Trey: Hello everyone and thank you all for joining us. Today's webinar, Ultraviolent Resistance for Plastics is presented by RTP Company. Your presenters today are Tim Duncan and Anna Kreofsky. Tim Duncan began working with our RTP Company in 1996, beginning his career as a Quality Manager for the then newest RTP Company facility in Fort Worth Texas. A few years later, he accepted the position of Global Color Technology Manager for the Color Division. He's held various titles and responsibilities over the years and remains part of the global color team. Joining Tim is Anna Kreofsky. Anna Kreofsky, Research and Development Color Engineer has been with RTP Company for eight years. Prior to working in the color engineering group, Anna was a product development engineer in the conductive plastics group. She has a degree in composite materials engineering from Winona State University.

My name is Trey McDonald with UL and I'll be moderating today's event. You can send us questions by typing them in the question box located on the screen, and our panelists will answer them at the end of the presentation. We are recording today's event and we'll send you a link via email when the slides and video have been posted to UL Prospector Knowledge Center. With that, I'd like to turn the presentation over to Tim. Tim?

Tim: Thanks, Trey. Thank you for the introduction and thanks everyone for joining Anna and myself for discussions on UV Stabilization and Resistance for Plastics. I thought I'd begin with just a brief introduction of RTP Company and the Color Division. You'll get a better understanding of our role within the organization and how we can speak of the various topics. RTP Company is an independent, privately owned custom compounder. We've been around since 1982 so 30 plus years of experience, a little more than 1500 employees. But the key to this slide is that we're independent. We're able to make material choices, additive selections, resin choices, colorant selections based on everything that's available in the world, including introduction to new products and tried and true examples of materials that have worked many, many times in the past. Now, that 1500 employees, 50 or so are product development engineers worldwide, which Anna is one of those engineers in that group, working specifically for the Color Division on Product Development, Process Development and supporting customer trials. Also, starting with the application development and having those opening discussions with the customer on how we can best suit their needs and objectives.

We're global manufacturing but we're centered in the Midwest, home is Winona Minnesota. You can see the concentration of facilities in North America, but we're happily able to support applications globally with locations both in Europe and in Asia. Now, RTP Company breaks our product development groups down into families. These families, these eight families include conductive, flame retardant, thermoplastic elastomers, structural, wear products, and film and sheet and, of course, color. Now, color is responsible for the rainbows of the color the aesthetic applications, but we're also responsible for the additive technology specifically additives related to UV stabilization. Now, RTP Color Division works on all of the engineering families, whether it's polyolefins or engineering materials, whether it's master batch or precolored or an exotic compound that combines multiple technologies. We have the regulatory knowledge, and as I said before, the experience to support your applications in almost any resin system.

Happily, we're able to support these markets, appliances automotive energy, and electrical just to name a few. Many of these have outdoor examples, where it's a cash machine that's going to see intermittent exposure depending on its location or automotive and energy applications like solar panels that are going to see an abundance of solar radiation. Happily, we can discuss all of these markets and applications with you. Today's agenda, we're gonna talk about specifically UV and weathering, what's the difference, what do those mean. Material choices, making the right decisions to protect your product, your part, from the elements. Material testing and reporting, how do we relate that testing and how do we communicate that to you and to your customers? We're gonna finish with some case studies, conclusions that we've drawn and open it up to questions from the group.

So let's start with, what's weathering of plastics? Weathering means what happens to your part when it's exposed to Mother Nature. Primarily, we're talking about solar radiation, extremes in temperature whether it's in the frozen tundra of the North or the desert southwest, and rain and other forms of precipitation and how that can influence behavior. Now, over time, exposure to sunlight and even artificial forms of UV radiation, will degrade plastics. Performance depends on the choices we make that entire polymer matrix everything coming together working as a system. Now weathering includes a variation in temperature precipitation and sunlight intensity, we're gonna focus primarily on the ultraviolet region of the electromagnetic spectrum today. Here's an example of that electromagnetic spectrum. We're all obviously aware of the visible light. The ultraviolet is the shorter energy wavelengths right before the visible light and in some cases, it bleeds a little bit into the visible blue and violet regions of that spectrum.

