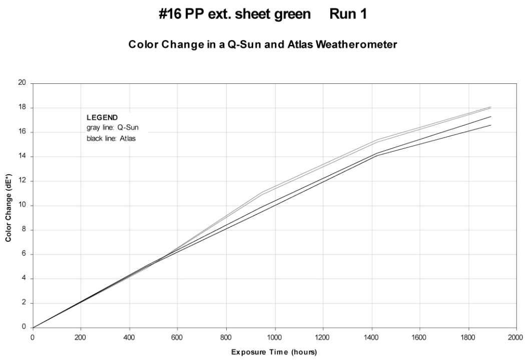

Figure 9

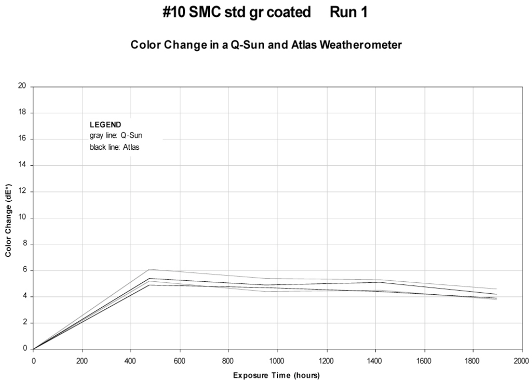

Figure 10

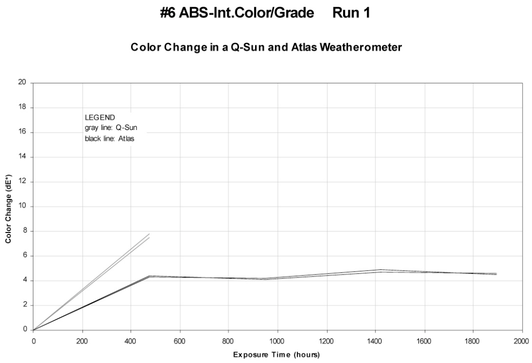

Figure 11

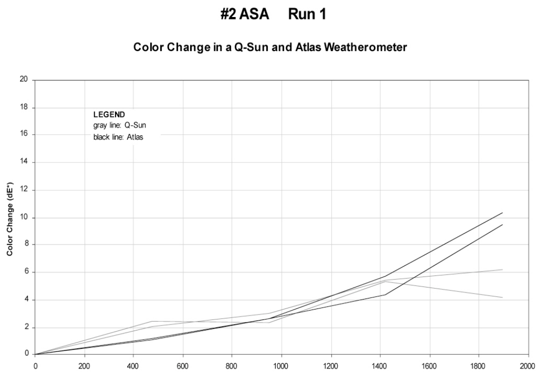

Figure 12

System Modifications

The results from the first round of performance benchmarking were promising. However it was necessary to understand why some of the results were not in complete agreement. Consequently, the team set about identifying how the two weathering devices were different. Several areas of potential difference were identified.

First, temperature was investigated. Black panel construction and location was examined in detail. The rotating drum tester was equipped with a painted steel black panel. The flat array tester was equipped with an anodized aluminum black panel. While the two types of black panels both accurately measure the temperature, experiments indicated that they heat up and cool down at different rates. Because the primary goal of this program was to have the flat array provide similar results to the rotating drum (and not necessaily to correlate with outdoors), the flat array was therefore modified to use a painted steel black panel of similar construction to the rotating drum machine.

Next the team set about trying to characterize what was happening at the individual specimen level. It was discovered that actual conditions at the specimen were sometimes different from those displayed by the tester's controller display.

In particular, the actual surface temperatures of certain plastics were monitored. They tended to heat up faster than the steel black panel and reach up to 20ºC higher than the set point. To make the flat array respond like the rotating drum tester, the locations of its chamber air temperature probe and relative humidity sensor were relocated.

The last critical system examined was the water spray. Because the rotating drum type device has only one nozzle, the specimens are only sprayed with water for three to five seconds every minute as they rotate past the nozzle at 1 rpm. This system delivers minimal water to the specimen surface. And, due to the vertical orientation of the specimen, the water quickly runs off.

To simulate this moisture-poor environment, it was necessary to modify the flat array's programming to allow a reduced volume of water spray. At the start of the experiments, the flat array had been delivering 20 seconds of continuous water spray for every one minute of programmed "spray time." This had been chosen as the default setting because it gave a good balance between simulating natural wetness conditions and machine operating costs.

A series of experiments were performed on several materials that were highly susceptible to moisture and temperature. Through this work, it was determined that to mimic the rotating drum environment, the flat array must deliver only 5 seconds of water spray for every programmed minute of spray.

Performance Benchmarking - Round 2

With all the key systems thoroughly studied and the appropriate modifications made, another round of performance benchmarking was performed.

The same xenon devices were used as in the earlier studies. The new experimental specimen set consisted of 12 specimens from the original set with an additional eight other specimens that were temperature and moisture sensitive.