As an example of this radiation and how it's perceived or how it's experienced around the world, here's an example of a radiation around the globe. Using North America as just the example, you can see that desert southwest receives a great deal more solar radiation than the north-west or the north-east where there's significant cloud cover. And even in sunny Florida, where the sun shines most everyday, there's a significant amount of rainfall that also influences that performance. Now, the point of this slide is to indicate that a part that's living in Sweden is very likely going to experience different environmental conditions than the same part in Western Australia, and we need to be aware of those differences. Now, there are different types of UV light, UV radiation accounts for only a small segment of the solar spectrum and happily some of this is absorbed by our own ozone layer. But how much reaches you and how much reaches the part depends on where the part's going to be located. And it's one thing to remember too that this varies from year to year. One measure of solar energy is a killer[SP] Langley, a unit of solar energy distributed over a specific area. Many of us have experienced, I'm gonna say unusual weather patterns, this last year. In the Midwest it was unusually warmer, less snowfall than typical. Other places in the country, other places in the world maybe experience temperature extremes and droughts. These conditions change.

We're going to focus a little more on the three basic types of UV light that we encounter when we're discussing stabilization of polymers. They're broken down into wavelengths. We'll begin with UV-A which is the longest of the wavelengths of the UV radiation, and this is related to tanning and premature skin aging in our day to day lives but it also contributes to the degradation of polymers. The UV-B, that's slightly shorter more energized and the most damaging covers the range from 290 nanometers to 315 nanometers. Prolonged exposure would cause a sunburn to those of us not wearing appropriate protection. As I said, fortunately, much of this is absorbed by the ozone layer, but what does get through is the most damaging and the most sensitive to polymers. Now, UV-C gets mentioned from time to time in our industry. Many times it's in medical or water purification used for germicidal application. Some of you may have an electric toothbrush that you take the tip off and you put in your UV sterilization overnight, these are those types of wavelengths. And while shorter still and less influence on polymers, they still contribute to yellowing and some degradation.

So what are the results of this exposure? Well, as the polymer begins to receive this light energy, it attacks and is absorbed by various chemical groups within the polymer actually ripping the chains apart. This process damages the ability of the material to perform as intended and this reduction of polymer change only further exacerbates the problem. It lowers the molecular weight in this irreversible chemical reaction. That loss of molecular weight affects our mechanical properties, the material is no longer as elastic as it was before. Strength is reduced, impact resistance is reduced. And, of course, it changes in appearance, yellowing for a natural polymer on uncolored polymer is very, very typical. But with colored materials, you may see the colors begin to fade, you may see them become darker or more yellow or they may completely change in hue. Cracking and crazing and loss of polymer at the surface is dramatic. Reducing the gloss of the material, we no longer have that shiny new appearance. And in severe cases, you actually see the chalking and the white residue. This white residue is dramatically degraded polymer on the surface. As these properties begin to fail, we see changes in dimension and warping in the materials.

So how do we mitigate this? What do we do to address this and to help the polymer perform better in our application? Well, as with any performance attribute or any discussion of material selection, we begin with the application. What does the part need to do? What chemical resistance might it need? And importantly, when we're talking about UV applications, where will this part live? Where is it gonna be located? Is it going to see intermittent sunlight? Is it going to see extremes in temperature? Is going to see substantial amounts of rainfall or other precipitation? All of these influence our choices. And expectations for our weather in UV performance refine our selection process. As we begin to talk about the material demands, as we begin to talk about our expectations we'll limit the number of polymers. We may begin to discuss the additives and fillers that further modify that polymer for mechanical processes. We'll talk about color we want it to be and we'll talk about stabilization requirements, how all of these things can work as a system completing that polymer matrix.

Now, I want to talk about these individually for a moment. We talk about the types of UV light, how that influences a particular polymer. Now selected polyethylene, polypropylene, ABS, polycarbonate and nylon, some of the major volume polymers used in the world, very different polymer systems. And as you can see, just by a quick glance, that they respond to different regions of that UV ABC wavelengths that we talked about earlier. Neat unmodified polyethylene and polypropylene are both prone to yellowing embrittlement. However, the use of UV stabilization in complementing those polymer compositions with appropriate raw materials have allowed them to be used in many, many different outdoor applications. Polyethylene significantly used in agricultural applications, sporting goods, tollways, industrial [inaudible 00:13:12], all of these things are possible because they're properly formulated and stabilized. Polypropylene has seen a tremendous growth in automotive applications because of the ability to stabilize these grades and improve their performance. Now, ABS on the contrary, UV stabilization grades are available for limited applications but typically ABS alone is unsuitable for any outdoor application short of being painted or some other sort of surface treatment to protect it.

There are differences in the polymers, in their ability to perform outdoors regardless of whether or not we can improve their performance and stabilization. As an example, if we aggressively stabilized ABC we do not turn it into ASA, a more like stable wheatherable polymer from that family. Polycarbonate is another example, outstanding material for mechanical properties, but it degrades with pronounced discoloration in increased haze in outdoor applications. Now, there are UV resistant grades but some of the best improvements are made by surface treatments or cap[SP] coatings in sheet or even an acrylic coating in some applications. Recognizing that the clear mechanical property performance of polycarbonate is valuable to many, many outdoor applications. We have to understand that no matter what we do to polycarbonate, we cannot turn it into another clear material acrylic or PMMA in regards to its ability to withstand weathering.

Now, onto another example of a highly utilized and valuable engineering polymer that it too yellows significantly and becomes brittle with UV exposure. However, carbon black formulations provide some of the best outdoor performance. The carbon black acting as a UV absorber and significantly improving the stabilization of nylon in the outdoor world. Additives and fillers influence the UV weather and performance of your parts as well. Functional additives like flame retardants or wear or where additives impact modifiers, dramatically can improve mechanical properties but making the wrong choices can catastrophically affect the way the material performs in its final outdoor environment. Fillers and reinforcements commonly used to make the material more rigid or stronger can be influenced by the choices of functional additives as well as the choices of some of the other additives namely colorants.

Now, colorant choices break into two basic categories, you have organic colorants that are sensitive to UV emissions much like the organic polymers that they're joining and inorganic pigments which have outstanding outdoor weatherability. The trade off here is typically in what we're trying to achieve aesthetically. Bright reds, yellows in oranges are impossible to achieve with inorganic pigments alone, and we have to use organic colorants that have generally lower light fastness. But it's selections of these and pairing the right materials together can still have an outstanding application outcome. As an example, you can take a bright safety yellow in a polyethylene or polypropylene. Appropriately stabilize the polymer, the right attitude or functional fillers are there, you've selected solid colorants but the exception being the grade of titanium dioxide that you used as the white. The difference in grades can be the difference between a successful program or catastrophic failure. You've done everything right and one weak link in the chain breaks all the synergy that we've been working for. UV stabilizers, this brings us to the most important part. How do we mitigate this damage? How do we protect the polymers, and in some cases, how do we protect the colored systems that we've created?

The UV stabilizers have been developed to improve this performance, and they're broken there basically into three categories. We have ultraviolet absorbers, which function by competing with the polymer to absorb that UV energy. Benzophenones, benzotriazole and even carbon black are common absorbers. Some of you may have heard the term Hindered Amine Light Stabilizers or HALS. This is another group of stabilizers that interrupts that degradation cycle. Now, a wide variety of these exist for many different reasons. Some to address the differences that we talked about earlier in specific polymers absorbing specific ranges of UV or being sensitive to specific wavelengths, others are to address differences in applications, Maybe we have a polyethylene application that is a thick wall part, it's a storage tank or agricultural fertilizers or chemicals. Or it's a polyethylene film application, you would not likely select the same stabilizers for those two extremes in [inaudible 00:19:04] extremes in final form of the material.

Additional advantages, the HALS provides some long term thermal stabilization...tongue twister for me today. Which brings up another point, there are long term thermal stabilizers that can conflict with Hindered Amine Light Stabilizers. So again, we're talking about the entire application, what's the expectations in making the right choices. I'm gonna briefly mention Quenchers just because it is a category that exists that does have broad use in agricultural films but the nickel Quenchers contain heavy metals. So largely they're not used as much as they were in the past, and they impart color to the final part. And they're less affected than Hindered Amine Light stabilizers. Each of these three function by different mechanisms but they're often combined for synergistic benefit. As an example, I mentioned earlier HALS and absorber combinations are common solutions for colored systems. When we have to use organic colorants, those organic colorants are sensitive to UV light the same as the polymers.

So it's kind of an oversimplification but I think sometimes it's helpful to think about the functionality. We have UV energy acting on our plastic material, our polymer matrix. The polymer is going to absorb some of that UV energy so we use UV absorbers to compete with that, to block that. This is much like using suntan lotion to protect your skin. The suntan lotion will absorb that UV energy and protect your skin from that, but just like sunscreen, it has to be reapplied. The UV absorbers are eventually consumed, none of this is permanent. Degradation of polymer change happens after the polymer has absorbed some of this very high energy short wavelength light. The white stabilizers are used to help mitigate that damage. Again, a loose correlation would be to consider Aloe Vera as the lotion that we apply after our skin has been damaged by the sun to mitigate or relieve some of that discomfort. So making the right choices has everything to do with whether or not you have a shorter service life, your part doesn't last as long, you can't enjoy the sunshine as long, or longer life, you're able to stay outdoors all day and your parts last for several years.