Nylon and ASA specimens were coated with a material proven to exhibit visual differences in the past. Two Lurans and two Ultramids were added. Both of these polymers have high thermal coefficients. Finally, two additional painted steel specimens were added.

The results were outstanding. The color and gloss measurements remained very similar for the specimens in both round one and two. In addition, the specimens which had shown a difference in round one, showed virtually identical results in round two (see Figures 13 and 14). Significantly, the visual differences that existed in round one were eliminated.

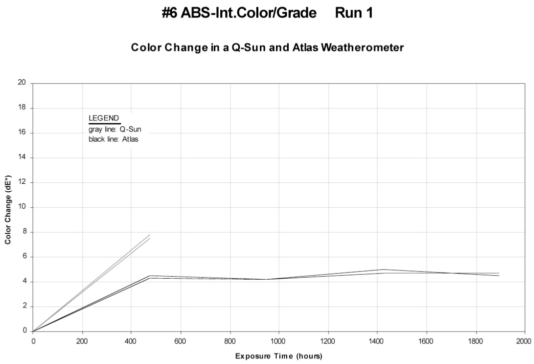

Figure 13 - Sample #6 Initial Run

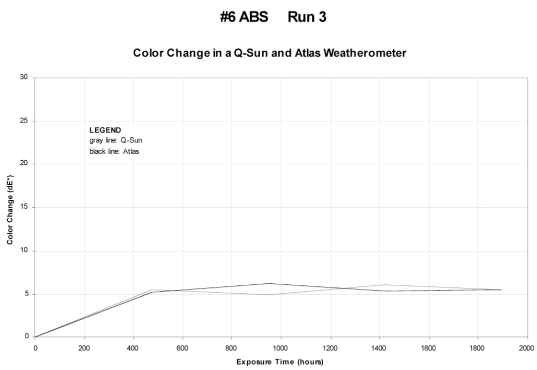

Figure 14 - Sample #6 Final Run

Results

1. Initial testing showed some difference in results on certain materials. Investigations of moisture and temperature parameters pointed to differences in tester design that had caused the discrepancies. These design differences were the result of imprecise descriptions of the exposure environment in the specifications.

2. Once the design discrepancies were addressed, the results came into agreement.

3. This series of experiments indicate that the current performance-based test methods would be significantly improved if they were modified to include more precise descriptions of both the temperature measurement system and the spray water environment.

4. The two xenon arc weathering testers of very different designs -- a rotating drum and a flat array -- gave comparable results on a wide range of exteriorgrade automotive materials. This demonstrates that performance-based test standards do work.

5. Now industry can utilize new designs in laboratory weathering testers confident that, if the standard is properly written and the tester manufacturer can demonstrate the ability to accurately control key test parameters, the user can expect to obtain good comparable data regardless of the type of xenon tester that is used.

The forward-looking policies of international standards bodies like ISO, ASTM, and SAE have been correct in their insistence that all test standards must be performance-based.

References

Atlas SunSpots – Volume 30, Issue 63, Fall 2000

Atlas SunSpots – Volume 31, Issue 65, Summer 2001

Atlas SunSpots – Volume 33, Issue 69, Spring 2003

Atlas SunSpots - Volume 33, Issue 70, Fall 2003

SAE J1960, *Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus*

SAE J2527, *Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Xenon Arc Apparatus*

SAE J1885, *Accelerated Exposure of Automotive Interior Trim Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus*

SAE J2412, *Accelerated Exposure of Automotive Interior Trim Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus*

SAE J2413, *Protocol to Verify Performance of New Xenon Arc Test Apparatus*

Brennan P., Fedor G., Roberts R., *Xenon Arc Exposure Results: Rotating & Static Specimen Mounting Systems Compared*

Fedor G., Brennan P., Pausch G., *Within-Chamber Uniformity of Xenon Test Chambers*

Brennan P., *Static & Rotating Xenon Arc Exposure Compared: Technical issues, practical considerations and how different types of hardware comply to new performance based test methods*

Boisseau J., Pattison L., Henderson K., Hunt R., *The Flaws in Accelerated Weathering of Automotive OEM Coatings*

Note

SAE Test Methods are available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

Q-Lab Corporation **www.q-lab.com**

Q-Lab Headquarters
Westlake, OH USA
Tel: +1-440-835-8700
info@q-lab.com

Q-Lab Florida
Homestead, FL USA
Tel: +1-305-245-5600
q-lab@q-lab.com

Q-Lab Europe, Ltd.
Bolton, England
Tel: +44-1204-861616
info.eu@q-lab.com

Q-Lab Arizona
Buckeye, AZ USA
Tel: +1-623-386-5140
q-lab@q-lab.com

Q-Lab Deutschland, GmbH
Saarbrücken, Germany
Tel: +49-681-857470
vertrieb@q-lab.com

Q-Lab China 中国代表处
Shanghai, China 中国上海
电话：+86-21-5879-7970
info.cn@q-lab.com