So how do we formulate? And this is a recap. We want to review the application and select polymers, reinforcement and additives that meet our performance objectives, and capitalize on the environment in which we anticipate our product will live. Colorants need to be chosen to achieve the aesthetic goals but they need to balance mechanical properties. We don't want to sacrifice too much of one property for another. We're happy to talk about compromises that are common and things that can be done to improve your weathering expectations. UV stabilization builds on these good choices, supporting a synergistic system to achieve the desired weathering performance, making the right UV decisions. Again, I said there are a variety of additives focused on specific wavelengths but also complementing specific applications, making the right choices, has everything to do with the yellow performing or the red performing the way you want it to in your application. As with all things in life, balance is key. Every component contributes to part performance and applications success, both positively and negatively. Making one wrong choice like the wrong choice [inaudible 00:23:10] can compromise all of the other [inaudible 00:23:11] choices that were made in that particular part composition. And with that discussion, I'm gonna turn it over to Anna to talk about how do we measure these properties, and how do we equate that information with real world weathering.

Anna: Thank you, Tim. So other important questions to ask are why and how we evaluate UV performance. So to begin, why is UV testing necessary? The testing is done to predict expected service life. We want to make sure to reduce any unexpected yield failures five or ten years down the road. How is UV performance evaluated? Materials can be exposed to natural or artificial UV radiation and then we can evaluate material properties based on change or property retention. So again, with natural testing and here is very the specimens and expose them to natural outdoor exposure at specific test sites. There's a few commonly recognized international test sites in North America, two of them being Florida and Arizona and these have different climates. Florida offers a subtropical climate, a high amount of sunlight, high year round temperatures and high humidity, along with some abundant rainfall. Arizona gives you the desert climate, high amount of sunlight, high year round temperatures with lower humidities. Being that they're outdoors, they're also exposed to other environmental factors beyond solar radiance, being different ambient temperatures. As you cycle through the days you get a daytime and nighttime temperatures along with humidity fluctuating as well. You can also...the parts are also exposed to pollution, which they are not in the laboratory.

With natural testing the results are not accelerated, so it takes one year of outdoor testing to get one year of actual data. The thing with natural testing is that the results are not identically reproducible as the climates change year over year. There are natural accelerant test methods available. These use special mirrors to concentrate the light, and also have different options such as water spray to increase humidity on the samples. With artificial accelerated weathering, we expose the samples to UV radiation from different light sources to the most common for polymeric materials, will be the Xenon Arc and the Fluorescence. With the artificial weathering, you accelerate the results so that you're able to come to a conclusion faster on if the material will perform outdoors. It also gives you the ability to reproduce results. Using the same test method, you can put different materials in or the same material in and get the same result over and over. And this is because the test methods continuously cycle the samples. There are different phases, the different phases can be different UV radiations, it can also incorporate water spray, various temperatures, humidity, to simulate outdoor situations. Different light filters can be used along with different cutoff wavelengths. Something to be aware of is that filters that allow for shorter wavelengths of UV light to pass through can be more aggressive than natural sunlight. Natural sunlight starts up about 295 nanometers while some of the other filter combinations may be around to 285. So those shorter wavelengths of light can be more aggressive on your polymeric material.

So correlation, I'm sure Tim can attest to this as well how many times we've been asked this question here. How many accelerated hours equal one year outdoor exposure? And the answer is, there is no direct correlation and that's because once that question is asked we have to ask ourselves, well when is it being used? Where is it being used? Are we having direct or indirect exposure? What test method are we comparing it to? There are just many variables that make it extremely challenging to answer that question.

So in all, we look to other suitable test methods to determine if the material is suitable for outdoor applications. We can look at industry standards and those being some automotive standards or other polymeric weathering standards. Couple examples here, we have SAE J2412, SAE J2527. The difference in those two being the 2412 is an interior automotive standard and the 2527 is exterior.

One thing that we think about is, is the test method appropriate for your environment? If your material is going to be used indoor and possibly just sitting on the window ledge, you don't need to expose it to an exterior test method. We can also look at standard reference materials to help predict service life parts, and these materials can also be used as the control in the weather chamber. Thus standard reference material is material that has been thoroughly tested and has known behavior. So we have a material that we have the background information on and it's been used outdoor and performs well. If we can weather that next to a new material, we can equate that, the better performance and accelerated artificial weathering is better for outdoor real world, in most cases.

So after the part has been weathered, we can look at different material properties. We can look at color change, first of all, we can look at the color by using a spectrophotometer. And a spectrophotometer measures color by numerically putting values on the color so we can define initial color target. And once we have our control, the samples are weathered and we can determine the change in color by reported delta values. The total color change, it can be reported in many different color spaces. Two common values will be Delta E or Delta ECMC, this reports the total color change. Delta ECMC of under three is a very common standard that would be acceptable in the automotive industry. Another visual evaluation will be fading, often measured by AATCC grayscale. This is a scale of one through five, a value of five having no fade and a value of one significant fading. And this test is performed by having the weather specimen next to the reference standard showing the scale of fading of five to one and looking at the standard, comparing it and choosing the value. Next, we can look at gloss on the surface and this is that shine or the luster of the material. It's the measure of the amount of light reflected by the sample. As the surface begins to deteriorate, we can see a loss in gloss and this can be a sign of material degradation. We can also visually use our eyes to look at the sample. This helps us to determine the failure mode, is the specimen crazing, is it chalking or is a blistering? This photo that I've inserted on the bottom of the slide here shows an example of the specimens, the stadium seats, having significant degradation due to UV radiation.

You can see that the chairs are turning white, they're chalking, and they're no longer that bright red that they used to be. We can also evaluate the material through physical mechanical property testing. We can look at the tensile strength, sort of the measure of the force per area to break the specimen when pulled. We can look at the flexural strength, which is the measure of material's resistance to deform under load, and also impact strength, measure material toughness when impacted abruptly. Can still absorb that energy? We can measure that by either a drop impact test or maybe a sharpie or [inaudible 00:32:42] the impact test where the lever swings down and hits the sample. Something to note is that pass-fail criteria is specified by the customer and often times it involves material maintaining a specific amount of its initial properties. Sometimes it's 70%, sometimes higher in the 80 or 90% retention.

So I have a few case studies to go over here. The first one is for a consumer good used in lawn and garden. The problem the customer had...the challenge was that it was a continuous outdoor use in a subtropical environment and they wanted their life expectancy to be greater than 10 years. Our UV solution was a UV stabilized polyethylene in many different custom colors. And we evaluated the material based on SAE J2527 with extended filters, which is an exterior automotive specification. In this case study, to give you a little bit more background on the customer, we evaluated the material based on color and not physical properties, as the part was not under any significant load throughout its life. This was a brand new application for the customer and so they were seeking out different suppliers. So when it came down to two different suppliers, we offered to accelerate the UV data from the competitive material and the RTP material.

And what you can see here is that delta E value or the total color change over the duration of the test. The competitive material had significant color change and continued catastrophically, right off the bat, where the RTP material retained most of its color throughout the duration of the test. By a 1000 kilojoules is a common duration for an exterior automotive standard test. [Inaudible 00:35:00] this brown material here, we weathered the competitive material versus the RTP recommended material. After 5000 kilojoules, the RTP material was relatively the same color. Again, this is the brown Mormon Earth beat colors so we're able to make good colorant choices trying to focus on inorganic colorant versus the organics which could be more susceptible to the UV radiation.

Another continuous outdoor use application that we worked in [inaudible 00:35:43] was for outdoor furniture. The solution was a UV stabilized polyethylene with a light fast colorant package. The challenge here was that the customer wanted chromatic bright colors. We were able to offer them a UV stabilized and custom color master batch for their application to let down into their polyethylene.

So, as Tim mentioned earlier on, the highly chromatic colors are the most challenging in that we have to sometimes use pigments that don't have the highest light fastness. And in this case, you can see that we have a very bright red...in this case we're not able to...we had regulatory restrictions, we were not able to use heavy metals so we had to use some organic colorants in conjunction with the inorganics. We were able to maintain the customer's visual aesthetics with the highly chromatic red but had to sacrifice a little bit of color fade given...or compromise on the color fade given the high chromatic color. Something to hit on here is that, after 5000 kilojoules the gloss retention was 100%. So looking at the whole system, we have the polymer base, the UV-C stabilization package and the pigment. We hit a home run with the polymer choice and UV stabilization package and we did our best with the pigments, given the bright red color choice. So not all colors are created equal. We have the same base present, same UV stabilization package but in this case we were targeting a different green color. And so we were able to choose better performing, light fast pigment, and after the 5000 kilojoules, we were able to maintain almost identical color to our initial control. And again, 100% gloss retention so the samples still had that shiny luster that they began with in the beginning.

So in conclusion, RTP supplies innovated colors and functional additives. There are several environmental factors that shorten the lifespan of a material, not just UV radiation but the temperature, humidity and pollution. Proper polymer matrix and UV stabilization is critical to the life expectancy of the part. There are some polymers that have better inherent UV stability than others. Appropriate weather testing is needed to validate our material. RTP Company has experience working with short term, long term, intermittent and continuous outdoor exposure applications, so we have all the bases covered. And weather and performance should be a conversation because of all the variables involved, it's not just a simple question. We wanna thank you for joining us this morning. If you just hang on a few minutes, we'll answer some questions momentarily.

Trey: Great, Anna. Thank you so much. A big thank you to both Anna and Tim, it was really great and informative presentation. We are going to move into our question and answer session period at this time. We've had a ton of great questions already come in, so we do have some great technical experts and both Anna and Tim on the line, so please do continue to send us those questions. Just to hit on a few of the questions about, where can we get a copy of the slides? Where can I get a copy of the presentation? We will be sending that to you via email so you should be checking your email for that in the coming days. But a lot of great questions have already come in, so we'll go ahead and turn that back over to Tim and Anna and we can go ahead and kick off the question and answer session.

Tim: Okay. Thanks, Trey. And yes, quite a few questions coming in and we appreciate the opportunity to answer those. Here's one that...more than one person has asked some variant on this question but two parts, what's the most difficult material in terms of UV resistance? And then, are there more difficult colors? Certainly, some resins are more a challenge. I mentioned ABS in some of the first discussions. TPUs depending on thermoplastic [inaudible 00:40:20]. Also, it tends to be materials that are sensitive to yellowing, are some of the greatest challenges because you can mitigate, to some extent, but the yellowing becomes such an influence on the physical appearance of the material. Those are some of the greatest challenges. We can certainly formulate to maintain mechanical properties but the visual can be a challenge. To aggravate that, and Anna touched on it a little bit, as the world has become increasingly aware of, not only the hazards to the people producing the heavy metal pigments but also the environmental impact, we've struggled as an industry with bright yellows, reds, and oranges, that there's just simply not rock solid replacements for the mix or for the heavy metal colorants that we use. So I would say, the most difficult ones tend to be red, yellow and orange. Greens and blues tend to be, just because of the colorant chemistries that are available. Some of the easier ones...and certainly black. Black is a color we like it's easy to stabilize and support. Anna, do you wanna take the next question?

Anna: All right. If I add UV stabilizer to ABS will it perform like ASA? I believe Tim touched on this a little bit but different polymers have different inherent UV stability. Even adding a significant amount of UV stabilizer to ABS, it will not perform like ASA, in fact, the cost might be more profound. So moving into an ASA system may be a better choice.

Tim: Here's a question about the wavelengths that were mentioned. And I apologize, probably should have delved a little deeper into the electromagnetic spectrum. But, let's talk about the visible spectrum just to kind of give a background. The visible spectrum is typically 400 nanometers through 700 nanometers, 400 being the region in the blue that we visibly see, 700 being in the bright reds that we see and then, of course, orange, yellow and green falling somewhat in the middle. So the wavelengths of light that we're talking about when we speak about all 280 nanometers, 3, 400 nanometers is that area of invisible light. We can't see it with our eyes, but it's those shorter higher energy wavelengths that attack organic molecules. So when we were talking or when I was talking about those particular wavelengths, each one of the polymer families is sensitive to slightly different regions. One or two or three wavelengths may be more sensitive to polypropylene than it is to say polycarbonate. And that's why there's an abundance of different additive choices to make. You wanna make the appropriate choice to protect the polymer that you've selected, and many times we use wavelength to communicate those differences. Hopefully that helps.

Anna: Got another good question here about accelerated weather testing. It asks, which standard is more repressive for automotive SAE or ASTM? Well, the question is you have to look at each individual standard the colorant [SP], the irradiance, the values, the filter combinations, what temperature setting. So it's not just an easy answer that one is more aggressive than the other, you really have to look at all the parameters that the test involves. Another one here, we've got, are there other physical property tests that can be performed before and after weathering? The answer is yes. I covered some of the standard physical properties for thermo plastics. Really any test that you would seem viable for your part would be acceptable, possibly a[inaudible 00:44:41] or FTIR or something in that nature would be appropriate as well.

Tim: There's one of the questions, do we have experiences with colorants that have negative influences on the performance in polymers? The sad truth is yes. After you've been in this industry for a while, there have been times where we have, in discussions with the customer, explored what is meant by their application or what the expected lifetime. As an example, Anna had a question about what do you get with a year. There are packaging applications where the expectation is that the part would survive a relatively short amount of time outdoors. I like to use the classic example of golf balls. Hopefully, many of you have had the opportunity to chase a white little ball through the woods. But when we buy the golf balls they're nice bright white and if you stumble across someone else's lost golf ball, you'll notice that the side that was exposed to sunlight is faded and yellowed relative to the side that maybe was buried in the grass. This is an application where the expectation is that golf ball is not gonna survive likely more than one round of golf. So the additives and the colorant selections that are made for that have an expectation of a relatively short life. So yes, we have experience with targeted failure modes, I like to say it that way. We don't want to use colorants that we know do not have a potential long time in relatively long applications. Hopefully that helps.

There's another question, it's kind of related, about maintaining gloss after aging. When we talk about protecting gloss, what...gloss is a nice shiny smooth surface. Now, the colorants are usually...obviously they're embedded in the polymer, so that polymer-rich first few microns of a part when it begins to fail because the polymer has not been properly stabilized, you'll begin to see this cracking and crazing. That creates irregular surfaces, and those irregular services scatter light so they tend to look chalky and white. One of the, kind of the telltale failure modes as to whether or not...why a system failed. Let's say you have a bright blue child's toy and that toy has been left on the playground for an extended period of time. And from a distance it appears to be a nice pastel blue because the polymer has failed at the surface, let's say polyethylene polypropylene has failed at the surface and you've got a nice chalky dusty surface. That indicates that the polymer was not properly stabilized. If I was to take a sharp object, a pocket knife, for example, and scrape away the first few microns and I see that underneath that it's still the same original blue color.

That would indicate whoever formulated this made the appropriate color choices, but they didn't properly stabilize the polyethylene and the polypropylene. Now, the inverse is also possible, that you could have a nice glossy surface but you're beginning to see a little bit of color fade. Anna briefly mentioned that when she was talking about one of the red applications that maintained 100% of its gloss but we were starting to see a little bit of color shift with time. That simply means that the organic colorant that was chosen, while a high performance organic colorant, certainly doesn't have the long term stability of some of the inorganic choices that are available. It's just simply beyond the scope or the ability of the available materials for that particular color. Anna, what else do we have here?

Are the additives we use routinely rows[SP] and breach compliant? The short answer is yes. Again, when we're talking about an application with a customer, our regulatory discussion is...may not be the first question, but it's certainly part of the first conversation. I think, Anna ended the conclusion with, weathering is a conversation it's not a question. Any time a customer ask us, "I need a material that will do X" and weathering is part of that, there's a number of questions we have to ask so that we're making the right choices and we're helping you make those choices. We want to with the data that we can provide, with the experience that we have, to be able to make suggestions to you, explain why we think that's an appropriate suggestion for your application and then explore other possibilities, if that's an interest.

Anna: All right. I have a question here and it says, what is the tradeoff between [inaudible 00:50:03] and using carbon black for UV stabilization? Well, carbon black is used as a common absorber in materials. But as we know carbon black is only offered in the color black. So as [inaudible 00:50:19] is a very economical choice compared to other absorbers which are fully colorable[SP], carbon black is effective absorber but in black only.

Tim: Speaking about making effective choices one of the questions here is, what about using HALS with polycarbonate? Sounds like the person asking the question has either had a bad experience or heard about a bad experience. Typically, HALS do not work well with polycarbonate. As truthfully, with any additive in any polymer system, the choices need to be chemically appropriate. And HALS, while it may have some use in PC, ABS, strictly speaking, it's not one that's recommended for polycarbonate use. Typically, polycarbonate is stabilized with absorbers.

There's a question here, plastic types that preserve their transparency. I guess...I'm going to assume relative to UV weathering. Certainly, there's some polymers, acrylic being one, that does an outstanding job of maintaining its transparency. It doesn't tend to yellow, it doesn't crack and craze as quickly as...and I mentioned polycarbonate, another amorphous material. Acrylic, having some mechanical properties challenges, it tends to be more [inaudible 00:51:58] than polycarbonate. So oftentimes, it's necessary to have a conversation about part design, can acrylic be used in a particular application as opposed to polycarbonate? The answer is maybe. And so, part design also helps us make choices. It is probably more common for customers to approach this with a part already design. And many times they've already selected the polymer and we're starting from a, not necessarily complete restriction, but with fewer choices than if we start the conversation with, what do you wanna build and where do you want it to live? So I would urge everyone who's working on a new development program to consider materials and keep it broad enough to where maybe you can consider part compromises or design compromises that will allow you to use materials that have known superior weatherability. I may be overstating it, but stabilizing a polymer improves its base performance, it does not change it into something else. No amount of stabilization is going to turn a polycarbonate into an extremely weatherable grade of acrylic, from just strictly UV standpoint. So it's those types of questions we need to understand. Many, many times I have customers call and ask about a UV stabilized ABS, not understanding that it's appropriate for an intermittent application at best and that no matter how robustly we stabilize ABS, ABS is not going to give, in many cases, not give satisfactory performance in a continuous outdoor environment.

Anna: Here's another question, it asks, does UV stabilized materials meet UL 7 Part 6 requirements? I am going to assume here that talking about the F1 requirement. And this is a requirement where it tests physical properties after being weathered, and must retain a [inaudible 00:54:20] 70% of its initial strength properties? It's gonna be evaluated on an individual basis, from polymer to polymer. And with the correct UV civilization package, I would be confident that most materials would pass this test.

Tim: Okay. Here's another question from a group asking about T02. T02 is used to support a catalyst, does it act as a catalyst in photo degradation of polymers as well? And the short answer is yes. That's why I'd mentioned earlier, making the correct choice the T02 and it's about the surface treatment on the grades. To be honest, that is a topic entirely that could consume another hour of discussion easily. But the short answer is, we wanna make the appropriate choices, understanding the weathering characteristics but also understanding the other materials that are part of that polymer compound matrix. T02 can also be very abrasive, as an example, and reduce the gloss fiber[SP] link resulting in less than expected impact performance. So there's a number of things to consider, not all T02s are created equal.

Here's a good question, do light stabilizers, HALS or any oxidants and any combination of those, does that help protect the color or mostly the physical properties of the substrate? Well, the primary focus is on the physical properties of the substrate. We're trying to protect the polymer because quite honestly, that's the majority of the material that's in your part in most cases, there are certainly some exceptions. The colorants tend to be in trace amounts and, as we discussed before, if we are motivated by the customer to formulate for very bright red or very bright yellow, in that case we are going to make choices about stabilizers, and also about colorants, that will allow a synergy or a complimentary behavior. So while, yes, the primary function of the stabilization is to support the polymer, there is some benefit to making correct choices with colorants and additives complementing those choices as well.

Do absorbers increase the surface temperature of the plastic? That's an interesting question, and it will depend on the absorb selected. As a classic example, the typical...when we're talking about organic absorbers, they tend to absorb a significant amount of the UV portion of the electromagnetic spectrum that we were talking about and they do dissipate that as heat. But where we usually see the greatest influence is when something inexpensive like carbon black has been chosen. Carbon black absorbs, almost uniformly, through a large portion of the electromagnetic spectrum which includes the infrared which is heat. That's the longer wavelengths of light, just beyond the visible red light that we can see. And so, certainly carbon black's use would dramatically increase the surface temperature of the part. Now fortunately, there are colorants that are available that are more solar reflective, that also have some benefit to UV stabilization providing a black color and reducing some of the solar build up. So again, those types of colorants are available and certainly if you have an application you wanna discuss, we're happy to support that.

Here's an excellent question. Anna mentioned standard reference materials and the question asks, can we buy those standard reference material somewhere? I think there's a little bit of confusion. What she's mentioning was, if a customer has a material that has proven performance, whether in standardized real world testing or just simply that they've had it sitting outdoors in Florida or Georgia or southern France for a number of years and they've been very, very happy with that formulation, what we can do is review the composition of that and help predict behavior in other applications or other colors. One of the things to mention is that, while we talk a great deal about testing and evaluation of materials and predicting behavior, don't think I'm just testing as a call insurance release criteria. When materials are certified for release lot to lot, those are based on compositions that have proven performance. So that's the reason when a standardized material in a study...you have a blue there that works very, very well and you want to produce a different shade of blue or maybe a shade of green or even a shade of yellow. We can use that blue that you have proven, real world performance, evaluated in accelerated environment and make reasonable, educated decisions and estimates about its performance in another color. So hopefully, that helps you better understand what was meant by standard reference material.

Anna: So here's a question, what's the difference between UV, between outdoor and in the office? And you can look at the spectral curves from the lighting in your office is going to get a different spectral curve then natural lighting outdoors. Also, there's influence. Say your part if sitting on the window sill, that glass pane is blocking some of the spectral radiation from the outdoor light. So there are different weather methods for interior and exterior situations.

Tim: I'm gonna take one more question because we've only allotted an hour for this. But just one more question because several of you have asked a very similar question. We mentioned polyethylene for use in outdoor garden furniture type but didn't mention polypropylene. Didn't wanna convey that there's a preference of one over the other, there is depending on the design of the chart or the chair or the furniture and expectations. Polypropylene is certainly widely, widely used. What it depends on are customers expectations for mechanical performance more than likely, but that's a unique situation. Again, there's so many questions we can't get to but I assure you, we will answer all of the questions and those answers and those answers will be posted online as quickly as we can do that. We would encourage each of you, if you have a specific application, to contact your local RTP sales engineer. Love to have a discussion with you about your specific concerns. And we, again, tremendously appreciate the support and the attention, and we thank you so much for joining us today. Trey?

Trey: Great, Tim. Thank you. Have a, like Tim said, a ton of great questions. So since we were not able to get to today, do be checking your email for those. A big thank you to everybody for attending today. We will be posting the slides for this webinar as well as the recorded copy so you can watch that again in your leisure and share that with others at your company. Thank you everybody for attending, and have a great rest of the day.